Data from the
NATIONAL HEALTH SURVEY

Series 11
Number 146

Hematocrit Values
Of Youths 12-17 Years
United States

Hematocrit values are presented and discussed by age, sex, race, and socio-economic level of youths 12-17 years of age in the United States, 1966-70.

DHEW Publication No. (HRA) 75-1628

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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Rockville, Md. December 1974

Series 11 reports present findings from the National Health Examination Survey, which obtains data through direct examination, tests, and measurements of samples of the U.S. population. Reports 1 through 38 relate to the adult program, Cycle I of the Health Examination Survey. The present report is one of a number of reports of findings from the children and youth programs, Cycles II and III of the Health Examination Survey. These latter reports from Cycles II and III are being published in Series 11 but are numbered consecutively beginning with 101. It is hoped this will guide users to the data in which they are interested.

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HEMATOCRIT VALUES OF YOUTHS 12-17 YEARS

Felix Heald, M.D., Paul S. Levy, Sc.D., Peter V. V. Hamill, M.D., M.P.H., and Michael Rowland[a]

INTRODUCTION

This report of hematocrit values as determined from blood samples of youths 12-17 years of age in the United States is one of a series of reports presenting findings from Cycle III of the Health Examination Survey. The means and selected percentiles of the hematocrit values are examined here by sex, age, race, family income, education, and geographic region of the United States. As described in a detailed report of its general plan and operation,[1] the Health Examination Survey (HES) is conducted in a succession of cycles.

Cycle I of the HES, conducted from 1959 to 1962, obtained information on the prevalence of certain chronic diseases and on the distribution of a number of anthropometric and sensory characteristics in the civilian, noninstitutionalized population of the continental United States, aged 18-79 years. The detailed plan of Cycle I is described in a previous report,[2] and most of the results are published in other reports of Series 11 in *Vital and Health Statistics.*

Cycle II of the HES, conducted from July 1963 to December 1965, involved selection and examination of a probability sample of noninstitutionalized U.S. children, 6-11 years. This program succeeded in examining 96 percent of the 7,417 children selected for the sample. The examination had two focuses: (1) factors related to healthy growth and development as determined by a physician, a nurse, a dentist, and a psychologist and (2) a variety of somatic and physiologic measurements performed by specially trained technicians. The detailed plan and operation of Cycle II and the response results are described in *Vital and Health Statistics,* Series 1-Number 5.[3]

HES Cycle III, conducted from March 1966 to March 1970, was essentially an agewise extension of Cycle II into adolescence. As described in detail in "Plan and Operation of a Health Examination Survey of U.S. Youths, 12-17 Years of Age,"[4] Cycle III was more similar to Cycle II than to Cycle I not only in form, content, and style but also in having its major emphasis on factors of "normal" growth and development rather than on chronic diseases. These analyses on "normal" growth and

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development of adolescents have been well underway since 1970, and some of the results from the battery of body measurements have already been published.[5-7]

This report, which presents the first of the findings from the sample of blood drawn from each youth, is closer in content to Cycle I than to Cycle II, because no blood specimen was obtained from the children in Cycle II. One was obtained from the adults in Cycle I and among the determinations made was the hematocrit. On the other hand, the present report, like those of Cycle II, primarily deals with factors relating to growth and development. As will be shown, there was a marked "growth" in the erythrocyte volume for adolescent boys, while that for adolescent girls remained essentially stationary.

In this report, the means and selected percentiles of the hematocrit values are examined by sex, age, race, family income, education of parent, and geographic region of the United States.

METHOD

At each of 40 preselected locations (see appendix I for sample design) throughout the United States, the youths were brought to the centrally located mobile examination center for an examination that lasted about 3½ hours. Six youths were examined in the morning and six in the afternoon. Except during vacations, they were transported to and from school and/or home.

When the youths entered the examination center, their oral temperatures were taken, and a cursory screening for acute illness was made; if illness was detected, the youth was sent home and reexamined later. The examinees changed into gymnasium-type shorts; cotton sweat socks; a terry-cloth robe; and, for the girls, a light, sleeveless topper. All six then proceeded to different stages of the examination, each one following a different route. The 3½-hour examination was divided into six 35-minute time periods, each consisting of one or more detailed examinations at a designated station. At the end of each period, the youths rotated to another station so that at the end of 3½ hours each youth had been given essentially the same examinations by the same examiners but in a different sequence. Four of these examination time periods were allocated to examinations by a pediatrician, a dentist, and a psychologist,[b] and the other two were allocated to a group of examinations performed by highly trained technicians. This last group of examinations consisted of X-rays of the chest and hand-wrist, hearing and vision tests, measures of respiratory function, a 12-lead electrocardiogram, a submaximal exercise tolerance test on a treadmill with chest leads to a continuous electrocardiogram, a battery of body measurements, grip strength, examination of blood and (on girls only) urine cultures for bacteria, and a privately administered health behavior and attitude questionnaire.

Blood Specimen and Microhematocrit

The development of the technique used by HES for obtaining and processing the blood specimen is described in appendix III. When the venipuncture needle was withdrawn from the arm, the tubing was partially drained, and two microcapillary tubes were two-thirds filled with the residual blood in the tubing. The ends were filled with Sealease and the tubes placed into a special autocrit carrying tray. The tray was centrifuged at 12,500 r.p.m. for 5 minutes, and a reading was taken on each tube directly on the tray. Care was taken to read immediately after centrifugation—the tubes were not allowed to sit for long periods of time. The reading was expressed as the percentage that the volume of the packed red blood cells comprised of the initial whole blood specimen in the microcapillary tube.

The microhematocrit was the only laboratory determination performed in the examination trailers on the blood specimen. The bulk of the blood samples, after preliminary preparation in the trailer's laboratory, were properly separated into their various subsamples and packed into specially devised Styrofoam containers for shipment via air freight to either the Immunogenetics Laboratory of The Johns Hopkins Univer-

[b]The entire examination by the psychologists consisted of two consecutive time periods (70 minutes). Two psychologists performed identical examinations simultaneously at separate stations.

sity, Baltimore, Md., or the Center for Disease Control (PHS), Atlanta, Ga.

Race

Race was recorded as "white," "Negro," and "other races"[c] (see appendix II). In Cycle III, the white youths constituted 84.74 percent of the total, the Negro youths 14.76 percent, and youths of other races only 0.50 percent. In Cycle II, white children constituted 85.69 percent of the examined subjects and Negro children, 13.86 percent. (The differential response rate by age, sex, and race is analyzed and discussed in appendix I. The increased proportion of Negro subjects in Cycle III was due to their better response rate—the overall Negro response rate was 96.6 percent and the overall white response rate was 89.1 percent.) As in Cycle II, because so few youths of "other races" were part of the sample, data for them have not been analyzed as a separate category. Whenever data are analyzed independent of a classification by race, however, data for these youths are included.

RESULTS

Sex and Age

The estimated number of youths falling into each of 16 groups according to hematocrit levels is shown by age and sex in table 1 along with selected percentiles, mean hematocrit levels, and standard deviations of the hematocrit distributions. Percentage distribution of hematocrits is given for these youths by age and sex in table 2.

In male youths, mean hematocrit levels increased consistently with age, from a low of 40.5 ml percent for 12-year-olds to a high of 45.8 ml percent for 17-year-olds (table 1 and figure 1). This represents an estimated increase of 5.3 ml percent or 1.06 ml percent per year over the 6 years of adolescence. In females, however, no such increase with age was seen; the mean hematocrit levels remained within the 40.3-40.7 ml percent range throughout adolescence (table 1 and figure 1). For each of the six age groups, mean hematocrit levels were higher in males than in females. Differences between the mean hematocrit levels of male and female youths increased consistently with age, from 0.2 ml percent for 12-year-olds to 5.2 ml percent for 17-year-olds.

The increase in mean hematocrit levels with age for male youths is also seen when the data are examined by percentiles (table 1). The 5th percentile for male youths increased consistently with age, from a low of 36.0 percent for

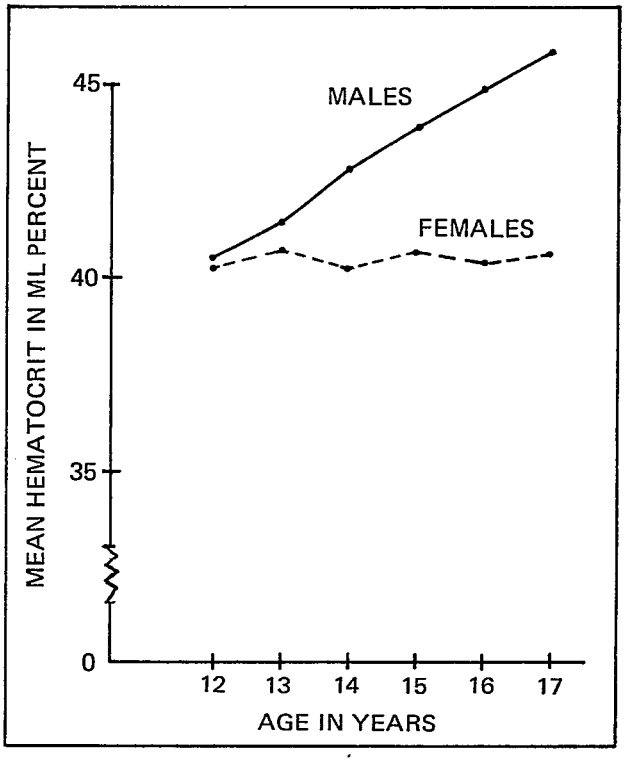

Figure 1. Mean hematocrit levels for youths aged 12-17 years, by age and sex: United States, 1966-70.

[c]The same classification scheme as used in the 1960 census was employed here. As described in the previously mentioned report on the operation of HES Cycle III,[4] this information was obtained at the initial household interview by the Bureau of the Census fieldworker. The accuracy of the information was checked at the subsequent home visit by the highly experienced representative from HES and again at the examination in the trailer. A final record check by birth certificate turned up only seven inconsistencies, and these were mostly pertaining to the category "other races." Hence, the possible extent of misclassification of the variable race, as described, is so minimal that it could have no effect on the data analyzed in this report. However, when comparing the present HES findings with those of other variously defined racial groupings in the world, the degrees of genetic admixture, as first discussed by Herskowitz[8] in 1928 and later by Glass and Li,[9] by Roberts,[10,11] and by Reed,[12] should be taken into consideration.

12-year-olds to a high of 41.2 ml percent for 17-year-olds. No such increase with age in the 5th percentile was seen for females. Values of this percentile for females remained within the 35.8-37.0 ml percent range throughout the 6 years of adolescence. The median, or 50th percentile, of the hematocrit distribution in male and female youths at each age showed the same variations with age and sex as the mean. At the upper end of the distribution, the 95th percentile for male youths increased with age from 45.2 ml percent in 12-year-olds to 50.3 ml percent in 17-year-olds. No such increase with age was seen in females.

In an attempt to gain further insight into the nature of the increase in hematocrit levels for male youths, data were analyzed for 6-month age groups from 12 to 18 years (table 3). Those youths who were between 12 years and 12¼ years were included in the 12-year age group; those between 12¼ and 12¾ years of age, in the 12½-year age group; those between 12¾ and 13¼, the 13-year age group; and so forth. Those male youths 17¾ years and over were included in the 18-year age group. There was an irregularity in the classification at the two extreme age groups because only youths over 12 years and under 18 years of age were eligible to participate in the examination.

Mean hematocrit levels in male youths for 6-month age groups increased consistently and rather uniformly with age, from a low of 40.4 ml percent for 12-year-old males to a high of 46.0 ml percent in 18-year-old males (table 3). An examination of successive differences between these means shows that the largest difference (0.8 ml percent) occurred between 14 and 14½ years of age. Differences of 0.6 ml percent or more, however, occurred between 13 and 13½ years (0.6 ml percent), 14½ and 15 years (0.6 ml percent), and 15 and 15½ years (0.7 ml percent). The smallest differences between means occurred at the two extreme age groups (which have irregular age compositions), where the difference in mean hematocrit between 12- and 12½-year-olds was 0.1 ml percent, and that between 17½- and 18-year-olds was 0.2 ml percent.

In describing the shape of the distribution of hematocrits, we have used three summary statistics—namely, the distance between the mean and the median, the distance between the 5th percentile and the median, and the distance between the 95th percentile and the median (table 4). In male youths, the median at each age was slightly higher than the mean, but the distance from the 5th percentile to the median was approximately the same as that from the median to the 95th percentile. Thus, the distribution for males at each age group was fairly symmetrical.

For females aged 12, 16, and 17 years, the mean and median hematocrits were always within 0.1 ml percent of each other; and the distance between the 5th percentile and median was nearly the same as that between the median and 95th percentiles, indicating symmetrical distributions. On the other hand, although the means and medians for females aged 13, 14, and 15 years were also virtually identical, the distance between the 95th and 50th percentiles was greater than the distance between the 5th and 50th percentiles by 1.0 ml percent or more. Since the means and medians coincided, this indicates that the lower 5-percent tail of the distribution is longer than the upper 5-percent tail, which, in turn, implies the presence of some very low hematocrit levels for 13-, 14-, and 15-year-old females.

Geographic Region, Sex, and Age

Mean hematocrits and standard errors of the mean hematocrits are shown in table 5 by geographic region, sex, and age; and the number of sample persons are shown in table 6 by the same variables. Within each geographic region, mean hematocrit increased with age in males but not in females, a finding consistent with the pattern discussed previously for the United States as a whole. The findings show no evidence of differences among regions with respect to mean hematocrit levels.

Race, Sex, and Age

Findings by race, sex, and age are shown in tables 7 through 11, and in figures 2 and 3.

The increase with age in mean hematocrit found for male youths in the United States as a whole was also found for Negro and white males

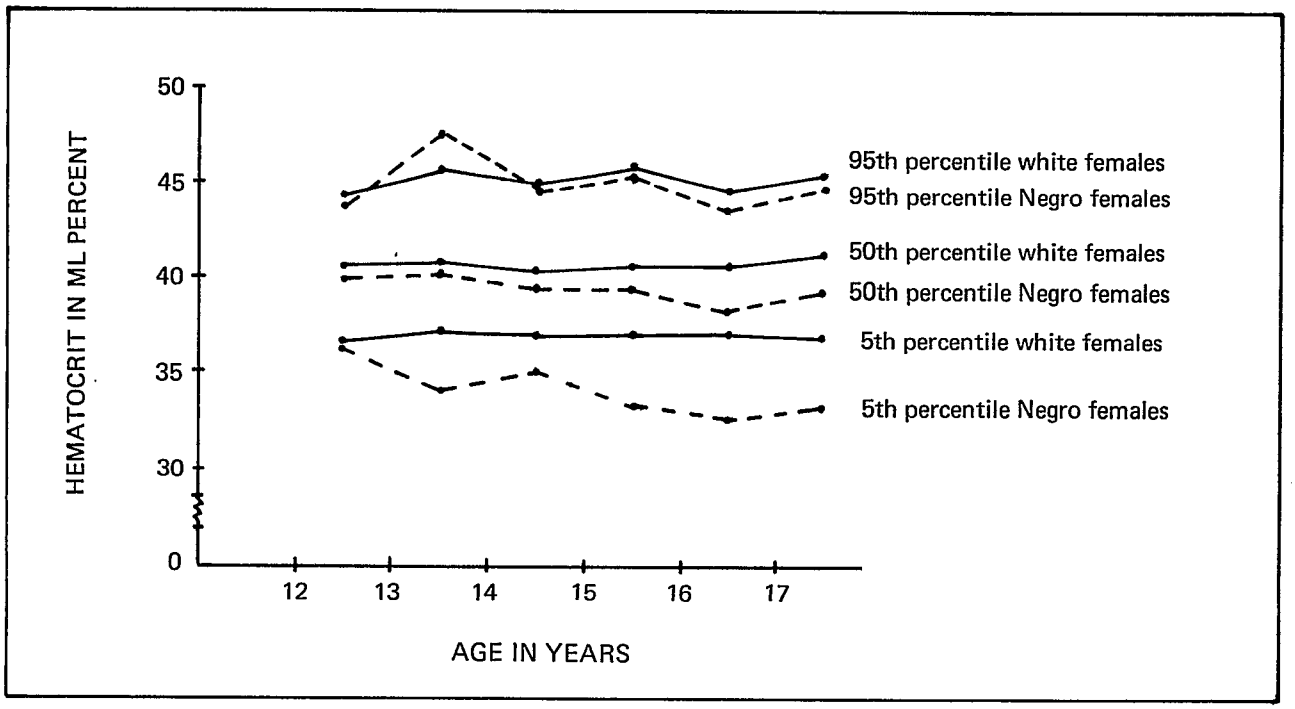

Figure 2. Median, 5th, and 95th percentiles of the hematocrit distribution of white and Negro females by age: United States, 1966-70.

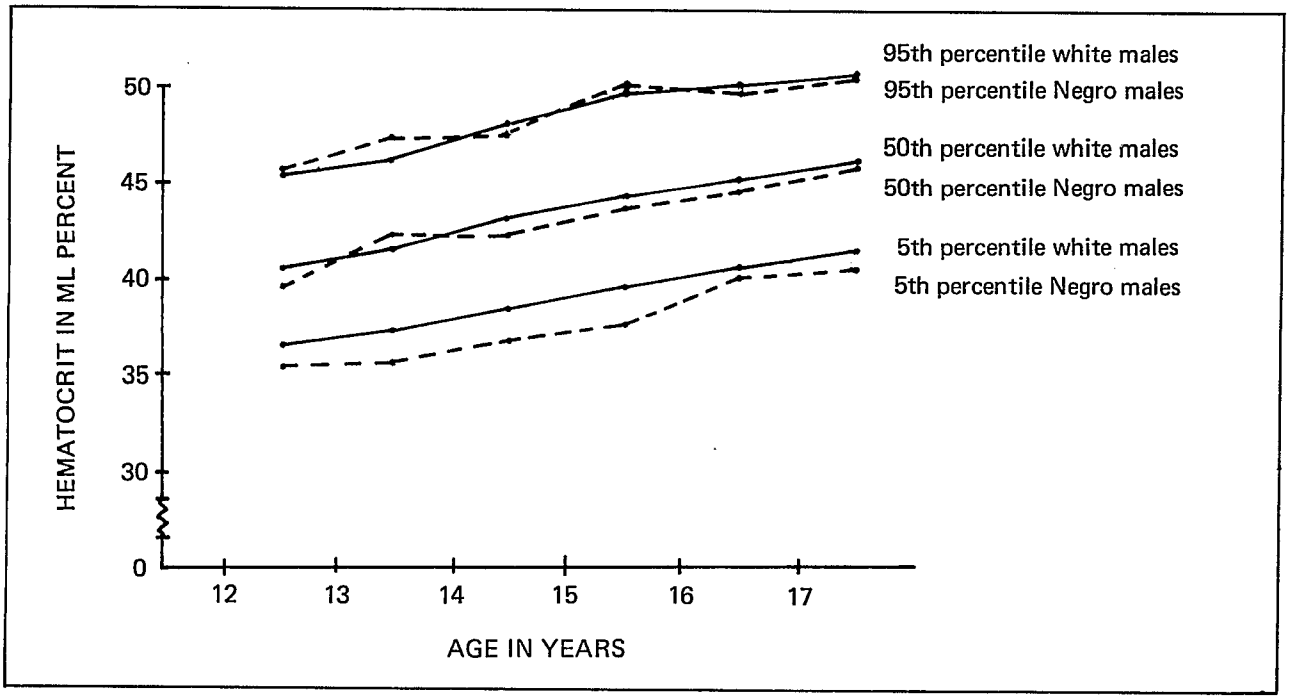

Figure 3. Median, 5th, and 95th percentiles of the hematocrit distribution of white and Negro males by age: United States, 1966-70.

separately (table 7). Mean hematocrit levels increased in white males, from a low of 40.6 ml percent for 12-year-olds to a high of 45.8 ml percent for 17-year-olds. In Negro males, mean hematocrit levels increased consistently with age from 39.6 ml percent for 12-year-olds to 45.7 ml percent for 17-year-olds. At each age, the mean hematocrit for Negro males was lower than that for white males of the same age.

In white female youths, there was no increase with age in mean hematocrit, with mean levels fluctuating between 40.4 and 40.9 ml percent. In Negro females, mean hematocrit levels were lower in the 16- and 17-year-olds than in the 13-, 14-, and 15-year-old youths. At each age, Negro females had lower mean hematocrit levels than white females, with the differences between races being very large (2.4 ml percent) for 16- and 17-year-old girls (table 7).

Selected percentiles of hematocrit levels are shown for white and Negro youths in tables 10 and 11 and figures 2 and 3. The differences in hematocrit levels between white and Negro youths at the 5th, 50th, and 95th percentiles are shown in table 8.

Differences between white and Negro males were primarily at the lower end of the distribution (figure 3 and table 8). The 5th percentile for white males was higher at each age than the corresponding percentile for Negro males, with these differences averaging 1.25 ml percent over all ages. At the middle of the distribution, differences between Negro and white males were much smaller, with the median for white males averaging 0.5 ml percent higher than that for Negro males. In sharp contrast, at the upper end of the distribution, there were no consistent differences between white and Negro males at the 95th percentile.

The hematocrit distribution for Negro males had more variability associated with it than that for white males (tables 10 and 11). The standard deviation of the hematocrit distribution was greater at each age for Negro males than for white males, as was the distance between the 95th and 5th percentiles. If one distribution has a lower median and greater variability than another, one would expect the differences between the two to be most striking at the lower end of the distribution, which is exactly what was observed in the hematocrit distributions of white and Negro males.

Similar patterns appear when the differences between the hematocrit distributions of white and Negro females are analyzed (tables 8, 10, and 11 and figure 2), except that the differences were more apparent for females and they were most striking for the older females (15-, 16-, and 17-year-olds). The 5th percentile for white females averaged 3.0 ml percent higher than that for Negro females, with 16-year-old white females having a 5th percentile that was 4.4 ml percent higher than their Negro counterparts (figure 2).

The median of white females was higher at each age than that of Negro females, and the difference was highest at the two oldest ages (2.4 ml percent for 16-year-olds and 2.0 ml percent for 17-year-olds). At the upper end, the 95th percentile for white females was higher than that for Negro females at all ages except 13 years. Again, as in males, differences between Negro and white females were largest at the lower end of the distribution, and smallest at the upper end.

In all but 12-year-olds, the standard deviation of the hematocrit distribution was higher for Negro females than for white females (tables 10 and 11).

Another way of looking at differences in hematocrit levels by race is shown in table 12, in which the percentage of persons with hematocrit levels below three cutoff points—i.e., 35.0 ml percent, 37.0 ml percent, and 39.0 ml percent—is shown by race, age, and sex. For both males and females at each age group, the percentage of Negroes having hematocrit levels below each of these cutoff points was much greater than the corresponding percentage of whites.

Annual Family Income, Sex, and Age

Mean hematocrit levels are given for male and female youths by annual family income in table 13. A small but clear increase in mean hematocrit occurred with increase in annual family income for both male and female youths at each age group. Hematocrit levels of males in families with annual incomes of $10,000 or more averaged (over all ages) 0.67 ml percent higher than those of males in families with annual incomes of less than $3,000, while the level of females in families with annual incomes of $10,000 or more averaged 1.08 ml percent higher than those

of females whose families had annual incomes of less than $3,000 (figure 4). Table 14 shows the 10th, 50th, and 90th percentiles of the hematocrit distribution by age and sex for those in families with annual incomes less than $4,000 and for those in families with annual incomes of $10,000 or more. Differences between youths whose families had annual incomes of $10,000 or more and those whose families had annual incomes less than $4,000 were generally greater at the 10th percentile than at the median and 90th percentiles.

Education of Parent, Sex, and Age

Mean hematocrit levels by education of parent, sex, and age are shown in table 15. An increase in mean hematocrit was found with increase in education of parent. Over all ages, those male youths whose parents had 13 years of education or more had mean hematocrit levels approximately 0.82 ml percent higher than those males whose parents had less than 8 years of education, while those females whose parents had 13 years of education or more had mean hematocrit levels approximately 1.13 ml percent higher than those females whose parents had less than 8 years of education (figure 5).

Annual Family Income, Education of Parent, Race, Sex, and Age

Mean hematocrit levels are given by annual family income, sex, and age (tables 16 and 17)

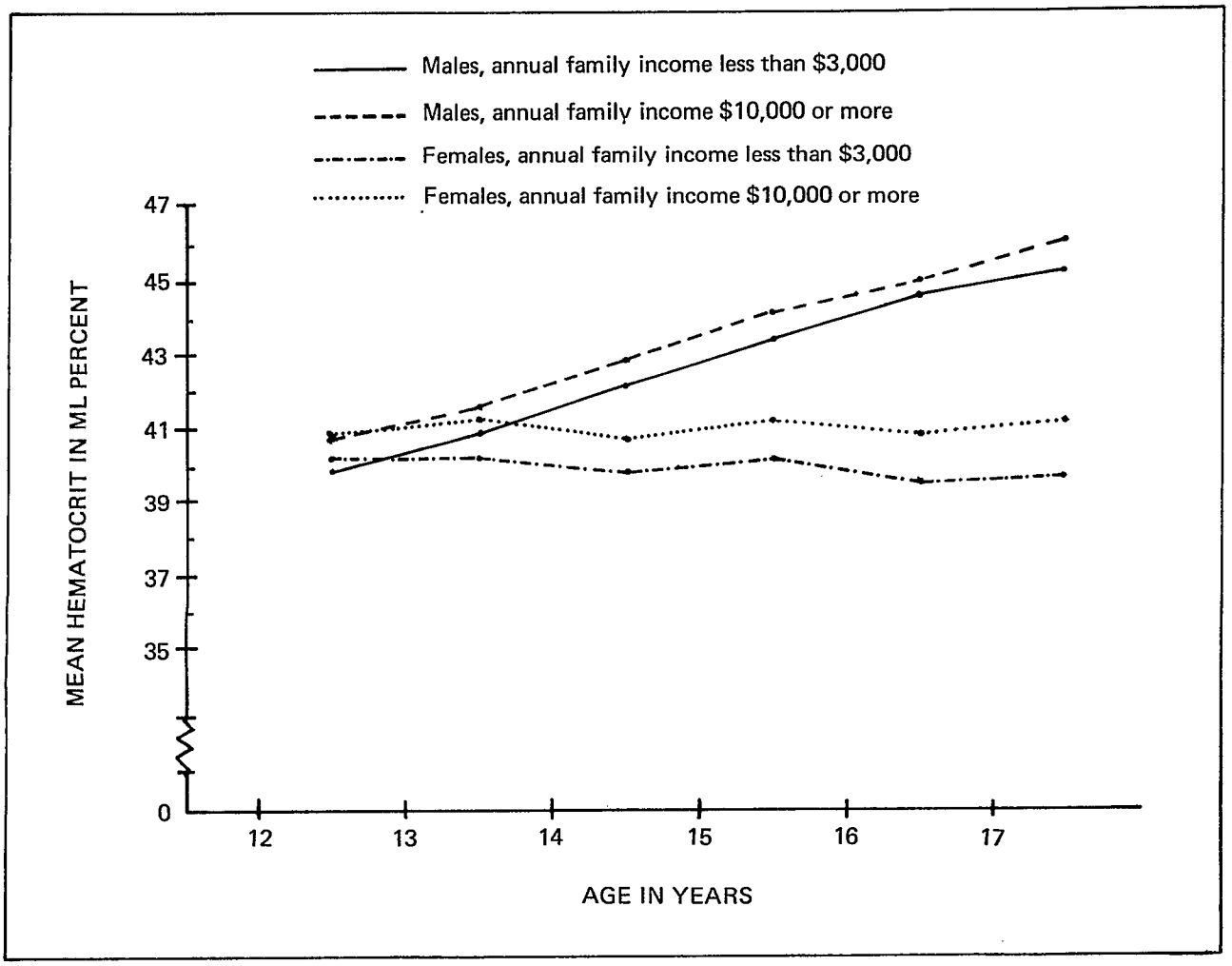

Figure 4. Mean hematocrit levels for youths aged 12-17 years, by annual family income, age, and sex: United States, 1966-70.

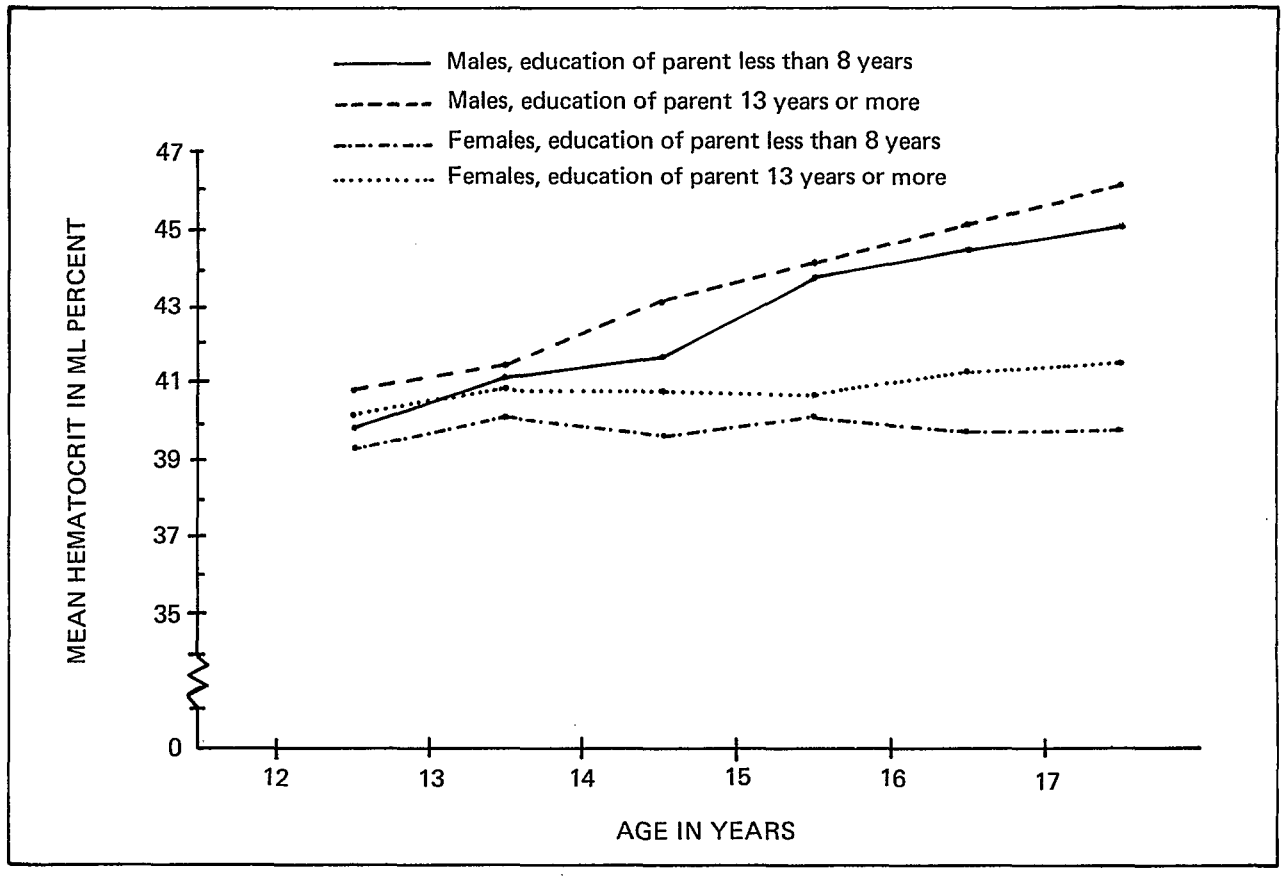

Figure 5. Mean hematocrit levels for youths aged 12-17 years, by education of parent, age, and sex: United States, 1966-70.

and by education of parent, sex, and age (tables 18 and 19) separately for white and Negro youths.

The relationships between mean hematocrit and annual family income and between mean hematocrit and education of parent, discussed previously for the population as a whole, held also for white youths when examined separately. Among white males and white females in all age groups, a consistent increase in mean hematocrit was found both with increase in annual family income and with increase in education of parent.

When data were examined separately for each age group (tables 17 and 19), there did not appear to be a consistent increase in mean hematocrit of Negro youths with increase in annual family income or with increase in education of parent. These estimates of mean hematocrit for Negroes, however, were quite unstable because of the relatively small numbers of Negroes in the sample, especially at the higher income and education groups. To compensate for this, the six age groups for females in tables 16 through 19 were collapsed into one table, and the combined data were examined for Negro and white female youths by education of parent and by annual family income (table A and figures 6 and 7). Even with all ages combined, the Negro female youths did not show a consistent increase in mean hematocrit with increase in annual family income or with increase in education of parent. At all levels of income and education, white female youths had mean hematocrits approximately 1.0-2.0 ml percent higher than Negro females of comparable family income or parental education.

A similar analysis was not performed for males because of the increase with age in mean hematocrit observed in both Negro and white males.

Table A. Sample size, mean hematocrits, and standard errors of the means for Negro and white female youths 12-17 years of age, by annual family income and education of parent

Income and education of parent	Negro female			White female		
	N (000)	$\bar{X}$	$s_{\bar{x}}$	N (000)	$\bar{X}$	$s_{\bar{x}}$
		Hematocrit in ml percent				
Annual family income						
Less than $3,000	495	39.3	.32	928	40.2	.39
$3,000-$4,999	400	38.9	.49	1,102	40.3	.24
$5,000-$9,999	407	39.7	.19	3,760	40.6	.14
$10,000 or more	117	39.4	.72	3,258	41.0	.15
Education of parent						
Less than 8 years	302	38.9	.28	784	40.1	.62
8-11 years	679	39.4	.22	2,337	40.4	.19
12 years	363	39.8	.32	3,600	40.8	.10
13 years or more	127	38.5	.90	2,752	41.0	.17

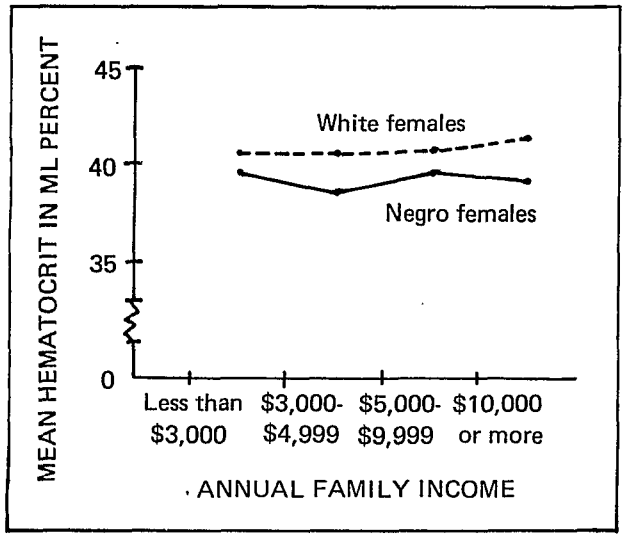

Figure 6. Mean hematocrit for white and Negro female youths aged 12-17 years by annual family income: United States, 1966-70.

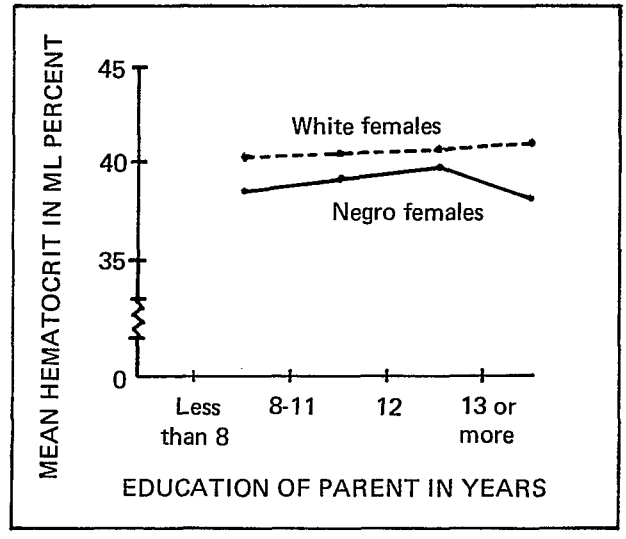

Figure 7. Mean hematocrit for white and Negro female youths aged 12-17 years by education of parent: United States, 1966-70.

DISCUSSION

The packed cell volume, or hematocrit value, is determined by centrifuging a standard amount of whole blood at 12,500 r.p.m. for 5 minutes. As a result of this procedure, the blood's cells are separated from the plasma and packed in the lower portion of the tube. The resultant hematocrit packed red cell volume can be measured very accurately.

The hematocrit value gives similar, but not identical, information on the hematological status of a subject, as does a hemoglobin or red blood cell count. Currently, the hematocrit is the simplest and single most accurate measurement of anemia or polycythemia available to the health profession. If the hematocrit is abnormal, then the hemoglobin and the number of red cells can be measured for more definitive hematological studies. Unfortunately, standard values for adolescents are difficult to construct due to the scarcity of studies that controlled the numerous variables influencing the normal hematocrit value in adolescence.

There are many variables that influence hematocrit values in healthy individuals, so that healthy persons vary widely with respect to their blood values.[13] Small differences may be associated with such factors as height, weight, and body types. Under ordinary circumstances, a small diurnal variation of about 4 percent from the mean hemoglobin has been observed.[14] Acute or chronic changes in hydration will influence the hematocrit concentration. It has been suggested that muscular activity can alter hematopoietic values. For example, strenuous exercise may lead to accelerated destruction of red cells;[15] however, sustained exercise by athletes can stimulate the erythropoietic system. Olympic athletes have mean hemoglobins that vary from 13.7 to 18.6 grams percent.[16] Because of this, blood values obtained after extreme exercise are of dubious significance. Extreme excitement resulting in erythrocytosis has been described.[17] On the other hand, climate, temperature, and season have relatively little influence on blood values.[13] Studies reporting on racial differences in erythropoietic values are few, inconclusive, and deal primarily with adults.[18,19] Low barometric pressure, which increases anoxemia, is accompanied by a compensatory increase in erythrocyte count and thus in the quantity of hemoglobin. The magnitude of the response depends on the degree, duration, and constancy of exposure to the low barometric pressure associated with high altitude.[d] Sustained exposure to high altitudes over months or years will lead to an increased concentration of red cells.[13] The significant physiologic factors (i.e., excluding diseases) affecting the erythrocyte count are (1) extreme physical exercise or excitement, (2) severe dehydration, (3) age, (4) sex, and (5) high altitude.[20] Age and sex, two of the most significant variables in this type of study, were carefully controlled in this survey. Extreme physical exercise, excitement, and high altitudes play a casual role in the results in this study. Severe dehydration, an uncommon event in an ambulatory population, is also a most unlikely factor that could possibly affect the results of the investigation.

Finally, most of the data reported in the literature differ from those of the HES because of the omission of those subjects who were anemic or suffered from recent blood loss, poor nutrition, and diseases of the blood. Therefore, those results are not strictly comparable to HES data, which were obtained from a population at large with no specific medical exclusions.

Anemia in some of our sample subjects may significantly affect the outcome of these HES data. (This important variable will be discussed fully under racial differences.) It has been demonstrated in a recent study that a normal juvenile population given therapeutic iron for a period of 3 months will show an increase in hemoglobin and mean corpuscular hemoglobin concentration.[21] However, there was no change in mean hematocrit values, indicating that a mild iron deficiency will not affect mean population hematocrit values. When using and interpreting HES values, it is important to keep in mind that these values represent the hematocrit status for the entire U.S. population aged 12-17 years and may or may not represent the optimal or maximal hematocrit values for this age group.

Age and Sex

Striking variations in erythropoiesis are known to be associated with age and sex. In these HES data, adjustment for age and sex is critical because the major differences in erythrocyte formation between males and females first occur during adolescence. In order to demonstrate this, studies need to be carefully designed to control for age and sex; most of the studies in the literature have failed to do this.

[d] A preliminary analysis of unweighted data showed the expected altitude gradient with a range of approximately 3 ml percent.

The effect of age and sex on hematocrit during childhood is not striking. Reported studies indicate a slight rise in hematocrit during childhood with no difference between boys and girls.[13,21,22] During adolescence, girls in the present study have a stable hematocrit, with little if any change with age (tables 1 and 3). This is also true in the few comparable studies that are available in the literature.[21-23] In sharp contrast, boys who enter adolescence with a hematocrit similar to that of girls show a steady increase with age during adolescence, almost reaching their adult values by the 17th year (tables 1 and 3). The increase in hematocrit in boys appears to reach its maximum between the ages of 14 and 14½ years. These ages are the period of life when many of the boys would be experiencing the biological expression of pubescence. Therefore, more than a casual relationship between the events of pubescence and changes in hematocrit in males is suggested. It has already been shown that increment in hemoglobin in adolescent males is closely related to the events of pubescence.[24] The postulation that this increase in erythropoiesis in the male is induced by androgens is compatible with our observations on males of same age.[25] Thus, the sex difference in hematocrit develops in the 13th year in our population and widens perceptibly by the 17th year. In a similar and comparable study of Swedish children and adolescents, the significant sex difference in hematocrit also occurred during the 13th year.[21]

By age 15, most teenage girls are menstruating. The daily loss of iron through menstruation ranges from 0.1 to 4.0 mg/day, the average being 0.7 mg.[26] Under normal living conditions and with an adequate diet, the teenager is able to replace these additional iron losses. If the diet is inadequate or if pregnancy with its higher iron requirement occurs, the teenage female may develop anemia.

Race

In one earlier study of healthy adult men, no racial differences in hemoglobin, hematocrit, or erythrocyte count were detected.[27] Subsequently, Cycle I HES data showed that with the exception of males aged 18-24, white adults had consistently higher mean hematocrits than Negro adults.

Differences in blood values between various samples of Negro and white children and adolescents have been reported recently. Owen[28] has reported a significantly lower hemoglobin in young Negro children compared with that in white children, even though an adequate amount of circulating iron in the serum was demonstrated. Pearson reported a prevalence of anemia (which he defined by a hematocrit value less than 34 ml percent) in Negro girls aged 14-17 years of 8.0 percent and a prevalence of anemia (as he defined by a hematocrit value less than 36 ml percent) in Negro males aged 14-17 years of 1.2 percent.[29] Unfortunately, Pearson's study had no white subjects to be used as a comparative reference. Data from the recent 10-State Nutrition Survey suggest that hematocrit values of Negroes are lower than those of white persons at most ages.[30] In addition, the study found that Negro children 6-12 years of age in States with both low and high income ratios have lower hematocrits than white children of the same age group. Further, it was found that only in States with low income ratios were the hematocrit values for Negro children 2-5 years of age lower than those for white children. Most recently, the preliminary findings from the Health and Nutrition Examination Survey (HANES) of the National Center for Health Statistics, which have just been published,[31] estimate mean hematocrit values for white youths 12-17 at 42.2 ml percent and those of Negro youths at 40.2 ml percent.

In the currently reported HES survey of youths 12-17 years of age, racial differences between Negro and white adolescents are very apparent. Because of the size and nature of the sample, these currently reported HES estimates are much more reliable than those referred to above. Both male and female white youths have consistently higher mean hematocrit values than Negro male and female adolescents, with differences between Negro and white youths being more apparent in females than in males and most apparent among older female adolescents (table 7). Descriptively, our findings further show that a substantially greater percentage of Negro female youths have hematocrit values below 35, 37, or 39 ml percent at all ages than

white girls; the same is true, although to a lesser extent, of Negro male youths when compared with white males of similar age.

It is unlikely that the racial differences in hematocrit found in our survey can be explained by anemias resulting from abnormal hemoglobin. The prevalence of sickle cell disease, sickle cell trait, and thalassemia, all known to cause anemia, was found to be only 0.24 percent in a group of Job Corps enrollees.[19] This low prevalence of anemia due to abnormal hemoglobin could not explain the racial differences found in our population.

One determinant of low hematocrit in adolescent girls is the occurrence of pregnancy with its higher demands for dietary iron at a time when growth and onset of menstruation also require increased iron. When this demand for increased iron is superimposed on chronically marginal nutritional intakes, excessively low hematocrits might result. This might be particularly true of Negro girls, since the rate of pregnancy for females of races other than white has been reported to be 11 times that of white girls between the ages of 10 and 14 years and 2.4 times that of white girls between the ages of 15 and 19 years.[32] This may partially explain the excessive number of Negro girls with low hematocrits, particularly as age increases.

If we apply Pearson's criterion for anemia in females (hematocrit less than 34 ml percent) to HES data, we would estimate that 6.8 percent of Negro adolescents 14-17 years of age are anemic, which closely compares with a prevalence of 6.0 percent found by Pearson. Likewise, applying Pearson's criterion for anemia in males (hematocrit less than 36 ml percent), we would extrapolate from HES data that 1.9 percent of Negro youths 14-17 years of age are anemic, a prevalence very close to the 1.2 percent found by Pearson for Negro males 14-17 years old.[29]

It is quite apparent from the recent reports mentioned previously as well as from HES data that a significant difference exists between hematocrit values for Negro and white teenagers. Furthermore, this difference is greater between females than between males. It is unlikely that all of the difference is due to an excessive proportion of cases of anemia among Negroes. There remains an apparent residual racial difference in the comparative percentile distributions (even at the 50th and 95th percentiles) among females that cannot be satisfactorily explained by these HES data.

Income and Education

There is clear evidence that level of family income is related to the level of hematocrit in both boys and girls (table 13 and figure 4). This effect is much more pronounced at the 10th percentile of the distribution than at the 90th percentile (table 8).

In a similar fashion, the level of education is clearly correlated with the level of hematocrit in the population. This is apparent at all ages for both boys and girls (table 15 and figure 5). This observation is not unexpected, since education and family income are known to be highly correlated.

Presumably, the major part of this socioeconomic effect lies in the greater amount of anemia found in lower socioeconomic groups. Perhaps, a rise in income results in better nutrition or medical care and, hence, a decrease in the likelihood of developing anemia. Alternatively, there may be a tendency for "anemic" families to be less successful economically. When interpreting associations between income and conditions of ill health, there is always the question of whether ill health is a *result* of low income or whether it is a *cause*. The present data, however, cannot ascertain which, if either, of these hypotheses is the important determinant of the observed socioeconomic differences.

Interaction Between Race and Socioeconomic Status

An important finding in these data is the lack of a clearcut increase in hematocrit with increase in socioeconomic status among Negro adolescents (tables 17 and 19). Even when all the age groups for females were combined (table A), there appeared to be no consistent socioeconomic effect for Negro females. The explanation for this may be nutritional. That is, even as Negro families rise up the socioeconomic ladder, they may still maintain their dietary habits of less affluent periods. Alternatively, there may be genetic or physiological factors that affect hematocrit and are resistant to changes in socioeconomic status. Again, it cannot be deter-

mined from the present data which, if any, of these speculations is the important determinant of the lack of a strong socioeconomic effect observed in Negro adolescents.

There was, however, in white adolescent males and females, a consistent increase in mean hematocrit with increase in socioeconomic status as measured by either family income (table 16) or education of parent (table 18). Since there was no age effect in female adolescents, it was possible to combine age groups for Negro and white females and, hence, to examine Negro-white differences at each level of income or education (table A). From this, it appears that the differences in mean hematocrit between white females at the highest socioeconomic levels (annual family income of $10,000 or more or education of parent of 13 years or more) and those at the lowest end (annual family income less than $3,000 or education of parent less than 8 years) are generally smaller than the differences observed between white and Negro female youths of comparable socioeconomic status.

General Comparability With Other Studies

There are only a few studies in the literature with which HES data can be somewhat compared. Unfortunately, most of the studies either combine boys and girls during adolescence and calculate a mean value or otherwise construct tables or arrange the data by age in such a way that makes a comparison with these HES data difficult.

Dibble,[23] however, reported a study in which the hematocrit values of boys and girls 12-15 years of age can be compared with those of HES youths. The hematocrit values among 12-year-old boys in three different school populations ranged from 38.7 ml percent to 43.0 ml percent; and for 15-year-olds, the range was from 43.3 ml percent to 45.0. The mean for HES boys at age 12½ was 40.5 ml percent and at age 15½, 43.9 ml percent. For 15-year-old girls, the range was from 37.1 ml percent to 40.7. Similarly, the mean for HES girls at age 12½ was 40.3 ml percent and at 15½, 40.7. Thus, the data between the two studies are quite comparable.

Wintrobe,[13] a frequently cited reference for normal values, grouped data by age up to 15 years and then reported normal values for adult males and females. At ages 11-15 years, the overall mean hematocrit is 39.0 ml percent. His published mean values for adult females and adult males are 42.0 and 47.0 ml percent, respectively. The most comparable HES females and males (i.e., 17-year-olds) have hematocrit values of 40.6 and 45.8 ml percent, respectively. Both values are slightly under the values found by Wintrobe. It appears that HES values would be similar to Wintrobe's if the age limits of our population had been extended into their twenties. Further comparisons with Wintrobe's normal data are not valid because of the grouping of his data.

Albritton's[22] standard values for 12-year-old boys and girls combined are slightly lower (39.6 ml percent) when compared with HES boys (40.5 ml percent) and girls (40.3 ml percent) of the same age. For boys and girls 14 years and over, Albritton's standard values are 47.0 and 42.0 ml percent, respectively. HES boys and girls aged 17 years have a mean hematocrit of 45.8 and 40.6 ml percent, respectively; both values are slightly lower than Albritton's.

Pearson[29] reported the hematocrit values for a large number of Negro children and youths. Again, his grouping of data during adolescence makes comparisons difficult. For Negro males aged 14-17 years in the Pearson study, mean hematocrit was 43.2 ml percent, whereas for those similarly grouped by age in the HES, the overall mean was 43.6 ml percent. For females 14-17 years, the mean hematocrit was 38.8 ml percent compared with that of 38.9 ml percent for comparable females in the HES. Thus the data from Pearson's study and the national estimates from the HES for Negroes aged 14-17 years are, on comparison, almost identical. A recent Norwegian study reports hematocrits for each year of age from 7 through 20 years.[21] The mean hematocrit for boys at age 12 years is 40.7 ml percent (40.5 for those in the HES) and at 17 years, 45.2 ml percent (45.8 for those in the HES). For girls at age 12, the mean hematocrit was 41.0 ml percent (40.3 for those in the HES) and at 17 years, 41.1 ml percent (40.6 for those in the HES). The data are remarkably comparable, most especially that for boys. Finally, the most recently available comparison of these HES data is that with the preliminary findings of the HANES data referred to earlier,[31] in which the

overall mean values are almost identical: In both the HES and the HANES, mean hematocrits of males aged 12-17 years are estimated to be 43.1 ml percent, while those for females in the HANES are estimated to be 40.7 ml percent and in the HES, 40.5 ml percent. Thus, the mean values of HES hematocrit data compared with similar data in the literature on adolescence are in close agreement.

The HES data can also be compared with two studies of young adults. First Greendyke's [27] study of 950 healthy enlisted men aged 17-29 years (with exclusions for any factor known to affect normal blood values) found the mean hematocrit to be 45.8 ± 2.5 ml percent, again quite close to HES values. Second, current data on teenagers can be compared with Cycle I data for adults (table 20).[18] It appears from the combined Cycle I and Cycle III data that the increase with age in mean hematocrit observed in Cycle III adolescents continues in males 18-24 years old (as observed from Cycle I data), but at a much slower rate, until "mature" levels of about 47.0 ml percent are reached. There then appears to be a decrease in mean hematocrit with age beginning with the age group 45-54 years. In Cycle III females, there was little or no apparent increase in mean hematocrit observed at ages 12-17. The mean hematocrit level for 17-year-old adolescent females was 40.6 ml percent and 41.4 ml percent for females aged 18-24. This would be compatible with an annual increase of 0.2 ml percent beginning with age 17. Female hematocrits seem to increase during adulthood to levels over 43 ml percent among postmenopausal women.

It appears from Cycle I data that mean hematocrit increases slowly throughout the adult life of women to reach levels of 43.7 ml percent around age 60. The data from Cycle III, however, indicate little if any evidence of increase during adolescence. Therefore, to account for the difference of 0.8 ml percent between 17-year-old females in Cycle III and those aged 18-24 years in Cycle I, one would have to hypothesize that the increase observed in Cycle I adult women begins shortly after age 18 or that there is a systematic artifact that gives artificially high levels to the Cycle I data. One would tend to reject the latter hypothesis, because the laboratory artifact would also have to be operating on the men, and the observed curve for men appears completely reasonable.

Finally, the question can be raised concerning the use of these data. Can the data be used as optimal physiological standards, or is their use restricted to being descriptive of the adolescent population in the United States during the sampling period? It is obvious that this is a representative sample for the United States that also includes all the abnormally low and high values secondary to disease. It is of interest, however, that the HES results for adolescents are almost identical to those reported by Natvig.[21] His study had one characteristic that is important to note. After initial measurements of blood indexes, a group of Norwegian children and adolescents were given elemental iron for 3 months. During this period, there was a significant rise in hemoglobin and mean corpuscular hemoglobin concentration, indicating mild iron deficiency in his "normal" population. At the same time, there was no change in their hematocrit. Therefore, the hematocrit may be normal in mild iron deficiency. The suggestion that HES data for adolescents may be quite close to or even representative of the optimal hematocrit values for adolescents could be supported by the similarity between the Norwegian and HES data on hematocrits during adolescence.

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LIST OF DETAILED TABLES

Table 1. Estimated number of youths aged 12-17 years in the population by hematocrit group and selected characteristics of hematocrit distribution, by sex and age: United States, 1966-70

Selected variable	Male						Female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
Hematocrit group	Estimated number of youths in population in thousands											
All groups	2,032	2,006	1,951	1,900	1,836	1,764	1,970	1,946	1,901	1,851	1,789	1,746
Under 29.0 ml percent	-	3	-	2	3	-	-	-	3	-	3	3
29.0-30.9 ml percent	2	-	-	-	-	-	-	-	3	3	3	2
31.0-32.9 ml percent	2	-	-	-	-	-	-	3	5	9	12	10
33.0-34.9 ml percent	15	10	3	-	-	-	18	27	26	18	20	21
35.0-36.9 ml percent	130	73	35	16	7	8	94	65	69	78	91	93
37.0-38.9 ml percent	329	248	132	81	31	10	391	352	433	343	343	278
39.0-40.9 ml percent	652	496	322	208	71	57	608	588	608	561	537	521
41.0-42.9 ml percent	487	554	465	364	242	135	506	466	410	427	434	410
43.0-44.9 ml percent	297	376	489	454	555	386	305	286	251	257	268	303
45.0-46.9 ml percent	89	159	305	436	434	479	39	101	56	112	56	65
47.0-48.9 ml percent	24	71	173	200	322	450	6	48	30	29	19	36
49.0-50.9 ml percent	3	16	24	99	118	173	3	11	5	6	3	4
51.0-52.9 ml percent	-	-	3	27	44	49	-	-	-	-	-	-
53.0-54.9 ml percent	-	-	-	3	9	15	-	-	-	-	-	-
55.0-56.9 ml percent	-	-	-	3	-	-	-	-	-	-	-	-
57.0 ml percent and over	-	-	-	6	-	-	-	-	-	6	-	-
Percentile	Hematocrit in ml percent											
5th	36.0	37.1	38.1	38.8	40.3	41.2	36.6	37.0	36.7	36.7	36.2	35.8
10th	37.3	38.2	39.2	40.1	41.7	42.4	37.6	37.8	37.6	37.7	37.3	37.3
25th	39.1	40.0	40.9	42.1	43.2	44.2	38.9	39.2	38.7	39.1	38.8	39.2
50th	40.6	41.8	43.0	44.2	45.0	46.1	40.4	40.7	40.3	40.6	40.4	40.7
75th	42.4	43.3	45.1	46.1	47.1	48.0	42.3	42.6	42.2	42.7	42.4	42.7
90th	44.1	45.2	47.0	48.3	48.8	49.6	43.4	44.3	44.0	44.5	44.1	44.2
95th	45.2	46.3	47.8	49.7	49.9	50.3	44.3	45.8	44.9	45.7	44.7	45.3
Mean age at time of examination (in years)	12.54	13.49	14.51	15.49	16.47	17.51	12.53	13.48	14.49	15.51	16.49	17.50
Mean hematocrit in ml percent	40.5	41.5	42.7	43.9	44.9	45.8	40.3	40.7	40.3	40.7	40.4	40.6
Standard deviation in ml percent	2.67	2.86	2.92	3.36	2.99	2.82	2.37	2.80	2.77	3.00	2.73	2.94
Standard error of mean	.17	.20	.17	.21	.21	.16	.17	.16	.18	.19	.18	.16

Table 2. Percent distributions of youths aged 12-17 years by hematocrit intervals, according to sex and age: United States, 1966-70

Hematocrit group	Male						Female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
	Percent distribution											
All groups	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 29.0 ml percent	-	.1	-	.1	.2	-	-	-	.2	-	.2	.2
29.0-30.9 ml percent	.1	-	-	-	-	-	-	-	.2	.2	.2	.1
31.0-32.9 ml percent	.1	-	-	-	-	-	-	.2	.3	.5	.7	.6
33.0-34.9 ml percent	.7	.5	.2	-	-	-	.9	1.4	1.4	1.0	1.1	1.2
35.0-36.9 ml percent	6.4	3.6	1.8	.8	.4	.5	4.8	3.3	3.6	4.2	5.1	5.3
37.0-38.9 ml percent	16.2	12.4	6.8	4.3	1.7	.6	19.8	18.1	22.8	18.5	19.2	15.9
39.0-40.9 ml percent	32.1	24.7	16.5	10.9	3.9	3.2	30.9	30.2	32.0	30.3	30.0	29.8
41.0-42.9 ml percent	24.0	27.6	23.8	19.2	13.2	7.7	25.7	23.9	21.6	23.1	24.3	23.5
43.0-44.9 ml percent	14.6	18.7	25.1	23.9	30.2	21.9	15.5	14.7	13.2	13.9	15.0	17.4
45.0-46.9 ml percent	4.4	7.9	15.6	22.9	23.6	27.2	2.0	5.2	2.9	6.1	3.1	3.7
47.0-48.9 ml percent	1.2	3.5	8.9	10.5	17.5	25.5	.3	2.5	1.6	1.6	1.1	2.1
49.0-50.9 ml percent	.1	.8	1.2	5.2	6.4	9.8	.2	.6	.3	.3	.2	.2
51.0-52.9 ml percent	-	-	.2	1.4	2.4	2.8	-	-	-	-	-	-
53.0-54.9 ml percent	-	-	-	.2	.5	.9	-	-	-	-	-	-
55.0-56.9 ml percent	-	-	-	.2	-	-	-	-	-	-	-	-
57.0 ml percent and over	-	-	-	.3	-	-	-	-	-	.3	-	-

Note.—Percents may not add to 100.0 due to rounding.

Table 3. Mean hematocrit, standard deviation, standard error, and percentiles for youths aged 12-17 years, by sex and by age in ½-year intervals: United States, 1966-70

Sex	$\bar{X}$	s_x	$s_{\bar{x}}$	Percentile						
				5	10	25	50	75	90	95
Male										
12 years	40.4	3.11	.41	35.2	35.7	38.9	40.5	42.7	44.4	45.7
12½ years	40.5	2.52	.15	36.7	37.6	39.1	40.4	42.3	44.1	44.8
13 years	40.9	2.85	.24	36.6	37.9	39.3	41.1	43.0	44.7	45.7
13½ years	41.5	2.85	.19	37.0	38.1	40.0	42.0	43.4	45.1	47.0
14 years	41.9	2.71	.20	38.0	38.7	40.2	42.2	43.8	45.8	47.0
14½ years	42.7	2.87	.22	38.1	39.2	41.1	43.1	45.0	46.7	47.6
15 years	43.3	3.19	.15	38.4	39.4	41.3	43.2	45.3	48.1	49.1
15½ years	44.0	3.24	.23	39.0	40.2	42.2	44.6	46.0	48.2	49.9
16 years	44.4	3.41	.27	39.4	41.0	42.7	44.8	47.1	48.3	49.3
16½ years	44.9	2.79	.24	40.4	41.7	43.2	45.1	47.1	48.7	49.7
17 years	45.3	2.83	.20	41.4	42.3	43.4	45.3	47.5	49.1	50.5
17½ years	45.8	3.14	.22	40.7	41.9	44.1	46.1	48.1	50.2	50.8
18 years	46.0	2.28	.25	42.8	43.2	44.7	46.3	48.0	48.9	49.7
Female										
12 years	39.9	2.16	.22	36.4	37.5	38.6	40.2	41.6	42.8	43.5
12½ years	40.3	2.45	.21	36.2	37.5	38.8	40.4	42.4	43.4	44.2
13 years	40.7	2.45	.18	37.2	38.0	39.3	40.8	42.4	43.8	45.1
13½ years	40.8	2.82	.21	37.0	37.8	39.1	40.8	42.6	44.3	45.7
14 years	40.6	2.85	.20	36.2	37.7	38.9	40.3	42.6	44.6	45.7
14½ years	40.2	2.77	.27	37.1	37.7	38.6	40.2	42.2	43.8	44.4
15 years	40.2	3.03	.19	35.9	37.2	38.6	40.3	41.9	44.1	45.6
15½ years	40.8	3.03	.28	37.2	38.1	39.1	40.6	42.7	44.8	45.8
16 years	40.5	2.77	.17	36.2	37.2	38.8	40.4	42.6	44.2	45.1
16½ years	40.4	2.64	.20	36.4	37.3	38.9	40.3	42.4	44.1	44.9
17 years	40.6	2.67	.24	36.3	37.7	39.2	40.8	42.6	44.1	44.4
17½ years	40.5	2.90	.20	35.8	37.2	38.9	40.4	42.6	44.3	45.7
18 years	40.6	3.33	.37	35.7	37.2	39.5	41.1	42.7	44.3	45.6

Table 4. Means, medians, differences between means and medians, differences between medians and 5th percentiles, differences between 95th percentiles and medians of hematocrits, and a ratio for youths aged 12-17 years by sex and age: United States, 1966-70

Selected variable	Male						Female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
Mean (ml percent)	40.5	41.5	42.7	43.9	44.9	45.8	40.3	40.7	40.3	40.7	40.4	40.6
Median (ml percent)	40.6	41.8	43.0	44.2	45.0	46.1	40.4	40.7	40.3	40.6	40.4	40.7
Mean-median (ml percent)	−0.1	−0.3	−0.3	−0.3	−0.1	−0.3	−0.1	0.0	0.0	+0.1	0.0	−0.1
50th-5th percentile (ml percent)	4.6	4.7	4.9	5.4	4.7	4.9	3.8	3.7	3.6	3.9	4.2	4.9
95th-50th percentile (ml percent)	4.6	4.5	4.8	5.5	4.9	4.2	3.9	5.1	4.6	5.1	4.3	4.6
Ratio $\frac{\text{95th-50th}}{\text{50th-5th}}$	1.00	0.96	0.98	1.02	1.04	0.86	1.03	1.38	1.28	1.31	1.02	0.94

Table 5. Mean hematocrits and standard errors of the means for youths aged 12-17 years, by geographic region, sex, and age: United States, 1966-70

Sex and age	Total	Northeast	Midwest	South	West	Total	Northeast	Midwest	South	West
	Mean hematocrit in ml percent					Standard error in ml percent				
Male										
12 years	40.5	40.7	40.5	40.0	40.7	.17	.18	.37	.22	.65
13 years	41.5	41.4	41.5	41.1	41.8	.20	.30	.55	.19	.52
14 years	42.7	42.7	42.6	42.7	42.9	.17	.26	.27	.47	.48
15 years	43.9	43.9	43.9	43.6	44.4	.21	.44	.31	.38	.65
16 years	44.9	44.9	44.3	44.6	45.8	.21	.26	.22	.33	.75
17 years	45.8	45.9	45.5	45.6	46.2	.16	.28	.40	.32	.44
Female										
12 years	40.3	40.5	40.3	40.4	40.1	.17	.38	.28	.27	.31
13 years	40.8	40.8	40.6	40.4	41.2	.16	.27	.19	.37	.43
14 years	40.3	40.3	40.5	39.9	40.4	.18	.29	.43	.31	.61
15 years	40.7	40.5	40.8	40.5	40.9	.19	.45	.24	.22	.57
16 years	40.4	40.6	40.9	39.7	40.2	.18	.25	.22	.57	.53
17 years	40.6	40.5	41.2	39.9	40.6	.16	.23	.33	.42	.46

Table 6. Number of youths aged 12-17 years in the sample of the Health Examination Survey, by geographic region, sex, and age: United States, 1966-70

Sex and age	Total	Northeast	Midwest	South	West
	Number of youths				
Male					
All ages, 12-17 years	3,545	870	922	890	863
12 years	643	173	167	149	154
13 years	626	162	163	149	152
14 years	618	156	162	150	150
15 years	613	137	162	163	151
16 years	556	124	152	149	131
17 years	489	118	116	130	125
Female					
All ages, 12-17 years	3,223	771	835	814	803
12 years	547	135	150	128	134
13 years	582	145	157	142	138
14 years	586	139	148	161	138
15 years	503	121	108	139	135
16 years	536	125	140	126	145
17 years	469	106	132	118	113

Table 7. Mean hematocrits and standard errors of the means for youths aged 12-17 years, by race, sex, and age: United States, 1966-70

Sex and age	Total	White	Negro	Total	White	Negro
	Mean hematocrit in ml percent			Standard error in ml percent		
Male						
12 years	40.5	40.6	39.6	.17	.19	.35
13 years	41.5	41.5	41.4	.20	.21	.41
14 years	42.7	42.9	41.7	.17	.19	.27
15 years	43.9	44.1	42.9	.21	.25	.32
16 years	44.9	44.9	44.4	.21	.24	.43
17 years	45.8	45.8	45.7	.16	.16	.47
Female						
12 years	40.3	40.4	39.7	.17	.19	.21
13 years	40.7	40.8	40.2	.16	.18	.29
14 years	40.3	40.4	39.4	.18	.19	.46
15 years	40.7	40.9	39.3	.19	.18	.39
16 years	40.4	40.7	38.3	.18	.17	.47
17 years	40.6	40.9	38.5	.16	.17	.51

Table 8. Differences between white and Negro youths aged 12-17 years with respect to selected percentiles of hematocrit levels: United States, 1966-70

Percentile	Percentile in white youths minus percentile in Negro youths											
	Male						Female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
5th	1.2	1.7	1.5	1.7	0.6	0.8	0.6	3.1	2.1	3.8	4.4	3.9
50th	0.9	-0.3	1.0	0.6	0.4	0.2	0.5	0.6	0.8	1.3	2.4	2.0
95th	-0.1	-1.1	0.4	-0.2	0.1	-0.1	0.7	-1.6	0.3	0.5	1.1	0.6

Table 9. Number of youths aged 12-17 years in sample of the Health Examination Survey, by race, sex, and age: United States, 1966-70

Sex and age	Total	White	Negro
	Number of youths		
Male			
All ages, 12-17 years	3,545	3,047	479
12 years	643	540	101
13 years	626	542	80
14 years	618	527	88
15 years	613	525	84
16 years	556	496	57
17 years	489	417	69
Female			
All ages, 12-17 years	3,223	2,688	520
12 years	547	455	88
13 years	582	490	91
14 years	586	484	101
15 years	503	425	73
16 years	536	441	93
17 years	469	393	74

Table 10. Estimated number of white youths aged 12-17 years in the population by hematocrit group and selected characteristics of hematocrit distribution, by sex and age: United States, 1966-70

Selected variable	White male						White female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
Hematocrit group	Estimated number of youths in population in thousands											
All groups	1,747	1,729	1,686	1,646	1,594	1,528	1,685	1,667	1,633	1,594	1,542	1,502
Under 29.0 ml percent	-	-	-	-	-	-	-	-	-	-	-	-
29.0-30.9 ml percent	-	-	-	-	-	-	-	-	3	-	-	-
31.0-32.9 ml percent	-	-	-	-	-	-	-	-	5	5	5	4
33.0-34.9 ml percent	10	-	-	-	-	-	12	11	17	6	5	12
35.0-36.9 ml percent	101	67	23	10	3	4	75	48	44	55	56	53
37.0-38.9 ml percent	252	200	88	49	24	10	319	298	355	274	266	222
39.0-40.9 ml percent	575	434	289	181	61	46	512	511	548	495	477	446
41.0-42.9 ml percent	445	513	410	326	198	112	439	425	346	373	407	381
43.0-44.9 ml percent	264	319	409	409	497	334	282	239	233	245	253	290
45.0-46.9 ml percent	73	133	296	377	394	427	36	93	48	101	56	55
47.0-48.9 ml percent	24	51	146	176	272	388	6	39	30	29	14	36
49.0-50.9 ml percent	3	11	22	84	99	149	3	3	2	6	3	4
51.0-52.9 ml percent	-	-	3	24	37	42	-	-	-	-	-	-
53.0-54.9 ml percent	-	-	-	3	9	15	-	-	-	-	-	-
55.0-56.9 ml percent	-	-	-	3	-	-	-	-	-	-	-	-
57.0 ml percent and over	-	-	-	6	-	-	-	-	-	4	-	-
Percentile	Hematocrit in ml percent											
5th	36.4	37.2	38.3	39.3	40.6	41.2	36.8	37.2	37.1	37.1	37.1	37.0
10th	37.6	38.2	39.5	40.3	41.9	42.4	37.7	38.0	37.7	38.0	37.9	37.7
25th	39.3	40.0	41.1	42.2	43.2	44.2	39.1	39.3	38.8	39.3	39.3	39.7
50th	40.7	41.8	43.1	44.2	45.0	46.1	40.5	40.8	40.3	40.7	40.7	41.1
75th	42.5	43.2	45.1	46.2	47.1	47.9	42.4	42.6	42.2	42.8	42.6	43.0
90th	44.1	45.1	47.0	48.3	48.7	49.6	43.5	44.2	44.1	44.6	44.2	44.2
95th	45.2	46.2	48.0	49.7	49.9	50.3	44.3	45.7	44.9	45.7	44.8	45.4
Mean age at time of examination (in years)	12.54	13.49	14.51	15.49	16.48	17.50	12.54	13.49	14.49	15.51	16.49	17.50
Mean hematocrit in ml percent	40.6	41.5	42.9	44.1	44.9	45.8	40.4	40.8	40.4	40.9	40.7	40.9
Standard deviation in ml percent	2.59	2.68	2.84	3.20	2.79	2.79	2.37	2.62	2.60	2.86	2.47	2.64
Standard error of mean	0.19	0.21	0.19	0.25	0.24	0.16	0.19	0.18	0.19	0.18	0.17	0.17
95th-5th percentile	8.8	9.0	9.7	10.4	9.3	9.1	7.5	8.5	7.8	8.6	7.7	8.4
95th-50th percentile	4.5	4.4	4.9	5.5	4.9	4.2	3.8	4.9	4.6	5.0	4.1	4.3
50th-5th percentile	4.3	4.6	4.8	4.9	4.4	4.9	3.7	3.6	3.2	3.6	3.6	4.1

Table 11. Estimated number of Negro youths aged 12-17 years in the population by hematocrit group and selected characteristics of hematocrit distribution, by sex and age: United States, 1966-70

Selected variable	Negro male						Negro female					
	12 years	13 years	14 years	15 years	16 years	17 years	12 years	13 years	14 years	15 years	16 years	17 years
Hematocrit group	Estimated number of youths in population in thousands											
All groups	280	262	256	241	231	225	272	275	266	235	243	237
Under 29.0 ml percent	-	3	-	2	3	-	-	-	3	-	3	3
29.0-30.9 ml percent	2	-	-	-	-	-	-	-	-	3	3	2
31.0-32.9 ml percent	2	-	-	-	-	-	-	3	-	3	7	6
33.0-34.9 ml percent	6	10	3	-	-	-	6	16	9	12	15	9
35.0-36.9 ml percent	28	6	12	6	4	3	19	17	26	23	32	40
37.0-38.9 ml percent	77	48	44	32	4	-	69	54	75	64	76	57
39.0-40.9 ml percent	72	51	33	28	11	12	93	77	60	58	61	72
41.0-42.9 ml percent	43	42	52	38	43	23	60	42	64	46	27	25
43.0-44.9 ml percent	33	57	75	46	58	45	23	47	18	12	13	13
45.0-46.9 ml percent	16	26	9	56	40	53	3	5	8	11	-	10
47.0-48.9 ml percent	-	16	27	18	42	59	-	9	-	-	5	-
49.0-50.9 ml percent	-	4	2	12	19	25	-	7	3	-	-	-
51.0-52.9 ml percent	-	-	-	3	8	7	-	-	-	-	-	-
53.0-54.9 ml percent	-	-	-	-	-	-	-	-	-	-	-	-
55.0-56.9 ml percent	-	-	-	-	-	-	-	-	-	-	-	-
57.0 ml percent and over	-	-	-	-	-	-	-	-	-	2	-	-
Percentile	Hematocrit in ml percent											
5th	35.2	35.5	36.8	37.6	40.0	40.4	36.2	34.1	35.0	33.3	32.7	33.1
10th	35.9	37.3	38.0	38.5	41.0	42.4	37.1	35.7	36.1	35.2	34.7	35.1
25th	38.1	38.9	39.5	40.3	42.7	43.4	38.3	38.3	38.1	37.7	37.0	36.7
50th	39.8	42.1	42.1	43.6	44.6	45.9	40.0	40.2	39.5	39.4	38.3	39.1
75th	42.0	44.2	43.9	45.4	47.2	48.2	41.5	42.4	41.4	41.3	40.2	40.6
90th	43.9	45.4	47.1	48.1	49.1	50.0	42.8	44.4	43.6	43.3	42.3	42.8
95th	45.3	47.3	47.6	49.9	49.8	50.4	43.6	47.3	44.6	45.2	43.7	44.8
Mean age at time of examination (in years)	12.55	13.46	14.52	15.49	16.45	17.57	12.48	13.43	14.46	15.50	16.47	17.50
Mean hematocrit in ml percent	39.6	41.4	41.7	42.9	44.4	45.7	39.7	40.2	39.4	39.3	38.3	38.5
Standard deviation in ml percent	2.98	3.79	3.26	4.14	4.00	3.02	2.32	3.62	3.49	3.62	3.29	3.82
Standard error of mean	0.35	0.41	0.27	0.32	0.43	0.47	0.21	0.29	0.46	0.39	0.47	0.50
95th-5th percentile	10.1	11.8	10.8	12.3	9.8	10.0	7.4	13.2	9.6	11.9	11.0	11.7
95th-50th percentile	5.5	5.2	5.5	6.3	5.2	4.5	3.6	7.1	5.1	5.8	5.4	5.7
50th-5th percentile	4.6	6.6	5.3	6.0	4.6	5.5	3.8	6.1	4.5	6.1	5.6	6.0

Table 12. Percent of youths with hematocrit determinations below certain levels, by age, sex, and race

Age and race	Percentage of males with hematocrit determinations below:			Percentage of females with hematocrit determinations below:		
	35.0 percent	37.0 percent	39.0 percent	35.0 percent	37.0 percent	39.0 percent
Total						
12 years	0.9	7.3	23.5	0.9	5.7	25.5
13 years	0.6	4.3	16.7	1.5	4.9	23.0
14 years	0.2	1.9	8.7	1.9	5.6	28.4
15 years	0.1	0.9	5.2	1.6	5.8	24.4
16 years	0.2	0.5	2.2	2.3	7.2	26.4
17 years	-	0.4	1.0	2.1	7.5	23.3
White						
12 years	0.6	6.4	20.8	0.7	5.2	24.1
13 years	-	3.9	15.4	0.7	3.5	21.4
14 years	-	1.4	6.6	1.5	4.2	26.0
15 years	-	0.6	3.6	0.7	4.1	21.3
16 years	-	0.2	1.7	0.6	4.3	21.5
17 years	-	0.3	0.9	1.1	4.6	19.4
Negro						
12 years	3.6	13.6	41.1	2.2	9.2	34.6
13 years	5.0	7.3	25.6	6.9	13.1	32.7
14 years	1.2	5.9	23.0	4.5	14.3	42.5
15 years	0.8	3.3	16.6	7.7	17.4	44.7
16 years	1.3	3.0	4.8	11.5	24.7	56.0
17 years	-	1.3	1.3	8.4	25.3	49.4

Table 13. Weighted sample size, mean hematocrits, and standard errors of the means for youths by age, sex, and normal family income: United States, 1966-70

Sex and annual family income	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$
Total male	Hematocrit in ml percent																	
All incomes	2,032	40.5	0.17	2,006	41.5	0.20	1,951	42.7	0.17	1,900	43.9	0.21	1,836	44.9	0.21	1,764	45.8	0.16
Less than $3,000	180	39.8	0.38	212	40.9	0.44	200	42.2	0.57	241	43.4	0.53	201	44.6	0.56	226	45.3	0.80
$3,000-$4,999	308	40.2	0.38	264	41.0	0.46	240	42.5	0.48	219	44.2	0.49	265	45.1	0.34	245	45.3	0.49
$5,000-$9,999	869	40.6	0.24	767	41.8	0.26	746	42.7	0.22	719	43.9	0.30	719	44.8	0.35	692	46.0	0.18
$10,000 or more	575	40.6	0.21	619	41.5	0.30	597	42.9	0.22	598	44.1	0.24	516	45.0	0.25	479	46.1	0.17
Don't know	55	40.9	0.57	65	41.3	0.53	100	43.5	0.81	76	44.2	0.47	82	44.8	0.85	49	44.5	0.82
Blank or refused	46	41.2	0.89	80	41.1	1.12	67	42.5	0.72	46	43.6	0.94	55	44.0	1.07	74	45.6	0.84
Total female																		
All incomes	1,970	40.3	0.17	1,946	40.7	0.16	1,901	40.3	0.18	1,851	40.7	0.19	1,789	40.4	0.18	1,746	40.6	0.16
Less than $3,000	257	40.2	0.45	268	40.2	0.38	213	39.7	0.31	258	40.2	0.50	246	39.5	0.46	182	39.6	0.47
$3,000-$4,999	274	40.0	0.35	301	40.6	0.38	300	39.9	0.46	264	40.0	0.31	166	39.2	0.44	206	39.6	0.45
$5,000-$9,999	722	40.3	0.25	802	40.7	0.15	720	40.4	0.25	700	40.7	0.26	650	40.3	0.17	586	40.7	0.27
$10,000 or more	600	40.7	0.21	494	41.3	0.24	554	40.7	0.22	533	41.2	0.27	594	40.9	0.27	628	41.1	0.28
Don't know	79	39.3	0.63	46	40.3	0.50	72	39.5	0.42	63	40.0	0.68	83	41.5	0.53	92	40.8	0.52
Blank or refused	37	40.4	9.15	35	41.0	1.07	42	39.6	0.65	32	42.4	3.18	50	40.8	0.62	52	40.7	1.25

Table 14. 10th, 50th, and 90th percentiles of hematocrit distributions for youths by age at last birthday and sex for the following income groups: less than $4,000 and $10,000 or more: United States, 1966-70

Age and sex	Distribution at the 10th percentile			Distribution at the 50th percentile			Distribution at the 90th percentile		
	Total	Less than $4,000	$10,000 or more	Total	Less than $4,000	$10,000 or more	Total	Less than $4,000	$10,000 or more
Male	Hematocrit in ml percent								
12 years	37.3	36.1	38.1	40.6	40.0	40.4	44.1	44.3	43.9
13 years	38.2	38.2	38.3	41.8	41.0	42.1	45.2	44.6	45.1
14 years	39.2	38.6	39.3	43.0	43.0	43.1	47.0	47.2	47.1
15 years	40.1	38.8	39.7	44.2	44.2	44.2	48.3	48.2	49.0
16 years	41.7	41.2	42.5	45.0	45.0	45.2	48.8	49.7	48.2
17 years	42.4	41.2	43.1	46.1	45.1	46.3	49.6	49.7	49.8
Female									
12 years	37.6	36.4	38.1	40.4	40.3	40.6	43.4	43.4	43.6
13 years	37.8	36.3	38.6	40.7	40.3	41.2	44.3	44.3	45.2
14 years	37.6	36.2	38.1	40.3	39.8	40.4	44.0	43.7	44.2
15 years	37.7	37.2	38.1	40.6	40.1	41.1	44.5	43.8	45.3
16 years	37.3	36.3	38.0	40.4	40.0	41.1	44.1	44.1	44.2
17 years	37.3	35.7	38.2	40.7	40.1	41.5	44.2	44.0	44.2

Table 15. Weighted sample size, mean hematocrits, and standard errors of the means for youths, by age, sex, and education of parent: United States, 1966-70

Sex and education of parent	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$
	Hematocrit in ml percent																	
Total male																		
All education groups . .	2,032	40.5	0.17	2,006	41.5	0.20	1,951	42.7	0.17	1,900	43.9	0.21	1,836	44.9	0.21	1,764	45.8	0.16
Less than 8 years	176	39.7	0.48	175	41.1	0.75	172	41.6	0.71	196	43.8	0.48	217	44.5	0.60	208	45.2	0.57
8-11 years	543	40.0	0.26	502	41.2	0.28	474	42.8	0.26	487	43.6	0.29	474	44.8	0.25	446	45.8	0.34
12 years	736	40.8	0.22	780	41.7	0.24	730	42.7	0.17	727	44.1	0.27	630	44.8	0.24	668	45.7	0.22
13 years or more	562	40.9	0.31	527	41.4	0.38	549	43.1	0.17	472	44.1	0.35	480	45.1	0.37	388	46.2	0.18
Unknown	16	39.6	8.96	23	42.3	0.89	25	41.9	1.69	18	45.1	2.01	35	45.7	0.58	54	45.8	0.90
Total female																		
All education groups . .	1,970	40.3	0.17	1,946	40.8	0.16	1,901	40.3	0.18	1,851	40.7	0.19	1,789	40.4	0.18	1,746	40.6	0.16
Less than 8 years	211	39.4	0.46	228	40.1	0.69	160	39.6	0.58	178	40.1	0.69	167	39.7	0.56	146	39.7	0.36
8-11 years	480	40.2	0.26	507	40.4	0.24	537	40.1	0.26	598	40.1	0.23	453	39.7	0.28	465	40.6	0.19
12 years	729	40.5	0.21	727	40.9	0.17	719	40.5	0.23	640	41.0	0.22	623	40.6	0.18	525	40.8	0.21
13 years or more	509	40.7	0.18	463	41.3	0.24	465	40.5	0.34	411	41.2	0.32	512	40.9	0.36	542	40.8	0.35
Unknown	41	39.4	0.55	22	*	*	21	39.1	1.38	22	40.9	9.29	34	40.7	1.56	67	39.6	1.28

Table 16. Weighted sample size, mean hematocrits, and standard errors of the means for white youths, by age, sex, and annual family income: United States, 1966-70

Sex and annual family income	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$
	Hematocrit in ml percent																	
White male																		
All incomes	1,747	40.6	0.19	1,729	41.5	0.21	1,686	42.9	0.19	1,646	44.1	0.25	1,594	44.9	0.24	1,528	45.8	0.16
Less than $3,000	111	39.9	0.76	127	41.0	0.70	110	42.3	0.81	153	43.6	0.54	129	44.9	0.69	142	44.8	1.22
$3,000-$4,999	209	40.7	0.46	180	41.0	0.47	190	42.7	0.62	151	44.6	0.60	211	45.4	0.36	181	45.7	0.50
$5,000-$9,999	786	40.6	0.25	681	41.7	0.26	662	42.8	0.23	653	44.0	0.32	632	44.9	0.36	640	45.9	0.18
$10,000 or more	557	40.6	0.21	606	41.5	0.30	579	43.0	0.23	578	44.1	0.24	501	45.0	0.26	459	46.1	0.17
Don't know	41	41.5	0.49	58	40.9	0.56	87	43.7	0.79	64	44.4	0.38	67	44.7	1.02	37	44.1	0.95
Blank or refused	43	41.1	0.92	76	41.2	1.14	57	42.8	0.82	46	43.6	0.94	55	44.0	1.07	68	45.8	0.94
White female																		
All incomes	1,685	40.4	0.19	1,667	40.8	0.18	1,633	40.4	0.19	1,594	40.9	0.18	1,542	40.7	0.17	1,502	40.9	0.17
Less than $3,000	180	40.3	0.61	160	40.5	0.55	138	40.0	0.32	183	40.1	0.62	156	40.5	0.44	111	40.0	0.68
$3,000-$4,999	195	40.1	0.42	229	40.6	0.45	211	40.2	0.56	207	40.5	0.41	113	39.7	0.63	146	40.6	0.33
$5,000-$9,999	641	40.3	0.27	729	40.7	0.97	661	40.4	0.26	611	40.9	0.27	589	40.5	0.19	529	41.0	0.27
$10,000 or more	571	40.8	0.23	482	41.3	0.24	535	40.7	0.23	508	41.3	0.25	571	41.0	0.22	591	41.1	0.27
Don't know	63	39.7	0.63	36	40.6	0.59	51	39.7	0.50	59	40.0	0.72	69	41.8	0.52	86	41.1	0.50
Blank or refused	34	40.4	9.17	31	40.6	0.99	36	39.7	0.71	27	42.9	3.93	44	41.2	0.57	40	41.6	9.36

Table 17. Weighted sample size, mean hematocrits, and standard errors of the means for Negro youths, by age, sex, and annual family income: United States, 1966-70

Sex and annual family income	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$
Negro male	Hematocrit in ml percent																	
All incomes	280	39.6	0.35	262	41.4	0.41	256	41.7	0.27	241	42.9	0.32	231	44.4	0.43	225	45.7	0.47
Less than $3,000	69	39.6	0.39	85	40.8	0.58	89	42.1	0.66	88	43.1	0.98	72	44.0	1.05	85	46.0	0.53
$3,000-$4,999	96	39.0	0.53	80	41.0	1.25	50	41.7	0.72	65	43.1	0.68	54	43.9	0.77	58	44.3	1.29
$5,000-$9,999	81	40.4	0.76	78	42.3	0.73	78	41.8	0.92	59	42.5	0.75	80	44.7	1.18	48	46.7	0.92
$10,000 or more	18	40.3	0.73	9	*	*	15	39.6	0.64	17	42.6	2.10	10	*	*	17	46.7	0.57
Don't know	14	39.2	9.24	6	*	*	13	42.0	1.84	12	*	*	15	*	*	12	45.7	10.29
Blank or refused	2	*	*	3	*	*	11	*	*	-	-	-	-	-	-	6	*	*
Negro female																		
All incomes	272	39.7	0.21	275	40.2	0.29	266	39.4	0.47	235	39.3	0.39	243	38.3	0.47	237	38.5	0.50
Less than $3,000	77	40.0	0.62	108	39.7	0.57	75	39.1	0.63	75	40.4	0.70	89	37.8	0.90	71	39.0	0.60
$3,000-$4,999	75	39.5	0.48	72	40.4	1.00	89	39.1	1.13	53	38.4	0.69	52	38.1	0.75	60	37.2	1.28
$5,000-$9,999	81	40.1	0.27	74	41.0	0.65	57	40.5	0.90	81	39.3	0.71	57	38.7	0.49	58	37.9	0.67
$10,000 or more	19	39.0	0.56	9	38.8	2.37	19	40.0	1.76	17	37.1	2.12	23	38.0	2.32	30	41.7	1.76
Don't know	16	*	*	9	*	*	21	39.0	0.62	3	*	*	14	40.0	1.51	6	*	*
Blank or refused	4	*	*	4	*	*	6	*	*	6	*	*	7	*	*	12	37.7	1.23

Table 18. Weighted sample size, mean hematocrits, and standard errors of the means for white youths, by age, sex, and education of parent: United States, 1966-70

Sex and education of parent	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$	N	$\bar{X}$	$s_{\bar{x}}$
White male	Hematocrit in ml percent																	
All education groups	1,747	40.6	0.19	1,729	41.5	0.21	1,686	42.9	0.19	1,646	44.1	0.25	1,594	44.9	0.24	1,528	45.8	0.16
Less than 8 years	119	40.1	0.76	104	41.1	1.20	145	41.8	0.83	139	43.8	0.62	169	45.1	0.63	143	45.1	0.79
8-11 years	412	40.1	0.28	391	41.4	0.30	341	42.9	0.35	380	43.9	0.35	371	44.7	0.29	342	45.8	0.37
12 years	675	40.8	0.23	713	41.6	0.23	662	42.9	0.17	652	44.1	0.32	580	44.8	0.24	632	45.8	0.22
13 years or more	528	41.0	0.32	501	41.4	0.40	523	43.1	0.18	461	44.2	0.33	446	45.1	0.40	363	46.2	0.18
Unknown	13	*	*	19	42.2	0.95	14	43.8	9.96	14	46.5	1.64	28	45.8	0.67	49	45.7	0.99
White female																		
All education groups	1,685	40.4	0.19	1,667	40.8	0.18	1,633	40.4	0.19	1,594	40.9	0.18	1,542	40.7	0.17	1,502	40.9	0.17
Less than 8 years	165	39.7	0.85	182	40.3	1.01	107	39.5	0.83	127	40.0	0.93	106	40.9	0.55	96	40.5	0.75
8-11 years	379	40.3	0.32	356	40.3	0.33	429	40.2	0.32	479	40.4	0.21	349	40.2	0.38	344	41.1	0.24
12 years	650	40.6	0.24	661	41.0	0.17	648	40.6	0.24	578	41.2	0.25	572	40.6	0.19	491	41.0	0.21
13 years or more	464	40.6	0.19	452	41.3	0.24	440	40.7	0.28	391	41.3	0.33	490	41.1	0.28	515	41.1	0.34
Unknown	26	39.5	0.55	16	*	*	9	*	*	20	41.1	9.38	24	41.3	1.63	55	39.3	1.57

Table 19. Weighted sample size, mean hematocrits, and standard errors of the means for Negro youths, by age, sex, and education of parent: United States, 1966-70

Sex and education of parent	12 years			13 years			14 years			15 years			16 years			17 years		
	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$	N	$\bar{X}$	$s_{\bar{X}}$
Negro male	Hematocrit in ml percent																	
All education groups	280	39.7	0.35	262	41.4	0.41	256	41.8	0.27	241	42.9	0.32	231	44.4	0.43	225	45.7	0.47
Less than 8 years	57	38.9	0.44	71	41.2	1.32	27	40.6	9.28	57	43.5	0.67	48	42.4	1.29	62	45.5	0.62
8-11 years	130	39.7	0.60	102	40.7	0.72	130	42.5	0.45	103	42.4	0.66	103	45.2	0.64	104	45.7	0.84
12 years	58	40.6	0.44	64	41.9	1.00	68	40.9	0.48	69	43.8	0.73	46	44.4	0.81	31	44.9	1.17
13 years or more	32	39.1	1.18	23	43.5	0.98	20	42.4	1.13	8	*	*	27	44.6	0.62	23	47.0	0.78
Unknown	3	*	*	3	*	*	11	*	*	3	*	*	7	*	*	6	*	*
Negro female																		
All education groups	272	39.7	0.21	275	40.3	0.29	266	39.4	0.46	235	39.3	0.39	243	38.3	0.47	237	38.5	0.50
Less than 8 years	46	38.5	0.64	46	39.4	0.92	53	39.6	0.82	47	40.6	0.96	61	37.6	0.95	50	38.0	0.77
8-11 years	96	39.7	0.31	147	40.4	0.54	106	39.6	0.59	109	39.0	0.64	104	38.0	0.43	117	39.2	0.63
12 years	79	39.8	0.29	65	40.6	0.56	71	40.1	0.64	63	39.0	0.78	50	40.2	0.56	35	38.9	1.13
13 years or more	35	41.3	0.39	11	*	*	25	37.4	3.08	14	39.3	0.40	18	*	*	24	35.2	1.32
Unknown	15	39.1	1.01	5	*	*	12	*	*	3	*	*	10	*	*	12	40.5	9.08

Table 20. Mean hematocrit by age and sex for HES Cycle III and Cycle I data

Cycle	Age group	Midpoint of age interval	Male		Female	
			Mean hematocrit in ml percent	Estimated increase per year in ml percent	Mean hematocrit in ml percent	Estimated increase per year in ml percent
Cycle III	12	12.5	40.5		40.3	
				1.0		0.5
	13	13.5	41.5		40.8	
				1.2		−0.5
	14	14.5	42.7		40.3	
				1.2		0.4
	15	15.5	43.9		40.7	
				1.0		−0.3
	16	16.5	44.9		40.4	
				0.9		0.2
	17	17.5	45.8		40.6	
				0.2		0.2
Cycle I	18-24	21.5	46.7		41.4	
				0.04		0.05
	25-34	30	47.0		41.8	
				−0.04		0.02
	35-44	40	46.6		42.0	
				−0.01		0.05
	45-54	50	46.5		42.5	
				−0.04		0.12
	55-64	60	46.1		43.7	
				−0.03		−0.05
	65-74	70	45.8		43.2	
				−0.07		−0.01
	75-79	77.5	45.1		43.1	

APPENDIX I
STATISTICAL NOTES

The Survey Design

The sampling plan of Cycle III of the Health Examination Survey followed a multistage, stratified probability sample of clusters of households in land-based segments in which a sample of the U.S. population (including Alaska and Hawaii) aged 12 through 17 years was selected. Excluded were those youths confined to institutions and those residing on any of the reservation lands set aside for use by American Indians.

The sample design of Cycle III is similar to that of Cycle II in that it uses the same 40 sample areas and the same segments. The decision to incorporate this feature into Cycle III was not made prior to the selection of the Cycle II sample, although it is consistent with the early concept of a single program for persons 6-17 years old. The final decision to use this identical sampling frame was made during the operation of the Cycle II program.

The successive elements for this sample design are primary sampling unit; census enumeration district; segment (a cluster of households); household; all eligible youths; and finally, the sample youth. Every eligible youth within the defined population has a known and approximately equal chance for selection into the sample.

The steps of drawing the sample were carried out jointly with the U.S. Bureau of the Census; the starting points were the 1960 decennial census lists of addresses and the nearly 1,900 primary sampling units (PSU's) into which the entire United States was divided. Each PSU is a standard metropolitan statistical area (SMSA), a county, or a group of two or three contiguous counties. These PSU's were grouped into 40 strata so that each stratum had an average size of about 4.5 million persons. This grouping was done in a manner which maximized the degree of homogeneity within strata with regard to the population size of the PSU's, degree of urbanization, geographic proximity, and degree of industrialization. The 40 strata were then classified into four broad geographic regions of 10 strata each and, within each region, cross-classified by four population density classes and by the rates of population change from 1950 to 1960. Using a modified Goodman-Kish controlled-selection technique, one PSU was drawn from each of the 40 strata.

The sampling within PSU's was carried out in several steps. The first was the selection of census enumeration districts (ED's). These ED's are small well-defined areas of about 250 housing units into which the entire Nation was divided for the 1960 population census. Each ED was assigned a "measure of size" equal to the rounded whole number resulting from a "division by nine" of the number of children aged 5-9 in the ED at the time of the 1960 census. A sample of 20 ED's in the sample PSU was selected according to a systematic sampling technique with each ED having a probability of selection proportional to the population of children 5-9 years at the time of the 1960 census date. From each ED a random selection of one measure of size (segment) was taken.

Minor changes required in the Cycle III design were that it be supplemented for new construction to a greater extent than had been necessary in Cycle II and that reserve segments be added. Although it was the plan for Cycle III to use the Cycle II segments, it was recognized that within several PSU's additional reserve segments would be needed to avoid the risk of having an insufficient number of examinees. This was prompted by the fact that four of the PSU's in

Cycle II had yields of less than 165 eligible children and several others were marginal in their yield. In addition, there was a 3-year interval between Cycle II and Cycle III, so that it was quite possible for some segments to have been completely demolished to make room for highway construction or urban redevelopment.

The time available for examinations at a particular location or stand, as they have been designated, is necessarily set far in advance of any preliminary field work at the stand. Therefore, the number of examinations that can be performed at a particular location is dependent on the number of examining days available. At the majority of locations, the number of days available, excluding Saturdays, is 17. At the rate of 12 examinations each day, this provides for 204 examination slots. Examinations are conducted on Saturdays if, for some reason, it is necessary. Because of rescheduling for cancellations or no-shows, the maximum number of youths that is considered for inclusion in the sample is 200. When the number of eligible youths exceeds this number, subsampling is performed to reduce the number to manageable limits. This is accomplished through the use of a master list, which is a listing of all eligible youths in order by segment, serial number (household order within segment), and column number (order in the household by age). After the subsampling rate has been determined, every nth name on the list is deleted, starting with the yth name, y being a randomly selected number between 1 and n. Youths who are deleted from the Cycle III sample but who were examined in Cycle II as well as any twin who may have been deleted are, if time permits, scheduled for an examination for inclusion only in the longitudinal study portion or twin study portion of the survey. Their data are not included in the report as part of the regular sample.

Since the strata are roughly equal in population size and a nearly equal number of sample youths were examined in each of the sample PSU's, the sample design is essentially self-weighting with respect to the target population; that is, each youth 12 through 17 years old had about the same probability of being drawn into the sample.

The adjustment upward for nonresponse is intended to minimize the impact of nonresponse on final estimates by imputing to nonrespondents the characteristics of "similar" respondents. Here "similar" respondents were judged to be examined youths in a sample PSU having the same age (in years) and sex as those not examined in that sample PSU.

The poststratified ratio adjustment used in Cycle III achieved most of the gains in precision that would have been attained if the sample had been drawn from a population stratified by age, color, and sex, and it made the final sample estimates of population agree exactly with independent controls prepared by the U.S. Bureau of the Census for the noninstitutional population of the United States as of March 9, 1968 (approximaate midsurvey point), by color and sex for each single year of age 12 through 17. The weight of every responding sample child in each of the 24 age, race, and sex classes is adjusted upward or downward so that the weighted total within the class equals the independent population control.

A more detailed description of the sampling plan and estimation procedures is included in *Vital and Health Statistics,* Series 2, Number 43,[3] [3] and in Series 1, Numbers 1,[1] 5,[3] and 8,[4] which describe the plan and operation of the first three cycles of the Health Examination Survey (HES).

Some Notes on Response Rates

As mentioned previously, the sample designs of the second and third cycles of the HES were similar. Differences did occur, however, in response rates of various subgroups of these samples, and these differences deserve some consideration here.

Most importantly, the number of youths selected for examination increased from 7,417 in Cycle II to 7,514 in Cycle III. The response rate, that is, the number of youths selected who were actually examined, decreased from 96 percent in Cycle II to 90 percent in Cycle III. Of the examined youths of Cycle II, 13.9 percent were Negro compared with 14.8 percent of those examined in Cycle III. This difference does not reflect a difference in the percentage of Negro youths selected for examination, but instead, a smaller decrease in response rate for

Negro youths between the two cycles than was the case for the white youths. In actuality, 13.8 percent of the sample selected for examination was Negro in Cycle III corresponding to 13.5 percent for Cycle II. However, whereas the response rate for white youths dropped from 95.6 percent in Cycle II to 89.1 percent in Cycle III, the response rate for Negro youths dropped a far lesser degree from 98.4 percent to 96.6 percent. Thus, better relative response from the Negro portion of the sample yielded a greater percentage of these youths actually examined during Cycle III than was the case during the previous sample.

Examination of sample sizes in this report clearly shows that at every age group there were fewer females actually examined than there were males of the same age. This again is not attributed to differences in numbers of youths selected in the sampling design, but rather to the following differential response rates between males and females:

Age	Male	Female
Total	91.4	88.7
12	93.5	91.3
13	93.2	91.9
14	91.7	90.7
15	91.6	87.9
16	89.8	87.7
17	87.6	81.8

Note that at each age group the response rate for males exceeded that for females.

A similar analysis of response rates can be done by age, race, and sex as follows:

Age	White male	Negro male	White female	Negro female
Total	90.5	87.6	87.4	95.8
12	92.6	99.0	90.1	98.9
13	92.5	98.8	91.1	96.8
14	91.0	87.8	89.6	96.2
15	90.7	97.7	86.4	98.6
16	89.2	95.0	86.6	93.0
17	86.5	95.8	80.2	91.4

The above clearly indicates that for all ages under consideration in Cycle III of the HES the response rate for Negro youths exceeded that for white youths of the same sex and age.

Reasons for differences in response rates are many, but may range from the incentive to get examined in order to miss a day of school, to fear of the examination itself, to inhibitions with respect to being examined. The worst response rate was recorded for the oldest females, that is, those aged 17 years.

Parameter and Variance Estimates

Because each of the 6,768 sample children has an assigned statistical weight, all estimates of population parameters presented in HES publications are computed taking this weight into consideration. Thus, $\bar{X}$, the estimate of a population mean, "μ," is computed as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} W_i X_i}{\sum W_i}$$

where X_i is the observation or measurement taken on the ith person and W_i is the statistical weight assigned to that person.

The HES has an extremely complex sampling plan, and obviously the estimation procedure is, by the very nature of the sample, complex as well. A method is required for estimating the reliability of findings that "reflects both the losses from clustering sample cases at two stages and the gains from stratification, ratio estimation, and poststratification."[3,4]

The method for estimating variances in the HES is the half-sample replication technique. The method was developed at the U.S. Bureau of the Census prior to 1957 and has at times been given limited use in the estimation of the reliability of results from the Current Population Survey. This half-sample replication technique is particularly well suited to the HES because the sample, although complex in design, is relatively small (6,768 cases) and is based on but 40 strata. This feature permitted the development of a variance estimation computer program that produces tables containing desired estimates of aggregates, means, or distributions, together with a table identical in format but that contains the estimated variance of the estimated statistics. The computations required by the method are simple, and the internal storage requirements are well within the limitation of the IBM 360-50 computer system used at the National Center for Health Statistics.

Variance estimates computed for this report were based on 20 balanced half-sample replications. A half sample was formed by choosing one sample PSU from each of 20 pairs of sample PSU's. The composition of the 20 half samples was determined by an orthogonal plan. To compute the variance of any statistic, this statistic is computed for each of the 20 half samples. Using the mean as an example, this is denoted $\bar{X}_i$. Then, the weighted mean of the entire, undivided sample ($\bar{\bar{X}}$) is computed. The variance of the mean is the mean square deviation of each of the 20 half-sample means about the overall mean. Symbolically,

$$\mathrm{Var}(\bar{X}) = \frac{\sum_{i=1}^{20} (\bar{X}_i - \bar{\bar{X}})^2}{20}$$

and the standard error of the mean is the square root of this. In a similar manner, the standard error of any statistic may be computed.

A detailed description of this replication process has been published in *Vital and Health Statistics*, Series 2, Number 14.[35]

Standards of Reliability and Precision

All means, variances, and percentages appearing in this report met defined standards before they were considered acceptably precise and reliable.

The rule for reporting means and percentiles consisted of two basic criteria. The first criterion was that a sample size of at least five was required. If this first criterion was met, then the second criterion, that the estimated coefficient of variation [i.e., the standard error of the mean divided by the mean ($s_{\bar{X}}/\bar{X}$)] was to be less than 25 percent, must have been demonstrated. Thus, if either the sample size was too small, or the variation with respect to the mean was too large, the estimate was considered neither precise nor reliable enough to meet the standards established for publication.

To illustrate these criteria, in table 17 values of the mean and standard error for 16-year-old Negro males from families with a total yearly income of $10,000 or more were replaced by asterisks (*) since the standard error with respect to the mean exceeded the criterion previously stated.

Imputation

In addition to the subject nonresponse discussed previously, the problem of item nonresponse merits consideration here. In this situation, information about a respondent is complete with the exception of a missing hematocrit value.

Missing data and values that fell outside a normal range and were deemed unlikely after examination of physician records were replaced by the value recorded for a randomly selected respondent of similar age, sex, and race. However, when only one of the two hematocrit values was missing, the recorded measurement was substituted for the unknown value. Imputation, where there was no value recorded for examinees, was necessary in 190 cases for hematocrits (2.9 percent of total respondents).

In effect, sample cases were sorted into categories within each of which the cases were expected to have high intraclass correlation (i.e., being relatively homogeneous). Those with missing values were then completed with a value randomly selected from within the category. This method of imputation preserves both the expected values and the distribution of values in each category to those of the respondent cases.

APPENDIX II
DEMOGRAPHIC VARIABLES

Regional and demographic characteristics by which the population has been classified for this report are defined as follows.

Age and sex.—Population was classified into 12 age-sex groups—the six ages 12-17 years by sex. Birth certificates were obtainable for verification of age for 92 percent of the youths. Age stated by the parents was accepted as the true age for the other 8 percent. Age is expressed as years attained at last birthday.

Race.—Hematocrit was reported by race for white and Negro youths. Youths of other races were not sampled sufficiently for comparison purposes; these youths represented only 0.55 percent of the sample.

Region.—Regional data are presented for four regions of the continental United States.

Region	*States Included*
Northeast . . .	Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, New Jersey
Midwest	Minnesota, Wisconsin, Michigan, Iowa, Missouri, Illinois, Indiana, Ohio
South	Delaware, Maryland, Virginia, District of Columbia, West Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana
West	Washington, Oregon, Idaho, Montana, North Dakota, South Dakota, Wyoming, Nebraska, Kansas, Colorado, Utah, Nevada, California, Arizona, New Mexico, Texas, Oklahoma, Alaska, Hawaii

Family income.—The income recorded was the total income received during the past 12 months by the head of the household and all other household members related to the head by blood, marriage, or adoption. This income was the gross cash income (excluding pay in kind) except in the case of a family with its own farm or business, in which case net income was recorded.

Education of parent or guardian.—This item was recorded as the highest grade that had been completed in school. The only grades counted were those that had been completed in a regular school in which persons were given formal education in graded or private schools, either day or night schools, with either full-time or part-time attendance. A "regular" school is one that advances a person toward an elementary or high school diploma, or a college, university, or professional school degree. Education in vocational, trade, or business schools outside the regular school system was not counted in determining the highest grade of school completed.

APPENDIX III
TECHNIQUES OF MEASUREMENT AND QUALITY CONTROL

Measurement

The HES blood-drawing technique and its historical development.—For a variety of reasons, it was decided not to attempt to draw a blood specimen on children 6-11 years of age in Cycle II. The children included in the national probability sample came from all regions of the country and all cultural and socioeconomic groupings and ways of life; some would never have been to a physician before; some would have had very bad memories and associations. In addition, by sampling the entire spectrum of behavioral and physical development extant in the United States, some of the 6-year-old children and even some of the 7-year-old children would be so immature as to present severe technical and behavioral problems. It was believed that fear, or extreme distaste, of having a blood sample drawn felt by many potential subjects might severely affect the response rate, which is so crucial to a survey like this. When it is remembered that the overall response rate for Cycle II was a remarkable 96 percent, it is difficult to argue with that line of reasoning. Of course, now it can never be known how great a diminution of the response rate the addition of a blood sample would have caused.

In the early planning stages of Cycle III, it was decided to obtain a blood specimen if at all feasible, that is, primarily if the price in diminished response rate and cooperation of the examinees would not be too high. Accordingly, in three separate pretests, investigations were conducted regarding the problem of developing a satisfactory blood-collection technique for this age group and examination setting. The optimum amount of blood drawn that would not have an emotional impact on the examinee and would not affect his performance in any of the procedures to follow was desired. The amount of usable blood that could be drawn posed a limiting factor on the number of blood chemistry tests that could be performed and made a difference in accepting or rejecting an entire possible area of the examination such as the nutritional assessment. Logistical problems also had to be resolved involving the handling, separating, and packaging of drawn blood so that there would be a minimum of blood loss and packaging error. For the refrigerated but unfrozen bloods, time from shipment to delivery was critical; therefore, arrangements had to be made with postal authorities to assure prompt delivery to the laboratories in order to avoid spoilage.

There was a trial-and-error process, and there was good advice and help from many sources in developing a satisfactory blood-drawing technique. The chief sources of help, outside of the immediate HES technical staff, were Dr. Wilma Bias and Dr. Bernice Cohen of The Johns Hopkins University; Dr. Gerald Cooper, Chief of Laboratories, Communicable Disease Center, Public Health Service, Atlanta, Georgia; the many teenage subjects during our pretest who gave valuable suggestions and who pointed out, either as overt advice or by their immediate reactions, specific points to be avoided; and, finally, the professional and technical division of the Becton-Dickinson Company, Rutherford, New Jersey. The latter, through several personal visits by a representative of their technical division, not only gave excellent technical advice on blood-collection techniques and the use of alternative equipment but also devised a special fitting that made the transfer from one vacutainer tube to another much smoother.

During the pretesting, it was learned that many subjects did not like to see any part of the

blood-drawing procedure, including their own blood in tubes. Therefore, a technique was employed that minimized the subject's attention to the operation. With the subject lying supine and by draping and by keeping the arm and tubes well below the level of the examination table, effective screening was achieved. After the skin area was cleansed with alcohol, the blood was then drawn from the antecubital fossa by the physician-nurse team. At the discretion of the physician, a tourniquet was used to fill the vein; however, once the needle was inserted into the vein, the tourniquet was taken off the arm so that the blood flowed freely.

A B-D blood culture needle and tube were used to draw blood. Using the specially prepared link fitting, the nurse inserted the short needle into a vacutainer tube holder. The tube was clamped with a hemostat until the vein was punctured and the vacutainer inserted into the holder.

From the one free-flowing venipuncture, a total of only 55 cm^3 of blood was collected in four separate vacutainer tubes from all male and almost half of the female subjects. (The difference being that all males had separate plasma drawn to be frozen and stored for future testosterone determination and almost half of the females provided a replicate blood specimen for quality control of the laboratory determinations; the remaining females had 40 cm^3 drawn.)

All test tubes were labeled with the examinee's number and left in the test-tube holding rack at room temperature for 1 hour. The nurse then placed the tubes in the laboratory refrigerator, along with 10 extra examinee identification labels, for the technicians.

An analysis that attempts to estimate the impact of the addition of a blood sample on the Cycle III sample response rate is in progress.

Hematocrit determinations.—After the B-D blood culture needle set was withdrawn from the arm, the tube was drained; and the two microcapillary tubes were two-thirds filled with the residual blood in the tubing. They were sealed with Sealease and centrifuged (International Model MB) for 5 minutes. Both specimens were read to the nearest percent directly from an International Micri-capillary Reader, Model CR.

The mean of the two readings expressed as the volume (in milliliters) occupied by the red cells per 100 milliliters of whole blood was recorded as the subject's hematocrit value.

Monitoring Systems

In addition to the sampling considerations already discussed, the quality of data collected is also a special concern. One of the main purposes of the monitoring system employed in the survey was to indicate whether the measurements produced by our measurement process attained the desired quality. A second major purpose was to make possible quantitative summary descriptions of residual measurement errors to aid in the interpretation of survey data.

The monitoring system as applied to the taking of blood samples consisted of a formal system of replicate examinations (described later in this appendix). Replicate measurements are useful for a variety of reasons, for example, as a means of increasing precision of estimates of individual measurements, as a training technique, and as a monitoring system that includes the objective of overall evaluation of measurement errors. These objectives are not incompatible, and replicate data collected primarily for one of these objectives often indirectly, if not directly, accomplish one or both of the remaining two. For this reason, replicate data are most often collected with a combination of these objectives in mind.

Methods of Taking Replicate Measurements

A major source of uncertainty in estimates derived from replicate measurements is in the inability to make the replicate measurement under precisely the same conditions and in the same manner as the original measurement. This uncertainty is difficult to evaluate, and most attempts are restricted to subjective statements concerning the direction and/or size of the bias and the need for concern in the analysis of data.

Each sample examinee had blood drawn into two microhematocrit tubes, and readings were obtained by the same technician according to the procedure described previously. Since the two blood samples were taken at the same time, diurnal variation in the hematocrit of the examinee would not be expected to be a source of

variation between the two readings. It is possible that differences may have occurred between the two specimens in duration of time centrifuged and in the time interval between the drawing and centrifuging of the blood sample. However, these differences were held within strict limits, and it is unlikely that they are a major source of variation between the two readings. The most important source of variation between the two readings by the same technician is likely to be a reading error. Part of the reading error is due to a "rounding error" in the last significant figure, since readings were taken to the nearest percent. Since the hematocrit value reported in the survey is an average of the duplicate readings by the same technician, the effect of rounding error would tend to be ameliorated. In the following analysis, the differences between the two readings by the same technician will be referred to as "intraobserver" differences.

A study was undertaken to evaluate the extent of variation between two observers reading the same microhematocrit tube. This was done by having a supervisory technician on Monday mornings read the hematocrits for the morning and enter the findings beside the originals. In the ensuing discussions, such differences will be referred to as "interobserver" differences.

Results of the Replicate Studies for Hematocrit

Two hematocrit readings were obtained by the same technician on 6,375 examinees (94.2 percent of the total sample). Replicate readings by another technician were obtained on 640 examinees (9.5 percent of the total sample) for a total of 1,280 replicate measures. All together, during the 4 years, 12 technicians participated in obtaining replicate measurements for this phase of the quality control program.

Since there were 12 technicians employed during Cycle III, it is of interest to ascertain whether each of the examiners had a representative number of replicate measurement sessions with respect to the number of examinations performed during the survey. It should be carefully noted that it was not possible to insure that each technician had equal chances to perform replicate measures, since the length of time various technicians associated with the survey team varied.

Table I presents the percentage of total examinations done in the survey, the percentage of intraexaminer replicates, and the percentage of interexaminer replicates participated in by each of the 12 technicians. Table I indicates some possible sources of bias that may affect the

Table I. Percent of regular Cycle III hematocrit examinations and replicate hematocrit examinations participated in by each technician

Technician number	Percent of regular Cycle III examinations	Percent of replicate examinations	
		Intraobserver	Interobserver
1	0.1	0.0	15.8
2	13.7	13.9	9.4
3	25.8	25.8	35.6
4	7.2	7.1	1.7
5	13.9	14.0	10.7
6	4.3	4.2	4.1
7	3.7	3.6	2.2
8	12.6	12.8	7.5
9	13.5	13.4	9.0
10	0.0	0.0	-
11	4.2	4.2	2.3
12	1.0	1.0	1.8

analysis of replicate data. The number of interexaminer replicate examinations is distributed between technicians disproportionately with respect to regular and intraexaminer replicate readings. For example, assume technician 3 was in very close agreement on his own readings, but his readings were very different from the other examiners'. Because of this technician's overrepresentation, the distribution of interexaminer differences would be considerably more skewed than it should have, since the technician does not agree well with the other technicians' measurements. Thus, the various combinations of observers for the interexaminer replicates and the proportions of intraexaminer replicates were not controlled so as to be balanced among the observers. In the survey proper, the examinations were similarly not (of necessity, since length of time the various technicians were associated with the survey varied) proportionately distributed among the observers.

The foregoing indicates that the distribution of numbers of replicate examinations done by each technician is not the same as the distribution of the total number of survey examinations done by each in Cycle III. This represents one of the inherent problems of the present replicate data, and limits to some extent implications to the survey as a whole. Nevertheless, the reader should be aware of the many problems confronting those who conduct large-scale health surveys,[3 6] and in this context, the present systematic approach to the collection of replicate data is adequate.

For both the intraobserver study and the interobserver study, frequency distributions of the absolute differences between replicate hematocrit readings are presented in table II.

As a summary statistic of the distribution of differences between replicate hematocrit readings displayed in table II, we have computed V—the percentage technical error of measurement—which is given by

$$V = \frac{100}{\bar{X}} \sqrt{\frac{\sum_{i=1}^{n} d_i^2}{2n}}$$

where

n is the number of pairs of measurements in the study,

Table II. Frequency and percent distribution of absolute differences between replicates for the interobserver and intraobserver studies of hematocrit measurement error

Absolute difference (in milliliters)	Interobserver study		Intraobserver study	
	Frequency	Percent of total	Frequency	Percent of total
Total . .	1,280	100.0	6,375	100.0
0	732	57.2	3,858	60.5
1	544	42.5	2,488	39.0
2	4	0.3	16	0.2
3	0	-	6	0.1
4	0	-	2	-
5	0	-	3	0.1
6	0	-	0	-
7	0	-	0	-
8	0	-	1	-
9	0	-	0	-
10	0	-	0	-
11	0	-	1	-

d_i^2 is the square of the difference between members of the ith pair of measurements ($i = 1, \ldots, n$), and

$\bar{X}$ is the arithmetic mean of the $2n$ measurements in the study.

The percentage technical error, V, can be interpreted as a "coefficient of variation" and is a dimensionless constant. It essentially describes the size of measurement error relative to the mean value of a measurement. For replicate hematocrit determinations obtained in the interobserver and intraobserver studies, the values of V are the following:

Study	V
Interobserver	1.12 percent
Intraobserver	1.14 percent

The interpretation of these statistics is that two observers reading the same microhematocrit tube would, on the average, record values that differ from each other by about 1 percent. Likewise, a single technician reading two microhematocrit tubes obtained from a single venipuncture processed under identical laboratory conditions would record values that differ from each other by an average of approximately 1 percent.

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