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Serum Cholesterol Levels of Adults

United States - 1960-1962

Serum cholesterol levels by age, sex, race, region, and income.

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In accordance with specifications established by the National Health Survey, the Bureau of the Census, under a contractual agreement, participated in the design and selection of the sample, and carried out the first stage of the field interviewing and certain parts of the statistical processing.

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IN THIS REPORT serum cholesterol levels are given for the civilian, noninstitutional population of the United States 18-79 years of age.

This report discusses the techniques used and the problems encountered in standardizing serum cholesterol determinations.

Mean serum cholesterol levels rise with age, the rate of increase varying by sex. Corresponding changes occur in the proportion of persons with high serum cholesterol levels. At ages 18-44 years, 3.9 percent of the men and 4.6 percent of the women had levels of 260 or more. At ages 45-54, 25.7 percent of the men had such high values; and at ages 65-74 years more than 50 percent of the women did.

In the South levels were lower for Negro men than for white men but there was no corresponding racial difference in the levels for women.

No significant differences in level by income were noted.

SYMBOLS

Data not available	---
Category not applicable	...
Quantity zero	-
Quantity more than 0 but less than 0.05	0.0
Figure does not meet standards of reliability or precision	*

SERUM CHOLESTEROL LEVELS IN ADULTS

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INTRODUCTION

It is well demonstrated that serum cholesterol levels are associated with the development of coronary heart disease. Evidence leading to this conclusion has been accumulating over a long period of time. Early in this century it was found that rabbits fed large quantities of cholesterol-containing food developed atherosclerosis.[1,2] It was also noted that this high-cholesterol diet was accompanied by a rise in the amount of cholesterol in the blood. Even earlier (1847) it had been demonstrated that cholesterol was present in atheromatous plaques.[3]

For some time, efforts to establish an association between serum cholesterol and coronary atherosclerosis in human beings led to conflicting results, chiefly because of methodological inadequacies. However, in 1947 it was shown that patients with angina pectoris and coronary disease had levels of total blood cholesterol substantially greater than those of normal controls.[4] Since then a series of studies, including several prospective studies, have reconfirmed this finding. Because of the medical importance of these facts, it was felt desirable to include a determination of serum cholesterol levels in the first cycle of the Health Examination Survey (HES) in order to provide reference data for the general adult population of the United States.

The data presented in this report come from a survey conducted by the Health Examination Survey between 1959 and 1962, in which examinations were performed on a probability sample of the civilian, noninstitutional population of the continental United States 18-79 years of age.[5] Some 6,672 persons were examined out of a sample of 7,700 who represented the 111 million adults in the target population. A detailed description of the sample and response has been published.[6] The examination, which lasted 2 hours, consisted of a standardized set of procedures to obtain information on certain chronic diseases, on dental health, and on the distribution of a number of anthropometric and sensory characteristics.

SERUM CHOLESTEROL DETERMINATIONS

Serum cholesterol determinations were done in the Lipid Standardization Laboratory at the Communicable Disease Center, Atlanta, Georgia, under the supervision of Dr. Gerald R. Cooper. The methods used and the technical problems encountered are described in Appendix I.

The development of a valid and reliable technique for the determination of total serum cholesterol has been slow and painful. As recently as the Cooperative Lipoprotein Study (1951-53) the problem of getting four different laboratories to make reproducible measurements was found to be one of the most difficult parts of the total enterprise and in the end one laboratory obtained persistently different results for reasons not fully understood then or now.

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Table A. Mean serum cholesterol levels and standard deviations of the population distribution for adults, by sex and age: United States, 1960-62

Age	Men		Women	
	Mean[1]	Standard deviation	Mean[1]	Standard deviation
18-24 years	178.1	40.7	184.7	47.9
25-34 years	205.9	44.6	197.9	41.9
35-44 years	226.8	49.4	213.6	45.3
45-54 years	230.5	45.6	236.8	50.0
55-64 years	232.8	49.0	262.3	63.0
65-74 years	229.5	47.3	265.7	58.8
75-79 years	224.5	48.7	245.3	65.7

[1]Mg. per 100 ml.

The difficulties in obtaining comparable results in different laboratories led to the initiation in 1958 of a Cooperative Program of Cholesterol Standardization with Dr. Cooper's laboratory acting as the central laboratory for the project.

The collection of specimens by the Health Examination Survey began late in 1959 and continued through 1962. Since this was early in the experience of the Lipid Standardization Laboratory, their methods and techniques were somewhat different from those they currently use. The determinations, which were obtained by a ferric chloride technique, have been adjusted in this report to the levels of the Abell-Kendall method which, on the basis of the current judgment of the Lipid Standardization Laboratory, are very close to the true values for total serum cholesterol. The rationale for these adjustments is given in Appendix I.

The difficulties inherent in the HES data only serve to point up the difficulties in any comparison of serum cholesterol values from different studies. Where the same standard methods are used, the HES data provide a reference in the general population of the United States.

SEX AND AGE

Serum cholesterol levels vary, as do most biological measurements, among individuals, between the two sexes, and among the various age groups; this has been demonstrated in a number of previous studies. The levels observed in this survey of adults in the age range 18-79 years are shown in table A and graphically in figure 1. In each sex group, the mean levels increase with age, but in different patterns. Levels for men increase rapidly to the decade 35-44 years. The rate of increase then flattens out, with levels reaching a peak in the decade 55-64 years and declining slightly thereafter. Mean levels for women are higher than those for men in the youngest age group, 18-24 years. They increase less rapidly than those for men in the midthirties and midforties, but increase much more rapidly than men's levels after age 45. As a consequence, the level for women exceeds that for men in the age group 45-54 years and at all ages thereafter.

The data in table A suggest that levels for both men and women decline in extreme age. The estimated levels for persons in the age group 75-79 years are, as shown in table A, subject to very large sampling variability, and the indicated means must be interpreted with caution. As a consequence, the data for this oldest age group have not been included in the analyses which follow.

The age trends presented in figure 1 and table A do not necessarily represent the expected history of cholesterol levels of any individual over time. They trace the mean levels for successive cohorts of persons born at different time periods, and living through subsequent periods charac-

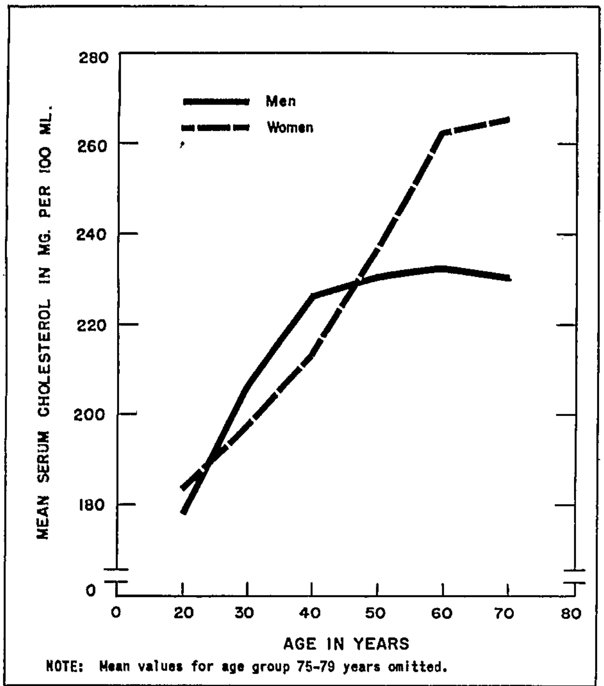

Figure 1. Mean serum cholesterol levels of adults, by sex and age: United States, 1960-62.

terized by rapid changes in conditions of living and causes of dying. Members of the older cohorts who are surviving today are undoubtedly different in many respects from those persons in the present cohorts who will survive to the same ages in the future.

Within each age-sex group there was a great deal of variability between individuals—much greater than was found between the mean values for various population groups. This is shown in terms of the standard deviations of the distributions by age and sex in table A and pictorially in the histograms in figure 2. The distributions for men, which were quite sharply peaked and skewed to the right at the ages below 35 years, became much more symmetrical and closely approached the Gaussian form in later years. The standard deviations increased with age, but remained in the range 40 to 50 mg. per 100 ml. The distributions for women were quite similar in shape to those for men, age group by age group. The standard deviations, however, were, in most age groups, larger. Detailed data on the distributions in the various age-sex groups, are given in tables 1 and 2.

Another way of looking at the distribution of cholesterol levels is to consider the proportion of persons in any age-sex group which exceeds some specified level. In several epidemiological studies it has been found that persons with higher serum cholesterol levels experienced a higher incidence of heart attacks. The risk of attack appears to increase progressively in relation to increase in cholesterol level, but there is no generally agreed-upon point at which levels should be termed "high." However, the level of 260 has conventionally been used as a cutting point in a number of epidemiological studies to distinguish "high" from less high or "low." In table B are shown the proportions of persons in each age group whose serum cholesterol levels were found to be above 260 in the HES sample. These proportions varied in men from a low of 3.9 percent in the age group 18-24 to a high of 25.7 percent in the age group 45-54 years. Among women, the proportion with levels of 260 or above increased with age from a low of 4.6 percent at ages 18-24 to a high of over 50 percent at ages 65-74 years. The proportions of persons whose levels exceeded any other specified amount may readily be computed from the data presented in tables 3 and 4.

An alternative way of looking at distributions is in terms of their decile values, which are presented in table 5.

REGION AND RACE

The sample design of the HES provided for stratification by three broad regions of the United States: The Northeast with 37 percent of the adult population, the West with 35 percent, and the South

Table B. Percent of adults with serum cholesterol level at 260 and over, by age and sex: United States, 1960-62

Age	Men	Women
Total, 18-74 years---	17.6	22.7
18-24 years---------------	3.9	4.6
25-34 years---------------	10.4	7.4
35-44 years---------------	20.2	12.9
45-54 years---------------	25.7	28.0
55-64 years---------------	23.5	49.7
65-74 years---------------	21.6	51.0

Table C. Age-adjusted[1] mean serum cholesterol levels of adults aged 18-74 years, by race and sex: United States, 1960-62

Sex	Total	White	Negro
	Mean serum cholesterol in mg. per 100 ml.		
Both sexes--	220.3	221.3	214.0
Male--------------	217.4	218.5	210.8
Female------------	223.1	224.1	214.0

[1]Adjusted to age distribution of the population of the United States.

Table E. Age-sex adjusted[1] mean serum cholesterol levels of adults aged 18-74 years living in the South, by sex and race: United States, 1960-62

Race	Total	Male	Female
	Mean serum cholesterol in mg. per 100 ml.		
White-----------	218.3	217.0	219.5
Negro-----------	212.5	207.0	217.5

[1]Adjusted to age-sex distribution of the population of the United States.

with 28 percent. There were 14 primary sampling units or "stands" in each region. Estimates are, therefore, available for each region, although the smaller sample sizes will necessarily result in estimates with variances relatively larger than those for national estimates.

The Negro population comprises about 10 percent of the total adult population of the United States, and over half live in the South. Thus, in considering differences in serum cholesterol levels between regions, it is desirable to take into account the differing distribution of races in the regions. Likewise, in considering differences between races, it is desirable to take into account variations in regional distribution. Regional differences are examined, therefore, for the white population only, while racial differences are examined both for the total population (table C) and for residents of the South.

Table D. Age-sex adjusted[1] mean serum cholesterol levels of white adults aged 18-74 years, by sex and region: United States, 1960-62

Region	Total	Male	Female
	Mean serum cholesterol in mg. per 100 ml.		
All regions--	221.6	218.8	224.1
Northeast--------	220.1	216.1	223.7
South------------	218.3	217.0	219.5
West-------------	225.4	222.3	228.2

[1]Adjusted to age-sex distribution of the population of the United States.

Table D presents age-sex-adjusted mean levels for the white adult population by region based on the detailed data in table 6. In Appendix I there is a discussion of differences between "stands," which appear to have resulted from laboratory variability. Since these differences may have been confounded with regional differences, the small differences shown for the white adults in the three regions should be interpreted with caution. The small excess reported for the West, while consistent for almost all age-sex groups (see table 6), would appear to be of little importance.

When the values for Negro and white persons living in the South are compared (tables E and 6), it appears that levels for Negro men are consistently below those for white men. There is no consistent difference between the two groups of women. The data are also consistent with the conclusion that Negro men resident in the South have lower levels than those living in other regions, but the sample outside of the South is so small that this interpretation must be viewed with caution. There is no indication that the levels of Negro women living in the South are different from those living in other regions.

Table F. Age-adjusted[1] mean serum cholesterol levels of white adults, by sex and annual family income: United States, 1960-62

Annual family income	Total	Male	Female
	Mean serum cholesterol in mg. per 100 ml.		
All income groups----	221.6	218.8	224.1
Under $4,000------	219.4	215.1	223.3
$4,000-$6,999----	222.0	219.3	224.4
$7,000 and over--	222.1	222.0	223.9

[1]Adjusted to age-sex distribution of the population of the United States.

FAMILY INCOME

The data reported in tables F and 7 suggest that mean cholesterol levels are not markedly different when the white population is divided into three income groups on the basis of family income. The relatively small sample of the Negro population does not permit a similar analysis.

DISCUSSION

The serum cholesterol levels in this survey of the adult population exhibit great variability within each subgroup of the population. An upward trend with age has been documented for both men and women, but this trend flattens and is probably reversed at a much earlier age for men than for women.

Together, sex and age are clearly the most important demographic variables affecting cholesterol level after taking into account the as yet unexplained innate biological variability. Race does not appear to be associated with important differences, although there is a suggestion that Negro men have levels slightly lower than those of white men. A much larger sample than was available in this survey would be required to document this difference more precisely, and to investigate whether it appears in areas outside the South.

None of the other demographic variables examined appear to have an important association with cholesterol level. Region of residence and family income do not appear, in this sample, to be importantly associated with cholesterol. Other demographic variables which were examined, but not reported here, were marital status, educational status, and size of place of residence. As would be expected from the preceding discussion, these analyses yielded negative findings.

The evaluation of serum cholesterol levels for population is beset with many problems. As is noted elsewhere in this report, the laboratory determination of serum cholesterol level is a difficult one; slightly differing procedures may give quite different results. Even when a procedure is standardized for a given laboratory, constant vigilance in the maintenance of controls is required to ensure that determinations made at one point in time are reasonably comparable with those made at a point distant in time.

Cholesterol levels in human populations are inherently variable. Other studies have shown that the level for an individual varies from day to day, and possibly from season to season, from his long-term mean level. Within any subgroup of the population there is great variability among individuals. In this survey, for example, the coefficients of variation in the different age-sex groups are of the order of magnitude of 20 percent; that is, the population standard deviation is about one-fifth as large as the mean value for any age-sex group. Moreover, the distributions of levels differ greatly by age, and, age by age, the levels for the two sexes differ. There is also some evidence of differences in levels between white and Negro adults.

In the body of the report, age-sex-adjusted mean values have frequently been used to illustrate differences in population groups. Often, however, these mean values will have little value in their own right in the face of great variability within groups. Thus, for example, it is noted that women have, on the average, higher serum cholesterol levels than men. This masks the fact that, in the different age groups of women, mean values will be found to vary, and that at some ages mean levels for women are lower than those for men and and at other ages higher. Whenever differences have been noted, reliance has been placed not only

Table G. Mean serum cholesterol levels, by sex and age for specified populations

Sex and age	White				Negro	
	Total U.S. HES 1960-62	Framingham, Mass. 1958-60	Tecumseh, Mich. 1959-60	Evans County, Ga. 1960-62	South, HES 1960-62	Evans County, Ga. 1960-62
Men	Mean serum cholesterol in mg. per 100 ml.					
25-34 years	207	---	205	203	195	192
35-44 years	228	233	221	220	217	208
45-54 years	231	237	233	223	227	214
55-64 years	234	235	229	226	230	215
65-74 years	230	---	224	221	224	220
Women						
25-34 years	198	---	196	199	194	199
35-44 years	214	217	212	221	212	219
45-54 years	234	246	230	237	227	220
55-64 years	265	262	251	259	243	237
65-74 years	267	---	256	260	266	243

on the summarizing adjusted mean values, but also on the patterns observed and reported in the detailed tables, even though, as noted above, these detailed tables are often based on estimates from relatively small cell frequencies. In general, then, reliance has been placed more on the examination of patterns than on formal tests of significance, since no fully satisfactory theory exists for this type of sampling and adjustment.

In the light of the known variability in serum cholesterol levels, a very large sample is required to establish patterns with any degree of precision. The sample in the present adult Health Examination Survey was indeed large when compared with other surveys which have included the evaluation of serum cholesterol levels; determinations were made for a total of 6,502 men and women. However, the highly clustered area sample, required to make possible a national probability sample in a survey of this type, leads to fairly sizable sampling errors. The need to distribute the sample over a broad age range (18-79 years), over both sexes and both principal racial groups, as well as geographically, results in small frequencies and, at times, large standard errors.

Appendix II includes counts of the actual number of observations in each cell when the observed sample of 6,502 persons is subclassified by age and sex. When the data are further subclassified on other demographic variables of interest such as race, region, income, education, or population-size group, the cell sizes become very small and the standard errors correspond-

Table H. Mean serum cholesterol levels for U.S. white adults and Japanese adults, by sex and age: Health Examination Survey, 1960-62, and Hiroshima, Japan, 1958-60

Sex and age	White adults	Japanese adults
Men	Mean serum cholesterol in mg. per 100 ml.	
30-39 years	219	150
40-49 years	231	157
50-59 years	231	157
60-69 years	233	160
Women		
30-39 years	208	152
40-49 years	224	161
50-59 years	258	177
60-69 years	265	179

ingly greater. The reader who has had experience in working with small samples in the face of large population variability will recognize the necessity of caution in making detailed comparisons.

On the other hand this survey does not stand alone. Other surveys made in general populations agree with respect to the mean levels of cholesterol found in U.S. adults by sex, age, and race. In table G are summarized data from earlier studies in Massachusetts,[7] Michigan,[8] and Georgia[9] which show distributions of cholesterol levels similar to those found in the present survey.

There is evidence, however, from a survey in Japan that the patterns of cholesterol levels there differ from those found in the United States. Table H shows that mean levels observed in a population survey in Hiroshima[10] in 1958-60 were well below those found in the HES survey for every age-sex group.

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DETAILED TABLES

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Table 1. Percent distribution of serum cholesterol levels of adult males, by age: United States, 1960-62

Serum cholesterol level (mg. per 100 ml.)	All ages, 18-74 years	18-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65-74 years
	Percent distribution						
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 100	0.1	0.4	-	0.1	-	0.2	-
100-119	0.7	2.5	0.6	0.6	0.1	0.5	-
120-139	2.5	11.5	2.0	0.8	0.2	0.8	1.3
140-159	6.4	18.7	7.6	3.8	3.4	3.0	2.8
160-179	11.6	24.8	17.3	8.8	5.7	6.7	6.2
180-199	14.5	15.9	20.2	11.3	13.2	10.9	16.2
200-219	17.7	13.0	18.8	20.4	20.0	14.4	16.8
220-239	17.0	6.8	14.9	20.3	18.2	21.9	18.7
240-259	11.9	2.5	8.2	13.7	13.6	18.2	16.4
260-279	8.3	3.0	5.9	8.5	12.0	11.3	8.3
280-299	4.7	0.3	2.5	4.6	8.4	5.2	7.2
300-319	2.6	0.2	0.8	3.9	3.9	3.5	2.6
320-339	1.1	0.2	1.0	1.0	0.8	2.1	1.8
340-359	0.5	-	-	1.1	0.6	0.5	0.6
360-379	0.2	-	-	0.6	-	0.2	0.6
380 and over	0.3	0.2	0.1	0.4	-	0.6	0.5
Number of persons in thousands	50,437	7,064	10,110	11,200	9,775	7,367	4,922

Table 2. Percent distribution of serum cholesterol levels of adult females, by age: United States, 1960-62

Serum cholesterol level (mg. per 100 ml.)	All ages, 18-74 years	18-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65-74 years
	Percent distribution						
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Under 100	0.6	0.3	-	-	-	-	0.3
100-119	0.7	2.6	0.8	0.6	-	-	0.4
120-139	2.1	6.3	3.6	1.2	0.6	-	0.4
140-159	6.4	19.2	10.7	4.7	2.1	0.1	0.4
160-179	11.7	21.1	18.6	13.1	5.2	3.4	4.6
180-199	14.3	20.4	22.1	18.7	10.1	4.1	2.8
200-219	16.7	15.1	18.7	23.8	16.9	10.2	8.8
220-239	13.0	6.1	12.0	14.8	18.1	12.0	13.8
240-259	12.4	4.5	6.1	10.3	18.9	20.4	17.6
260-279	8.2	2.1	3.1	5.8	12.7	13.8	15.8
280-299	6.3	0.6	2.9	4.1	9.0	15.0	8.5
300-319	3.6	0.8	0.8	1.3	2.6	9.2	11.5
320-339	2.5	0.7	0.2	0.5	2.3	7.0	7.1
340-359	1.0	0.2	0.2	0.4	0.9	3.0	2.3
360-379	0.6	-	0.1	0.2	0.1	1.3	2.8
380 and over	0.5	-	0.1	0.4	0.3	0.3	3.0
Number of persons in thousands	55,119	8,136	11,085	11,979	10,163	7,783	5,974

Table 3. Cumulative percent distribution of serum cholesterol levels of adult males, by age: United States, 1960-62

Serum cholesterol level (mg. per 100 ml.)	All ages, 18-74 years	18-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65-74 years
	Cumulative percent distribution						
Under 100	0.1	0.4	-	0.1	-	0.2	-
Under 120	0.8	2.9	0.6	0.6	0.1	0.7	-
Under 140	3.3	14.4	2.6	1.5	0.3	1.5	1.3
Under 160	9.6	33.1	10.2	5.3	3.7	4.4	4.1
Under 180	21.2	57.9	27.5	14.1	9.4	11.1	10.3
Under 200	35.7	73.8	47.7	25.4	22.6	22.1	26.5
Under 220	53.4	86.8	66.5	45.8	42.6	36.4	43.3
Under 240	70.4	93.6	81.4	66.1	60.8	58.3	62.0
Under 260	82.4	96.1	89.6	79.8	74.3	76.5	78.4
Under 280	90.6	99.0	95.5	88.3	86.3	87.8	86.7
Under 300	95.3	99.4	98.0	93.0	94.7	93.0	93.9
Under 320	97.9	99.6	98.9	96.9	98.6	96.4	96.5
Under 340	98.9	99.8	99.8	97.9	99.4	98.6	98.3
Under 360	99.4	99.8	99.8	99.0	99.9	99.1	98.9
Under 380	99.6	99.8	99.8	99.6	99.9	99.3	99.5

Table 4. Cumulative percent distribution of serum cholesterol levels of adult females, by age: United States, 1960-62

Serum cholesterol level (mg. per 100 ml.)	All ages, 18-74 years	18-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65-74 years
	Cumulative percent distribution						
Under 100	0.1	0.3	-	-	-	-	0.3
Under 120	0.8	2.9	0.8	0.6	-	-	0.7
Under 140	2.8	9.2	4.4	1.8	0.6	-	1.1
Under 160	9.3	28.3	15.1	6.5	2.7	0.1	1.5
Under 180	20.9	49.4	33.8	19.6	7.9	3.5	6.0
Under 200	35.2	69.8	55.8	38.3	18.1	7.7	8.8
Under 220	51.9	84.9	74.5	62.1	35.0	17.9	17.6
Under 240	64.9	91.0	86.5	76.8	53.0	29.9	31.4
Under 260	77.3	95.4	92.6	87.1	72.0	50.3	49.0
Under 280	85.5	97.5	95.7	93.0	84.7	64.1	64.8
Under 300	91.8	98.2	98.6	97.1	93.7	79.1	73.3
Under 320	95.4	99.0	99.3	98.4	96.3	88.3	84.7
Under 340	97.8	99.7	99.6	98.9	98.6	95.3	91.8
Under 360	98.8	99.9	99.7	99.3	99.5	98.3	94.2
Under 380	99.4	99.9	99.9	99.5	99.6	99.6	97.0

Table 5. Decile values of the distribution of serum cholesterol levels in adults, by age and sex: United States, 1960-62

Sex and decile	All ages	18-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65-74 years	75-79 years
	Serum cholesterol level in mg. per 100 ml.							
Men								
1	161	134	159	172	180	174	179	164
2	178	146	172	191	196	196	192	179
3	192	157	182	203	206	210	203	197
4	204	164	192	214	216	223	216	209
5	215	173	202	224	228	232	229	223
6	228	181	212	234	238	242	237	233
7	239	194	225	245	252	253	247	246
8	255	208	237	261	267	266	263	272
9	279	226	260	286	287	284	290	294
Women								
1	161	140	151	166	185	205	204	185
2	178	152	165	180	201	222	223	212
3	193	162	176	190	213	240	239	224
4	205	172	185	201	225	249	250	234
5	218	180	192	210	237	259	261	245
6	233	190	203	218	248	274	273	252
7	249	200	213	231	256	287	294	262
8	266	211	227	245	269	300	310	278
9	294	236	250	268	287	322	334	305

NOTE: 10 percent of the persons in any specified group have serum cholesterol levels less than or equal to decile 1, 20 percent have levels less than or equal to decile 2, etc.

Table 6. Mean serum cholesterol levels of adults, by sex, age, race, and region: United States, 1960-62

Sex and age	White				Negro	
	Total	Northeast	South	West	Total	South
	Mean serum cholesterol in mg. per 100 ml.					
Both sexes (age-sex adjusted)	221.6	220.1	218.3	225.4	214.3	212.5
Men (age-adjusted)	218.8	216.1	217.0	222.3	210.5	207.0
18-24 years	179.3	178.5	172.5	185.1	[1]170.4	[2]165.5
25-34 years	207.1	204.6	209.6	207.9	[1]195.0	[2]196.2
35-44 years	228.1	224.9	226.4	233.5	217.2	[1]216.5
45-54 years	231.4	232.0	224.3	234.5	[1]226.6	[2]214.4
55-64 years	233.6	[1]224.6	238.4	237.9	[1]229.5	[2]231.5
65-74 years	229.9	[1]228.9	[1]227.2	232.2	[2]224.0	[2]215.7
Women (age-adjusted)	224.1	223.7	219.5	228.2	217.8	217.3
18-24 years	185.7	186.0	182.8	188.2	[1]183.1	[1]184.0
25-34 years	198.0	200.6	194.7	197.8	197.9	[1]193.8
35-44 years	214.2	211.9	212.6	217.9	213.1	[1]212.2
45-54 years	237.6	236.1	230.2	244.7	[1]232.2	[1]227.2
55-64 years	264.9	265.2	257.7	269.4	[2]239.0	[2]242.6
65-74 years	267.4	264.9	[1]260.0	[1]276.2	[2]258.2	[2]266.0

[1]Cell estimate based on sample of 50-99 persons.

[2]Cell estimate based on sample of less than 50 persons.

NOTE: Mean values for men age-adjusted to age distribution of U.S. male population; mean values for women adjusted to U.S. female population.

Table 7. Mean serum cholesterol levels of white adults, by sex, age, and annual family income: United States, 1960-62

Sex and age	All incomes	Under $4,000	$4,000-$6,999	$7,000 and over
	Mean serum cholesterol in mg. per 100 ml.			
Both sexes (age-sex adjusted)	221.6	219.4	222.0	222.1
Men (age-adjusted)	218.8	215.1	219.3	220.0
18-24 years	179.3	177.9	181.2	[1]175.8
25-34 years	207.1	201.2	211.4	[1]206.8
35-44 years	228.1	[1]223.6	225.9	229.4
45-54 years	231.4	[1]231.5	230.2	231.3
55-64 years	233.8	227.6	[1]226.7	[1]241.2
65-74 years	229.9	225.9	[2]242.4	[1]234.9
Women (age-adjusted)	224.1	223.3	224.4	223.9
18-24 years	185.7	185.3	191.7	[1]180.2
25-34 years	198.8	193.3	194.9	204.7
35-44 years	214.2	216.5	208.8	217.8
45-54 years	237.6	238.0	234.7	237.8
55-64 years	264.9	260.4	[1]271.6	260.8
65-74 years	267.4	269.6	[2]274.0	[1]258.3

[1]Cell estimate based on sample of 50 to 99 persons.

[2]Cell estimate based on sample of less than 50 persons.

NOTE: Mean values for men age-adjusted to age distribution of U.S. male population; mean values for women adjusted to U.S. female population.

APPENDIX I

SERUM CHOLESTEROL DETERMINATIONS

A blood specimen was collected from each examinee in a 15 cc. Sheppard-Keidel tube. The tube was kept at room temperature for a minimum of 1 hour following venipuncture and then refrigerated for a minimum of 6 hours to assure a good clot. The blood clot was freed gently from the tube and the tube was then centrifuged for 20 minutes. An aliquot of 1 cc. of serum was transferred to a prenumbered serum vial and frozen. Twice a week the accumulated vials were placed in styrofoam containers, packed with dry ice, and shipped to the Lipid Standardization Laboratory at the Communicable Disease Center, Atlanta, Ga.

Determinations of total serum cholesterol concentration were made by a modified ferric chloride procedure.[11,12] These values were converted to comparable Abell-Kendall values by a method to be described later.

All samples were run in duplicate. If the difference between duplicates exceeded 20 mg.%, the analysis of that specimen was repeated. Each day five standards were analyzed in duplicate and two aliquots from a large lyophilized serum pool were assayed for quality control. The difference between those two aliquots (R) and the mean of the two aliquots were calculated. Unusually large differences or unusually deviant mean values were taken as indicators that the laboratory was going out of control.

The technical error $\left(\frac{\sum_{i=1}^{n} R_i^2}{2n}\right)$ was computed for only 17 of the 42 "stands" of the Health Examination Survey. For that group of stands it averaged 5.1 mg.%. Since the control specimens were randomized over three runs (6 working days) this estimate of technical error includes short-term day-to-day variation as well as variation during the same day.

Long-term variation is more difficult to assess. Two inconclusive indicators are available. The first is variation from stand to stand. Table I gives deviations from the expected for white examinees at each stand. The expected value for a stand is computed by weighting age-sex specific mean serum cholesterol levels for all white examinees with the age-sex distribution of the specific stand. Since the people differ from stand to stand, there will be variation in level. In general, this variation seems to be unpatterned and the size of the deviations to be no greater than would be expected in random samples from the total population. The exception

Table I. Deviation of actual from expected mean serum cholesterol levels of white examinees, by stand: Health Examination Survey, 1960-62

Stand	Deviation in mg. %
1	14.0
2	-5.9
3	4.8
4	7.3
5	22.6
6	18.8
7	19.9
8	15.4
9	1.0
10	3.1
11	7.0
12	4.5
13	-4.6
14	-3.8
15	-3.0
16	-5.2
17	-6.1
18	-5.8
19	3.4
20-22	-0.2
23	0.0
24	-9.8
25	-7.3
26	-0.6
27	-7.7
28	-13.8
29	-17.3
30	3.4
31	9.4
32	3.9
33	-2.4
34	-11.5
35	3.8
36	-12.3
37	-21.9
38	-6.4
39	-13.9
40	-2.7
41	-1.4
42	-13.5

NOTE: If A is the actual mean serum cholesterol value for a stand and E is the expected, the deviation for that stand is A-E. The expected value for a stand, E, is $\sum n_i x_i / \sum n_i$, where n_i is the number of persons at that stand in a specified age-sex group and x_i is the mean for all stands of the serum cholesterol values for white examinees in that age-sex group.

Table II. Comparison of independent determinations on aliquots of the same specimen for total serum cholesterol

Stand	Number of specimens	Mean serum cholesterol in mg. %		
		Lab A	Lab B	Difference (A-B)
Total	101	234.84	230.15	4.69
13	9	230.55	238.00	-7.45
14	5	219.40	217.40	2.00
15	8	237.75	225.50	12.25
17	11	245.54	243.00	2.54
19	10	228.40	219.70	8.70
20-22(1)	9	257.11	252.88	4.23
20-22(2)	5	212.20	209.20	3.00
23	6	244.83	237.83	7.00
25	10	251.30	247.70	3.60
26	7	226.14	216.14	10.00
29	6	228.67	227.00	1.67
31	5	224.80	213.20	11.60
33	10	222.40	217.50	4.90

NOTE: Lab A is the Lipid Standardization Laboratory.

to this occurs in stands 4 through 9, where there is evidence of a rise in mean levels and a subsequent drop. Examination of data from stand 5 indicates a substantial rise from the first to the second half of this stand, while during stand 8 there is a substantial drop from the first to the second half; and this drop continues through stand 9. Since these stands have relatively little in common except that they were completed in succession, it is difficult to believe that this trend represents population differences; in any event the trend *within* stands 4, 8, and 9 almost certainly does not represent population differences. Thus, the likely explanation of this variation is some technical artifact. This artifact would measurably affect regional comparisons but would have only minor effects on other demographic comparisons.

The second set of evidence comes from replicate measurements made in another laboratory. This covers a period of about a year beginning with stand 13 and continuing through stand 33. Determinations at the Lipid Standardization Laboratory averaged 4.7 mg.% above those of the other laboratory (table II). Analysis of variance indicates no significant variation in this difference from one stand to another, that is, the laboratory difference was fairly constant over the period of comparison. It seems likely, however, that stand 13 is an exception. All 9 specimens were read lower at the Lipid Standardization Laboratory than at the other laboratory, whereas for the other 92 specimens only 19 differences were in that direction and they were scattered through the various stands. In any event, leaving stand 13 aside, it is reasonable to argue that the interlaboratory differences were essentially constant over all the remaining stands, 14 through 33. It is impossible to say which laboratory was out of control on stand 13.

One of the most difficult questions in the use of these data was the scale on which to report them. When the Lipid Standardization Laboratory began determinations on the HES specimens it was their judgment that the manual ferric-chloride method was the one most likely to eventually become the method of choice. By the time they had completed work on the HES specimens they had come to the opinion that determinations could be made about as reliably by the Abell-Kendall method as by the ferric-chloride and that the Abell-Kendall method in their hands yielded results closer to "true" cholesterol

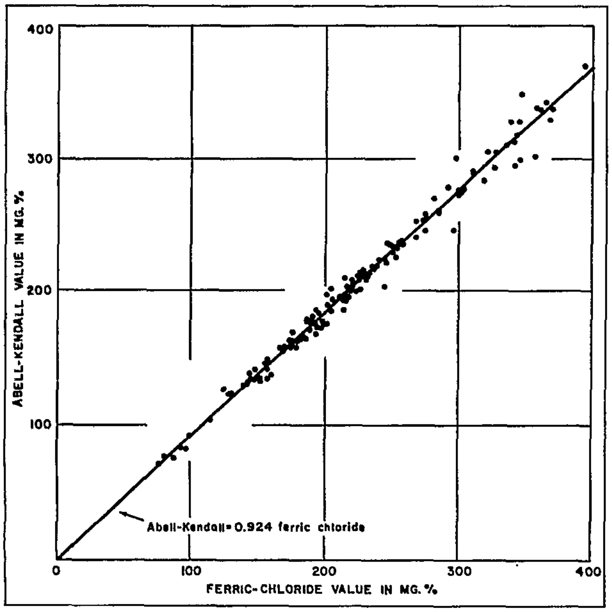

Figure I. Determinations of total serum cholesterol on aliquots of the same specimen, by the ferric-choloride and Abell-Kendall methods.

values as determined by gas chromatography. With some misgivings the HES decided to convert all reported values to estimated Abell-Kendall values.

To do this it was necessary to have determinations by both methods on the same specimens. A series of 134 specimens were available from the Lipid Standardization Laboratory. On each specimen there were three determinations by the Abell-Kendall method and three determinations by the ferric-chloride method. These determinations were made after the completion of HES determinations, so they represent a different laboratory experience than the HES determinations. The mean ferric-chloride value for this series was 232.5 mg.%, with values ranging from 76.2 to 733.5 mg.%. The mean Abell-Kendall value for the series was 214.7 mg.% with values ranging from 71.2 to 677.7. The regression equation obtained on this series was

$$Y = -0.60 + .926\,X$$

where

Y = Abell-Kendall value

X = ferric-chloride value

Since the constant (-0.60) is indistinguishable from zero in a sample of this size, it was decided to use the conversion

$$Y = 0.924\,X$$

When this is used a set of predicted values are obtained which correspond well to the measured values. The mean absolute difference in this series between the predicted and actual Abell-Kendall values was 4.1 mg.%. Differences ranged from -16.5 to +25.8. The individual values are plotted in figure I, each point representing the average ferric-chloride and average Abell-Kendall determination on the same specimen. Three sets of values were too large to fit on the graph. They are as follows:

Ferric-chloride	*Abell-Kendall*	*0.924 ferric-chloride*
733.5	677.7	677.8
496.9	462.4	459.1
449.3	413.6	415.2

In this series the correspondence between actual and predicted values is very good. Whether such close correspondence is also true for the HES series cannot be stated with full assurance. It is known, for example, that bromides can introduce artifacts into ferric-chloride determinations of serum cholesterol. There is no measure of how frequent such artifacts were in the HES series, but they would constitute a problem whether or not the values were translated to Abell-Kendall levels.

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APPENDIX II

STATISTICAL NOTES

The Survey Design

The first cycle of the Health Examination Survey employed a highly stratified multistage probability design in which a sample of the civilian, noninstitutional population of the conterminous United States 18-79 years of age was selected. At the first stage, a sample of 42 primary sampling units (PSU's) was drawn from among the 1,900 geographic units into which the United States was divided. Random selection was controlled within regional and size-of-urban-place strata into which the units were classified. As used here a PSU is a standard metropolitan statistical area or one to three contiguous counties. Later stages result in the random selection of clusters of typically about four persons from a neighborhood within the PSU. The total sample included some 7,700 persons in 29 different States. The detailed structure of the design and the conduct of the survey have been described in previous reports.[5,6]

Reliability

The methodological strength of the survey derives especially from its use of scientific probability sampling techniques and highly standardized and closely controlled measurement processes. This does not imply that statistics from the survey are exact or without error. Data from the survey are imperfect for three major reasons: (1) results are subject to sampling error, (2) the actual conduct of a survey never agrees perfectly with the design, and (3) the measurement processes themselves are inexact even though standardized and controlled.

The first-stage evaluation of the survey was reported in reference 6, which dealt principally with an analysis of the faithfulness with which the sampling design was carried out. This study notes that out of the 7,700 sample persons the 6,670 who were examined—a response rate of over 86 percent—gave evidence that they were a highly representative sample of the civilian, noninstitutional population of the United States. Imputation of nonrespondents was accomplished by attributing to nonexamined persons the characteristics of comparable examined persons as described in reference 6. The specific procedure used amounted to inflating the sampling weight for each examined person in order to compensate for sample persons at that stand of the same age-sex group who were not examined.

While it is impossible to be certain the serum cholesterol levels were the same in the examined and the nonexamined groups, there is no obvious reason to suspect any difference.

Table III. Number of persons with serum cholesterol measurements, by sex and age: Health Examination Survey, 1960-62

Age	Both sexes	Men	Women
Total, 18-79 years	6,502	3,035	3,467
18-24 years	921	406	515
25-34 years	1,390	661	729
35-44 years	1,453	691	762
45-54 years	1,212	533	679
55-64 years	836	410	426
65-74 years	551	262	289
75-79 years	139	72	67

Table IV. Number of persons with missing serum cholesterol measurements, by sex and age: Health Examination Survey, 1960-62

Age	Both sexes	Men	Women
Total, 18-79 years	170	56	114
18-24 years	24	5	19
25-34 years	31	14	17
35-44 years	34	12	22
45-54 years	40	14	26
55-64 years	25	8	17
65-74 years	13	3	10
75-79 years	3	-	3

Table V. Standard errors of mean serum cholesterol levels, by sex and age: United States, 1960-62

Sex and age	Standard error
Both sexes	In mg. per 100 ml.
Total, 18-79 years	1.69
Men	
Total, 18-79 years	2.47
18-24 years	5.10
25-34 years	3.07
35-44 years	3.01
45-54 years	3.25
55-64 years	4.37
65-74 years	7.45
75-79 years	25.48
Women	
Total, 18-79 years	1.08
18-24 years	4.10
25-34 years	2.79
35-44 years	2.83
45-54 years	3.14
55-64 years	4.01
65-74 years	5.60
75-79 years	26.28

In addition to persons not examined, there were some persons whose examinations were incomplete in one particular or another. Table III gives the number of persons by age and sex for whom serum cholesterol values are available. Table IV gives the distribution of missing specimens. Most of the losses were accidental. The mean values tabulated assume that the mean values for missing specimens in any age-sex group were the same as those for persons of the same age-sex group from whom specimens were obtained.

Sampling and Measurement Error

In the present report, reference has been made to efforts to minimize bias and variability the measurement techniques.

The probability design of the survey makes possible the calculation of sampling errors. Traditionally the role of the sampling error has been the determination of how imprecise the survey results may be because they come from a sample rather than from the measurement of all elements in the universe.

The estimation of sampling errors for a study of the type of the Health Examination Survey is difficult for at least three reasons: (1) measurement error and "pure" sampling error are confounded in the data—it is not easy to find a procedure which will either completely include both or treat one or the other separately, (2) the survey design and estimation procedure are complex and, accordingly, require computationally involved techniques for the calculation of variances, and (3) from the survey are coming thousands of statistics, many for subclasses of the population for which there are a small number of sample cases. Estimates of sampling error are obtained from the sample data and are themselves subject to sampling error when the number of cases in a cell is small or, even occasionally, when the number of cases is substantial.

Estimates of approximate sampling variability for selected statistics used in this report are presented in tables V-VIII. These estimates have been prepared by a replication technique which yields overall variability through observation of variability among random sub-

Table VI. Standard errors for percent of adults with serum cholesterol levels of 260 or more, by sex and age: United States, 1960-62

Sex and age	Standard error
Both sexes	In percent
Total, 18-79 years	1.35
Men	
Total, 18-79 years	1.99
18-24 years	2.35
25-34 years	1.86
35-44 years	0.93
45-54 years	2.48
55-64 years	3.23
65-74 years	3.80
75-79 years	11.08
Women	
Total, 18-79 years	1.00
18-24 years	1.17
25-34 years	1.48
35-44 years	2.00
45-54 years	1.82
55-64 years	2.43
65-74 years	3.07
75-79 years	7.21

Table VII. Standard errors for percent of adults with specified serum cholesterol levels, by sex: United States, 1960-62

Serum cholesterol level in mg. per 100 ml.	Men	Women
	Standard error in percent	
Under 100	-	0.22
100-119	0.57	0.33
120-139	0.81	0.77
140-159	1.59	1.07
160-179	2.04	1.52
180-199	2.26	1.92
200-219	2.30	1.99
220-239	2.32	2.01
240-259	2.32	1.89
260-279	2.24	1.92
280-299	2.04	1.55
300-319	1.70	1.40
320-339	1.21	1.16
340-359	0.95	1.00
360-379	0.67	0.87
380-399	0.35	0.55
400-419	0.17	0.47
420-439	0.10	0.32
440-459	0.20	0.35
460 and over	0.20	0.25

samples of the total sample. The method reflects both "pure" sampling variance and a part of the measurement variance.

In accordance with usual practice, the interval estimate for any statistic may be considered the range within one standard error of the tabulated statistic, with 68 percent confidence; or the range within two standard errors of the tabulated statistic, with 95 percent confidence.

Small Numbers

In some tables magnitudes are shown for cells for which sample size is so small that the sampling error may be several times as great as the statistic itself. Obviously in such instances the statistic has little meaning in itself. Such numbers, if shown, have been included to convey an impression of the overall story of the table.

Table VIII. Standard errors of mean serum cholesterol levels in adults, by sex and selected characteristics: United States, 1960-62

Characteristic	Men	Women
Race	Standard error in mg. per 100 ml.	
White	2.25	1.72
Negro	3.61	1.81
Income of white adults		
Under $4,000	2.46	2.20
$4,000-$6,999	1.67	1.67
$7,000 and over	2.25	2.27

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