THE NORMAL VALUE AND PHYSIOLOGICAL VARIATIONS OF ERYTHROCYTES AND HEMOGLOBIN IN MAN

by

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I. NORMAL VALUES

A. REVIEW OF RECENT LITERATURE

1. Introduction. Unlike most physiological constants commonly used in medical practice, the normal ranges for erythrocytes and hemoglobin have been based on a surprisingly small number of observations on normal subjects. It is only in recent years that this fact has become generally recognized and that the establishment of normal values based on more nearly adequate series has has been attempted (Dyke, 1929; Boerner, 1931).

The values most often quoted for the normal erythrocyte count, five million in men and four and one-half million in women, appear to have originated with the observations of Vierordt in 1852 and Welcker in 1854, each of whom sampled two normal subjects in each sex. These data have been accepted down to the present time and are to be found in most textbooks, although the whole subject has been subjected to a rigid reexamination in recent years.

The question of normal values in hemoglobin is complicated by the custom of designating amount of hemoglobin as per cent of normal instead of in figures indicating an absolute quantity per unit volume of blood. The normal value which serves as one hundred per cent is of necessity an arbitrary one in the absence of extensive sampling under certain predetermined and fully controlled conditions. Indeed, an arbitrary standard might be practicable if the same standard were universally employed. Since this seems unlikely, after many years' usage of widely differing standards, the designation of hemoglobin in grams per 100 c.c. of blood is desirable. With the recognition and wider use of this method, and with the perfection of dependable and accurate methods for estimating hemoglobin, considerable progress toward the establishment of normal hemoglobin values has been made.

2. Normal Erythrocyte Values. One of the first studies made on the blood of a large series of adults was that of Emerson (1907). This study indicates that the mean erythrocyte count for 171 healthy medical students is 5.43 million. The counts were made by the students themselves. Emerson later reports (1921) a series of 176 men students with a mean erythrocyte count of 5.00 million.

Chamberlain (1911) conducted a study on the blood of 687 soldiers and found an average red cell count of 5.20 million.

Haden (1922, 1923) undertook to reexamine the whole question of erythrocyte and hemoglobin standards by making careful studies on 52 normal individuals of various ages. He found a mean count of 5.08 million erythrocytes in 20 men between 18 and 30, a mean count of 4.865 million for 20 men between 20 and 40 years of age. This series was later (Haden, 1933a) increased to 100, the data of which are shown in Tables I and II. Haden (1933b) recently published data accumulated from 1924 to 1930 from student counts made on their own blood. These data show a mean count in 230 men of 5.00 million.

Gram and Norgaard (1923) undertook a similar study for the purpose of establishing the relation between cell count, cell volume and amount of hemoglobin in normal individuals. They found for mean erythrocyte count, 5.45 million in 10 men and 4.65 in 10 women.

Osgood (1926) continued the type of work begun by Haden and by Gram and Norgaard but on a larger scale. He studied a series of 137 men, finding a mean red cell count of 5.39 million in men. His investigation was continued (Osgood and Haskins, 1927) with a corresponding study of the blood in 100 young women. The mean red cell count found was 4.80 million.

Wintrobe and Miller (1929) followed with a study of normal men, a value of 5.85 million erythrocytes being observed. Wintrobe (1930) also studied 50 women, finding a mean erythrocyte value of 4.93 million.

Foster and Johnson (1931) carried out an investigation in New Orleans similar to that of Wintrobe and Miller, finding the average erythrocyte count in 100 men between 18 and 30 to be 5.26 million. Price-Jones (1931) recorded a mean count of 5.43 for 100 male London subjects examined.

Other authors who have carried out studies on smaller series are Komocki (1924), Sackett (1925), Horneffer (1928), Thorner (1930), Cabigting (1930), Parodi (1930) and Tenconi (1931). The values found by these investigators are shown in Table I, together with the mean erythrocyte count of the present study.

Chia Yu Tien (1931) found a mean value of 5.12 in 320 Chinese living in Manchuria and quotes Kitashima as having found 5.24 million and Sakai, 5.46 million as mean values in studies on normal Japanese.

Wintrobe (1933) has recently published another study of the blood in 86 normal men and 101 women. The erythrocyte averages were 5.48 and 4.82 million, respectively. Goldhamer and Fritzell (1933) carried out similar studies on 100 healthy boys aged 12 to 17, in whom a normal mean erythrocyte value of 4.72 million was found.

3. Normal Hemoglobin Values. One of the largest series of careful estimations of hemoglobin in normal individuals is that of Williamson (1916) who made observations on 919 individuals chosen from various age groups in both sexes. His data, however, have been questioned because of the method employed. The spectrophotometer was used for determinations, a recrystallized solution of hemoglobin serving as standard. According to Peters and Van Slyke (1931), the absolute values found by Williamson are inaccurate on this account, since the process of recrystallization cannot be effected without chemical alteration of the hemoglobin.

The normal hemoglobin values obtained by Haldane and Smith (1900,1901), 13.8 grams per 100 c.c. for men and 12.3 grams per 100 c.c. for women, have been widely accepted and have been in common use for over 30 years. Only recently have additional studies cast doubt upon their accuracy. The values obtained by Haden (1922, 1923) comprised the largest accurate series of hemoglobin determinations until the work of Osgood and Haskins (1926, 1927). Other extensive studies in the U. S. have been made by Wintrobe and Miller (1929), by Wintrobe (1930, 1928-29, 1933), by Ester and Johnson (1931) and by Price-Jones (1931) with the collaboration of Dill (1931).

Other studies were made in various countries by Horneffer (1928), Orias (1930a), Parodi (1930), Sokhey (1930), Parjono, Radsma and Joenoes (1930), Tenconi (1931), Thorner (1931), Schmoll (1931) and by Jenkins and Don (1933). These are given in Table II, together with the figures obtained by the author (Walters, 1934c).

4. Normal Packed Cell Volume Values. Comparatively few careful studies of the normal value for volume of packed cells have been made. Haden's observations (1922, 1933) included data for volume of packed cells in normal individuals, an accurate method being employed and a practically isotonic anticoagulant solution being used.

Since the procedure followed by Osgood (1926) and by Wintrobe and Miller (1929) employed powdered oxalate as an anticoagulant, corrections were applied to their original figures. Osgood, using 20 mg. powdered oxalate for 10 c.c. of blood, obtained an average total volume of 44.84 c.c. of packed cells per 100 c.c. of blood in the 94 subjects who were so examined. This figure was increased by 3.5 per cent to correct for shrinkage of the cells, giving a revised figure of 46.4 c.c. packed cells per 100 c.c. of blood. Ninety per cent of the values ranged between 40 and 50 c.c.

The corrected mean of Wintrobe and Miller is 46.5 c.c. of packed cells per 100 c.c. of blood. This was obtained by adjusting for the 6.7 per cent shrinkage in volume with the 40 mg. of oxalate per 10 c.c. of blood used by them. Of the corrected values, 85 per cent ranged between 40 and 50 c.c.

The series of Pearl and Ђnor (1927) is one of the largest single studies 6 packed cell volume in normal men. Other studies by Wintrobe and Miller (1929), Wintrobe (1930, 1933) and by Foster and Johnson (1930-31) have followed. These are given in Table III which includes also the author's own data. Rowntree, Brown and Roth (1929) studied the packed cell volume of normal men, finding a mean value of 42.2 c.c. in 49 subjects of various ages. However, these individuals were observed under basal conditions, which, as will be shown, give values below the commonly accepted normal level.

B. STUDY OF 100 NORMAL MEN IN KANSAS

1. Methods. The present study is based upon the observations made on 100 men between the ages of 20 and 30. The subjects were medical and college students, all of whom had been found in good health by thorough physical examination. Since previous examination has shown that both muscular activity (Hawk, 1904) and rest (Walters, 1933a, 1933b, 1934a) produce significant fluctuations in the erythrocyte count, the samples of blood were drawn as soon as the subjects presented themselves at the laboratory. No other effort was made to control physical activity. The data are, therefore, believed to be comparable to previous studies in which the subjects have, also, apparently been chosen at random with respect to physical activity. Most of the observations were made during the month of September.

A 6 c.c. quantity of blood was drawn from an arm vein, 5 c.c. being placed in a 15 c.c. graduated centrifuge tube containing 1 c.c. of 1.6 per cent sodium oxalate solution. The 1 c.c. of blood was placed in a second tube containing a small amount of dry oxalate and was later used for making counts and hemoglobin determinations. All tubes were tightly stoppered immediately, and samples were centrifuged or diluted before any known changes which would affect any of the observations could occur in the blood. Precautions were taken to prevent stasis in arm veins when withdrawing blood.

Cell volume was ascertained by centrifuging the tubes containing the 5 c.c. of blood in 1.6 per cent oxalate for one hour, which is considered adequate by Haden (1930), at a speed of 2800 r.p.m. in a centrifuge with a working radius of 13.5 cm. The tubes were allowed to return to room temperature before readings were made. The percentage of cells was calculated from the readings of the graduated scale on the tube.

Erythrocyte counts were made after dilution in Trenner pipettes, in Levy-Hausser chambers having improved Neubauer ruling, all of which apparatus had been tested by the U. S. Bureau of Standards. The pipettes were agitated for three minutes in a mechanical shaker which was carefully checked to eliminate the possibility of any mechanical hemolysis. At least two dilutions with Hayem's solution were made from each sample and, if necessary, additional dilutions were made until counts from separate pipettes were obtained which agreed within 100,000 cells. Blood was thoroughly mixed by repeated inversion of tubes before samples were taken out, and diluted samples were allowed to settle completely in the chamber before counting. Trenner pipettes were checked with U. S. Standard Thoma pipettes and were found to give concordant readings.

Hemoglobin was estimated by the Newcomer method. Determinations were made after the acid hematin solution had stood for one hour. All readings were made by daylight. Each reading recorded is the average of six observations of the colorimeter. In order to verify the dependability of the Newcomer disc, the apparatus was checked against the Van Slyke oxygen capacity method on 10 different samples of blood. The results were as follows:

Blood Sample Number	Newcomer Method	Oxygen Capy. Method	Variation of Newcomer
1	10.86	10.84	+ 0.02
2	11.48	10.89	+ 0.59
3	11.83	11.86	+ 0.03
4	13.35	13.34	+ 0.01
5	14.84	14.52	+ 0.32
6	15.23	15.24	- 0.01
7	15.15	15.30	- 0.15
8	16.12	15.79	+ 0.33
9	15.20	15.85	- 0.65
10	25.78	25.81	- 0.03

Because of the close correspondence of this series of comparative determinations, no corrections were applied to the Newcomer readings. All cell counts and hemoglobin determinations were made by the author.

2. Presentation of Data. The mean erythrocyte count found in the subjects of the present study was 4.84 million per cubic millimeter of blood, the counts ranging from 4.10 to 5.55 million. Of this number, 90 per cent lay between 4.31 and 5.35 million.

The average hemoglobin observed was 15.12 gm. per 100 c.c. of blood, 90 per cent of the figures lying between 13.25 and 17.03 gm. The extremes were 12.89 and 18.70 gm.

The mean total cell volume in this series is 46.5 c.c. packed cells per 100 c.c. of blood, with 92 per cent of the total volume determinations between 43 and 50 c.c.

The data are given in full in Table VII.

C. SIGNIFICANCE AND INTERPRETATION OF NORMAL VALUES

1. Hemoglobin Coefficient and Color Index. The term hemoglobin coefficient was introduced by Osgood (1926) and was defined by him as "the number of grams of hemoglobin per hundred cubic centimeters of blood calculated to a red cell count of 5 million per cubic millimeter." For the calculation of color index, for which some arbitrary 100 per cent standard is required, this hemoglobin coefficient is usually used.

The hemoglobin coefficient is, of course, somewhat lower in women than in men and shows considerable variation in the hands of different investigators. Osgood, on the basis of his own observations and the data of previous investigators, recommended the use of the hemoglobin coefficient, 14.7 gm., to represent 100 per cent. Wintrobe adopted 14.6 gm. as a more accurate figure to represent 100 per cent.

The inadaptability of a hemoglobin coefficient derived largely from one or two series to all localities is demonstrated by employing the figure used as 100 per cent by Wintrobe and Miller, in four of the sepatate series being compared. The data of Osgood and of Wintrobe and Miller, when so treated, show a mean color index of 1. Haden's subjects show a mean color index of 1.07 and those of the present series, 1.08, with Wintrobe's 100 per cent figure. If, however, a hemoglobin coefficient is calcuhted from the combined data of Haden and of this study, the resulting figure, 15.59 gm., when used as 100 per cent hemoglobin, gives a mean color index of 1.006 for the subjects of the present series, 85 per cent of which are between 0.85 and 1.15.

2. Volume Coefficient and Volume Index. "Volume coefficient" is the term proposed and defined by Osgood (1926) as "the volume of packed red cells per hundred cubic centimeters of blood calculated to a red cell count of 5 million." In the calculation of volume index, this coefficient is employed as 100 per cent value for packed cell volume.

In spite of the fact that the various average figures for total volume of packed cells agree so closely, the great divergence in red cell counts produces volume coefficients in each instance which are widely separated. Osgood's corrected volume coefficient is 43.04 c.c., while the high average cell count found in Wintrobe and Miller's subjects gives a volume coefficient of 39.94. Foster and Johnson calculated 44.4 as the volume coefficient of their 40 subjects. Osgood, as well as Wintrobe and Miller, employed 41 c.c. as 100 per cent in their calculations, giving volume indices of 1.00 and 0.97 respectively. The use of 41.0 c.c. as 100 per cent would give a volume index in Haden's group of 1.12 and in this series, of 1.18. Obviously, again, the standard chosen as 100 per cent must, judging from the above calculations, be a local one, at least for the present. If the data of Haden and of this series are combined, a volume coefficient of 47.4 c.c. is derived, which, when considered as 100 per cent total cell volume, gives a mean volume index in this series of 1.017 with 90 per cent between 0.89 and 1.15.

Saturation Index. The figure derived by dividing color index by volume index has been designated as "saturation index" by Haden (1923). Its normal value is usually one. However, as may be seen from the results obtained by various investigators (Table IV), the coefficients which have been used as 100 per cent in the calculation of the indices vary widely. While most of the indices shown are approximately 1, the values would vary greatly if the same hemoglobin and volume coefficients were employed in calculation of the indices in all series. This is, of course, due to the widely different values found by various observers in red cell count and hemoglobin. As will be shown below, the differences are probably technical rather than actual.

Although the indices have been valuable clinically in the differentiation of anemias, their widespread use has been prevented by any agreement as to the standards which are to be employed as 100 per cent normals. Employing the standards used by Wintrobe, a hemoglobin coefficient of 14.6 gm. and a volume coefficient of 41 c.c., the 100 subjects of Wintrobe and Miller average 1.02, the Oregon men, 0.98, and Haden's Kansas City group, 0.96 in saturation index. The series under consideration would average 0.92. If, however, 15.59 gm. hemoglobin and 47.4 c.c. packed cells are taken as 100 per cent standards, the mean saturation index obtained is 0.99 in this series, with 90 per cent ranging between 0.85 and 1.12.

4. Corpuscular Constants. The method of calculating mean corpuscular volume, hemoglobin and hemoglobin concentration has been explained frequently elsewhere (Haden, 1925; Wintrobe, 1931), and is therefore omitted here. Mean corpuscular volume refers to the average volume of individual erythrocytes, stated in cubic micra. Mean corpuscular hemoglobin expresses the average amount of hemoglobin in micromicrograms (grams x 10^{-12}) present in the erythrocytes. Mean corpuscular hemoglobin concentration expresses the amount of hemoglobin in proportion to the volume of the erythrocyte and is stated in percentage.

The mean corpuscular volume obtained in this study, 96.5 cubic micra, is higher than that found in any of the other series compared in Table V. The normal range for the age group, sex and conditions of this study is found between 82 and 107 cubic micra, since 90 per cent of the observations occurred within those limits.

These figures tend to confirm the relationship suggested by the work of Emmons (1927-28) on various mammalian as well as human bloods, that the volume of the individual erythrocyte appears to vary inversely with the total number found, a larger corpuscular volume tending to compensate for the smaller number of cells. Thus, the total volume of erythrocytes would be independent of geographic variation.

Haden's average for mean corpuscular volume in men is 92 cubic micra. Wintrobe found 79.8 cubic micra for an average, while the mean figure calculated from Osgood's data is 86.1 cubic micra. Foster and Johnson's figure is 85.9.

Since the calculation of corpuscular volume, hemoglobin and hemoglobin concentration is simple and does not involve any arbitrary standard, these constants have been recommended frequently in preference to the volume, color and saturation indices for clinical work. However, it is clear that even for the application of these terms to specific cases, well-established normals for the given locality, age group, and sex should be known. For example, although Wintrobe (1931) states that "values above 95 cubic micra or below 75 cubic micra are probably a manifestation of abnormality", more than half of the normal subjects observed in the present investigation showed a corpuscular volume greater than 95 cubic micra.

The average figure for mean corpuscular hemoglobin found in the subjects of this study was 31.4 micromicrograms, with 92 per cent lying between 25 and 27 micromicrograms. This mean is almost identical with Haden's average of 31.0 micromicrograms for 35 men between eighteen and thirty, and agrees closely with the average figure found by Foster and Johnson, 30.03 micromicrograms. The same mean was observed both by Osgood and by Wintrobe and Miller, 29.2 micromicrograms.

The average found by the author for corpuscular hemoglobin concentration was 32.4 per cent. Ninety-one per cent of the calculations lay between 27.5 and 36.5 per cent. Haden's average of 33.7 per cent and Osgood's, 33.9 per cent, are in close agreement with this figure. Wintrobe found an average of 36.6 per cent, while Foster and Johnson recorded a mean of 34.77. Horneffer calculated a mean corpuscular hemoglobin of 32.4 for his series of 40 healthy men. The criticism of his method of hemoglobin determination has already been mentioned.

D. FACTORS RESPONSIBLE FOR DIFFERENCES IN NORMAL VALUES

1. Geographic Locality. The comparatively wide differences which have been found to exist in hemoglobin and erythrocyte count have frequently raised the question of possible geographic variations (Haden, 1929) other than the well-recognized increase with altitude.

Parjono, Radsma and Joenoes (1930) compiled data on blood iron and oxygen capacity in an effort to find some correlation between the amount of hemoglobin and geographic latitude. The data used were found insufficient to establish any clear relationship.

In Tables I and II are listed erythrocyte and hemoglobin determinations from various geographic localities. From these figures it is apparent that any correlation on the basis of geographic locality is very difficult, since in several cases investigators working in the same locality have secured widely different results. There are, however, few striking differences.

2. Living Habits. Many other factors than geographic location are doubtless existent, as for example, in the case of the difference found between poorer natives and the better situated students and native doctors in the Java group of Parjono. For this particular difference, these authors suggest the prevalence of intestinal worms among the poorer classes as a possible explanation.

Orias (1930b, 1930c) found a definite difference between common soldiers, officers and students in Buenos Aires (Table II). He concludes that social condition is an important factor in hemoglobin level. Horneffer (1928) also noted this difference, finding 16.25 gm. as the mean value for 20 students and 15.80 gm. as the mean for 20 soldiers.

As a basis for explaining a difference observed in the mean hemoglobin level of subjects in the United States and in London, Price-Jones (1931) suggested that the motoring habits of American subjects may have produced a slow chronic poisoning by carbon monoxide, as a result of which the oxygen pressure is constantly being slightly reduced and the bone marrow compensating for the useless carboxyhemoglobin by making more red cells and hemoglobin and producing a relative polycythemia. That this suggestion has a reasonable basis is shown by the following citations.

Nasmith and Graham (1906) found that guinea pigs living continuously in a dilute carbon monoxide atmosphere were able to increase the quantity of hemoglobin and the number of erythrocytes to compensate for the loss in oxygen-carrying capacity. This was confirmed by Egdahl (1923) who also noted a polycythemia in human subjects after repeated exposures to small or moderate amounts of carbon monoxide. Experiments by Sayers, Yant, Levy and Fulton (1929) in which six men were exposed four to seven hours daily over a period of 68 days to mixtures containing two, three and four parts of carbon monoxide per 10,000 parts of air showed that a distinct increase in hemoglobin and red cells occurs under such conditions.

Jenkins (1932) after investigating the blood of workers exposed to motor exhaust fumes found that chronic or intermittent exposure to carbon monoxide tends to raise the hemoglobin concentration but considers the stimulus inadequate to account for the difference cited by Price-Jones.

Gettler and Mattice (1933), after a careful study of the carbon monoxide content of the blood of various groups of subjects, came to the conclusion that smoking is apt to be the most conspicuous factor in determining the carboxyhemoglobin of an individual under normal conditions when he is not exposed to obvious high percentages of the gas. Hanson and Hastings (1933) found the hemoglobin of smokers to be 3 to 4 per cent saturated with carbon monoxide while that of non-smokers averaged 1.5 per cent saturation.

Table VI compares the mean erythrocyte count, total hemoglobin and corpuscular hemoglobin in smokers and non-smokers, based on a survey of the subjects in the groups later designated as Series I, II and III in this study.

In practically all smokers studied (Walters, 1934b), the habit was of two or more years' duration, and virtually all used cigarets exclusively. Those using one package of 20 or more per day have been designated for convenience as "heavy" smokers. The subjects have been chosen from two groups. In Series I, blood samples were drawn at random with reference to physical activity, while in Series II, the subjects were sampled after a one-half hour rest period in bed.

The data of Table VI indicate that neither the differences between smokers and non-smokers, nor between "heavy" smokers and non-smokers are significant, since no difference observed is greater than four times its probable error.

3. Technical Differences. It is likely that one of the most important and perhaps the principal factor responsible for the differences seen in Tables I and II is some type of difference in technic employed. This is apparent when one considers the fact previously mentioned, that different investigators in the same locality have obtained widely different values.

It is impossible to tell what specific differences may have prevailed. The only technical difference which presents itself in this study is the use of Trenner pipettes. These, it is believed, may have influenced the counts on the side of greater accuracy, since Thoma pipettes in the hands of students frequently give higher counts due to aspiration of the blood column beyond the ruling, with subsequent withdrawal, which leaves cells adhering to the walls of the bore.

II. PHYSIOLOGICAL VARIATIONS

A. INTRODUCTION

During a study in which normal subjects were fed with a substance believed to have hematopoietic properties, fetal calf liver, Walters and Woodard (1933) found that unexplained but statistically significant physiological variations were so numerous and of such magnitude as to render impossible the certain identification of changes in quantity of erythrocytes as being due to the substances administered.

B. EFFECT OF MUSCULAR INACTIVITY

In an effort to ascertain under what conditions an accurate estimate of the erythrocyte count and hemoglobin is possible, studies of the blood were made on a series of 80 men (Series II), following a one-half hour rest in bed, with the idea of eliminating the exercise as a factor tending to increase the red cell count.

Comparison of the mean values for this group with those of Subjects 1-80 (Table VII) which are designated as Series I showed decidedly lower values in the resting subjects (Table IX).

A third group of 20 men was then studied, first after random activity, subjects being sampled immediately upon entrance into the laboratory, then one hour later, after spending the intervening time in a state of muscular inactivity, lying in the recumbent position. This group, Subjects 81-100, is designated as Series III. Comparative data for these individuals are shown in Table X. The data of Table X show that the average erythrocyte count after an hour of muscular inactivity is .44 million lower than before lying down. A diminution in erythrocyte count is seen in all of the 20 subjects, the greatest decrease being 780,000 cells. In quantity of hemoglobin, a decrease is seen in 16, no change in three and an increase in one of the 20 subjects. The average decrease is 1.05 gm. and the maximum, 3.39 gm. per 100 c.c. of blood.

All subjects except one show a decline in volume of packed cells after muscular inactivity. The mean difference after rest is 3.1 c.c. and the maximum decrease is 5.5 c.c. packed cells per 100 c.c. blood. The average packed cell volume of 42.2 c.c. found by Rowntree, Brown and Roth (1929) in 49 normal men of various ages under basal conditions is in accord with the data of this study.

In order to ascertain whether the decreases found are of sufficient magnitude to be other than of fortuitous origin, the statistical significance of each difference was calculated. For the difference between Series I and Series II, the following formula was applied (Dunn, 1929):

$$\text{Probable Error of Difference} = (PE_{\text{Mean I}})^2 + (PE_{\text{Mean II}})^2$$

In the case of Series III, the probable error of the difference was calculated by applying the usual formula for probable error of the mean to the difference between random activity and rest for each subject. A difference has been considered statistically significant whenever it is greater than four times its probable error.

The difference between the subjects of Series I and those of Series II in erythrocyte count, quantity of hemoglobin and volume of packed cells is in each case too great, according to the statistical analysis, to be due to chance. This is also true of the same differences between the random and resting values of the individuals in Series III.

A significantly lower figure is seen in mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration in the subjects of Series II who were sampled after one-half hour of inactivity than in the random activity group, Series I. Since no significant change occurred in the corpuscular values of Series III, where the same subjects were examined both before and after rest, and since the corpuscular volume difference is negligible, the interpretation of this significant decrease is not clear.

The fact that the corpuscular values show no significant change in the observations of Series III suggests that the alterations seen in total hemoglobin and total volume of packed cells are due to a decrease in the proportion of erythrocytes in the circulating blood rather than to any modification in individual cells. Two types of change could cause such a fall in red cell count: (1) An increase in plasma volume which would produce a relative decrease in number of cells, or (2) a redistribution of cells in the circulatory tract with the withdrawal of erythrocytes into storage depots, which would cause an absolute decrease of cells.

C. DISCUSSION OF VARIATIONS IN ERYTHROCYTES AND HEMOGLOBIN

1. Fluctuations Due to Alterations in Plasma Volume. Thompson, Thompson and Dailey (1928) demonstrated a definite increase in plasma volume in patients assuming the supine position after having maintained the standing still position for some time. These investigators concluded that there is a loss of approximately 11 per cent of the total plasma volume due to capillary filtration when subjects continue the standing still position for 20 to 30 minutes, which is made up again in the same length of time after the recumbent position is assumed. These results were verified by Waterfield (1931)

in a study of eight normal subjects. It is doubtful, however, that these findings are applicable to the subjects of Series II and III, since their physical activity, although purposely left uncontrolled, was always preceded by a walk of at least fifty to one hundred yards to reach the laboratory.

Cassinis and Bracaloni (1930) found that the hydremic curve of blood varies less than one per cent during one to three hours of repose and also that in 40 to 130 minutes of walking, the curve does not differ in any noteworthy degree from that of repose. This is in agreement with the work of Lee, Carrier and Whipple (1922), who observed that dogs exercised at a run for 20 minutes, although decreasing in weight as much as 12 ounces by fluid loss, maintained a constant plasma volume. Broun (1922) noted a slight increase of plasma volume in most of his dogs after short periods of exercise, but the variation averaged only about 3.6 per cent.

Priestley (1916) noticed that drinking 1 per cent sodium chloride solution produced a lowering of blood hemoglobin, although ingestion of water did not. Stebbins and Leake (1927) noted a slight fall in the specific gravity of human blood after the ingestion of food. Solarino and Cattaino (1930) observed in dogs and in man an erythropenia following administration of a meat meal or of hydrochloric acid having approximately the same concentration as that of gastric juice. The number of erythrocytes in the blood reverted to normal in three to four hours. Solarino (1931) found a corresponding augmentation in water content of the blood which reached its height during the second hour of digestion. A cell decrease during digestion was also observed in rabbits by Raposo and Fevereiro (1931). Waterfield (1931), on the contrary, after determining blood volume in a subject, first in the fasting state, then after the taking of food, concluded that even a large meal has no appreciable effect on blood volume. Rud (1922-23) and Smith (1931) found that meals produced no significant change in erythrocytes.

Of the 80 subjects in Series II, 61 were sampled between 2:00 and 2:30 p.m., or about one and one-half to two hours after the noon meal. The mean erythrocyte count in these subjects is 4.53 million. Fifteen subjects of the series were sampled between 3:00 and 3:30 p.m. or two and one-half to three hours after the noon meal. These subjects showed a mean count of 4.68 million.

It is difficult to tell what proportion of the .25 million average difference between the subjects of Series I and II is due respectively to digestive effect and to the period of inactivity. That the latter is an important factor is indicated by observations on the subjects of Series III, most of whom were sampled at about 10:00 and 11:00 a.m. Since all subjects attended 7:30 a.m. classes, this was approximately three and four hours after breakfast. Thus, during the fourth hour of digestion when, according to Solarino, the erythrocyte count should have recovered from the digestive effect and returned to normal, a drop much larger than the difference between Series I and II is seen.

2. Fluctuations Due to Alteration in Number of Circulating Erythrocytes. That muscular activity, even for short periods of time, results in notable increases in circulating erythrocytes has long been known. The older literature was reviewed by Hawk (1904) who also did considerable work on the subject, and his findings have been verified many times by subsequent investigators. The mechanism of the erythrocytosis produced by muscular activity is now fairly well understood.

The extensive researches of Barcroft (1931), of Binet (1930), and of Scheunert and Krzywanek (1927) have definitely established the spleen as a storage depot of blood cells, capable of increasing the oxygen-carrying capacity of the blood by the extrusion of considerable quantities of erythrocytes. Although these investigators worked almost entirely with lower animals, the experiments of Benhamou, Jude and Marchioni (1929) with the effects of exercise and epinephrin upon splenectomized human subjects and those of Yang and Chang (1930) upon human subjects with splenomegaly indicate that the spleen performs a similar function in man.

The sensitivity of the spleen to emotional disturbances was shown by Hargis and Mann (1925) in dogs and confirmed by Barcroft (1930) and by Izquierdo and Cannon (1928) demonstrating the fact that an emotional polycythemia may occur very abruptly. The same type of reaction was seen in human subjects by Benhamou, Marchioni and Nouchy (1929) using radiographs. As Arnold and Krzywanek (1928) have pointed out, since the venapuncture is distasteful to some individuals, the determination of an absolute resting value in human subjects may be difficult. The wide variation in the amount of decrease seen for various subjects in Series III may perhaps be explained on this basis.

Whether other areas of the vascular tract are also capable of storing and concentrating blood has long been a question. Erlanger's (1921) review article discusses the literature to 1921 on this question in connection with its bearing on relative blood volume changes. Lamson (1921) considered the liver responsible for epinephrin erythrocytosis. Kahlstorf and Ludwig (1931) also conclude, from their experiments upon guinea pigs and rabbits, in which india ink injected into the blood stream showed a delayed mixing with the blood of liver capillaries, that this organ acts in the capacity of a blood reservoir.

Rein (1933) and his collaborators, by measuring the inflow and outflow of blood entering the liver, showed that it is capable of withholding an amount of blood from the circulation equal to as much as half its own weight. Bauer, Dale, Poulsson and Richards (1932) have demonstrated the sluice mechanism which regulates blood outflow from the liver in dogs. Barcroft, Nisimaru and Ray (1932) conclude from their experiments with carbon monoxide that the liver may contain large quantities of blood which are capable of transfer, but that it is not a store, since a red corpuscle spends a relatively short time traversing the organ in comparison with the spleen. Barcroft, Benatt, Greeson and Nisimaru (1931) have also demonstrated by the carbon monoxide method that under certain conditions the subpapillary plexus of the skin may store considerable quantities of blood.

According to Rein (1933), the normal organism has a tendency to maintain the lowest degree of circulatory activity consistent with its requirement at any given time, and will accordingly withdraw blood into storage areas whenever possible. The investigations of Cook and Rose (1930) are in agreement with this view. They showed that in cats recovery of the contracted spleen following muscular activity commences within one minute after cessation of the exercise.

The drop in erythrocyte count, hemoglobin and packed cell volume seen in the subjects of Series III after a one-hour period of inactivity seems to represent an absolute decrease in the number of circulating erythrocytes, caused by the withdrawal of cells into storage, principally into the spleen, where Barcroft and Florey (1928) have shown concentration may occur through the drainage of fluid by lymphatics. Schennert and Krzywanek (1927) failed to find any evidence that the erythrocyte storage function had been taken over by any other organ in dogs which had been splenectomized one year previously. The efforts of Benhamou, Jude and Marchioni (1929) to produce erythrocytosis were likewise negative in human subjects with splenectomy of as long as three and six years duration.

The decrease in resting subjects probably represents the converse of the erythrocytosis which occurs in exercise, emotion, etc., both types of adjustment reflecting the delicate balance which at all times appears to adapt the oxygen-carrying capacity of the blood to the requirements of the tissues.

3. Diurnal Variations. It is possible that the changes which have been designated as "diurnal variations" may be only manifestations of splenic activity. This explanation is suggested by the observations of Rabinovitch and Strean (1924) who noticed that the variations in hemoglobin were very small in patients with advanced heart failure, and of Mills (1925) who found the same condition in patients with secondary anemia. Since the spleen contracts in response to anoxemia in the spinal cord, it is possible that no splenic reserve exists in such patients as those cited, in whom some degree of oxygen want is probably present. The constant hemoglobin level observed suggests abolition of the splenic discharge and re-storage of red cells described above.

D. THE DIRECTION OF FUTURE RESEARCH

The whole subject of diurnal variations and the "bone marrow rhythm" fluctuations of Sabin (1928), Cunningham, Doan and Kindwall (1925) need thorough investigation. Before a thorough study is possible, however, the limits of error in blood counting need clearer definition. It will also be necessary to ascertain the limit of error in the hematocrit methods employed. When these are known, it will then be necessary to learn what limits of variation exist in blood sampling itself, for the blood is probably not a homogeneous suspension of cells, and immediately consecutive samples will doubtless show considerable variation.

When these limits of error in technic are well known, serial studies in the erythrocyte and hemoglobin level will be able easily to establish or disprove the existence of constant diurnal variations and significant fluctuations due to bone marrow activity.

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REFERENCES

1. Arnold, A. and W. Krzywanek. 1928. Ein Weiterer Beitrag zur der Frage der Erythrocytenvermehrung in menschlichen Blut nach korperlicher Arbeit, Arch. f. d. ges. Physiol. 220:361.

2. Barcroft, J. 1930. Some Effects of Emotion on the Volume of the Spleen, J. Physiol. 68:375.

3. Barcroft, J. 1931. Stores of Blood, Vet. J. 87:466.

4. Barcroft, J., and H. W. Florey. 1928. Some Factors Involved in the Concentration of Blood in the Spleen, J. Physiol. 66:231.

5. Barcroft, J., A. Benatt, C. E. Greeson and Y. Nisimaru. 1931. The Rate of Blood Flow Through Cyanosed Skin, J. Physiol. 73:344.

6. Barcroft, J., Y. Nisimaru and G. B. Ray. 1932. Observations on the Time Taken for Corpuscles to Traverse the Liver, J. Physiol. 74:44.

7. Bauer, W., H. H. Dale, L. T. Poulsson and D. W. Richards. 1932. The Control of Circulation Through the Liver, J. Physiol. 74:343.

8. Benhamou, E., Jude and Marchioni. 1929. La Splenocontraction a l'Adrenaline chez l'Homme Normal, Compt. Rend. Soc. Biol. 100:456; La Splenocontraction a l'Effort chez l'Homme Normal, Ibid, 100:458.

9. Benhamou, E., Marchioni and Nouchy. 1929. La Splenocontraction a l'Emotion chez l'Homme Normal, Compt. Rend. Soc. Biol. 100:461.

10. Binet, L. 1930. La Rate Organe Reservoir, Paris.

11. Boerner, Fred. 1931. Standard Normals and Normal Ranges in Hematology, Am. J. Clin. Path. 1:391.

12. Broun, G. O. 1922. Blood Destruction During Exercise. I. Blood Changes Occurring in the Course of a Single Day of Exercise, J. Exp. Med. 36:481.

13. Cabigting, P. L. 1930. Blood Examination Among Normal Filipinos, Philippine Is. M. A. J. 10:319.

14. Cassinis, U. and L. Bracaloni. 1930. Ulterior Ricerche Sulla Curva Idremica a Riposo, Nella Marcia e Nella Corsa, Arch. di Fisiol. 28:128, 1930.

15. Chamberlain, W. P. 1911. The Red Blood Corpuscles and the Hemoglobin of Healthy Adult American Males Residing in the Philippines, Philippine J. Sc. 6:483.

16. Cook, S. F. and M. I. Rose. 1930. The Recovery of the Spleen from Contraction Induced by Exercise, Am. J. Physiol. 92:240.

17. Dill, D. B. 1931. Quoted by Price-Jones.

18. Dyke, S. C. 1929. Blood Standards. A Criticism of the Generally Accepted Normal Values, Lancet 1:681.

19. Emmons, W. F. 1927-28. The Interrelation of Number, Volume, Diameter and Area of Mammalian Erythrocytes, J. Physiol. 64:215.

20. Dunn, H. L. 1929. Application of Statistical Methods in Physiology, Physiol. Rev. 9:275.

21. Egdahl, A. 1923. Chronic Carbon Monoxide Poisoning, J. A. M. A. 81:282.

22. Emerson, C. P. 1907. The Blood of Normal Young Adults, Johns Hopkins Hosp. Bull. 18:29.

23. Emerson, C. P. 1921. Clinical Diagnosis, Philadelphia. p. 484.

24. Erlanger, J. 1921. Blood Volume and Its Regulation, Physiol. Rev. 1:177.

25. Foster, P. C. and J. R. Johnson. 1930-31. Oxygen Capacity and Hemoglobin Content of Normal Blood of Men, Proc. Soc. Exp. Biol. & Med. 28:929.

26. Gettler, A. O. and M. R. Mattice, 1933. The "Normal" Carbon Monoxide Content of the Blood, J. A. M. A. 100:92.

27. Goldhamer, S. M. and A. I. Fritzell. 1933. A Study of the Red Blood Cell Count and Hemoglobin in the Adolescent Male, J. Lab. & Clin. Med. 19:172.

28. Gram, H. C. and A. Norgaard. 1923. Relation Between Hemoglobin, Cell Count and Cell Volume in the Venous Blood of Normal Human Subjects, Arch. Int. Med. 31:164.

29. Haden, R. L. 1922. The Normal Hemoglobin Standard. J. A. M. A. 79:1496.

30. Haden, R. L. 1923. Accurate Criteria for Differentiating Anemias, Arch. Int. Med. 31:766, 1923.

31. Haden, R. L. 1925. The Volume and Hemoglobin Content of the Erythrocytes in Health and Disease, Folia Haemat. 31:113.

32. Haden, R. L. 1929. Geographic Variations in the Size of the Red Blood Cell, J. Lab. & Clin. Med. 14:1120.

33. Haden, R. L. 1930. The Technic of Determination of the Relative Mass, the Individual Cell Volume, and the Volume Index of the Erythrocytes of Man, J. Lab. & Clin. Med. 15:736.

34. Haden, R. L. 1933a. Personal Communication.

35. Haden, R. L. 1933b. Hemoglobin Standards, Am. J. Clin. Path. 3:85.

36. Haldane, J. 1901. The Colorimetric Determination of Hemoglobin, J. Physiol. 26:497.

37. Haldane, J. and J. L. Smith. 1900. The Mass and Oxygen Capacity of the Blood in Man, J. Physiol. 25:331.

38. Henson, H. B. and A. B. Hastings, 1933. The Effect of Smoking on the Carbon Monoxide Content of Blood, J. A. M. A. 100:1481.

39. Hargis, E. H. and F. C. Mann. 1925. A Plethysmographic Study of the Changes in Volume of the Spleen in the Intact Animal, Am. J. Physiol. 75:180.

40. Hawk, P. B. 1904. On the Morphological Changes in the Blood After Muscular Exercise, Am. J. Physiol. 10:384.

41. Horneffer, L. 1928. Das Blut des Menschen, mit neuren Methoden untersucht, Arch. f. d. ges. Physiol. 220:703.

42. Izquierdo, J. J. and W. B. Cannon. 1928. Studies on the Conditions of Activity in Endocrine Glands. XXIII. Emotional Polycythemia in Relation to Sympathetic and Medulliadrenal Action on the Spleen, Am. J. Physiol. 84:545.

43. Jenkins, C. E. 1932. The Hemoglobin Concentration of Workers Connected with Internal Combustion Engines, J. Hygiene, 32:406.

44. Jenkins, C. E. and C. S. D. Don, 1933. The Hemoglobin Concentration of Normal English Males and Females, J. Hyg. 33:36.

45. Kahlstorf, A. and H. Ludwig. 1931. Tierexperimentelle Untersuchungen zur Localisation der Blutdepots, Ztschr. f.d.ges. exper. Med. 76:804.

46. Kamocki, W. 1924. Uber die Zahl der roten Blutkorperchen bei gesunden erwachsenen Menschen, Virchow's Arch. 253:386.

47. Lamson, Paul D. 1921. The Part Played by the Liver in the Regulation of Blood Volume and Red Corpuscle Concentration in Acute Physiological Conditions, J. Pharm. Exp. Therap. 16:125.

48. Lee, F. W., E. B. Carrier and G. H. Whipple. 1922. Simultaneous Determinations of Plasma and Hemoglobin Volumes. Influence of Fluids by Mouth and Vigorous Exercise. Am. J. Physiol. 61:149.

49. Mills, E. S. 1925. Hourly Hemoglobin Variations in Anemias, Arch. Int. Med. 35:760, 1925.

50. Nasmith, G. G. and D. A. L. Graham. 1906. The Haematology of Carbon-Monoxide Poisoning, J. Physiol. 35:32.

51. Orias, O. 1930a. La Cantidad de Hemoglobina Sanguinea en Hombres y Mujeres Adultos Sanos en la Republica Argentina, Rev. Soc. Argent. de Biol. 6:395.

52. Orias, O. 1930b. Factores Que Influencian la Cantidad de Hemoglobina de la Sangre, Rev. Soc. Argent. de Biol. 6:410.

53. Orias, O. 1930c. Teneur du sang en Hemoglobine chez l'Homme en Argentine. Facteurs qui l'influencent, Compt. Rend. Soc. Biol. 105:711.

54. Osgood, E. E. 1926. Hemoglobin, Color Index, Saturation Index and Volume Index Standards, Arch. Int. Med. 37:685.

55. Osgood, E. E. and H. D. Haskins. 1927. Relation Between Cell Count, Cell Volume and Hemoglobin Content of Venous Blood of Normal Young Women, Arch. Int. Med. 39:643.

56. Parjono, W. Radsma and M. Joenoes. 1930. Das Sauerstoffbindungsvermogen, der Eisengehalt und der Hemoglobingehalt des Blutes, bei den Tropenbewohnern, Arch. Neerland. de Physiol. 15:73.

57. Parodi, A. S. 1930. Numero de Reitrocitos y Volumen Globular Humanos en Buenos Aires, Rev. Soc. Argent.de Biol. 6:426.

58. Pearl, R. and J. R. Miner. 1927. A Biometric Study of the Relative Cell Volume of Human Blood, in Normal and Tuberculous Males, Bull. Johns Hopkins Hosp. 40:3.

59. Peters, J. P. and D. D. Van Slyke. 1931. Quantitative Clinical Chemistry, Vol. 1, Baltimore, p. 544.

60. Price-Jones, C. 1931. The Concentration of Hemoglobin in Normal Human Blood, J. Path. & Bac. 34:779.

61. Priestley, J. G. 1916. The Regulation of Excretion of Water by the Kidneys, J. Physiol. 50:304.

62. Rabinovitch, I. M. and G. Stream. 1924. Hemoglobin Content of the Red Blood Cells in Relation to Their Surface Area, Arch. Int. Med. 34:124.

63. Raposo, L. S. and A. Fevereiro, 1931. Mecanisme de l'Erythrocytose. L'Hypoglobulie Digestive. Compt. Rend. Soc. Biol. 107:1173.

64. Rein, H. 1933. Die Blutreservoire des Menschen, Klin. Wchnschr. 12:1.

65. Rowntree, L. G., G. E. Brown and G. M. Roth. 1929. The Volume of the Blood and Plasma, Philadelphia, p. 52-56.

66. Rud, E. J. 1922-23. Le Nombre des Globules Rouges chez les Sujets Normaux et Leurs Variations dans les Diverses Conditions Physiologiques, Acta Med. Scand. 57:325.

67. Sabin, F. R. 1928. Bone Marrow, Physiol. Rev. 8:191.

68. Sabin, F. R., R. S. Cunningham, C. A. Doan and J. A. Kindwall, 1925. The Normal Rhythm of the White Blood Cells, Bull. Johns Hopkins Hosp. 37:14.

69. Sackett, G. E. 1924-25. Hemoglobin and Iron in Blood, J. Lab. & Clin. Med. 10:1018.

70. Sayers, R. R., W. P. Yant, E. Levy, and W. B. Fulton. 1929. Effect of Repeated Daily Exposure of Several Hours to Small Amounts of Automobile Exhaust Gas, Pub. Health Bull. 186.

71. Scheunert, A. and F. W. Krzywanek. 1927. Weiteres uber die Milz als Bultkorperchenreservoir, Arch. f. d. ges. Physiol. 217:261.

72. Schmoll, G. 1931. Das Blut des Menschen, mit neuren Methoden untersucht, Arch. f. d. ges. Physiol. 227:160.

73. Sokhey, S. S. 1930. Quoted by Price-Jones.

74. Solarino, G. 1931. Sul Comportamento del Contenuto in Acqua del Sangue Durante Il Periodo Digestivo e Sui Fattori Che lo Determinano, Boll. Soc. Ital. di Biol. Sper. 6:304, 1931.

75. Solarino, G. and V. Cattaino. 1930. Eritropenia digestiva e fattori che la determinano, Boll. Soc. Ital. Biol. Sperim. 5:985.

76. Smith, C. 1931. Normal Variations in Erythrocyte and Hemoglobin Values in Women, Arch. Int. Med. 47:206.

77. Stebbins, G. G. and C. D. Leake. 1927. Diurnal Variations in Blood Specific Gravity in Normal Dogs and Humans, Am. J. Physiol. 80:639.

78. Tenconi, J. 1931. Relations entre le taux de l'hemoglobine, le volume et le nombre des Hematies dans les anemies et les polyglobulies, Compt. Rend. Soc. Biol. 108:133.

79. Thompson, W. O., P. K. Thompson and M. E. Dailey. 1927-28. The Effect of Posture Upon the Composition and Volume of the Blood in Man, J. Clin. Inves. 5:573.

80. Thorner, W. 1930. Uber die Zellelemente des Blutes im Trainingszustand. Untersuchunt an Olympiakampfern in Amsterdam, Arbeitsphysiologie, 2:116.

81. Tien, C. Y. 1931. On the Normal Blood Picture of Chinese, J. Oriental Med. 14:40.

82. Walters, O. S. 1933a. Inactivity as a Factor in Erythrocyte and Hemoglobin Variations, Am. J. Physiol. 105:96.

83. Walters, O. S. 1933b. The Influence of the "Basal Condition" on the Quantity of Circulating Erythrocytes and Hemoglobin, Bull. Univ. of Kans. Sch. Med. 4:6, (December).

84. Walters, O. S. 1934a. The Erythrocyte Count, Quantity of Hemoglobin and Volume of Packed Cells in Normal Human Subjects During Muscular Inactivity, Am. J. Physiol. 108:118.

85. Walters, O. S. 1934b. A Comparison of Erythrocyte Count, Total Hemoglobin and Corpuscular Hemoglobin in Smokers and Non-Smokers, J. A. M. A. (In Press).

86. Walters, O. S. 1934c. Normal Erythrocyte, Hemoglobin and Packed Cell Volume Standards in Young Men, J. Lab. & Clin. Med. (In Press).

87. Walters, O. S. and P. H. Woodard. 1933. Observations on the Blood of Normal Human Subjects During Fetal Liver Feeding, Am. J. Physiol. 104:364.

88. Waterfield, R. L. 1931. Effects of Posture on Circulating Blood Volume, J. Physiol. 72:110.

89. Williamson, C. S. 1916. Influence of Age and Sex on Hemoglobin, Arch. Int. Med. 18:505.

90. Wintrobe, M. M. 1928-29. Hemoglobin Standards in Normal Men, Proc. Soc. Exper. Biol. & Med. 26:848.

91. Wintrobe, M. M. 1929. The Volume and Hemoglobin Content of the Red Blood Corpuscle, Am. J. Med. Sc. 177:513.

92. Wintrobe, M. M. 1931. The Direct Calculation of the Volume and Hemoglobin Content of the Erythrocyte, Am. J. Clin. Path. 1:147.

93. Wintrobe, M. M. 1930. Blood of Normal Young Women Residing in a Sub-Tropical Climate, Arch. Int. Med. 45:287.

94. Wintrobe, M. M. 1933. Blood of Normal Men and Women, Bull. Johns Hopkins Hosp. 53:118.

95. Wintrobe, M. M. and M. W. Miller. 1929. Normal Blood Determinations in the South, Arch. Int. Med. 43:96.

96. Yang, C. S. and H. C. Chang. 1930. The Effect of Adrenalin on the Circulating Blood Volume in Individuals with Normal and Enlarged Spleens and After Splenectomy, Chinese J. Physiol. 4:21.

A P P E N D I X

TABLES I TO XI

TABLE I

ERYTHROCYTE COUNT IN VARIOUS LOCALITIES

INVESTIGATOR	LOCALITY	Men			Women		
		NO. SUBJ.	AGE RANGE	ERYTH. COUNT	NO. SUBJ.	AGE RANGE	ERYTH. COUNT
Chamberlain	Philippine Is.	702	---	5.20	---	---	---
Emerson	Baltimore	176	20-25	5.00	---	---	---
Haden	Kansas City	70	18-50	4.95	30	18-50	4.38
Haden (Student Counts)	Kansas City	250	---	5.00	---	---	---
Komocki	Poland	17	20-40	5.97	---	---	---
Sackett	Kansas City	14	---	5.09	---	---	---
Osgood and Haskins	Oregon	137	19-30	5.39	100	18-30	4.80
Horneffer	Germany	40	19-29	4.97	---	---	---
Wintrobe and Miller	New Orleans	100	20-30	5.85	50	17-30	4.93
Parodi	Buenos Aires	50	18-30	5.50	---	---	---
Cabigting	Philippine Is.	22	15 up	4.75	179	15 up	4.26
Thorner (Olympic Ath.)	Amsterdam	42	20-30	5.24	---	---	---
Schmoll	Germany	--	---	---	40	19-30	4.56
Foster and Johnson	New Orleans	115	18-30	5.26	---	---	---
Tenconi	Buenos Aires	50	---	5.30	---	---	---
Price-Jones	London	100	---	5.43	---	---	---
Tien (Chinese)	Manchuria	320	19-64	5.12	---	---	---
Wintrobe	Baltimore	86	---	5.48	101	---	4.82
Walters	Kansas	100	20-30	4.84	---	---	---

TABLE II

HEMOGLOBIN IN VARIOUS LOCALITIES

INVESTIGATOR (Method)	LOCALITY	Men			Women		
		NO. SUBJ.	AGE RANGE	HEMO-GLOBIN	NO. SUBJ.	AGE RANGE	HEMO-GLOBIN
Haden (Van Slyke)	Kansas City	70	18-50	15.34	30	18-50	13.37
Osgood-Haskins (Mod. Newc.-Van Slyke)	Oregon	137	19-30	15.76	100	18-30	13.7
Horneffer (Burker)	Germany	40	19-29	16.03	---	---	---
Wintrobe-Miller (Newc.-V.S.)	New Orleans	100	20-30	17.0	50	17-30	13.76
Orias (Newcomer)	Argentine (Soldiers)	1104	---	14.46	---	---	---
Orias (Newc.-V.S.)	Argentine (Officers)	65	---	15.06	---	---	---
Orias (Newc.-V.S.)	Argentine (Students)	82	---	15.3	116	---	13.93
Parodi (Newcomer)	Argentine	50	18-30	15.4	---	---	---
Sokhey (Van Slyke)	Bombay	121	---	15.3	101	---	12.9
Parjono, et al. (Van Slyke)	Java (Poorer Natives)	19	---	14.63	---	---	---
Parjono, et al. (Van Slyke)	Java (Students and Doctors)	16	---	16.12	---	---	---
Tenconi (Newc.-V.S.)	Argentine	50	---	14.8	---	---	---
Thorner (Burker)	Amsterdam (Olympic Ath.)	42	20-30	14.42	---	---	---
Foster-Johnson (Van Slyke)	New Orleans	115	18-30	15.63	---	---	---
Price-Jones (Van Slyke)	London	100	20-61	14.5	---	---	---
Dill (Van Slyke)	Boston	40	---	15.4	---	---	---
Schmoll (Burker)	Germany	---	---	---	40	20-30	13.70
Jenkins-Don (Burker-V.S.)	England	118	---	15.85	---	---	---
Wintrobe (Newc.-V.S.)	Baltimore	86	---	16.0	101	---	14.1
Walters (Newc.-V.S.)	Kansas	100	20-30	15.12	---	---	---

TABLE III

VOLUME OF PACKED CELLS IN VARIOUS LOCALITIES

		Men		Women	
Investigator	Locality	Number Subjects	Volume	Number Subjects	Volume
HADEN	Kansas City	70	45.5	30	39.8
OSGOOD	Oregon	137	46.4*	100	42.4*
PEARL-MINER	Milwaukee	272	45.59	--	--
WINTROBE-MILLER	New Orleans	100	46.5	50	39.5
FOSTER-JOHNSON	New Orleans	40	46.7	--	--
WINTROBE	Baltimore	86	47.0	101	42.0
WALTERS	Kansas	100	46.5	--	--

TABLE IV

VOLUME AND HEMOGLOBIN COEFFICIENTS IN VARIOUS LOCALITIES

	Number Subjects	Sex	Hemoglobin Coeff.	Hemoglobin Index	Volume Coeff.	Volume Index	Satur. Index
HADEN	70	M	15.50	1.01	46	1.00	1.01
HADEN	30	F	15.26	.99	45.5	.99	.99
OSGOOD	137	M	14.66	1.00	43.0	1.00	1.00
OSGOOD-HASKINS	100	F	14.3	1.00	42.8	1.00	1.00
WINTROBE-MILLER	100	M	14.53	1.00	39.9	.97	1.02
WINTROBE	50	F	13.97	.98	40.3	.93	1.05
WALTERS	100	M	15.71	1.01*	48.3	1.02	.99

TABLE V

CORPUSCULAR VALUES IN MEN AND WOMEN

INVESTIGATOR	Men				Women			
	NO. SUBJ.	CORP. VOL.	CORP. HB	CORP. HB CON.	NO. SUBJ.	CORP. VOL.	CORP. HB	CORP. HB CON.
Haden	70	92	31.0	33.7	30	91	30.5	33.5
Osgood and Haskins	137	86.1	29.2	33.1	100	88.5	28.5	32.2
Horneffer	40	--	32.4	--	--	--	--	--
Wintrobe and Miller	100	79.8	29.2	36.6	50	80.1	28.0	35.2
Thorner *	42	--	27.5	--	--	--	--	--
Price-Jones*	100	--	26.7	--	--	--	--	--
Foster and Johnson	100	85.9	30.02	34.8	--	--	--	--
Schmoll	--	--	--	--	40	--	30.2	--
Wintrobe*	86	85.8	29.2	34.01	101	87.1	29.3	33.6
Bie and Moller	10	83.9	26.7	31.8	10	81.7	28.1	34.4
Gram and Norgaard	7	85.2	27.6	32.4	6	88.0	27.9	31.7
Tenconi*	50	--	27.9	--	--	--	--	--
Walters	100	96.5	31.4	32.4	--	--	--	--

TABLE VI

COMPARISON OF ERYTHROCYTE COUNT, TOTAL HEMOGLOBIN AND CORPUSCULAR HEMOGLOBIN IN 100 SMOKERS AND NON-SMOKERS

Series I -- Sampled After Random Activity

	No. Subjects	Erythrocytes (Million)	Total Hemoglobin (Gm. per 100 c.c. Blood)	Corpuscular Hemoglobin (Micromicrograms)
NON-SMOKERS	28	4.77 ± .0413	15.23 ± .1589	32.1 ± .4538
SMOKERS	11	4.88 ± .0583	14.51 ± .2943	29.9 ± .6288
Difference		.11 ± .0714	.72 ± .3344	2.2 ± .7754

Series II -- Sampled After 1/2 Hour Rest

	No. Subjects	Erythrocytes (Million)	Total Hemoglobin (Gm. per 100 c.c. Blood)	Corpuscular Hemoglobin (Micromicrograms)
NON-SMOKERS	25	4.59 ± .0432	13.46 ± .0914	29.6 ± .3134
ALL SMOKERS	36	4.58 ± .0342	14.01 ± .1303	30.6 ± .2293
"HEAVY" SMOKERS	20	4.52 ± .0496	13.86 ± .1804	30.7 ± .3264
Difference - Smokers and Non-Smokers		.01 ± .0551	.55 ± .1604	1.0 ± .3883
Difference - "Heavy" Smokers and Non-Smokers		.07 ± .0657	.40 ± .2022	1.1 ± .4524

TABLE VII

BLOOD FINDINGS IN 100 NORMAL MEN AGED 20 TO 30

SERIES I

No.	Age	Erythro-cytes	Total Hb	Hb Coeff.	Vol. Pkd. Cells	Vol. Coeff.	Corp. Vol.	Corp. Hb.	Corp. Hb. Conc.	Color Index	Volume Index	Satur. Index
1	22	4.31	13.44	15.59	48.8	56.6	113.2	31.2	27.5	1.00	1.19	0.83
2	21	5.33	13.44	12.61	46.6	43.7	87.4	25.2	28.8	0.81	0.92	0.88
3	21	5.29	15.64	14.78	44.0	41.6	83.1	29.6	35.5	0.94	0.88	1.08
4	28	4.83	15.90	16.46	48.9	50.6	101.2	32.5	32.5	1.05	1.05	0.99
5	22	4.93	15.64	15.86	44.6	45.2	90.4	31.7	35.1	1.02	0.96	1.06
6	20	4.72	17.03	18.04	46.1	48.8	97.7	36.1	36.9	1.15	1.03	1.12
7	23	4.33	15.90	18.36	43.6	50.3	100.7	36.7	36.5	1.17	1.06	1.11
8	27	4.72	14.03	14.86	44.6	47.2	94.5	29.7	31.5	0.95	0.99	0.96
9	20	4.36	16.74	19.20	43.5	49.9	99.8	38.4	38.4	1.22	1.06	1.16
10	20	5.09	14.90	14.62	45.3	44.5	89.0	29.3	32.9	0.94	0.94	1.00
11	21	4.66	16.17	17.35	46.8	50.2	100.4	34.7	34.6	1.11	1.06	1.05
12	20	4.47	15.39	17.22	43.4	48.6	97.1	34.4	35.5	1.11	1.03	1.08
13	23	4.10	15.90	19.39	44.8	54.6	109.3	38.8	35.5	1.24	1.16	1.07
14	20	4.77	16.45	17.24	47.9	50.2	100.4	34.5	34.3	1.11	1.06	1.05
15	20	4.40	14.90	16.93	41.1	46.7	93.4	33.9	36.3	1.09	0.99	1.10
16	20	5.05	15.90	15.74	50.0	49.5	99.0	31.4	31.8	1.01	1.04	0.97
17	22	4.29	14.90	17.37	47.4	55.3	110.5	34.7	31.4	1.12	1.16	0.96
18	20	5.38	15.90	14.78	48.8	45.3	90.7	29.6	32.6	0.95	0.96	0.99
19	21	4.96	17.03	17.17	45.7	46.1	92.1	34.3	27.3	1.10	0.97	1.14
20	20	4.91	16.17	16.47	48.8	49.7	99.4	32.9	33.1	1.06	1.05	1.01
21	20	4.53	17.66	19.49	47.0	51.9	103.8	39.0	37.6	1.24	1.09	1.14
22	21	5.45	15.14	13.89	43.1	39.5	79.1	27.8	35.1	0.89	0.83	1.07
23	21	4.56	17.34	19.01	50.0	54.8	109.6	38.0	34.7	1.22	1.15	1.06
24	20	4.62	17.34	18.77	48.7	52.7	105.4	37.5	35.6	1.21	1.12	1.08
25	20	4.50	15.14	16.82	45.0	50.0	100.0	33.6	33.6	1.08	1.06	1.02
26	20	5.00	15.90	15.90	44.4	44.4	88.8	31.8	35.8	1.02	0.94	1.09
27	20	5.31	13.44	12.66	44.2	41.6	83.2	25.3	30.4	0.81	0.88	0.92
28	22	4.75	15.64	16.46	45.7	48.1	96.2	32.9	34.2	1.05	1.01	1.04
29	21	4.83	13.63	14.11	43.1	44.6	89.2	28.2	28.2	0.90	0.94	0.96
30	20	4.54	15.64	17.23	43.3	47.7	95.4	34.4	36.1	1.10	1.00	1.10
31	25	4.28	15.90	18.58	44.6	52.1	104.2	37.1	35.7	1.18	1.09	1.08
32	20	4.82	14.90	15.46	42.2	43.8	87.6	30.9	35.3	1.00	0.93	1.08
33	22	4.75	15.64	16.46	46.8	49.3	98.5	32.9	33.4	1.05	1.04	1.01
34	20	4.56	15.90	17.44	48.0	52.6	105.3	34.9	33.1	1.12	1.11	1.01
35	22	4.91	16.74	17.05	50.0	50.9	101.8	34.1	33.5	1.09	1.07	1.02
36	20	4.50	15.14	16.82	43.9	48.8	97.6	33.6	34.5	1.08	1.03	1.04
37	21	4.42	13.63	15.42	47.1	53.3	106.6	30.8	28.9	0.99	1.13	0.88
38	20	4.60	14.90	16.20	46.5	50.5	101.1	32.4	32.0	1.04	1.06	0.98
39	20	4.52	13.07	14.46	47.9	53.0	106.0	28.9	27.3	0.92	1.11	0.83
40	21	4.72	17.34	18.37	46.8	49.6	99.2	36.7	37.1	1.18	1.05	1.12
41	23	5.06	15.14	14.96	46.1	45.6	91.1	29.9	32.8	0.96	0.96	1.00
42	21	4.72	14.22	15.05	43.7	46.3	92.6	30.1	32.5	0.97	0.98	0.99
43	25	5.13	13.82	13.46	42.7	41.6	83.2	26.9	32.4	0.86	0.87	0.99
44	21	5.08	14.44	14.21	47.4	46.7	93.3	28.4	30.5	0.92	0.99	0.93
45	26	4.88	14.22	14.53	46.8	48.0	95.9	29.1	30.4	0.93	1.01	0.92
46	22	5.55	16.45	14.82	47.0	42.3	84.7	29.5	35.0	0.95	0.89	1.07
47	21	4.56	13.44	14.74	41.1	45.1	90.1	29.5	32.7	0.95	0.96	0.99
48	20	5.01	14.67	14.64	48.4	48.3	96.6	29.3	30.3	0.94	1.02	0.92
49	22	5.10	13.63	13.36	45.9	45.0	90.0	26.7	29.9	0.85	0.95	0.90
50	28	5.33	13.82	12.95	49.4	46.3	92.7	25.9	28.0	0.83	0.97	0.86

TABLE VII

(Continued)

No.	Age	Erythro-cytes	Total Hb	Hb Coeff.	Vol. Pkd. Cells	Vol. Coeff.	Corp. Vol.	Corp. Hb	Corp. Hb. Conc.	Color Index	Volume Index	Satur. Index
51	23	4.49	14.03	15.59	47.4	52.8	105.6	31.2	29.6	1.00	1.11	0.90
52	24	4.88	15.14	15.51	48.9	50.1	100.2	31.0	31.0	0.99	1.05	0.94
53	20	4.89	16.74	17.12	50.0	51.1	102.2	34.2	33.5	1.08	1.07	1.02
54	26	4.88	15.90	16.29	43.9	45.0	90.0	32.6	36.2	1.04	0.95	1.09
55	23	4.99	17.03	17.06	49.6	49.7	99.4	34.1	34.3	1.09	1.05	1.04
56	25	4.54	15.14	16.68	46.9	51.7	103.3	33.3	32.3	1.07	1.09	0.98
57	21	4.27	13.63	15.96	46.8	54.8	109.6	31.9	29.1	1.02	1.16	0.88
58	21	4.88	13.25	13.58	43.5	44.6	89.1	27.2	30.5	0.87	0.94	0.92
59	21	4.97	15.64	15.73	45.9	46.2	92.4	31.7	34.1	1.01	0.98	1.03
60	23	4.80	15.39	16.03	44.7	46.6	93.1	32.1	34.4	1.03	0.98	1.05
61	20	4.74	13.63	14.38	43.5	45.9	91.8	28.8	31.3	0.92	0.97	0.95
62	20	4.67	13.44	14.39	45.6	48.8	97.6	28.8	29.5	0.92	1.03	0.90
63	20	5.03	14.03	13.95	47.5	47.2	94.4	27.9	29.5	0.89	0.99	0.90
64	20	4.89	14.44	14.77	48.9	50.0	100.0	29.5	29.5	0.95	1.05	0.90
65	21	4.53	14.67	16.15	45.8	50.6	101.2	32.4	32.0	1.03	1.07	0.97
66	22	4.99	13.44	13.47	47.8	47.9	95.8	26.9	28.1	0.86	1.01	0.85
67	22	4.85	13.82	14.24	47.9	49.4	98.8	28.5	28.9	0.92	1.04	0.88
68	22	5.45	12.89	11.83	51.1	46.9	93.8	23.7	25.2	0.76	0.99	0.77
69	20	5.14	13.07	12.71	48.0	46.7	93.4	25.4	27.2	0.82	0.98	0.83
70	20	5.23	16.17	15.46	44.7	42.7	85.5	30.9	36.2	0.99	0.90	1.11
71	23	4.83	16.74	17.33	46.5	48.2	96.3	34.7	36.0	1.10	1.01	1.08
72	20	4.92	14.03	14.26	40.7	41.4	82.7	28.5	34.5	0.92	0.88	1.05
73	30	4.68	18.00	19.23	51.6	55.1	110.3	38.5	34.9	1.22	1.15	1.06
74	22	4.68	14.90	15.92	46.0	49.2	98.3	31.8	32.4	1.02	1.04	0.99
75	21	5.08	18.70	18.41	51.0	50.2	100.4	36.8	36.7	1.18	1.06	1.11
76	21	4.87	15.39	15.80	45.1	46.3	92.6	31.6	34.1	1.02	0.98	1.04
77	20	5.17	14.56	14.08	48.8	47.2	94.4	28.2	29.8	0.90	1.00	0.90
78	22	4.86	15.02	15.45	45.0	46.3	92.6	30.9	33.4	0.99	0.98	1.01
79	20	5.15	15.14	14.70	48.5	47.1	94.2	29.4	31.2	0.94	0.99	0.95
80	21	4.61	14.13	15.33	44.4	48.9	96.3	30.7	31.8	0.99	0.98	0.97
81	20	4.27	13.63	15.96	49.3	57.7	115.5	31.9	27.6	1.02	1.22	0.84
82	21	4.43	13.92	15.71	48.7	55.0	109.9	31.4	28.6	1.00	1.15	0.86
83	21	4.90	15.90	16.22	48.8	50.0	99.6	32.4	32.6	1.04	1.05	0.99
84	25	4.94	15.39	15.58	46.9	47.5	94.9	31.2	32.8	1.00	1.00	1.00
85	22	4.99	14.44	14.47	47.4	47.5	94.9	28.9	30.5	0.93	1.00	0.93
86	26	5.05	14.44	14.30	48.0	47.5	95.0	28.6	30.1	0.92	1.00	0.92
87	22	5.39	17.34	16.09	53.8	49.9	99.8	32.2	32.2	1.03	1.06	0.97
88	26	4.32	14.90	17.25	45.7	52.9	105.8	34.5	32.6	1.12	1.13	0.99
89	23	5.19	13.72	13.22	49.0	47.2	94.4	26.4	28.0	0.85	0.99	0.85
90	26	5.05	14.03	13.89	44.4	44.0	87.9	27.8	31.6	0.89	0.93	0.96
91	24	4.78	14.67	15.35	44.7	46.8	93.5	30.7	32.8	0.98	0.98	1.00
92	28	4.95	14.90	15.05	43.5	44.0	87.9	30.0	34.3	0.97	0.93	1.04
93	29	4.85	13.82	14.25	49.0	50.5	101.0	28.5	28.2	0.92	1.06	0.86
94	22	4.86	14.56	14.98	45.0	46.4	92.6	30.0	32.4	0.96	0.98	0.98
95	26	4.58	15.02	16.40	47.4	51.7	103.5	32.8	31.7	1.04	1.09	0.96
96	21	5.11	16.02	15.68	48.2	47.2	94.3	31.4	33.2	1.01	1.00	1.01
97	21	5.35	16.59	15.51	47.9	44.8	89.5	31.0	34.6	0.99	0.94	1.05
98	27	4.61	14.67	15.91	44.4	48.2	96.3	31.8	33.0	1.02	1.02	1.00
99	23	5.23	14.56	13.91	49.5	47.3	94.6	27.8	29.4	0.89	0.99	0.89
100	25	5.19	16.31	15.71	46.5	44.8	89.6	31.4	35.1	1.01	0.94	1.07
MEAN		4.84	15.12	15.71	46.5	48.3	96.5	31.4	32.4	1.01	1.02	0.99

TABLE VIII

BLOOD FINDINGS IN 80 NORMAL MEN AGED 20-30, SAMPLED AFTER A 1/2 HOUR PERIOD OF INACTIVITY -- SERIES II

Subject No.	Erythrocytes	Total Hemoglobin	Total Vol. Packed Cells*	Corp. Volume	Corp. Hemoglobin	Corp. Hb. Conc.
101	4.91	13.64	45.3	92.3	27.8	30.1
102	4.66	13.44	41.2	88.4	28.8	32.6
103	4.39	13.25	42.8	97.5	30.9	31.0
104	4.58	13.64	44.6	97.4	29.8	30.6
105	4.42	13.66	44.2	100.0	30.9	30.9
106	4.03	12.73	42.4	105.2	31.6	30.0
107	3.85	13.04	44.6	115.8	33.9	29.2
108	4.06	13.38	44.1	108.6	33.0	30.3
109	4.01	12.98	45.5	113.5	32.4	28.5
110	4.65	14.71	46.8	100.6	31.6	31.4
111	4.65	14.34	45.4	97.6	30.8	31.6
112	4.45	12.81	43.0	96.7	28.8	29.8
113	4.81	13.92	48.0	99.8	29.0	29.0
114	4.87	12.63	48.4	99.4	25.9	26.1
115	4.80	13.63	45.0	93.8	28.4	30.3
116	4.59	14.13	45.6	99.3	30.8	31.0
117	4.31	13.63	42.1	97.7	31.6	32.4
118	4.56	13.92	45.6	100.0	30.5	30.5
119	4.57	12.55	40.9	89.5	27.5	30.7
120	4.42	13.63	43.0	97.3	30.8	31.7
121	4.66	14.79	47.8	102.6	31.7	30.9
122	4.66	13.25	42.7	91.6	28.4	31.0
123	4.92	13.25	46.0	93.5	26.9	28.8
124	4.41	13.53	42.1	95.5	30.7	32.1
125	3.81	10.20	37.6	98.7	26.8	27.1
126	4.82	12.63	47.0	97.5	26.2	26.9
127	4.47	12.31	45.6	102.0	27.5	27.0
128	4.07	11.29	42.5	104.4	27.7	26.6
129	4.57	12.07	43.9	96.1	26.4	27.5
130	4.56	13.07	46.7	102.4	28.7	28.0
131	4.80	13.34	46.3	96.5	27.8	28.8
132	4.76	12.81	43.4	91.2	26.9	29.5
133	4.96	13.27	45.5	91.7	26.8	29.2
134	4.57	13.63	41.1	89.9	29.8	33.2
135	4.89	14.13	47.5	97.1	28.9	29.7
136	5.00	14.13	43.5	87.0	28.3	32.5
137	4.98	14.46	45.4	91.2	29.0	31.9
138	4.55	12.89	45.0	98.9	28.3	28.6
139	4.62	14.56	42.2	91.3	31.5	34.5
140	4.44	13.63	41.9	94.4	30.7	32.5
141	4.59	14.13	43.4	94.6	30.8	32.6
142	4.14	12.47	39.5	95.4	30.1	31.6
143	4.53	13.44	41.7	92.1	29.7	32.2
144	4.86	13.92	43.0	88.5	28.6	32.4
145	4.90	14.56	45.1	92.0	29.7	32.3

TABLE VIII — (Continued)

Subject No.	Erythro-cytes	Total Hemoglobin	Total Vol. Packed Cells	Corp. Volume	Corp. Hemoglobin	Corp. Hb Conc.
146	4.99	15.26	46.1	92.4	30.6	33.1
147	5.07	14.22	42.9	84.6	28.0	33.1
148	3.97	14.21	43.8	110.3	35.8	32.4
149	4.13	13.44	48.8	118.2	32.5	27.5
150	4.62	14.22	42.7	92.4	30.8	33.3
151	4.61	13.92	41.9	90.9	30.2	33.2
152	4.98	15.03	44.3	89.0	30.2	33.9
153	4.37	14.34	44.4	101.6	32.8	32.3
154	4.64	14.56	45.7	98.5	31.4	31.9
155	4.94	15.51	46.6	94.3	31.4	33.3
156	4.93	15.39	45.3	91.9	31.2	34.0
157	4.20	14.13	41.6	99.0	33.6	34.0
158	4.92	16.51	47.3	96.1	33.6	34.9
159	4.18	13.72	42.3	101.2	32.8	32.4
160	4.92	14.56	43.2	87.8	29.6	33.7
161	4.16	12.15	39.0	93.8	29.2	31.2
162	4.23	12.41	38.2	90.3	29.3	32.5
163	4.74	16.02	43.7	92.2	33.8	36.7
164	4.64	14.68	45.7	98.5	31.6	32.1
165	4.21	13.63	40.0	95.0	32.4	34.1
166	4.92	14.76	43.6	88.6	30.0	33.9
167	4.87	14.34	45.3	93.0	29.4	31.7
168	4.98	16.02	45.8	92.0	32.2	35.0
169	3.82	12.89	40.4	105.8	33.7	31.9
170	4.47	13.72	41.3	92.4	30.7	33.2
171	4.59	15.39	43.3	94.3	33.5	35.5
172	4.41	13.44	42.7	96.8	30.5	31.5
173	4.66	14.56	45.6	97.9	31.2	31.9
174	4.42	13.92	43.1	97.5	31.5	32.3
175	4.54	13.92	42.3	93.2	30.7	32.9
176	4.83	14.03	40.8	84.5	29.0	34.4
177	4.45	13.25	41.8	93.9	29.8	31.7
178	4.65	13.07	42.2	90.8	28.1	31.0
179	4.95	13.82	45.4	91.7	27.9	30.4
180	4.41	12.89	41.2	93.4	29.2	31.3
Mean	4.569	13.742	43.790	96.13	30.14	31.42

TABLE IX

COMPARISON OF SERIES I AND II

	After Random Activity Subjects 1-80	After Half Hour Rest Subjects 81-160	Difference
ERYTHROCYTES	4,820,000	4,570,000	250,000
HEMOGLOBIN	15.17	13.74	1.43
VOLUME PACKED CELLS	46.3	43.8	2.5
MEAN CORP. VOLUME	96.2	96.1	.1
MEAN CORP. HEMOGLOBIN	31.6	30.1	1.5
MEAN CORP. HEMOGLOBIN CONC.	32.6	31.4	1.2

TABLE X

ERYTHROCYTE COUNT, QUANTITY OF HEMOGLOBIN AND PACKED CELL VOLUME FOR 20 SUBJECTS BEFORE AND AFTER A ONE-HOUR PERIOD OF INACTIVITY

Subject No.	Erythrocyte Count			Quantity of Hemoglobin			Packed Cell Volume		
	Before	After	Decr. or Increase	Before	After	Decr. or Increase	Before	After	Decr. or Increase
81	4.27	4.21	.06	13.63	13.63	.00	49.3	46.8	2.5
82	4.43	4.19	.24	13.92	13.92	.00	48.7	44.6	4.1
83	4.90	4.43	.47	15.90	13.82	2.08	48.8	43.6	5.2
84	4.94	4.36	.58	15.39	13.82	1.57	46.9	42.8	4.1
85	4.99	4.53	.46	14.44	13.72	.72	47.4	45.9	1.5
86	5.05	4.59	.46	14.44	15.39	<u>.95</u>	48.0	47.4	.6
87	5.39	4.99	.40	17.34	15.90	1.44	53.8	50.8	3.0
88	4.32	4.26	.06	14.90	13.82	1.08	45.7	45.0	.7
89	5.19	4.41	.78	13.72	13.72	.00	49.0	45.7	3.3
90	5.05	4.76	.29	14.03	12.81	1.22	44.4	42.5	1.9
91	4.78	4.04	.74	14.67	13.07	1.60	44.7	44.0	.7
92	4.95	4.44	.51	14.90	14.35	.55	43.5	43.6	<u>.1</u>
93	4.85	4.60	.25	13.82	12.72	1.10	49.0	45.9	3.1
94	4.86	4.46	.40	14.56	13.16	1.40	45.0	40.6	4.4
95	4.58	4.07	.51	15.02	11.63	3.39	47.4	41.8	5.6
96	5.11	4.52	.59	16.02	15.39	.63	48.2	43.4	4.8
97	5.35	4.88	.47	16.59	15.64	.95	47.9	45.2	2.7
98	4.61	4.28	.33	14.67	12.72	1.95	44.4	40.0	4.4
99	5.23	4.56	.67	14.56	13.25	1.31	49.5	46.0	3.5
100	5.19	4.60	.59	16.31	15.39	.92	46.5	41.0	5.5
MEAN	4.90	4.46	.44	14.94	13.89	1.05	47.4	44.3	3.1

TABLE XI

STATISTICAL SIGNIFICANCE OF DECREASE IN CIRCULATING ERYTHROCYTES AND HEMOGLOBIN FOLLOWING INACTIVITY

	Difference between mean values of Series I, sampled after random activity and Series II, sampled after ½ hour of inactivity.			Difference between mean values of Series III after random activity and after 1 hour of inactivity.		
	Difference ± Probable Error	Diff. / P. E.	Signif.	Difference ± Probable Error	Diff. / P. E.	Signif.
ERYTHROCYTES	250,000 ± 33,000	7.6	+	440,000 ± 29,700	14.8	+
HEMOGLOBIN	1.43 ± .125	11.4	+	1.05 ± .139	7.6	+
VOLUME PACKED CELLS	2.5 ± .257	9.7	+	3.1 ± .262	11.8	+
MEAN CORP. VOLUME	.1 ± .765	.13	-	2.3 ± .801	2.9	-
MEAN CORP. HEMOGLOBIN	1.5 ± .309	4.9	+	.6 ± .338	1.8	-
MEAN CORP. HEMOGLOBIN CONCENTRATION	1.2 ± .277	4.4	+	.2 ± .281	.7	-