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Hematologic performance of Navajo children; effect of altitude on iron deficiency anemia of childhood

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HEMATOLOGIC PERFORMANCE OF NAVAJO CHILDREN

EFFECT OF ALTITUDE ON IRON DEFICIENCY ANEMIA OF CHILDHOOD

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Hematologic Performance of Navajo Children - Effect of Altitude on Iron Deficiency Anemia of Childhood

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ABSTRACT

The extent of anemia was investigated in 211 Navajo children who came under the care of the outpatient department and field health services of the Gallup Indian Medical Center, Gallup, New Mexico. Hemoglobin and hematocrit determinations were performed on these children, who were selected in approximately equal numbers from two age groups --- 9 through 24 months, and 4 through 6 years. Using sea-level hematocrit norms as indices of anemia, it was found that virtually no anemia existed in either group. However, the altitude of the reservation is 6,500 feet, and hematocrit can be expected to rise with increases in altitude. Therefore mean corpuscular hemoglobin concentration (MCHC), which is unaffected by altitude, was calculated, and a value of less than 32% was used as an index of iron deficiency. According to this criterion, 30.1% of Group I (9 through 24 months) and 13.1 % of group II (4 through 6 years) were iron deficient. A decrease in frequency of anemia after infancy has been documented in studies of other homogeneous racial and socioeconomic groups. The prevalence of iron deficiency, defined as a low MCHC, among Navajo children, particularly in Group II, remains somewhat higher than expected, and may be attributable to marginal compensation for altitude.

INTRODUCTION

Iron deficiency anemia is the most widespread nutritional deficiency among children in the United States. Although the exact incidence is unknown, its occurence seems to be related to birthweight, pregnancy related variables, socioeconomic class, age, and locality.

Over forty years ago MacKay[1] documented the almost universal prevalence of iron deficiency anemia among poor children in London's East End. In the 1930's Guest reported a 30% incidence of iron deficiency among infants in Cincinnati, and noted a positive correlation between frequency and severity of anemia and low socioeconomic class. Some twenty years later he repeated his study,[2] and found that the incidence of anemia remained unchanged, despite pediatric and nutritional advances. Many studies of both hospitalized and non-hospitalized children have shown that iron deficiency anemia continues to be a problem, especially during infancy.[3-16]

Most investigators agree that there is an inverse relationship between birthweight and the prevalence of iron defiency in infancy.[17] The low birthweight infant is both at greater risk and also tends to develop anemia at an earlier age than his normal counterpart because of a lower total iron endowment at birth and because of a proportionally greater rate of growth.[18] Foman and Weckwirth[19] in a study of almost 10,000 infants showed that 11.1% of low birthweight two year olds had hemoglobin concentrations of less than 8.0 mg.%, compared to 5.7% of their mature counterparts. These differences disappear with increasing age.

In addition to birthweight, parity, birth order, and spacing of pregnancies appear to be related to the development of anemia in the infant.[2,18] It is difficult, however, to interpret with certainty the meaning of these pregnancy related variables because of their complex interrelationship with such factors as socioeconomic class and race.

Since MacKay's study it has become clear that children from low socioeconomic class are indeed at greater risk for developing anemia.[3,4,6,7,9,14,15,16] Hillman[3] has shown that anemia tends to be more common in children from families who are on welfare. Owen[20] has reported that low hemoglobin and hematocrit values, as well as low percentage of transferrin saturation, are much more common among infants from low socioeconomic background than among their counterparts from more economically favored groups. Fuerth[21] has documented a 3% incidence of anemia among nine month old infants from middle class backgrounds, a figure generally much smaller than that seen among comparably aged infants from less favored backgrounds. However, even the relatively small incidence of anemia among middle and upper middle class infants cannot serve as grounds for complacency when one realizes that actual anemia is a late manifestation of iron malnutrition.

There is little firm data about ethnic differences in the occurence of anemia. Katzman[12] reported that black teenage girls in New Haven had a higher prevalence of anemia than their white lower class or Puerto Rican counterparts. Hillman[3] reported that in a lower class neighborhood in New York City, black children at all ages had higher rates of anemia

than white or Puerto Rican children. However, Haughton, in a similar study in the same city, reported no such ethnic difference.

Although in general it is recognized that iron deficiency anemia is most frequent in infancy, few studies have documented its age related occurence, particularly beyond the age of six. Pearson[11] performed hematocrit determinations on more than 3,000 children, and found that anemia was frequent (14.8%) in infancy, but by preadolescence had declined to 2.6%. Subsequent compensatory ability was marginal in girls, however, for after puberty and especially during pregnancy, anemia recurred with considerable frequency. Katzman[12] in a similar study of intercity children documented a similar pattern in age related occurence of anemia.

Although this age related pattern seems to represent a valid observation, the incidence of anemia within a given age group is not fixed, but varies with locality. Pearson[10] documented considerable variation in the incidence of anemia among preschool children from five cities in the United States. Moreover, its occurence seemed to be unaffected by mass programs of iron supplementation.

Questions which have remained largely unanswered concern the clinical significance of iron deficiency anemia. It is known that the peak incidence of anemia occurs between nine and twenty four months, coincident with the greatest rate of growth, and that afterwards it spontaneously tends to correct itself as the rate of growth decelerates and the infant assumes a more varied diet. It is also known that in iron de-

ficient animals and humans, the activity of some enzymes and cofactors, such as cytochrome C and aconitase, is decreased.[18] Studies have correlated iron deficiency anemia with increased frequency and severity of respiratory infections,[9] with feeding disturbances, with pica, with behavioral and learning problems,[22] and with occult blood loss.[23] A recent study[24] has reported that the use of therapeutic iron in premature infants causes vitamin E deficiency. None of these studies are conclusive, however, and the current posture concerning the significance of iron deficiency anemia is that it is a measurable hematologic manifestation of a general malnutrition problem.

Several studies on the nutritional state of Navajo children have been performed since the U.S. Public Health Service first assumed for health care on the reservation. Darby[25] reported in 1956 that there was no problem with anemia or protein malnutrition on the reservation. However, a study[26] at Many Farms, Arizona in 1958 reported that 15% of children under six years of age were anemic. In 1967 McDonald[27] reported that 10% of children up to four years of age who were admitted to Indian Service hospitals were anemic. The same year Welty[28] reported a 14% incidence of anemia as well as significant growth retardation among a group of non-hospitalized children up to five and one half years of age. The Greasewood Nutrition Study[29] in 1970 found that in a group of children up to five and one half years of age, 1 of 44 males and 3 of 44 females were anemic on the basis of hemoglobin values, and 0 of 46 males and 1 of 36 females were anemic on the basis of hematocrit determinations. In addition, of 30

children from 0 to 2 years of age, 9 were below the third percentile and 21 were below the fiftieth percentile in height. The study concluded that "the nutritional status of the population ... was surprising in that infants and children appeared to be in reasonably good health."

All of the above studies on the Navajo used arbitrarily defined values of hemoglobin and hematocrit as indices of anemia, since the range of normal for these parameters has never been defined for the Navajo tribe at the altitude of the reservation (6,500 feet). This study attempted to define age related differences in the incidence of iron deficiency anemia among Navajo children, using mean corpuscular hemoglobin concentration (MCHC) as an index of hypochromia and therefore inadequate iron utilization. The normal erythropoeitic response to increased altitude consists of an absolute increase in the number of circulating erythrocytes, without a change in morphology.[17] This results in increased hemoglobin and hematocrit values, but MCHC remains unaffected. Only in the face of inadequate iron for hemoglobin synthesis does MCHC decrease, reflecting a hypochromia which is the hallmark of iron deficiency. Since anemia by definition consists of a decreased hematocrit, hemoglobin, or red blood cell count, it is possible that inadequate hematologic compensation for increased altitude might be reflected not in actual anemia, but in hypochromia (i.e. decreased MCHC).

This study also sought a relationship between suboptimal iron nutrition and growth retardation.

METHODS

Data were obtained from 211 Navajo children who came under the care of either the pediatric clinic or the field health services of the Gallup Indian Medical Center, Gallup, New Mexico during the months of July, August, and September of 1971. The children were selected from two age groups. Group I (9through 24 months of age) comprised 103 children, 46 males and 57 females. Group II (4 through 6 years of age) comprised 108 children, 57 males and 51 females. All of the children from Group I were seen in pediatric clinic. Eighty four of the 108 children from Group II did not present at the clinic, but received physical examinations for Head Start or other preschool programs under the services of the field health department. All of the children included in the study were one half or more full-blooded Navajo, as determined from their health records.

On each child the data were obtained --- age, sex, hematocrit, hemoglobin, height, weight, and diagnosis. Blood samples were obtained from freely flowing capillary blood. Hematocrit was determined using the microhematocrit method. Hemoglobin values were determined by the cyanmethemoglobin spectrophotometric method. Height and weight determinations were either performed at the time of examination or were taken from the patients' records if determined within the previous month.

Many children presented at the pediatric clinic with diarrhea. Any child who showed evidence of dehydration such as absence of tears and decreased moisture of the buccal mucosa were excluded from the study. Likewise, any child who,

after being seen in the clinic, was admitted to the hospital was also excluded from the study.

From hemoglobin and hematocrit data, mean corpuscular hemoglobin concentration was calculated, and a value of less than 32% was used as an index of hypochromia and therefore inadequate hemoglobin synthesis.

Data were also obtained from the Navajo tribal headquarters in Window Rock, Arizona. This furnished information about the age related incidence of anemia throughout the reservation.

RESULTS

Results are summarized Figures 1 through 10 and Tables 1 through 6. Table 1 indicates mean hemoglobin, hematocrit, and mean corpuscular hemoglobin concentration (MCHC) for both study groups, and the percent iron deficient in each group, as judged by an MCHC of less than 32%. All sample means are higher than normal means. 30.1% of infants 9 through 24 months are iron deficient. This percentage declines to 13.1% in children 4 through 6 years of age.

Figures 1 and 2 represent superimposed percentage distribution curves for hematocrit, using data from the present study as well as data from Pearson's and Katzman's studies. Although the ages which are plotted are not exactly comparable, it is apparent that for both graphs, the hematocrit curves for the present study are distributed to the right of the curves from the other studies. This range of higher hematocrit values for the Gallup study is further analyzed in Table 2.

Table 2 compares the results obtained by Pearson in Gainesville, Florida and those obtained by Katzman in New Haven with data from the present study. Figures were extracted from the Gallup data using age-group and normative-value criteria established by Pearson and Katzman. The sample mean hematocrits for both groups in the present study are significantly higher than those obtained by Pearson or Katzman. Using hematocrit criteria established by Pearson and Katzman, the Gallup data reveals no anemia in Group I and a frequency of only 1.9% in Group II. However, when MCHC of less than 32% is used as an index of suboptimal iron nutrition, the data

reveals a higher prevalence of iron deficiency for both groups.

Figures 3 through 8 are percentage distribution curves for hemoglobin, hematocrit, and MCHC values, by age group. They have fairly normal curvatures, indicating probably representative population sampling. The curves of Group I are somewhat skewed to the left, which reflects the high frequency of iron lack in that group.

Figure 9 is a scattergram for hematocrit by age group and sex, while Figure 10 is a scattergram for MCHC by age group alone. Figure 9 shows a greater proportion of low hematocrit values in Group I than in Group II, with no sex predominance in any portion of the scattergram. Figure 10 shows a greater number of iron deficient individuals (i.e. MCHC less than 32%) in Group I than in Group II, with no clustering pattern of anemia within these age groups.

Table 3 lists the relative frequency of diagnoses in patients from Group I. Of note is the fact that gastroenteritis was the second most frequent disease seen in the clinic. Table 4 shows the relative frequency of gastroenteritis among normal patients and among patients with suboptimal iron nutrition. Any child with gastroenteritis who showed evidence of dehydration was excluded from the study. A chi-square test yielded a p value of less than 0.05, which indicated that it is highly unlikely that results were skewed by the inclusion of infants with gastroenteritis.

The information in Table 5 was gathered from data found at the Navajo tribal headquarters in Window Rock, Arizona. The number of cases of iron deficiency anemia diagnosed per 1,000 initial outpatient visits are listed, both for the

Navajo reservation as a whole, and for the Gallup service unit. The same age related pattern of anemia emerges as was found by Pearson and Katzman. Anemia is most frequent in early childhood, after which it decreases, only to reappear to a lesser extent during adolescence. Of interest is the fact that among the Navajo, iron deficiency remains a problem throughout later life, with a prevalence of one third to one half that found in early life.

Table 6 lists the height and weight characteristics of Group I. The patients are divided into two groups, those in the 25th percentile or more, and those who fall below the 25th percentile. The relative frequency of iron deficiency within each percentile group was remarkably similar, whether height or weight was the parameter measured. In addition, those infants who fell into the 25th percentile or more showed a significantly higher frequency of iron lack than those who fell below the 25th percentile. This data is consistent with the theory that iron deficiency during infancy is at least in part a result of an increased proportional rate of growth. No clear pattern emerged withrespect to sex differences in the frequency of suboptimal iron nutrition.

DISCUSSION

The results of this study are similar to those of other surveys designed to detect nutritional anemia in that they demonstrate a high frequency of iron lack during infancy with a decrease during later childhood. Although this age related pattern of deficiency clearly emerges, of perhaps greater significance is the fact that the rate of iron deficiency in later childhood, as well as during infancy, remains higher than that found in age-matched groups from other disadvantaged populations.

In addition, the data compiled from the tribal records at Window Rock indicate, although in a very rough and cursory fashion, that iron deficiency may constitute a health problem for the older Navajo population as well. The Window Rock records give low rates of anemia for all age groups. However, if the age related pattern is itself valid, the absolute incidence of iron lack might be much higher than reported, as evidenced from the data in the present study. The difference between actual and reported figures might be due to failure to report or to look for iron deficiency.

In examining the prevalence of anemia among Navajo children, it was found that mean hemoglobin and hematocrit values were elevated above normal, and that, using criteria established by Pearson and Katzman, virtually no anemia was found to exist. However, upon using MCHC as a hematologic index which, unlike hemoglobin and hematocrit, remains unaffected by altitude, rates of iron deficiency were established which, for both age groups, exceeded actual anemia, documented by hemoglobin and hematocrit, as obtained by Pearson and Katzman. This data,

coupled with the finding that larger and heavier infants have higher rates of iron lack than their smaller, lighter counterparts, suggests that two factors influence the incidence of iron deficiency among Navajo children. First is the proportionally greater rate of growth during childhood, and particularly during infancy. Second is the increased iron requirements imposed by living at an altitude of 6,500 feet. Thus, the higher rates of iron deficiency found in Navajo children may be explained by marginal hematologic compensation for altitude in the face of already increased iron demands imposed by childhood growth.

Table 1: Hematologic Indices and Rates of Iron Deficiency

	Group I (9-24 mos.)	Group II (4-6 yrs.)
Hematocrit		
N =	101	106
Normal mean value (sea level)	35.0%	37.0%
Experimental value ± std. dev.	36.83 ± 3.01%	38.57 ± 2.71%
Hemoglobin		
N =	95	108
Normal mean value (sea level)	11.2 mg.%	12.6 mg.%
Experimental value ± std. dev.	12.00 ± 2.45mg.%	13.01 ± 1.02mg.%
MCHC		
N =	93	106
Lower level of normal	32%	32%
Experimental value ± std. dev.	32.65 ± 2.63%	33.68 ± 1.90%
Percent iron deficient	30.1%	13.1%

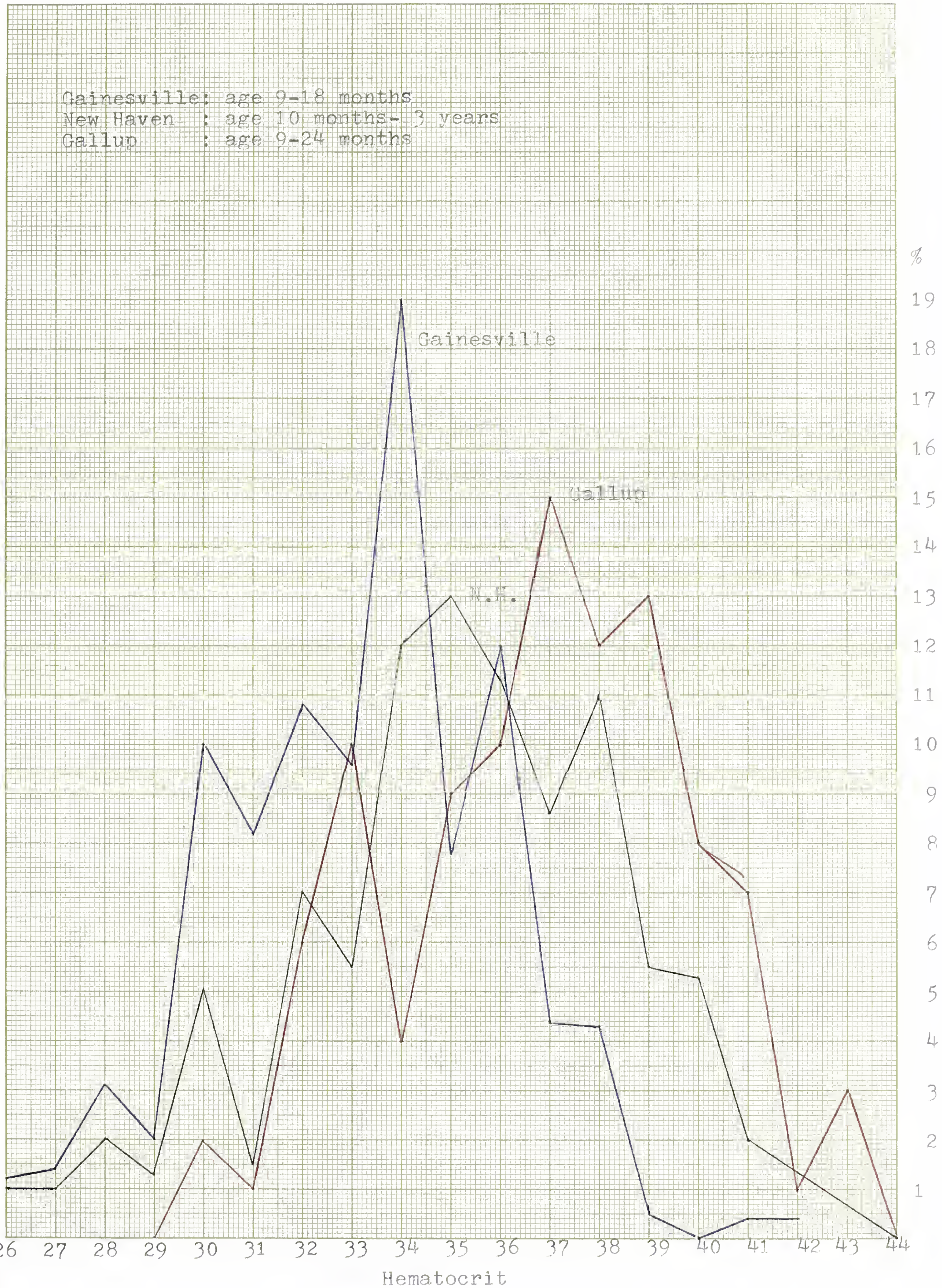

Figure 1: Distribution of Hematocrits - Gainesville, New Haven, and Gallup

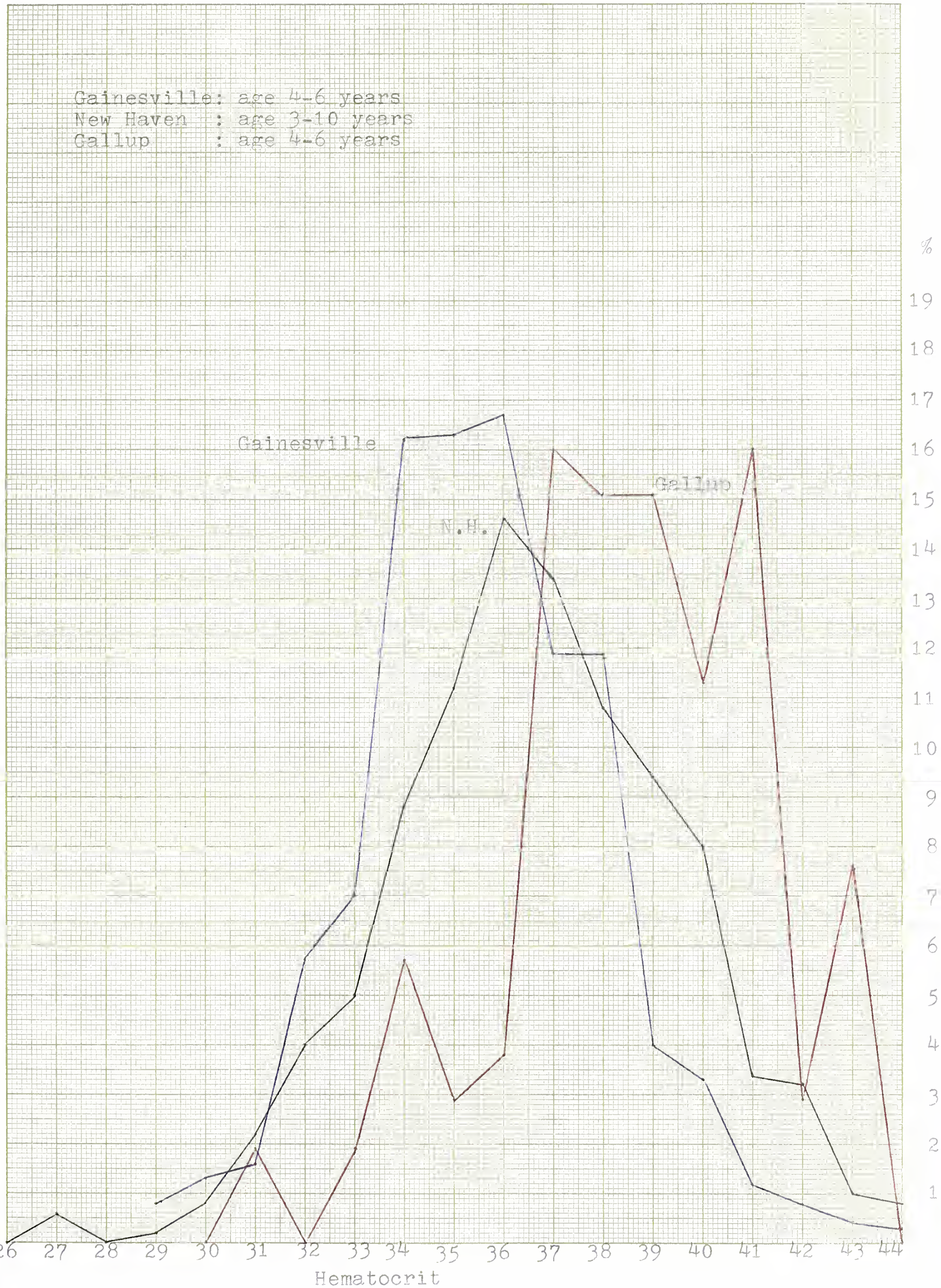

Figure 2: Distribution of Hematocrits - Gainesville, New Haven, and Gallup

Table 2: Frequency of Anemia - Comparison of Gainesville, New Haven, and Gallup Studies

Age Group	Study	Index	# Patients	Lower Level of Normal	Mean Value	% Anemic	% Iron Deficient
9-18 mos.	Gainesville	Hct.	244	30%	32.2%	14.8%	
	New Haven	Hct.	97	30%	34.1%	11.3%	
	Gallup	Hct.	74	30%	36.0%	0%	
	Gallup	MCHC	67	32%	32.6%		34.3%
4-6 yrs.	Gainesville	Hct.	1450	32%	35.6%	4.5%	
	New Haven	Hct.	310	32%	36.2%	7.4%	
	Gallup	Hct.	106	32%	38.6%	1.9%	
	Gallup	MCHC	106	32%	33.7%		13.1%

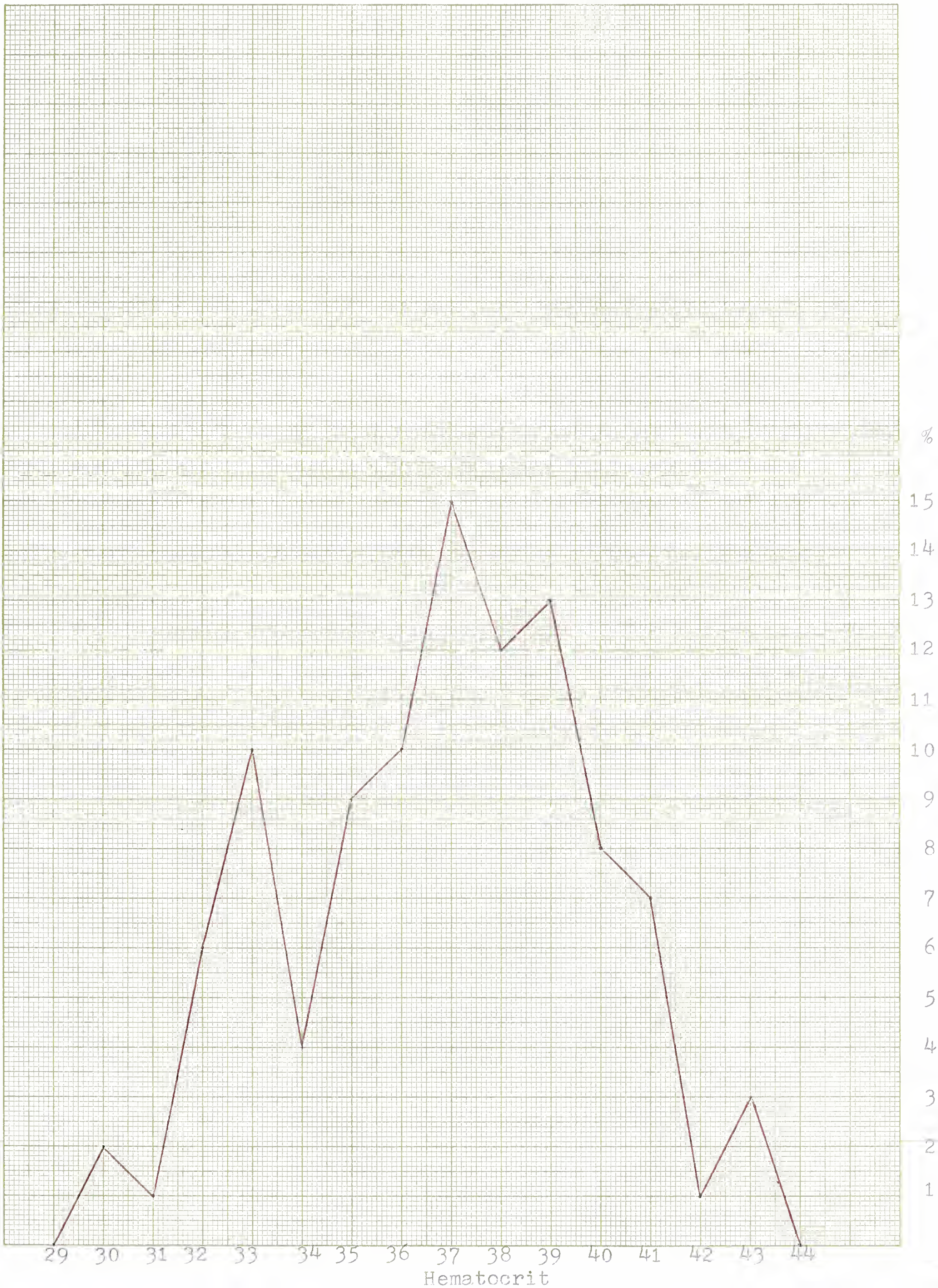

Figure 3: Distribution of Hematocrits - Group I (N=101)

Figure 4: Distribution of Hematocrits - Group II (N=106)

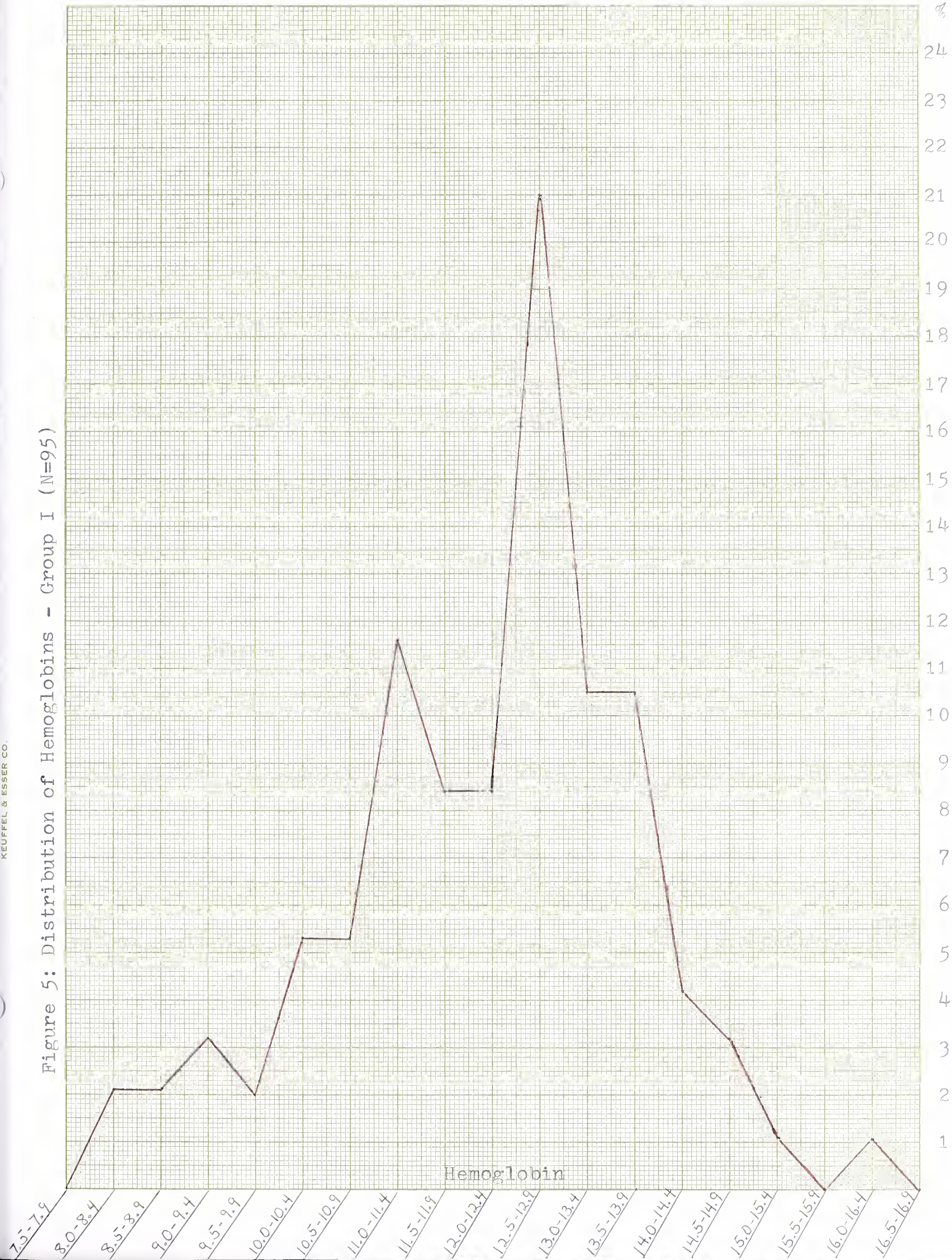

Figure 5: Distribution of Hemoglobins - Group I (N=95)

Figure 6: Distribution of Hemoglobins - Group II (N=108)

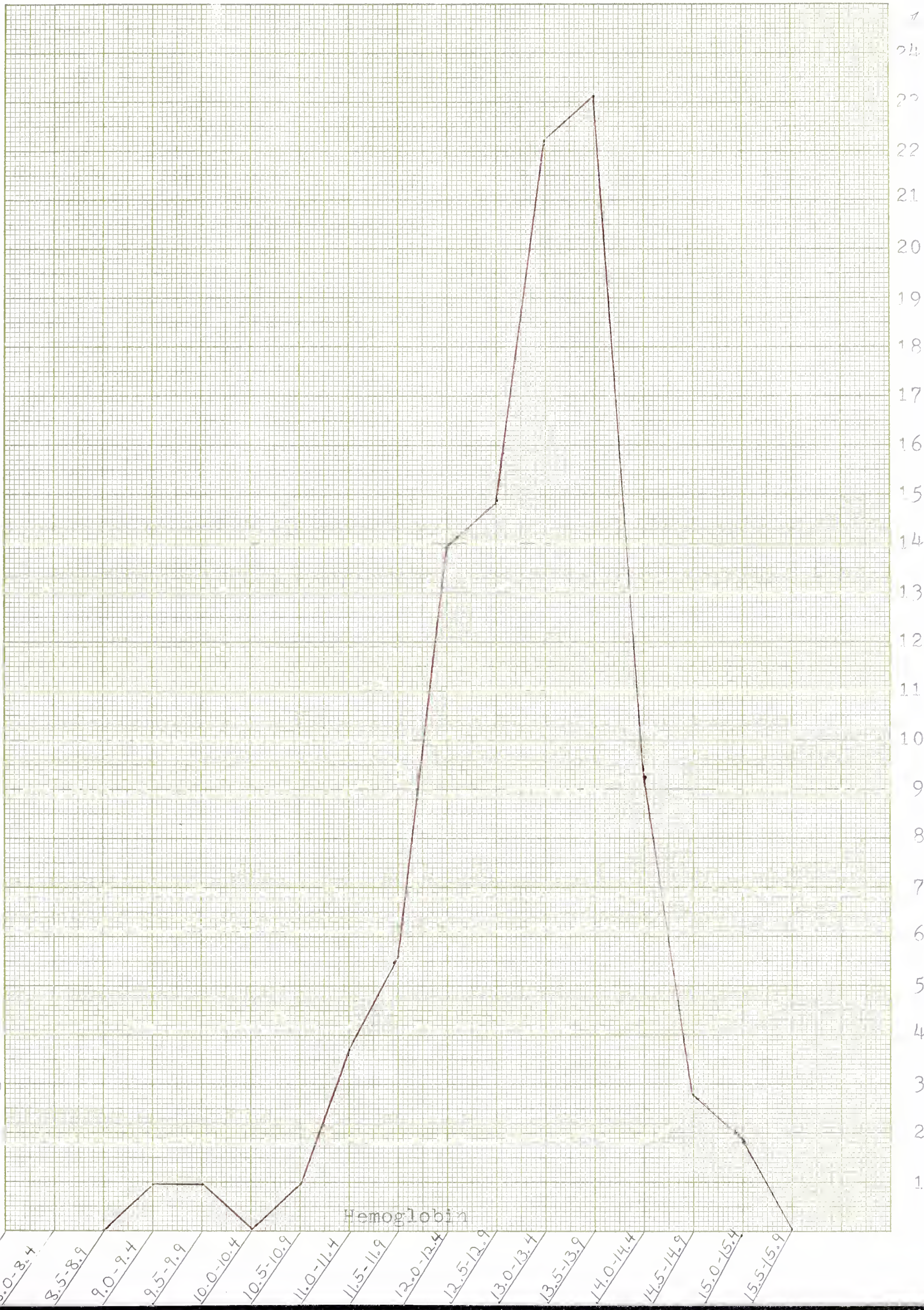

Figure 7: Distribution of MCHC's - Group I (N=93)

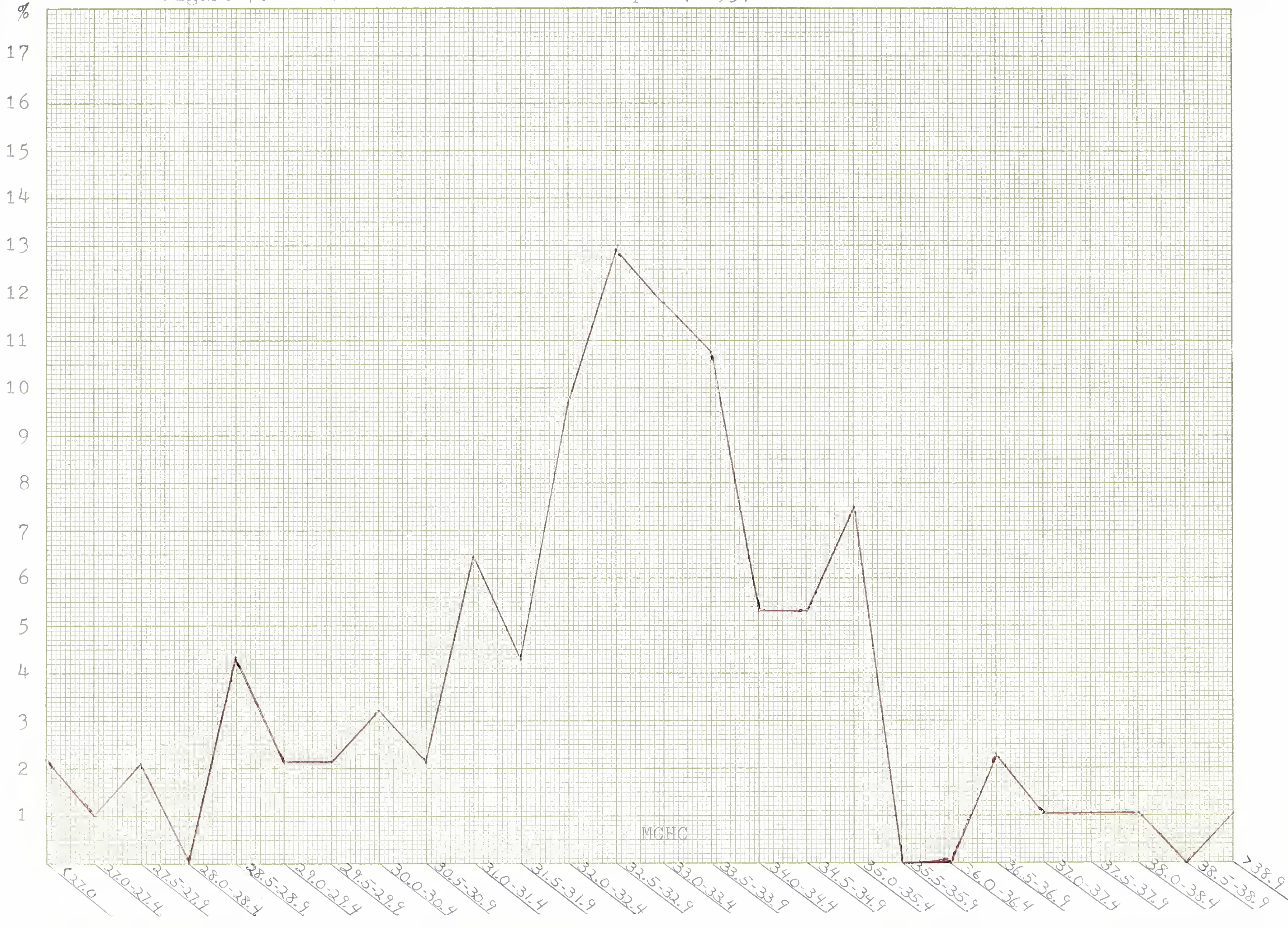

Figure 8: Distribution of MCHC's - Group II (N=106)

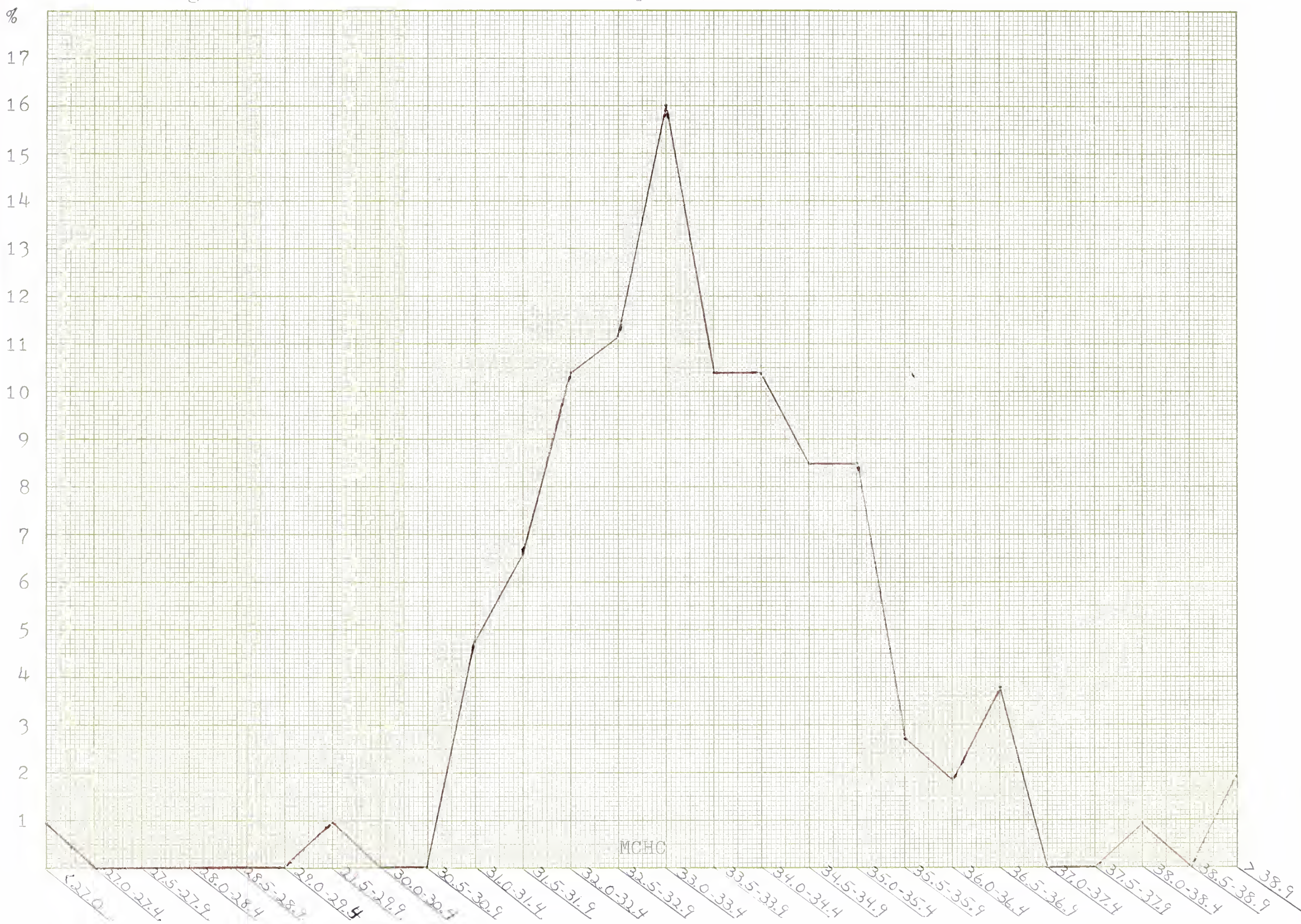

Figure 9: Scattergram of Hematocrits - Group I (N=101), and Group II (N=106)

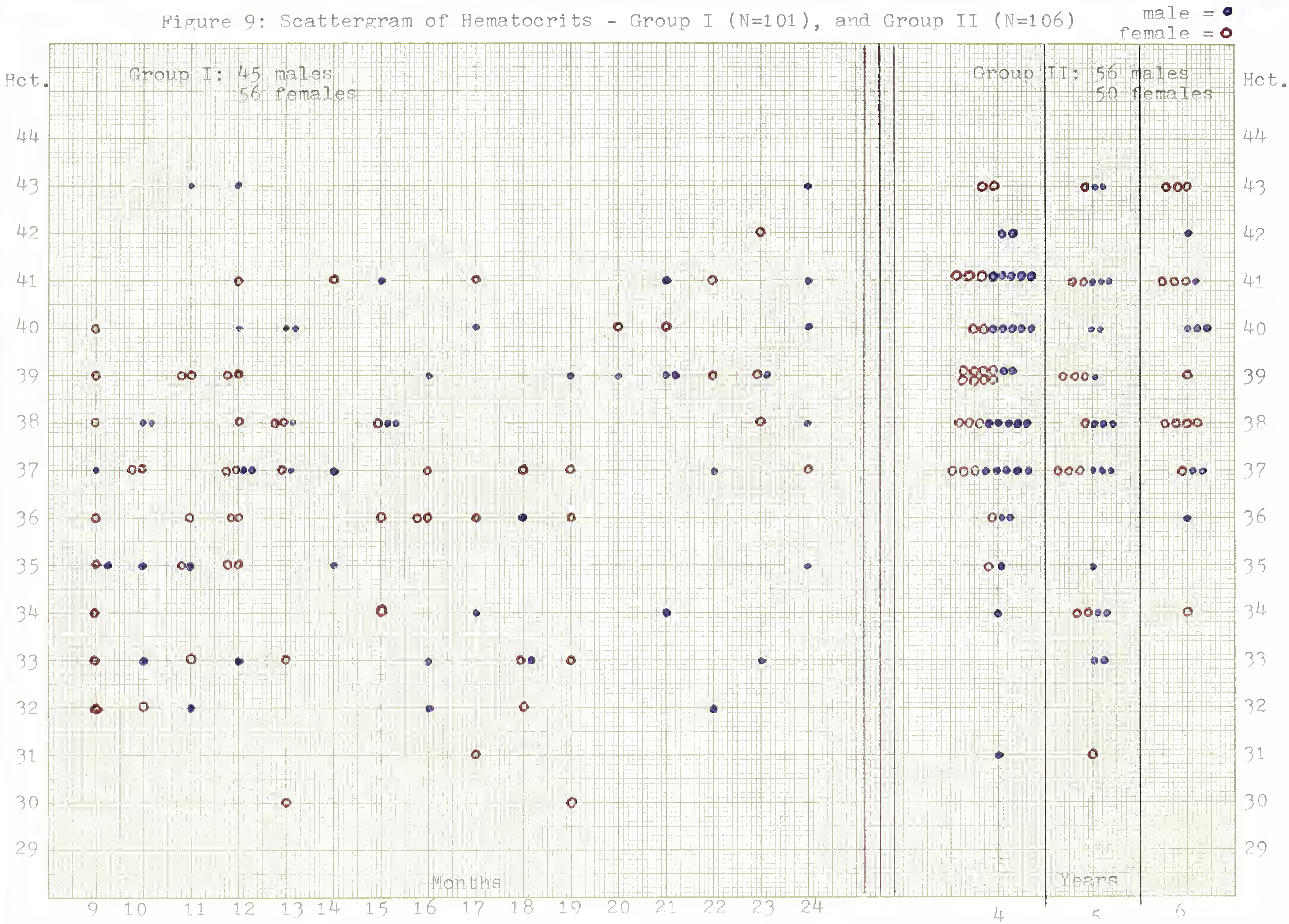

Figure 10: Scattergram of MCHC's - Group I (N=93), and Group II (N=106)

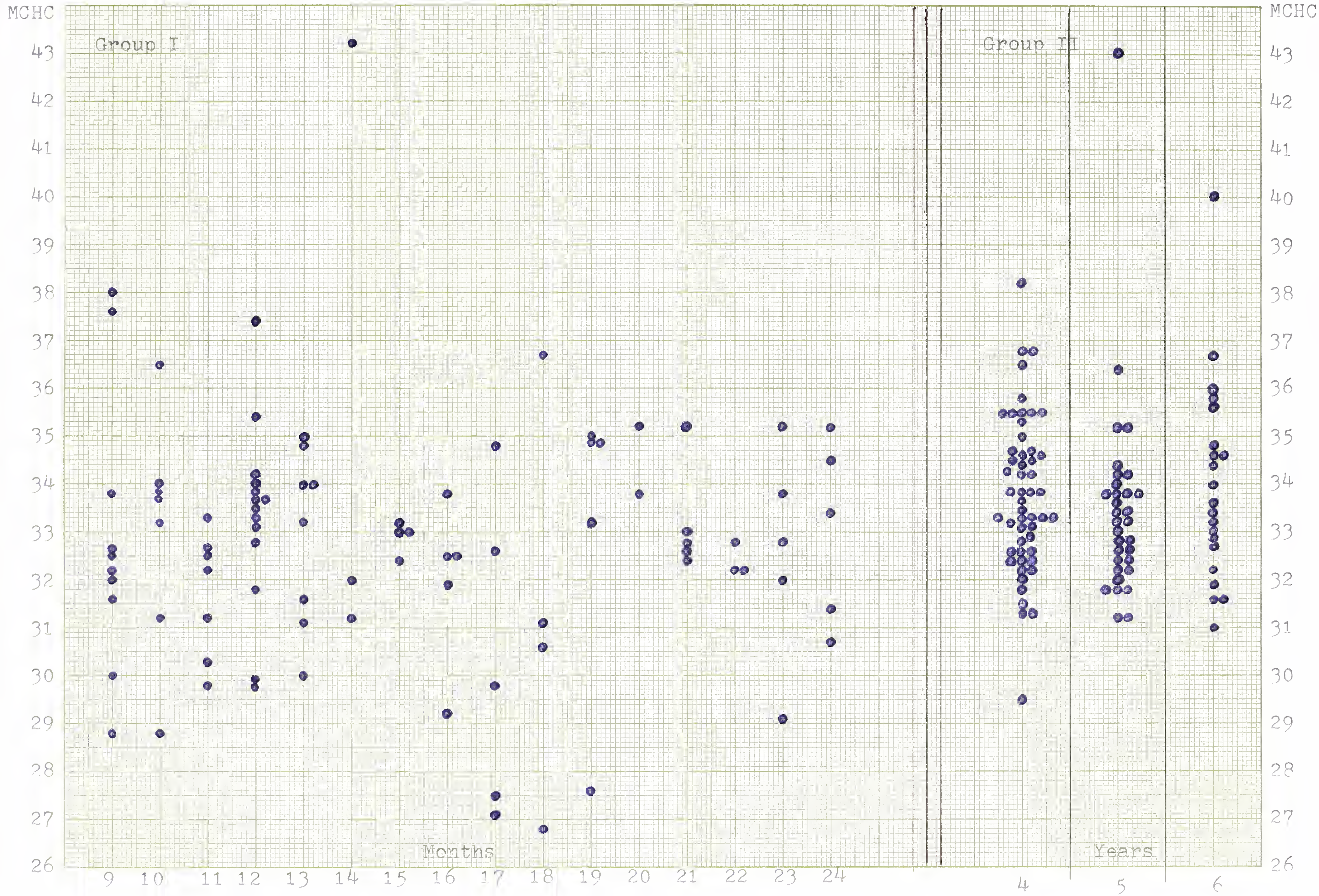

Table 3: Diagnoses of Patients from Group I (9-24 mos.)

Diagnosis	# Patients	%
well-baby care	22	23.4%
upper resp. infect.	20	21.2%
gastroenteritis	12	12.8%
otitis media	11	11.7%
skin diseases	9	9.6%
other	20	21.2%
Total	94	100 %

Table 4: Patients with Gastroenteritis - Group I (9-24 mos.)

	Normal Patients	Patients with Iron Lack
# Patients	67	27
# with Gastroenteritis	8	4
% with Gastroenteritis	11.9%	14.8%

•p"less than 0.05

Table 5: Number of Cases of Iron Deficiency Anemia per 1,000 Initial Outpatient Visits ($x10^{-3}$)

Age	Navajo Reservation	Gallup Service Unit
0-27 days	0.93	0
28-364 days	1.29	1.07
1-4 years	1.44	1.37
5-9 years	0.18	0.45
10-14 years	0.07	0
15-24 years	0.43	0.66
25-44 years	0.51	0.49
45-64 years	0.30	0.15
over 65 years	0.15	0.45

Table 6: Height and Weight Characteristics - Group I (9-24 mos.)

	Percentile	# Patients	# Iron Deficient	% Iron Deficient
Height:	less than 25th %	24	7	29.2%
	25th % and greater	27	11	40.7%
Weight:	less than 25th %	25	7	28.0%
	25th % and greater	40	15	37.5%

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