AN EPIDEMIOLOGIC STUDY OF BLOOD PRESSURE LEVELS IN A BIRACIAL COMMUNITY IN THE SOUTHERN UNITED STATES [1, 2]

BY

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INTRODUCTON

A recent symposium on the epidemiology of hypertension (1) may well prove to be of great importance in the understanding of this disorder, not so much for the considerable body of information made available therein, but more for the deficiencies in present knowledge which were disclosed. These deficiencies were excellently summarized by Clark and Morsell (2) as follows: "(1) There are no consistent standards for blood pressure measurement; (2) there are no established criteria for defining hypertension; (3) none of the existing studies is based on a scientific sample of the population of the country or any subdivision of it; and (4) although the various studies leave no doubt that hypertension is a health problem of great magnitude which varies according to age, sex and race, they do not answer the question as to the actual extent of this problem."

Although it is perfectly proper to refer to the epidemiology of hypertension, it should be realized that there are serious difficulties in this approach, largely due to the unfortunate fact that there is no general agreement on a definition of hypertension or hypertensive disease. Yet it is accepted that the first step in an epidemiologic investigation is the definition of terms, including a decision as to who is to be counted as a case (3). The use of a very stringent definition would produce general agreement regarding the cases so identified, but would probably ignore many persons with milder degrees of hypertension. This state of affairs is analagous to the study of poliomyelitis when only patients with paralysis could be identified as cases. If the definition is extended

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to include milder cases, many workers believe that the true situation would be obscured by the introduction of an unknown proportion of spurious cases.

This impasse may be circumvented if the problem of classification into categories of normal and abnormal is ignored, and consideration is restricted to the epidemiology of blood pressure. However, even in this more basic area, there is a major difficulty. The true values for blood pressure are generally thought to be reflected most accurately by direct measurements of intra-arterial pressure. These measurements involve the use of intricate apparatus and considerable opportunity for technical errors, and in their present state of development are not suitable for general use, so that indirect methods of estimating blood pressure must be used in epidemiologic investigations. However, considerable disagreement exists among various workers regarding the relation of blood pressure values obtained by direct intra-arterial measurements to those obtained by indirect methods (4–7). Which indirect method is used does not appear to be a troublesome matter since there appears to be fairly good agreement among them (7). It must also be remembered that blood pressure in an extremity need not necessarily bear a constant relationship to blood pressure in other vessels of the body.

In spite of the discrepancies between direct and indirect measurements, all workers have shown a fairly linear relationship between them. Since this is so, high values by indirect sphygmomanometry will tend to be equally high on a relative scale by the direct method. It is possible therefore to make valid comparisons between groups of persons examined by the indirect method. Of the 3 indirect methods (palpatory, oscillatory and auscultatory) the last has come to be almost the only one used in English-speaking countries, and was used for the vast majority of reported studies on population groups.

From the preceding discussion of the deficiencies in our knowledge, it will be readily understandable that the epidemiology of blood pressure is still in its descriptive phase, in which efforts are largely centered on describing the blood pressure levels associated with demographic, environmental and genetic factors. As these associations are better understood, it will become increasingly fruitful to develop hypotheses regarding the nature of the disease, and to test them against existing knowledge.

The present study was designed to fill some of the gaps in the knowledge of blood pressure levels in the general population. A sample of the population of Muscogee County, Georgia, was selected in such a way that there was no serious bias either for or against the inclusion of persons with abnormal blood pressures. The examinations were conducted with considerable care for accuracy and consistency, and under conditions which were believed to be representative of the usual living conditions of the population. Since this was a biracial community, it was possible to relate blood pressure levels to race, sex and age, not only affording valid comparisons among these demographic groups in a single community for the first time, but also making it possible to assess the extent of the problem of hypertension in terms of prevalence. In addition, the association of a number of environmental factors to blood pressure levels was also studied.

Historical review

The modern methods for making indirect measurements of blood pressure were available by 1905, and aside from variations in criteria for diastolic pressure, have remained essentially unchanged to the present time. Most of the early studies on blood pressure levels cannot be compared with more recent ones because of differences in techniques, those relating to cuff width apparently being most important. All of the early students of the problem recognized that mean systolic pressure increased with age, and a rough guide to expected systolic pressure was formulated as 100 plus the subject's age in years. This concept is still encountered with surprising frequency among the laity, and even among older practising physicians.

From 1905 to 1915, there was lively interest in the determination of normal blood pressure. Janeway, Brunton and Cook (cited in Master, Garfield and Walters (17)), were the leaders in these investigations and in 1915 agreed that over 135 millimeters up to middle life, and 145 or 150 millimeters thereafter, should be regarded as abnormally high levels of systolic pressure, if found on repeated examinations. Life insurance companies, whose business in the United States had shown remarkable growth after 1900, were greatly interested in the possibility that blood pressure would help in assessing life expectancy. Their data began to be available after 1910, and indicated excess mortality among persons with blood pressures which deviated more than 15 millimeters from normal values which were set at about 120 millimeters for young persons, and 135 millimeters at age 60. Persons with lower blood pressures than these suffered excess mortality from pulmonary tuberculosis, and those with higher pressures from cardiovascular and renal causes.

Alvarez (8) was the first person to raise any question about these generally accepted normal standards. His study of nearly 15,000 entrants to the University of California indicated that there was a rather wide range of pressures, which could be represented by curves of distribution which showed slight positive skewness from normal. He suggested that the mode might be a better expression of the mid-point of the normal range than the mean or median. Among his male students, 28 per cent had systolic pressures of 135 millimeters or more, while only 5.5 per cent of the females had pressures in this range. He was troubled by this discrepancy between the sexes which he was unable to explain, and suggested that previous blood pressure standards, based on population samples even more highly selected than his, might not make sufficient allowance for normal variation. He was also unable to find any indication of a rise in mean blood pressure with age between the ages of 16 and 40.

In the last 30 years there have been a large number of reports on blood pressure levels as related to race, sex or age. Three excellent reviews of the literature are available. Kean and Hammill (9) and Bays and Scrimshaw (10) have made thorough and critical reviews of the studies relating primarily to blood pressure levels in different races. They have pointed out that most of them are of limited value because of the high degree of selection of the population samples, the lack of such basic data as sex and age, or the failure to state the conditions under which the examinations were made. They felt that only cautious conclusions were warranted regarding the variations of blood pressure with race—that mean blood pressure did not always increase with age, and that although there appeared to be true variations in blood pressure levels associated with race, it was impossible to estimate whether this variation was genetic or environmental in origin.

Morsell (11) has presented a critical review of the literature pertaining to the extent of hypertension in the United States. He felt the available evidence indicated that mean blood pressure did increase with age; that among whites, mean blood pressure was higher for males in young adult life, and higher among females in older ages; and that Negroes tended to have higher blood pressures than whites. In his opinion, the case for variation with age was best documented, and that for the differences between Negroes and whites the least well substantiated by the published evidence. The lack of definite knowledge was again attributed to the selection of particular segments of the population for study, and to the failure to use consistent methods of examination and reporting.

The state of our present knowledge can be illustrated by brief summaries of some of the better studies. Contrary to the belief of Bays and Scrimshaw (10), we feel that blood pressure levels of population groups are better described by the mean values rather than the proportion of the group classified as hypertensive, and that the descriptive value of the mean is greatly enhanced by addition of the standard deviations. Consequently, those studies reporting blood pressure levels only in terms of the proportion of hypertensives will be disregarded in this summary.

Adams (12) reported on a total of 28,221 blood pressure readings on 14,000 individuals, 8,000 whites and 6,000 Negroes, examined between 1920 and 1930 in the course of routine pre-employment or annual physical examinations in a large industry, presumably located in New Orleans. He found that mean systolic and diastolic pressures both increased with age, and that at all ages the values for Negroes were higher than those for whites. The difference between the races in mean systolic pressure increased with age, whereas that for mean diastolic pressure remained constant.

Wetherby (13) studied 5,540 out-patients attending the University of Minnesota medical clinic, excluding clear-cut cases of glomerulonephritis and aortic regurgitation. The blood pressures were recorded at the end of a history and physical examination, about 30 to 120 minutes after the subjects arrived at the clinic. Mean blood pressures among females were higher than among males for most age groups, but the difference was not marked until after the age of 50.

Reed and Love (14) and Jenss (15) studied blood pressures recorded in the medical records of U. S. Army officers, representing repeated observations over a period of years. Both found rises in blood pressure with age after the age of 30. This increase with age was much less marked than in other studies, possibly because officers with hypertensive disease were retired from the service. Jenss (15) noted that officers with high initial readings tended to have lower rises in blood pressure on subsequent examinations than did those with low initial readings.

In a paper which had considerable influence on medical thinking and practice, Robinson and Brucer (16) reported on the examination of 11,383 persons living in and around Chicago and from an income class able to afford an insurance policy of $1,000 or more. These persons had periodic physical examinations after they had been accepted for life insurance. In this study there was also an increase in mean blood pressure with age, but the authors felt that this was not due to a gradual increase of the blood pressure of most persons with age, but rather to a more sudden shift of a limited number from the ranks of the normal to those of the hypertensives. This argument was based on two observations. The first was that the mean pressures of persons with readings under 140/90 showed only slight increase with age, and that 60 per cent of these persons had pressures under 120/80. Second, in a 10-year follow-up study of 500 subjects, they did not find a significant increase in blood pressure among those with initial readings under 120/80. On the basis of these findings, they proposed that 120/80 be accepted as the upper limit for normal blood pressure. The first argument is very close to stating that, if one disregards persons whose blood pressure increases considerably with age, one would then expect not to find a considerable increase of blood pressure with age among the remainder. In regard to their second argument, if there is a fraction of the population whose blood pressure remains below 120/80 during life, it must be very small, for as can be seen from the findings of Master, Garfield and Walters (17), Hamilton et al. (18) and those to be presented in this paper, persons with these blood pressure levels comprise an exceedingly small proportion of the population at ages 65 and over. In addition, the population studied by Robinson and Brucer (16) was twice selected, first as good life insurance risks, and second as volunteers for periodic health examinations.

Master, Garfield and Walters (17) have published a small book in which is presented an extension of the findings of Master, Dublin and Marks (19). Their conclusions are based on a study of more than 15,000 persons, "mostly white," examined for employment at 11 different Army airfields and industries in 10 widely scattered cities in the United States. They also noted an increase of mean blood pressure with age. Mean systolic pressures were higher for males than for females to age 45, and higher for females thereafter. Mean diastolic pressures were also higher for males, but with increasing age the differences became very slight. These authors proposed new definitions for normal and abnormal blood pressures which were based on their findings and the concept that for each sex-age group the central 80 per cent of the frequency distribution was normal, and the extreme 5 per cent definitely abnormal. They made the tacit assumptions that the proportion of persons with abnormal blood pressure did not change with age, and that their findings could be considered as representative of the entire population. The first assumption does not seem reasonable in view of the generally observed increase of most chronic conditions with age, and the second assumption is not justified in view of the fact that their subjects did not include nonwhite persons nor those who for one reason or another did not choose to seek employment.

Hamilton et al. (18) made a careful analysis of blood pressures recorded on a sample of patients attending the clinics for skin diseases, varicose veins, orthopedics, fractures, and dental treatment at St. Mary's Hospital in London. Their subjects were examined in a room of the outpatient clinic after sitting quietly with the arm bared for 15 minutes. Twelve subjects were examined at a time. Their findings were essentially the same as those of the preceding study except that their mean blood pressure levels were somewhat higher among the females, and the rise in mean blood pressure in the older age groups was somewhat more marked. They pointed out that limits for normal blood pressure must be selected arbitrarily at the present time, regardless of how the problem is approached, but favored the use of a sex- and age-adjusted score which in essence is a complicated method of applying the type of standard suggested by Master, Garfield and Walters (17), and which seems to be open to the same objections. In most respects, this was a very carefully executed and reported study.

Although in our opinion the preceding studies are the best for epidemiologic purposes, it is readily apparent that none of the examined groups can be considered as truly representative of the entire population nor of any geographic subdivision. It is possible to compare the results of each study with the others in terms of mean blood pressures for specified race-sex-age groups, and for several of them the presentation of the standard deviations allows a comparison of the nature of the frequency distributions as well. Furthermore, the technical procedures of measuring blood pressure seem to have been comparable. However, none of these workers has attempted to measure blood pressure under ordinary living conditions, or examined the possibility of variations between different observers. While these factors may not be important, it cannot be assumed that this is so until they are recognized and studied.

Materials and methods

Selection of sample

The selection of a representative sample was made possible by the record system of the Muscogee County Tuberculosis Study, a cooperative project of the Georgia State Health Department, Muscogee County Health Department, and the U. S. Public Health Service. The population base for the sample was the census conducted by the Muscogee County Tuberculosis Study in September, 1946, under the direction of a supervisor loaned by the Bureau of the Census. In this instance, however, the household schedules were retained by the Study and used as the basis for a master index file.

To assist in the identification of individual records in the master index file, each person was assigned a serial number. In the 1946 chest x-ray survey, these numbers were assigned to each participant in sequence of examination, by date and place of examination. Following the census in September, 1946, the survey and census records were matched. Persons not examined in the survey were then assigned serial numbers in sequence by households.

The 1946 census population of Muscogee County, Georgia, was 95,638 persons, 70 per cent of them whites and 30 per cent Negroes. Of these persons, 50,021 had been examined in the 1946 survey. An appreciable, but unknown, proportion of the population consisted of Army personnel and their dependents, since Muscogee County is adjacent to Ft. Benning, a large Army post. Further details of the census and survey are given by Burke, Schenck and Thrash (20).

For several studies it has been necessary to obtain estimates of emigration from the county. This has been done by sampling the 1946 census population, and endeavoring to ascertain the whereabouts of each person so selected. In 1954, in addition to locating each individual, it was decided to determine the blood pressure of the persons who were still living in the county at that time.

The sampling procedure was simply

the selection of all individuals in the 1946 census population whose serial numbers ended in 29 and 71. This procedure yielded a 2 per cent systematic sample in which the presence of more than one individual from a given household was somewhat less likely than would have been the case with truly random selection. This was so because of the method of assigning serial numbers. It is known that participation in the 1946 survey tended to be an "all-or-none response" in that if one person from a household was examined, there was a greater likelihood that other members of the household would be examined than would be anticipated by random selection (20). Conversely, there was a higher proportion of households with no person examined than would be expected from chance alone. Since in these households serial numbers were assigned in sequence, it would have been impossible to find members from the same household with serial numbers ending in 29 and 71. Consequently the sample was biased to the extent that only households in which at least one member was examined in the survey could have had more than one member represented in the sample.

However, the effect of this bias must be quite slight since truly random sampling would be expected to select less than 4 per cent of individuals from households which had already been represented in the sample (21). There is no other a priori reason for not considering this sample representative of the 1946 census population.

An essential step after selecting a sample is to determine its similarity to the base population for the pertinent characteristics which are available for comparison. Table 1 shows that the sample and census populations agree very well in their race and sex composition, and table 2 shows similar agreement for age composition.

It seemed desirable to compare the census and sample populations in regard to their health status. The only measure of health readily available was the prevalence of suspected tuberculosis and cardiovascular disease detected in the 1946 survey. Participation in the survey is shown in Appendix table 1. The sample and census populations contained similar proportions of survey participants among each race-sex group except for Negro males for whom the sample is somewhat deficient in persons

TABLE 1

1946 census population, and 1954 sample and examined population, by race and sex

Race and sex	Number of persons			Percentage distribution		
	1946 census	1954 sample	Examined population	1946 census	1954 sample	Examined population
Totals	95,638*	1,912	1,162	100.0	100.0	100.0
White male	31,848	620	331	33.3	32.4	28.5
White female	35,070	708	437	36.7	37.0	37.6
Negro male	12,846	261	168	13.4	13.7	14.5
Negro female	15,860	323	226	16.6	16.9	19.4

* Includes 14 persons with race or sex not stated.

TABLE 2

Age distribution of 1946 census population and of 1954 sample and examined populations

Age in 1946	Number of persons			Percentage distribution		
	1946 census	1954 sample	Examined population	1946 census	1954 sample	Examined population
Totals	95,638	1,912	1,162	99.9	100.0	100.2
0–4	10,470	194	117	10.9	10.2	10.1
5–9	8,070	157	111	8.4	8.2	9.6
10–14	7,447	153	82	7.8	8.0	7.1
15–19	7,480	151	81	7.8	7.9	7.0
20–24	10,118	211	105	10.6	11.0	9.0
25–34	19,412	392	232	20.3	20.5	20.0
35–44	14,376	294	202	15.0	15.4	17.4
45–54	9,025	181	123	9.4	9.5	10.6
55–64	5,124	103	68	5.4	5.4	5.9
65–74	2,937	56	37	3.1	2.9	3.2
75+	1,037	20	4	1.1	1.0	0.3
Not stated	142			0.1		

who participated in the 1946 survey. In regard to abnormalities detected in the survey photofluorograms, the sample is again quite similar to the base population, as is shown in Appendix table 2. The essential similarity of the census and sample populations in respect to race, sex and age composition, and to health status as measured by a chest x-ray survey lends credibility to the belief that the sample was representative of the entire 1946 population.

Certain problems are introduced by the lapse between the enumeration of the population and the examination of the sample. The blood pressure study was done between July 1, 1954, and March 31, 1955, the majority of observations being obtained in the 5-month period from October, 1954, through February, 1955. Since more than 8 years had elapsed since the original identification of the base population, losses were sizeable, particularly those due to deaths and emigration, as shown in table 3. Of the 1,912 persons in the sample, observations were obtained on 1,162 (61 per cent). Of the 750 persons not examined, only 52 were still residents of the county: 18 of these could not be examined because they were in the Armed Services or state institutions outside of the county, and 34 refused to allow their blood pressure to be taken. Fortunately, these losses among persons still residents of the county, though concentrated among the whites, are spread quite evenly among the various age and sex groups, except for a disproportionate number among persons 65 years of age and older. Deaths between 1946 and 1954 accounted for the failure to examine 99 persons, who comprised about 5 per cent of the whites and 7 per cent of the Negroes in the sample.

The most serious loss from the sample population was due to emigration. Persons were classified as having moved out of the county only after repeated home visits; contacts with neighbors, employers and the Armed Services; and in some instances, investigation by a retail credit agency. In about two thirds of these instances, a definite forwarding

TABLE 3

Status of persons in population sample at time of 1954 blood pressure study by race, sex and age

Race-sex	Age in 1954	Total in sample	Persons examined		Persons not examined			
					Residents		Nonresidents	
			No.	Per cent	Refused	Not in county*	Dead	Moved
Totals		1,912	1,162	60.8	34	18	99	599
White male	Total	620	331	53.4	12	7	31	239
	8–14	105	63	60.0			1	41
	15–24	90	44	48.9	2	2	2	40
	25–34	100	40	40.0		2	1	57
	35–44	128	65	50.7	1	1	3	58
	45–54	96	59	61.5	2	1	5	29
	55–64	56	39	69.6	2		4	11
	65+	45	21	46.7	5	1	15	3
White female	Total	708	437	61.7	18	2	26	225
	8–14	85	45	53.0	2		1	37
	15–24	97	56	57.7			1	40
	25–34	170	87	51.2	2		2	79
	35–44	134	96	71.6	3		4	31
	45–54	88	62	70.5	3		3	20
	55–64	63	46	73.0	2	1	4	10
	65+	71	45	63.4	6	1	11	8
Negro male	Total	261	168	64.4	3	6	20	64
	8–14	41	31	75.6	1			9
	15–24	57	37	65.0		3	1	16
	25–34	34	21	61.8		2	3	8
	35–44	59	34	57.6		1	3	21
	45–54	37	25	67.5	2		5	5
	55–64	22	15	68.2			4	3
	65+	11	5	45.5			4	2
Negro female	Total	323	226	70.0	1	3	22	71
	8–14	37	33	89.2				4
	15–24	55	37	67.3			1	17
	25–34	80	44	55.0		3	4	29
	35–44	64	47	73.4			1	16
	45–54	42	32	76.2	1		4	5
	55–64	21	17	80.9			4	
	65+	24	16	66.7			8	

* In state institutions or Armed Services.

address could be obtained. Emigration affected the young adults most markedly. If it is postulated that the blood pressure levels of those who moved away differed from those who remained in the county, then emigration would have introduced a serious bias. However, there is no known reason to accept such a postulate. Medical facilities in Muscogee County are sufficiently good that it seems most unlikely that any appreciable number of persons would move out of the county to obtain medical treatment.

In any event, the effect of these losses can be gauged by a comparison of the examined group with the census and sample populations. Table 1 shows white males were somewhat under-represented, and the others slightly over-represented in the examined population. Persons aged 10 to 24 in 1946 were also under-represented (table 2); this seems related to the greater emigration at these ages shown in table 3. The proportion of white persons participating in the 1946 survey was higher among the group examined in 1954 than it was among the census or sample population, as is shown in Appendix table 1. This can be explained by two factors. First, older persons were not examined in the survey to the same extent as other age groups, and this age group has suffered the greatest losses due to deaths. Second, many of the young adults not examined in the survey are known to have been Army personnel or dependents, and these groups are most likely to have moved from the county. Both of these factors were much more important for whites than for Negroes, and tend to increase the proportion of 1946 survey participants in the group examined in 1954. Appendix table 2 shows that the prevalence of abnormalities detected in the survey photofluorograms was similar for the examined group and for the entire sample population.

Another comparison can be made between the total sample and the portion examined in 1954. This concerns the housing characteristics of the populations as recorded in 1946. Appendix table 3 gives such a comparison for two criteria of housing. The proportion of home owners was quite similar for the two groups. Among those living in rented houses, the only appreciable discrepancy was noted among persons living in houses renting for $30 a month or more. The examined population contained a considerably smaller proportion of such persons than did the total sample. The houses were also graded according to heating, lighting and cooking facilities; and the presence or absence of running city water, indoor flush toilets and baths. These criteria were combined to form a "socio-economic index" in which the numerical grade varied directly with the adequacy of housing. Reference to Appendix table 3 shows that the examined population contained a slightly smaller proportion of persons living in better housing than did the original sample, and that this was most evident among persons living in rented houses. This is probably related to the mobility of the Army personnel and dependents enumerated in the 1946 census, since the types of housing most often occupied by these persons corresponds to those for which the percentage of examinations in 1954 was the lowest.

The problem of illness in the sample population caused minor difficulties. When it was discovered that a subject was ill, the observer contacted the family physician before attempting to examine the subject. In a few instances, the illness was considered terminal and the physician advised against making the examination; such persons were classified as refusals. In the remainder, the observer waited until the subject had recovered before making further contact with him. It is also known that some individuals who refused examination but did not appear outwardly ill were in fact under the care of a physician. Several were stated to have hypertensive disease, and others among the group who refused to be examined may also have had hypertension. Consequently, it is possible that the group of refusals may have been unduly weighted with persons who had high blood pressure. But since the proportion of refusals was so low (less than 1.8 per cent of the total sample) it does not seem likely that refusals for reasons associated with hypertension or hypertensive disease could have seriously biased the examined population.

In summary, the population examined in 1954 differed from the original population enumerated in 1946 in containing a smaller proportion of the following groups: young adults, principally white males; Negro male participants in the 1946 survey; and persons who in 1946 lived in rented houses with better facilities. To what extent these known (and possibly other unknown) biases introduced by the time lapse between enumeration and examination are related to blood pressure levels is not certain, although their effect presumably is not great. In spite of these known defects, the population examined in this study is more representative of a general population in regard to blood pressure levels than any group reported to the present time.

Blood pressure determinations

In determining the blood pressures of the examined population, the recommendations of the American Heart Association (4) were followed. There were a total of 9 examiners: 8 nurses and 1 physician. Three of the nurses made 76 per cent of the blood pressure readings, and 3 others 23 per cent. All examiners studied the recommendations of the American Heart Association, and practiced the recommended procedures on the office staff until it was certain that they had achieved adequate familiarity with the method.

Considerable effort was made to obtain all readings in the subjects' home environment; this was achieved for 91 per cent of the subjects. When this was impossible because of working hours or other reasons, the subject was offered the choice of having the reading made at his place of employment or at the Muscogee County Health Center. Five per cent of the subjects were examined at work, and 4 per cent at the Health Center.

Mercury manometers were used for all determinations, with careful attention to maintaining the proper level of mercury in the instrument, and to the porosity of the filter disc. The cuffs were 13 centimeters in width, and of the wrap-around type. Spirit-levels were provided for each sphygmomanometer in order to be certain that the mercury column was vertical at the time of reading. In all instances, the subject was seated as comfortably as possible. Determinations were made on the right arm. Care was taken that the clothing did not constrict the upper arm and the border of the cuff was placed about 1 centimeter above the antecubital fossa. During the reading, the observer's eye was kept at the approximate level of the mercury meniscus. The blood pressure was determined 3 times in succession, with care to relieve all compression in the cuff between each determination, but only the third reading was recorded.

This decision was based on the work of Diehl and Lees (22), who studied 100 freshmen at the University of Minnesota. Blood pressures were recorded every 5 minutes for 1 hour. They concluded that "the mean of the first three readings of the series shows significant decreases between consecutive readings, but after the third reading the difference between any two consecutive readings is less than the probable error of the difference." Because of these findings, in addition to the general clinical impression that repeated blood pressure determinations tend to "desensitize" the subject to sphygmomanometry, it seemed advisable to take repeated readings. In order to keep the effects of repeated readings as constant as possible, an arbitrary standard was needed, and the selection of the third reading as the one to be recorded seemed reasonable. However, it should be noted that the examiners did not allow 5 minutes to elapse between readings, but repeated them as soon as they were certain that all of the pressure in the cuff had been released.

Systolic pressure was defined as the first appearance of the Korotkow sounds, and diastolic pressure as the point of their disappearance. Both pressures were measured to the nearest even number, it being our opinion that a greater degree of accuracy than this was not feasible. In no instance was the subject informed of his blood pressure reading. Instead, the reading was mailed to his personal physician. This procedure not only avoided misunderstandings which might have arisen from readings different from those previously reported to the subject by his physician, but also afforded an opportunity, by identifying the subject's personal physician, to obtain office readings for comparison with the field readings.

In addition to determining the 1954 residence status of the sample population and measuring the blood pressure of the residents, another procedure was performed on a portion of the examined sample. In 1950, a tuberculin test was done as part of a BCG vaccination program in Muscogee County, Georgia, and in Russell County, Alabama. As a check of the effectiveness of this program it was desired to determine the subsequent tuberculin sensitivity of the adult participants in the program. Consequently, all persons in the 1954 sample between the ages of 25 and 65 who had been examined in the 1950 program were asked to submit to a tuberculin test, with 0.0001 milligram PPD-S. For this portion of the sample, the blood pressure was measured before and after the administration of the tuberculin test, and again 40 to 80 hours later when the tuberculin reaction was measured. The second blood pressure determination was not an independent observation since it was taken only a short time later when the examiner still recalled the first reading. The nurse who measured the tuberculin reaction and who also made the third blood pressure determination had no knowledge of the results of the previous examinations.

There were 312 persons who had tuberculin tests in addition to determinations of their blood pressure. For this group, it was necessary to decide whether the first, second or third blood pressure reading was most nearly comparable with the readings for the rest of the examined group. On general considerations, the first reading seemed the most reasonable one for comparison, since the conditions under which it was taken were most like those for persons who did not also receive a tuberculin test. A comparison of the second and third blood pressure readings with the first determination was made to determine the magnitude and direction of any differences which might exist. If no large or inconsistent differences could be found, then the problem of which reading to utilize would be of little or no importance.

There was very little difference between first and second readings on the same subjects, although the latter tended to be a little lower. Systolic pressures averaged 0.70 millimeter lower on the second reading, and diastolic pressures 0.47 millimeter lower. There was no discernible trend by race, sex or age; by examiner; nor by initial height of blood pressure. As an incidental by-product of this comparison of blood pressures measured before and after the administration of a tuberculin test, it may be concluded that the stimulus of a skin test does not cause an appreciable rise in blood pressure in an adult population.

The third blood pressure readings on this group, taken 40 to 80 hours later, were appreciably lower than the first readings, averaging 5.2 millimeters lower for systolic and 1.5 millimeters lower for diastolic pressures. Whether the decrease in blood pressure is due to the subjects' becoming accustomed to the procedure is not known, although this would seem to be a likely explanation. In any event, it seemed reasonable to utilize the first blood pressure determinations on this group of persons as those most comparable to the others, and unless otherwise stated, blood pressures in this study will be those taken before the tuberculin test was administered.

When the deviations of the third from the first readings were studied in relation to the height of the initial reading, it was apparent that persons with high initial pressures tended to show the greatest subsequent decrease, while persons with the lowest pressures tended to show a slight increase on the subsequent determination. This was true for both systolic and diastolic pressures, and is demonstrated in table 4. Hamilton et al. (18) noted similar changes when the initial blood pressure of 180 subjects was compared with the results of a second examination 3 to 4 weeks later. In our series there was no correlation between size of tuberculin reaction and change in blood pressure level.

The tendency for persons with blood pressures at the extremes of the frequency distributions to have values on subsequent examinations which are closer to the mean values for the entire population is merely another example of "regression towards the mean," first noted by Galton in his studies on heredity in 1877 (23). In this instance, if it is accepted that the blood pressure of each individual varies over a given range, it can be readily understood that the group of persons with systolic pressures under 115 millimeters Hg at the first examination would be weighted with persons whose blood pressure happened to be at a low point of their particular range at this time. These individuals, when examined later, would be expected to show a somewhat higher mean blood pressure since it would be unlikely that all of them would again be examined when their blood pressure was again at its low point. Similar reasoning explains the tendency of persons with systolic blood pressures over 155 millimeters Hg to have lower mean blood pressures on subsequent examination. Consequently, it seems clear that chance alone can account for the phenomenon of regression towards the mean. The existence of this phenomenon lends emphasis to the wisdom of obtaining several blood pressure determinations as a "baseline" before attempting to evaluate the effect of therapeutic procedures.

TABLE 4

Mean change from initial blood pressure of tuberculin-tested persons of subsequent observations two to three days later, by height of initial observation

Systolic pressure			Diastolic pressure		
Initial range*	Number of subjects	Mean deviation* on subsequent observation	Initial range*	Number of subjects	Mean deviation* on subsequent observation
Under 115	80	+4.0	55–74	115	+3.5
115–134	120	−4.6	75–94	143	−4.1
135–154	64	−9.7	95–114	34	−6.0
155 and over	38	−18.8	115 and over	10	−9.8

* Figures are expressed in millimeters of mercury.

Standardization of observers

Whenever more than one observer participates in a study, the problem of comparability of observers arises. One method of comparing results of different observers in this study would have been to examine the means and standard deviations of the series of measurements made by each observer. However, in order to complete the study as expeditiously as possible, each nurse tended to work within definite geographic areas, and this selection would have made it difficult to determine whether the readings were truly comparable. In any case, such a comparison could have been possible only after a considerable number of observations had been made, too late for any remedial action. Consequently, early in the course of this study, it was arranged to have each of 4 nurses determine the blood pressure on the other members of the Health Department staff. These 4 nurses made 84 per cent of all the blood pressure determinations in the study and 97 per cent of the initial determinations.

As each staff member came to be examined, he was asked to select at random a card on which was stated the order of examination by the 4 nurses. There were 24 of these cards, one for each possible order of examination. When all of the cards had been drawn, they were collected, mixed in a box, and used again. It is believed that this method tended to even out the variations known to be associated with repeated testing. The technique of determining blood pressure was the same as described in the previous section. In no case did the examining nurse know the results of preceding observations. Sixty individuals were examined in this fashion, all on the same day, and in the same place.

Since there was no method whereby the true blood pressure of these subjects could be known, it was decided to use the mean of the readings by all 4 nurses as the most satisfactory measure of the true blood pressure for each individual. Table 5 gives the mean deviations of each observer from the group means. The frequency distribution of these values is shown graphically in Appendix figure 1. It will be noted that two examiners tended to read below, and two above the group mean. Examiner no. 1 who was the nurse with the greatest experience in taking blood pressures agreed most closely with the group mean. However, since there were undoubtedly real fluctuations in blood pressure between successive examinations, the variations depicted in table 5 seem to fall within reasonable limits, and indicate that the accuracy and precision of each of the examiners was satisfactory for the purposes of this study.

Another important phase of quantitative measurements concerns the terminal digit preferences of different observers. Although the pattern of digit preference can be altered by training, it is doubtful if this influence can ever be avoided entirely. In this study each examiner had a fairly distinctive pattern, but nearly all showed some tendency to record more readings ending in zero than in any other digit. The results for the entire group are shown in Appendix table 4, and for each of the 4 principal observers in Appendix figure 2. This analysis clearly shows that any subdivision of the data into groups of less than 10 millimeters would be influenced markedly by terminal digit preference. Consequently, in this presentation the data have been grouped into 10-millimeter units, from readings ending in 5 to those ending in 4, thereby placing in the center of each frequency those readings ending in zero. It seems quite likely that the saw-toothed appearance of the frequency polygons of blood pressures reported by Master, Garfield and Walters (17) is due to their selection of 5-millimeter units, and to the preference of their examiners for zero as the terminal digit. In our data, and also in those of Master, Garfield and Walters (17), it can be demonstrated that the higher the blood pressure reading, the more marked is the preference for a figure ending in zero. This is shown in Appendix table 5.

Results

Blood pressure levels in relation to race, sex and age

Previous studies have shown quite consistent patterns of variation of blood pressure in relation to race, sex and age (12, 13, 15–18, 24–27). Most of the studies in which a comparison between racial groups is possible have been reported from the United States, comparing whites and Negroes (9, 10). These have shown that the average blood pressure in adults is higher for Negroes than for whites, and that the discrepancy tends to increase with age. Studies in which a similar comparison between the sexes is possible are largely confined to whites, and indicate that whereas white males have higher average blood pressures in young adult life than do fe-

TABLE 5

Variation of blood pressure readings by individual observers, Health Department Personnel Study

Parameters	Systolic pressure*				Diastolic pressure*			
	Observer number				Observer number			
	1	2	3	4	1	2	3	4
Mean difference from group mean	−.1	+1.7	−3.4	+1.8	−1.0	+1.6	−2.3	+1.8
Standard deviation of individual difference from group means	4.6	5.0	5.4	5.2	3.3	3.6	3.8	3.5
Standard error of mean difference	.59	.64	.70	.67	.43	.46	.49	.45

* In millimeters of mercury.

TABLE 6

Systolic and diastolic blood pressures, by race, sex and age

Race-sex-age groups		No. of subjects	Systolic pressure			Diastolic pressure		
			Mean	Standard dev.	Coeff. of variation	Mean	Standard dev.	Coeff. of variation
White males	8–14	63	110.0	12.8	11.6	64.0	10.2	15.9
	15–24	44	122.7	9.4	7.7	73.5	10.2	13.9
	25–34	40	121.5	12.1	10.0	78.5	11.7	14.9
	35–44	65	123.8	13.6	11.0	82.5	10.8	13.1
	45–54	59	132.6	23.4	17.6	86.1	15.2	17.6
	55–64	39	144.8	27.8	19.2	84.9	14.5	17.1
	65+	21	147.5	24.0	16.3	84.2	13.9	16.5
White females	8–14	45	105.8	12.5	11.8	66.5	10.4	15.6
	15–24	56	112.9	10.9	9.7	66.3	11.6	17.5
	25–34	87	112.6	11.2	10.0	72.3	8.9	12.3
	35–44	96	120.9	15.4	12.7	76.9	8.3	10.8
	45–54	62	135.5	22.2	16.4	82.5	12.4	15.0
	55–64	46	146.6	28.2	19.2	82.3	14.0	17.0
	65+	45	157.4	26.0	16.5	81.8	15.1	18.5
Negro males	8–14	31	106.1	16.6	15.6	65.1	9.7	14.9
	15–24	37	126.5	15.3	12.1	77.7	10.0	12.9
	25–34	21	132.9	15.6	11.7	81.1	11.7	14.4
	35–44	34	142.8	19.4	13.6	91.5	13.7	15.0
	45–54	25	150.6	27.5	18.3	96.2	16.3	16.9
	55–64	15	166.7	31.3	18.8	95.9	15.5	16.2
	65+	5	146.8	22.8	15.5	81.6	15.5	19.0
Negro females	8–14	33	111.0	21.0	18.9	70.7	9.8	13.9
	15–24	37	125.9	19.2	15.3	78.3	14.7	18.8
	25–34	44	124.9	17.7	14.2	80.1	13.7	17.1
	35–44	47	146.3	31.9	21.8	90.5	20.2	22.3
	45–54	32	158.2	33.4	21.1	93.6	15.2	16.2
	55–64	17	170.0	33.2	19.5	96.6	16.9	17.5
	65+	16	172.6	30.7	17.8	88.6	13.5	15.2

males, there is a tendency for blood pressures to be higher among females after the age of 40. This is particularly true of systolic blood pressures. With the exception of some primitive peoples (9, 28, 29), average blood pressures increase with age, although the rate of this increase varies considerably according to the race and sex of the examined population, and possibly with environmental factors also.

The findings of this study are in general agreement with those reported previously, and are given in table 6 and figure 1. Mean systolic pressures were higher among Negroes than whites at all ages, with the exception of Negro males under the age of 15. For both races, there was a rather marked rise from age 8 through 14 to 15 through 24 years, least marked among white females. After the age of 25, there were considerable differences between the race-sex groups in regard to the variation of systolic pressure with age. For white males, the level remained constant until the age group 35 through 44, following which a steady increase with age was noted. For white females, this increase started earlier and was somewhat more marked, so that in the older age groups mean systolic pressures exceeded those of white males. Among Negro males, a rather similar rate of increase with age was noted, but with no evidence of leveling off after adolescence. Negro females showed a pattern similar to that of white females, with a constant level until age 35, and subsequently a more rapid rate of increase with age than that for Negro males, so that the mean systolic pressure for females exceeded that for males in the older age groups.

Mean diastolic pressures also showed a definite increase with age for all race-sex groups, but much less marked than the rate of increase with age for systolic pressures. White females had the lowest mean diastolic pressures at all ages except in the youngest age group. Negroes had the highest diastolic pressures, with no significant differences be-

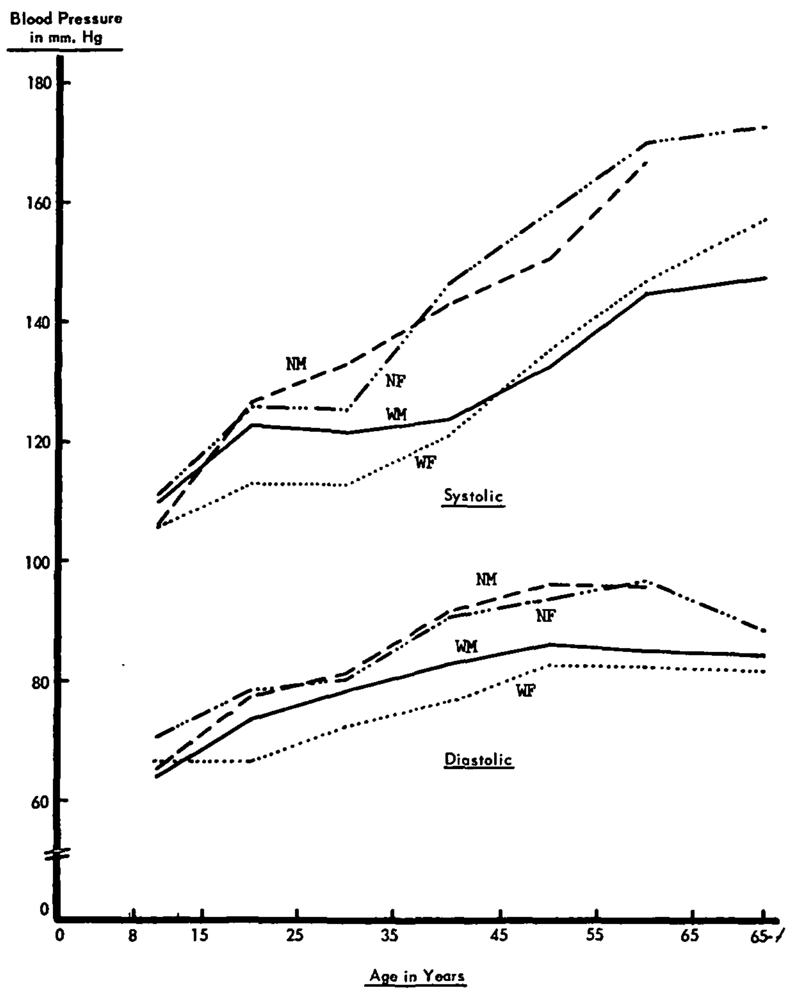

FIGURE 1. Mean systolic and diastolic blood pressure by race, sex and age.

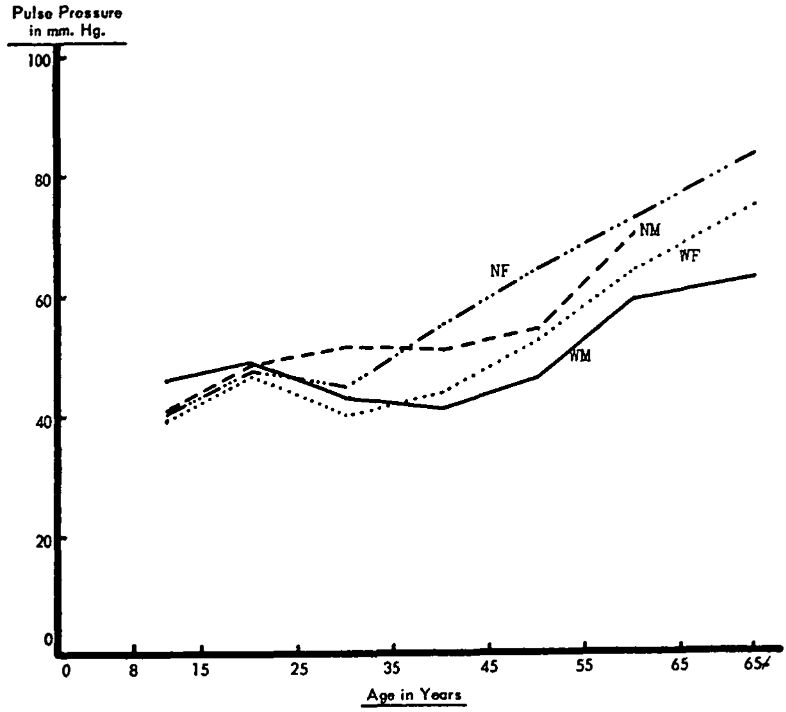

FIGURE 2. Mean pulse pressure by race, sex and age.

tween the sexes in this respect. Diastolic pressures among white males occupied an intermediate position.

As might be expected from the preceding descriptions of the changes in systolic and diastolic pressures with age, mean pulse pressures also showed considerable variation with age for each race-sex group. At all ages after 25, Negroes had higher mean pulse pressures than whites, and after age 35 females had higher pulse pressures than males. The rates of change with age were similar for both races, as can be seen in figure 2.

These findings confirm the observation that high blood pressure in the older age groups is more common in females than in males, and that this is due to a relatively greater increase in systolic pressure of females. It has been shown that prognosis depends more on the height of the diastolic than that of systolic pressure, and this observation may partially explain the better prognosis for white females with high blood pressure than for white males (30a), since among white females the mean diastolic pressure is considerably lower throughout adult life than it is for white males.

The frequency distributions of the blood pressure values for each race-sex-age group are shown in Appendix tables 6 and 7, and in figures 3 and 4. Broken lines have been entered to indicate systolic pressures of 150 millimeters of mercury and diastolic pressures of 90 millimeters of mercury, which together represent a commonly accepted level above which hypertension is considered to be present. For all race-sex groups, there is a shift of the frequency distributions to the right with advancing age, and also a flattening of the distributions. These changes are more marked for systolic than for diastolic pressures, and for each age group, more marked for Negroes than for whites. As has been noted by others (17, 18, 31) there is no real indication of two overlapping distributions (one for the normal range, and another for hypertension) nor can a dividing line be drawn at any point which would clearly separate normal from abnormal blood pressure.

It has been noted that blood pressures among the general population showed a distribution that is skewed to the right (18). This was true of the present material also but is much more marked for the total examined population than for the various subgroups. There was considerable variation between the race-sex-age groups in this respect. In order to study the similarity of these distributions to a "normal" curve, their cumulative values were plotted on probability paper. For systolic pressures among whites, the plots indicated essentially normal distribution for the age groups 8 through 14 and 15 through 24, some skewness to the right after 25, and normal distribution again for persons over the age of 65. For Negro males, there was essentially the same pattern except for a greater skewness to the right in the young adult age groups. However, for Negro females the distribution of systolic pressures showed moderate skewness to the right from age 8 to 44, and fairly normal distributions from 45 to 64. For both Negro males and females, there were too few subjects over the age of 65 to ascertain the characteristics of the frequency distributions. For diastolic pressures, the distributions for all race-sex-age groups were essentially normal. In no instance did the skewness

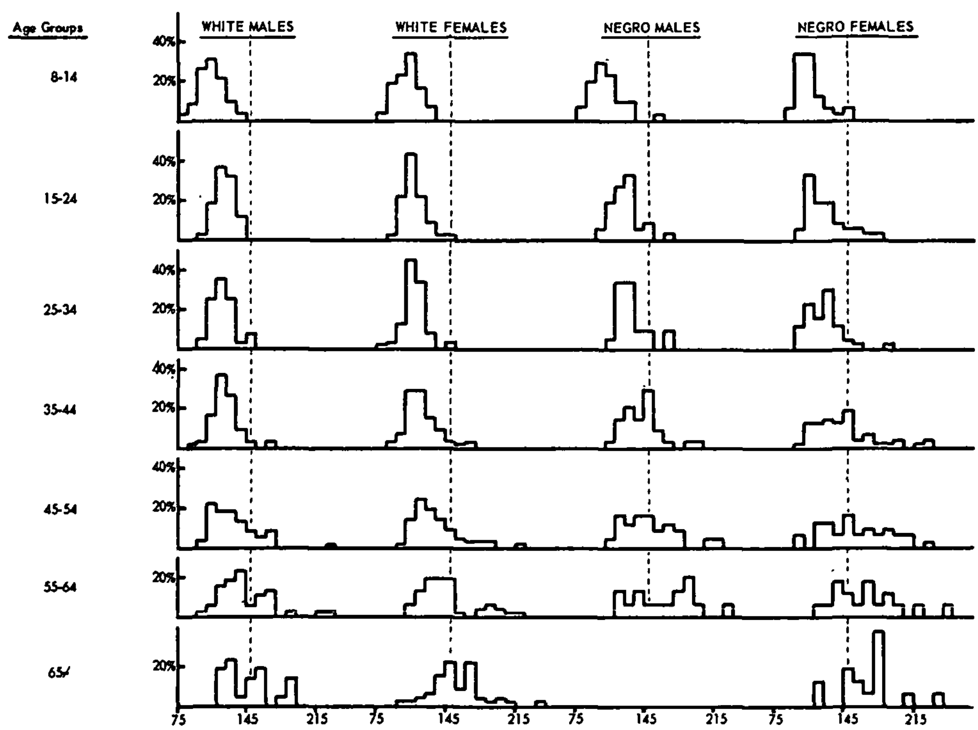

FIGURE 3. Frequency distributions of systolic blood pressure by race, sex and age.

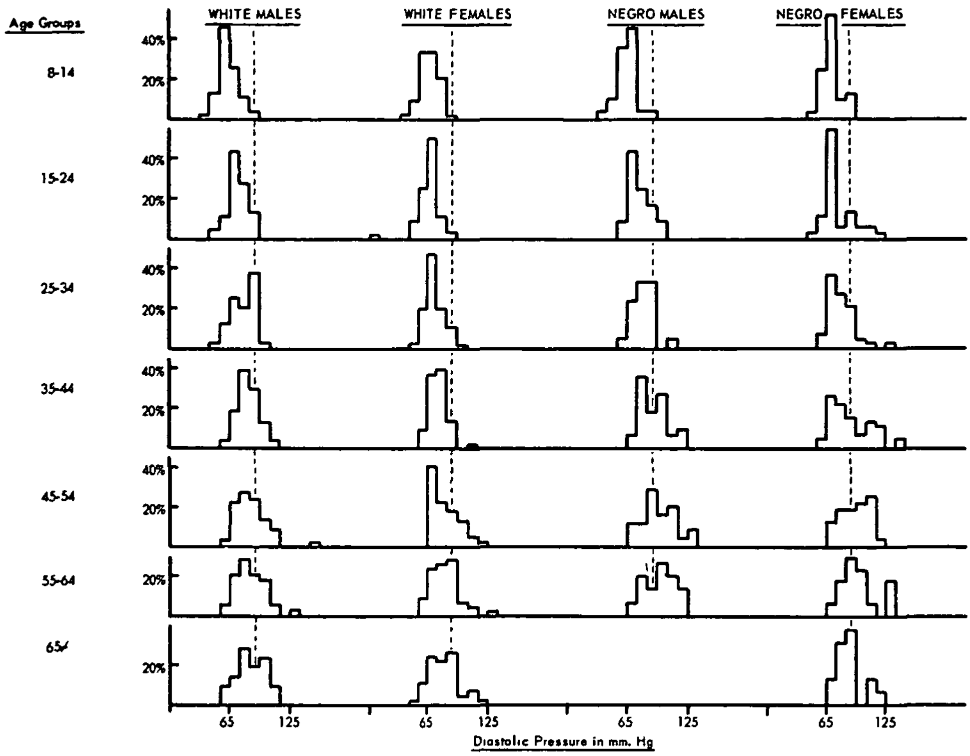

FIGURE 4. Frequency distributions of diastolic blood pressure by race, sex and age.

to the right seem sufficient to vitiate the application of the usual statistical formulas based on the normal curve of distribution. This conclusion is strengthened by the fact that the mean and median values were nearly identical for each distribution.

Moderate variation around the mean values for systolic and diastolic pressures was observed in all race-sex-age groups, as illustrated by the values for standard deviations and coefficients of variation in table 6, and graphically by the distributions in figures 3 and 4. The variability of the systolic pressures showed a similar pattern with age for all of the race-sex groups. There was decreased variability after the age group 8 through 14 until 35. After this age, there was an increase until age 55 and no increase thereafter. For white males and females, there was almost the same degree of variation at each age group. Negroes showed more variation than whites and Negro females more than Negro males, until age 55, following which the degree of variation was similar for all race-sex groups. There was no discernible pattern of variation of the diastolic pressures by race, sex or age, the coefficients of variation ranging between 14 and 18 per cent for most of these subgroups.

In studying the individual blood pressure values for each race-sex-age group, a fairly definite pattern of the relationships of diastolic to systolic pressures was noted. Most obvious was the observation that a high systolic pressure was likely to be associated with a high diastolic pressure. This correlation was most marked in middle age and least in the youngest and oldest age groups. After considerable searching for an adequate numerical expression of this relationship, it was felt that it was best measured by the regression coefficient of diastolic on systolic pressures, i.e., the average amount of change in diastolic pressure per unit change in systolic pressure. These relationships are shown in table 7. Although there were differences between the race-sex groups, an analysis of variance indicated that these differences were not statistically significant. However, there was a significant trend with age which could be fairly well approximated by a quadratic curve.

The physiologic implications of this finding cannot be stated with certainty from the present study, but it is possible to develop a hypothesis at the risk of over-simplification. The systolic pressure is determined largely by the force of the cardiac contraction and by the stroke out-put; except in instances of aortic regurgitation and shunts between the systemic and pulmonic circulation, diastolic pressure is governed largely by the elasticity of the vascular system. In general, as systolic pressure increases, diastolic pressure also increases but not proportionately, since the elasticity of the larger vessels decreases with increasing internal pressure and as elasticity decreases, the discrepancy between systolic and diastolic pressure becomes greater.

Elasticity is known to be altered by changes in the vessel walls. In the aorta, elasticity decreases with age, presumably due to increased atherosclerotic changes. In the muscular arteries, changes in elasticity with internal pressure are related to the state of muscle fiber contraction. When the vessel is relaxed, elasticity tends to vary inversely with the internal pressure; when the vessel is contracted, the relationship is reversed (32b). The elasticity of muscular arteries is also decreased by arteriosclerosis, the prevalence of which is known to increase with age.

In a sense, the regression coefficients in table 7 are indices of mean elasticity of the arterial system for the various age groups. As elasticity decreases, diastolic pressure does not rise as rapidly with increase in systolic pressure as it does when elasticity is normal. The regression coefficient is a measure of this relationship of change in diastolic to change in systolic pressure, and conse-

TABLE 7

Regression coefficients of diastolic on systolic pressures, by race, sex and age

Age group	White males		White females		Negro males		Negro females	
	Regress. coeff.*	S.E.	Regress. coeff.*	S.E.	Regress. coeff.*	S.E.	Regress. coeff.*	S.E.
8–14	.34	.09	.45	.11	.23	.10	.44	.08
15–24	.39	.16	.34	.14	.33	.10	.62	.08
25–34	.44	.14	.56	.07	.51	.11	.64	.07
35–44	.54	.07	.39	.04	.60	.07	.56	.04
45–54	.56	.05	.41	.05	.52	.06	.42	.04
55–64	.42	.05	.37	.05	.42	.07	.48	.05
65+	.40	.10	.34	.07			.12	.11

* All regression coefficients in this table are positive.

quently varies directly with the degree of elasticity. It will be noted in table 7 that the regression coefficient of diastolic on systolic pressure tended to increase with age to middle life, and to decrease thereafter. It is reasonable to assume that this pattern reflects changes in elasticity of the arterial system with age.

It is possible to offer an explanation for the observed relationships of diastolic to systolic pressure at various ages, if it is assumed that in adolescence and young adult life the muscular arteries are more relaxed than in later life. If this is so, then even though the larger arteries showed normal elasticity, the arterial system as a whole would react to increased internal pressure as a somewhat inelastic system because of the relaxed state of the muscular arteries. Thus with increase in systolic pressure, the increase in diastolic pressure would not be marked, and the regression coefficient of diastolic on systolic pressure would be low.

In middle age, if there is increased tonus of the muscular arteries without appreciable loss of elasticity of the large vessels, the arterial system as a whole would react to changes in internal pressure as an elastic system, and diastolic pressures would show relatively greater increases with increases in systolic pressure. The regression coefficient in this instance would be larger.

In later life, as the effects of atherosclerosis on the large vessels and arteriosclerosis on the muscular arteries become more marked, the arterial system loses elasticity, and changes in diastolic pressure again become lower in proportion to changes in systolic pressure. This is reflected in the lower values for the regression coefficients in the older age groups.

Relation of syphilis to blood pressure levels

"To the abuse of alcohol, the poisons of lead and lues, and hard labor, most of the arterial changes are attributed" (33). As indicated by this quotation, syphilis was once considered to be an important cause of arterial hypertension. It is difficult to find any basis for this opinion except for the observation that syphilis often affects the arteries, and that arterial pathology is often associated with hypertension. The work of Stoll (33) is often referred to as supporting the older viewpoint that syphilis was causally related to hypertension. He studied a group of 50 white individuals with a systolic pressure over 160 millimeters. The criterion for the presence of syphilis was a positive Wassermann reaction, a positive luetin test, or both. Only 33 per cent of the group had positive Wassermann reactions, and 82 per cent reacted positively to luetin. On the basis of one or both of these tests, Stoll concluded that 90 per cent had syphilis. However, he apparently used Noguchi's culture luetin which often gives positive reactions in persons who do not have syphilis (34). He did not study a control group, so that there is no evidence to indicate whether or not there was an unusual proportion of persons with positive Wassermann reactions among his hypertensive group. No conclusions can be drawn from this material regarding the association of syphilis and hypertension.

In later years, the etiologic relationship of syphilis to hypertension was either denied (30b) or ignored (32c). The denial was based partly on the observation that the treatment of syphilis did not appear to cause a lowering of blood pressures in patients who also had hypertension, and partly on the study of Horine and Weiss (35). These authors studied 666 cases of essential hypertension admitted to the wards of Louisville City Hospital, and 2,000 controls from the wards and clinics of the same institution. Their criterion of syphilis was a positive blood Wassermann reaction. They found that the proportion of persons with positive Wassermann reactions was slightly higher among the controls than among the hypertensives, and that this was true for whites and Negroes of both sexes. However, their controls which included clinic patients are not entirely comparable with their cases which consisted only of hospitalized patients. In addition, they made no age adjustment of their data. This is an important omission when both variables (blood pressure levels and the results of serological tests for syphilis) have been shown to vary considerably with age.

Harris (36), reporting on a series of cases from a Veterans Administration study, showed a slightly higher prevalence of systolic hypertension and a slightly lower prevalence of diastolic hypertension among persons with syphilis than among persons with negative Wassermann reactions. His conclusions, in direct contradiction to his findings, were that syphilis might be related to diastolic hypertension, but not to systolic hypertension.

In a study of 1,000 Negro factory workers, Allen (37) found a slightly greater proportion with hypertension among those with positive Wassermann reactions than among those with negative reactions. Again, the age distribution of the two groups was not given and the significance of this observed difference cannot be assessed.

As part of a long-term follow-up study of untreated syphilis in male Negroes, two reports have been made of blood pressure levels among the syphilitic and also among a control group selected to match the syphilitic group in respect to age and general social level (38, 39). Both of these studies showed appreciably higher blood pressures among the syphilitic group than among the control group. This was true at all ages. Both systolic and diastolic levels were elevated among the syphilitics, the difference between the two groups being more marked for systolic pressures.

Some evidence from the present study also bears on the relationship of syphilis and hypertension. The 1946 survey in Muscogee County included a brief history regarding syphilis, and Kahn and Mazzini serological tests for syphilis, as well as chest x-rays. All persons with positive serology, or with a history of syphilis, were recalled for a second serological test, and for a clinical history and examination performed by physicians trained in venereal diseases. In addition, the survey records were matched against the records of the Venereal Disease Clinic of the Health Department, so that persons with previously diagnosed syphilis were identified as cases even if they denied syphilis and had negative serological reactions at the time of the survey. On the basis of all the available evidence, persons were then classified by the venereal disease clinicians as positive or negative for syphilis.

The prevalence of syphilis among the white population in the survey was very low, and consequently whites have been excluded from the analysis. There were 243 Negroes among the examined portion of the 1954 sample who had had serological tests for syphilis in the 1946 survey.

Among the 48 persons classified as positive for syphilis, 5 had positive serological reactions only. How many of

TABLE 8

Mean blood pressures in 1954 among Negroes with serological tests for syphilis in 1946 survey, by syphilis status in 1946, sex and age

Sex	Age in 1954	Positive for syphilis			Negative for syphilis		
		No.	Syst.	Diast.	No.	Syst.	Diast.
Male	Total	14	150.5	94.7	88	136.0	84.7
	15–24	2	114.0	73.0	26	127.6	77.0
	25–34	0			15	129.7	80.4
	35–44	4	143.8	97.0	23	140.2	89.5
	45–54	5	158.4	95.2	15	143.5	94.5
	55–64	2	165.0	104.0	7	148.0	88.0
	65+	1	182.0	108.0	2	148.0	77.0
Female	Total	34	155.8	93.8	107	138.4	84.9
	15–24	1	154.0	88.0	22	126.9	79.4
	25–34	9	137.3	85.8	23	119.3	75.5
	35–44	12	161.8	97.7	30	141.1	88.9
	45–54	8	151.5	92.0	18	156.6	92.1
	55–64	3	191.3	104.0	10	159.4	93.2
	65+	1	180.0	90.0	4	157.5	86.0

the 48 have had treatment is not known, nor is it clear from the available evidence how many of these persons still had positive serological tests for syphilis at the time of the blood pressure examinations in 1954. Among the 195 persons classified as negative for syphilis, 7 were considered to have false positive serologic reactions. It is not known how many of the individuals classed as negative have developed syphilis subsequent to the 1946 survey. Consequently, the 1946 syphilis status of these individuals, although reasonably well established at that time, probably does not give an accurate picture of their status in 1954. However, it is likely that the changes occurring in the 8 years between the two examinations would operate in the direction of obscuring any differences in blood pressure levels which might be related to the presence of syphilis.

The mean blood pressure for the 243 persons with serological tests in the 1946 survey are shown in table 8, according

TABLE 9

Mean observed and expected blood pressures in 1954 among Negroes with serological tests for syphilis in 1946 survey, by syphilis status in 1946*

1946 syphilis status	No.	Systolic pressure		Diastolic pressure		Pulse pressure	
		Obs.	Exp.*	Obs.	Exp.*	Obs.	Exp.*
Positive	48	154.3	146.1	94.1	89.3	60.2	56.8
Negative	195	137.3	141.3	84.8	86.8	52.0	54.5

* See text for method of calculating expected mean values.

to their status in regard to syphilis in 1946, and by sex and age. It will be noted that the mean pressures, both systolic and diastolic, are higher among the syphilitics than the nonsyphilitics in almost every sex-age group.

Because the numbers in the individual sex-age subgroups are quite small, it seemed desirable to combine the data for sex and age. The results are shown in table 9. The expected values shown therein were derived by first multiplying the mean race-sex-age specific systolic and diastolic pressures for the entire examined portion of the sample by the number of persons in each sex-age subgroup in table 8, summing the results and dividing by the total number of persons in each syphilis category. The resulting values are the blood pressures expected for groups of similar race-sex-age composition, assuming that blood pressure was not related to the presence or absence of syphilis. In every instance, the observed blood pressures for persons positive for syphilis in 1946 exceed the expected values, while the observed pressures for persons negative for syphilis are lower than the expected values. This is a statistically significant difference and strongly suggests that some factor associated with syphilis is also associated with elevated blood pressure, or that there is a causal relationship between syphilis and blood pressure elevation. In the absence of any known pathogenetic factor whereby syphilis could cause hypertension to this extent, the former alternative, that there is a factor or factors related to both syphilis and hypertension, is more attractive. The findings of the present study give no clue regarding the nature of such a factor or factors.

Diurnal variations in blood pressure

Previous studies have been reported as showing a gradual increase in blood pressure during the day (40–43). In view of these reports, the findings in the present study were examined to see if the height of the blood pressure bore any relation to the time of day at which it was measured. The findings are given in table 10 for systolic pressure only, since none of the previous studies considered diastolic pressures. All of the morning readings were taken between 8 A.M. and noon, and the afternoon readings between noon and 10 P.M., with those between 6 and 10 P.M.

TABLE 10

Mean blood pressures by time of day when observations were made

Race-sex group	No. of subjects			Mean systolic blood pressure				Mean diastolic blood pressure			
				Observed		Expected*		Observed		Expected*	
	Total	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Total	450	156	294	133.8	129.8	132.4	132.5	81.0	80.0	81.6	81.2
White male	108	34	74	135.5	127.2	128.5	129.0	81.2	81.1	81.3	81.6
White female	184	69	115	126.4	124.6	125.2	124.8	76.5	76.1	76.2	76.6
Negro male	58	18	40	133.6	140.6	136.4	147.9	82.1	83.4	84.2	85.9
Negro female	100	35	65	146.6	135.4	148.5	140.6	89.0	83.4	88.4	86.1

* See text for method of calculating expected mean values.

comprising only 4.4 per cent of the total readings.

The expected values in table 10 were calculated in a manner similar to that described in the preceding section. These are the mean systolic and diastolic pressures which would have been expected from the different race-sex-age composition of the two populations, assuming that there was truly no difference between blood pressure levels recorded in the morning and those recorded in the afternoon. The observed morning blood pressures were slightly higher than the afternoon pressures, the difference being slightly greater than would have been expected from the race-sex-age composition of the two populations. While the difference is not significant, and of no clinical importance, the results are not consistent with the generally held belief that there is a slow gradual increase of blood pressure throughout the day.

The discrepancy between this finding and the conclusions of the previous studies is not as marked as it might appear from the brief statements in medical text books. Erlanger and Hooker (42) studied one subject, and reported a slight rise in blood pressure following meals. When the subject fasted, there was no rise during the course of the day. Diehl (41) recorded blood pressures twice on each of his 100 subjects, once in the morning after awakening, and again before the evening meal. His lower readings in the morning appear to be related to the fact that his subjects had not yet started their usual activities and hence his findings do not pertain to blood pressure changes during the course of the day. Mueller and Brown (43) reported a rise of blood pressure during the day, when blood pressures were recorded hourly on a group of hospitalized patients. However, when their data for 26 nonhypertensive patients are re-examined by grouping their results into morning (8 A.M. to noon) and afternoon (noon to 6 P.M.) readings, it is found that the average afternoon pressures were slightly lower than the average morning pressures. Brooks and Carroll (40) do not give the data upon which their conclusions are based. Their study is weakened by the fact that they apparently were highly selective in deciding which patients to include in their analyses, and also because they did not make any adjustment for race, sex and age.

Although there is good evidence that blood pressure falls during sleep, and rises shortly after awakening, it now seems questionable that there is a slow progressive increase during the course of the day.

Effect of place of test

As mentioned earlier, considerable effort was exerted to secure blood pressure examinations in the subjects' homes. However, this could not be accomplished for 106 individuals, comprising 9 per cent of the examined group. These persons were examined at their place of employment or at the Muscogee County Health Center. Because others (44–46) have shown that home blood pressures readings were often considerably lower than those obtained in physicians' offices, it seemed necessary to determine whether mean blood presures for those examined in places other than their homes were different from the means of the total examined group. Table 11 shows, by race and sex, the mean blood pressures observed in these 106 persons, compared with those expected from their age composition. It will be noted that there is a remarkably close agreement between observed and expected values except for systolic pressures for white

TABLE 11

Mean blood pressures among persons examined elsewhere than at home

Race-sex group	No. examined	Systolic		Diastolic	
		Observed	Expected*	Observed	Expected*
WM	44	134.2	129.5	83.6	83.6
WF	21	123.2	123.0	76.1	76.2
NM	27	143.4	142.5	89.0	89.3
NF	14	151.7	143.7	88.6	87.9

* Expected mean blood pressure calculated by applying mean observed values for each race-sex-age group to numbers in each subgroup examined elsewhere than at home.

males and Negro females. However, if these individuals were excluded from the total examined population, the mean systolic pressures for these race-sex subgroups would be lowered by only 1 millimeter Hg. Since the persons not examined at home were not concentrated in any age group, it is felt that their inclusion does not influence the results to a significant degree.

Comparison of nurses' field readings with physicians' office readings

Since the procedure of reporting blood pressure readings to the physician of the subjects' choice made it possible to identify the physician most likely to have examined the persons in the sample, office blood pressure readings could be compared with field readings in a number of instances. Unfortunately, there were only 93 persons who had had office blood pressures recorded by their private physicians within 3 months of the blood pressure determinations in this study. The comparison for this group is shown in table 12. On the average, the office readings were slightly higher than the home readings, a finding similar to that of others (44–46). For males, the office readings were lower than the field readings, whereas for females the reverse was true. It should be pointed out that the comparison for males was based on a small number of subjects, so that one would hesitate to place any great confidence in this finding. However, since the field readings were all made by female nurses, and the office readings by male physicians, one is tempted to speculate that the blood pressure of the subject tends to be higher when the examiner is of the opposite sex. More extensive observations would be needed to confirm this speculation.

Comparison with other studies

Much of the value of the present study is related to a comparison of the

TABLE 12

Comparison of blood pressures recorded in the home with those recorded in a physician's office within 3 months of home readings, by race and sex

Race and sex	Mean systolic pressures				Mean diastolic pressures			
	No.	Home	Office	Difference	No.	Home	Office	Difference
Totals	93	130.5	132.4	+ 1.9	91	77.2	81.1	+3.9
White male	16	140.3	136.4	− 3.9	16	82.0	79.6	−2.4
White female	60	126.0	129.4	+ 3.4	58	74.5	80.2	+5.7
Negro male	6	166.2	146.2	−20.0	6	93.0	90.4	−2.6
Negro female	11	122.2	134.9	+12.7	11	75.4	82.5	+7.1

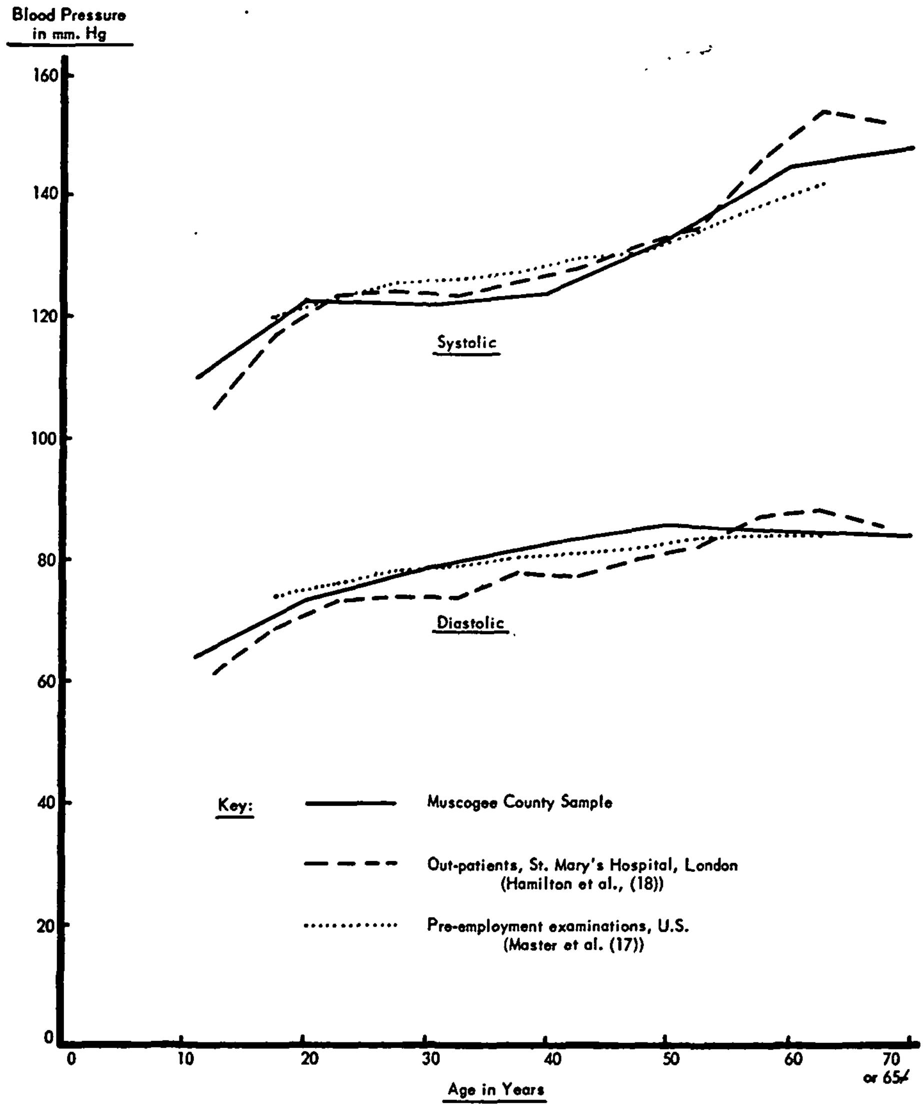

FIGURE 5. Mean blood pressure readings from selected studies, for white males by age.

findings with those of other similar studies, particularly those of Master, Garfield and Walters (17), and Hamilton et al. (18). Both of these studies can be criticized because of the selection of their subjects. Blood pressures reported by Master and his coworkers were drawn from a large number of observations recorded during pre-employment examinations of civilian workers in 11 large industries and Army airfields in 10 cities in various parts of the United States. Although their data are not analyzed for race, it is stated to be "mostly white." It appears to be biased in the direction of containing fewer hypertensives than might be expected in the general population. Hamilton et al. made their study on all outpatients attending certain clinics of St. Mary's Hospital, London, on selected days in 1951. It is quite likely that this population contained a somewhat higher proportion of persons with high blood pressure than might be expected in the general population. For both studies the conditions of observations probably caused some increase over the usual blood pressure of the subjects. The present study, although based on a reasonably representative sample of the population of Muscogee County, Georgia, is also selected in the sense that its findings relate only to a restricted geographic area.

Hamilton and his coworkers compared the mean systolic and diastolic pressures reported by them with those recorded by four other groups of workers, including those of Master and associates. There was fairly good agreement when the mean values from each study were

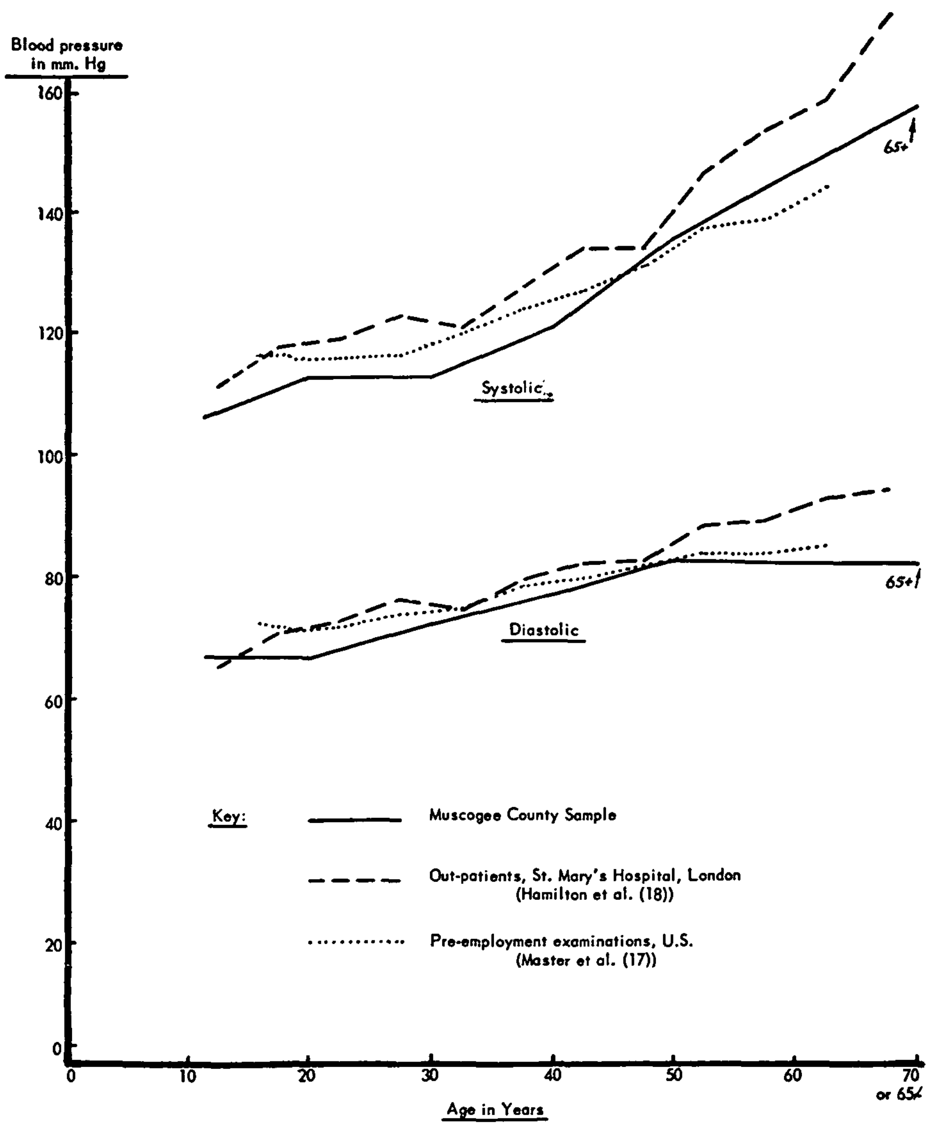

FIGURE 6. Mean blood pressure readings from selected studies, for white females by age.

plotted by sex and age. A similar comparison of the results of the present study is shown in figures 5 and 6. For reasons of clarity, only the comparisons with the findings of Master, Garfield and Walters, and of Hamilton et al. are shown. It will be noted that there is considerable similarity in the general features of the curves and that the differences in the mean levels are not sufficiently great to be disturbing. This is particularly true of the observations on white males. For white females, the mean pressures for the hospital outpatient group tend to be higher than those from the present sample. Those from applicants for employment tend to occupy an intermediate position. These differences are in the directions which might be predicted from the selection and observational conditions of these two studies, as mentioned in the preceding paragraph.

In spite of these differences, the striking finding appears to be the good agreement in the pattern of blood pressure changes with sex and age for whites. The conformity becomes more impressive when the standard deviations are also compared. These measures of the spread of the individual observations are also very similar for the 3 studies. In regard to the absolute values of mean pressures for the various sex-age groups, it is believed that the present study, because of the lack of bias for or against persons with abnormal blood pressures, yields values more nearly representative of a white population than previous studies.

Discussion

The degree of intra-arterial tension or "blood pressure" is related to a number of normal and abnormal bodily states. These conditions may be conveniently considered under 3 headings: normal variations due to physiological or psychological conditions, variations associated with recognized disease states, and finally definitions of the normal range of blood pressure.

Since the blood pressure of all persons appears to vary from time to time, a single reading may be considered as a sample from an unknown point in the subject's spectrum of blood pressure levels. Such an isolated observation may often lead to an erroneous conclusion about the usual blood pressure of a given individual. But, for a group of persons, each observed at a different point in time and under varying conditions, it may reasonably be assumed that the variations in opposite directions will tend to average out, and that the mean value for the group will be quite representative of the average blood pressure of persons in that group under the conditions of observation. The observed deviations from the mean could be minimized by measuring the blood pressure under basal conditions. However, although basal blood pressures may be desirable for some purposes, they are certainly less representative of the blood pressure level of the population under usual living conditions than are casual blood pressures, particularly if these casual observations are taken when the subjects are in their usual environment and engaged in their usual activities. The present study was deliberately designed to obtain observations of blood pressures in persons in their ordinary environment since it was believed that the results would thereby be more representative than if the observations were taken under basal conditions or in an environment foreign to daily experience.

A number of factors other than recognized disease states appear to influence blood pressure levels, sometimes to a marked degree. Physical exercise produces an increase in systolic pressure, and if strenuous, sometimes a decrease in diastolic pressure as well (32d). The pressures usually return to pre-exercise levels after a few minutes of rest. Although the degree of physical exertion experienced by subjects in this study prior to their examination is not known, the time required to explain the nature of the study program to them and the fact that each subject was comfortably seated before making the observations probably allowed sufficient rest to remove the effects of previous exertion.

Emotional factors also tend to increase the blood pressure. This provides another argument for making observations at home, since most subjects will presumably be less fearful in a familiar environment than in strange surroundings. To alleviate any apprehension which might be associated with physicians or a clinical atmosphere, the observations were made by nurses dressed in ordinary street clothes. The generally favorable reaction to the Health Department and the Tuberculosis Study, as well as the assistance of the medical profession and publicity media in the community appeared to have been most helpful in securing the willing cooperation of the subjects in the sample. Some measure of this is afforded by the low proportion of refusals. In addition, conditioning the subjects to the procedure by repeating the observation 3 times in succession should also minimize the effects of emotional reactions related to sphygmomanometry.

Obesity is known to be associated with elevated blood pressure. It is possible, however, that the observed association may be partially due to errors in the indirect method of determining blood pressure, since it has been found that the discrepancies between the findings of direct and indirect methods vary with arm circumference and body build. Unfortunately, this aspect has not been thoroughly studied and somewhat contradictory findings have been reported.

Ragan and Bordley (5) compared direct and indirect measurements of arterial pressure in 40 subjects, not counting those with aortic insufficiency. For the entire group, they noted fairly good agreement between the two methods in regard to systolic pressures. Diastolic readings by the indirect method were somewhat higher than the direct readings, a difference which was considered to be overcome by the use of the point of disappearance of sounds instead of muffling as the criterion of diastolic pressure (4). They noted that differences between direct and indirect readings appeared to be related both to arm circumference and to the shape of the pulse wave. Among persons with obese arms and a sustained wave of systolic pressure, the indirect readings tended to be too high. Persons with thin arms and a short, sharp rise in systolic pressure tended to have auscultatory readings lower than those obtained by the direct intra-arterial method. A re-examination of their basic data indicates that the corrections for arm size to be applied to the indirect readings did not change with the height of the blood pressure.

Van Bergen et al. (7) obtained somewhat contradictory results in their study on 70 postoperative patients. They found that all indirect measurements yielded values below those recorded by the direct intra-arterial method, and that the discrepancy became greater with increasing blood pressure. The trend of the discrepancy between indirect and direct systolic pressures varied considerably according to the body build of the subjects. For obese patients, indirect readings of 100 millimeters were about 25 millimeters too low, and the deficiency increased to about 35 millimeters when the systolic pressure by the indirect method was 150 millimeters. For thin patients, the corresponding deficiencies in the indirect values were approximately 10 and 65 millimeters, respectively. Patients of medium build showed an intermediate trend. For systolic blood pressures of 115 millimeters by the indirect method, patients of all body builds had direct readings about 30 millimeters higher. No data regarding the relation of body build to diastolic readings were presented.

If the reasonable assumption is made that there is a good correlation between obesity and arm circumference, the findings of Van Bergen et al. (7) suggest that the correction to be applied to systolic blood pressures obtained by the indirect method should vary both with arm size and height of blood pressure. The findings of Ragan and Bordley (5) indicate that the correction does not depend on the height of the blood pressure. Van Bergen et al. (4) studied anesthetized patients, whereas Ragan and Bordley used unanesthetized subjects. There were also some differences in technics in the two studies. Although the two groups are therefore not entirely comparable, it is difficult to explain the contradictions in their findings on this basis.

The failure to make any allowance for the possible relationship of arm circumference to the other factors under analysis would seem to be a fault of all recorded blood pressure studies on population groups. An exception to this is the study of Pickering and his associates on hospital out-patients. Although they failed to record arm circumference in their original series of observations (18), a second study on a similar group of patients (47) indicated that in their sample of white patients arm circumference changed but little with age, and consequently that the corrections for arm circumference suggested by the work of Ragan and Bordley (5) did not alter the observed pattern of blood pressure levels for sex and age.

It is our impression that the prevalence of obesity is higher among adult Negro females than among other race-sex-age groups in Muscogee County. This impression is strengthened by observations made in a multiphasic screening program in Atlanta, Georgia, in 1950 (48). In this program, it was found that the prevalence of obesity (defined as 20 per cent or more overweight) among Negro females was 26 per cent, as compared with 10 per cent for white males, 8 per cent for white females, and 11 per cent for Negro males. Consequently, it may well be that the blood pressure levels reported for Negro females in Muscogee County were affected more than those of the other race-sex groups by errors which may be related to obesity.

Since it is not possible at this time to reconcile the conflicting evidence regarding the relationship of obesity to errors in indirect sphygmomanometric readings, speculation regarding the possible effects of obesity on the findings reported in this study does not seem warranted. This and other similar studies would be on firmer ground if arm circumference of the subjects had been recorded, since it might then be possible to make suitable corrections for the effect of arm size when the current confusion regarding the relationship of indirect to direct measurements has been resolved.

A number of disease entities can also result in elevations of blood pressure. Those known to do so are listed below (32c).

I. Conditions associated with rise in systolic pressure only:
   A. Increased stroke output of heart:
      1. Bradycardia
      2. Aortic regurgitation
      3. Arterio-venous fistula
      4. Patent ductus arteriosus
      5. Severe anemia
      6. Paget's disease of bone
      7. Thyrotoxicosis
      8. Fever
   B. Decreased elasticity of aorta
      1. Atherosclerosis
      2. Syphilis
II. Conditions associated with rises in systolic and diastolic pressures:
   A. Diseases of urinary system:
      1. Glomerulonephritides—(types A and B of Longcope; types I and II of Ellis)
      2. Chronic pyelonephritis
      3. Polycystic kidney
      4. Obstruction of urinary tract
      5. Vascular lesions of the kidney
      6. Amyloid contracted kidney
      7. Radiation nephritis
   B. Diseases involving other systems:
      1. Coarctation of aorta
      2. Pheochromocytoma
      3. Cushing's syndrome
      4. Polyarteritis nodosa
      5. Pre-eclamptic toxemia of pregnancy
      6. Post-toxemic hypertension
   C. Essential hypertension.

It will be recognized at once that most of these conditions are rather uncommon, and consequently of little importance in a random sample of the general population. Only those conditions associated with a decreased elasticity of the major vessels, the nephritides, and essential hypertension appear to be sufficiently common to merit consideration. The possible effects of atherosclerosis have been discussed in an earlier section, and are believed to account for much of the observed increase in mean pulse pressure noted in the older age groups.

Aortic regurgitation may have pronounced effects on blood pressure, causing a fall in diastolic pressure which is often associated with a compensatory rise in systolic pressure. The only common causes of aortic regurgitation are rheumatic and syphilitic valvular disease. The prevalence of aortic regurgitation due to rheumatic valvular disease is not known, but in the writer's opinion is quite unusual in the population of Muscogee County. Among the white population in this study, aortic regurgitation due to syphilis is rare, as may be indicated by the fact that in the 1946 survey the proportion of positive serological tests for syphilis among whites was lower than 5 per cent in every age group. Among Negroes, the proportion was much higher, rising to 33 per cent at ages 30 to 49, and then falling slightly with increasing age. However, after examining several thousand Negroes because of abnormal cardiovascular shadows revealed by chest photofluorograms, we are reasonably certain that aortic regurgitation is decidedly uncommon among Muscogee County Negroes also. Consequently, it does not seem likely that clinically recognizable aortic regurgitation could have affected the mean blood pressure levels in this study.

However, syphilis is believed to affect the elasticity of the major vessels by its effects on the media of the vessel wall. It is possible that sufficient damage can be done to alter vascular elasticity without producing evidence which can be recognized clinically as due to syphilitic vascular disease, and that such loss of elasticity could produce an increased pulse pressure, or accentuate the similar effect attributable to atherosclerosis.

A study of blood pressure levels among the examined Negro population as related to evidence of syphilis has been reported in a previous section. Both systolic and diastolic pressures tended to be elevated among the syphilitic group as compared with the nonsyphilitics. Pulse pressures were also greater among the syphilitics, but only to a degree compatible with the generally higher levels of systolic and diastolic pressure. There was no indication of aortic regurgitation or loss of aortic elasticity.

There is no ready explanation for the observation that blood pressures are higher among Negroes with evidence of syphilis than among those without such evidence. No pathological effects of syphilis are known which are likely to produce an increase of blood pressure to the extent observed here (30b), and consequently the association is not likely to be one of cause and effect.

Since the prevalence of syphilis among Negroes participating in the 1946 survey was much higher than that among whites, it may reasonably be asked if the observed differences in blood pressures between the two races might be explained by the observed association of high blood pressure with syphilis. If the mean blood pressure levels among Negroes negative for syphilis in 1946 are compared with those of whites of comparable ages, it is readily seen that the Negroes still have higher mean blood pressures than whites. These differences between the two races are nearly as great as those shown in table 6 for the entire examined portion of the 1954 sample. It would therefore appear that factors related to syphilis can account for only a small portion of the observed differences in blood pressure between whites and Negroes.

It is difficult to judge how often hypertension is due to diseases of the kidneys, particularly chronic glomerulonephritis and chronic pyelonephritis. Smith (49) stated that hypertension in the United States is only rarely due to renal disease, while Schroeder (50) claimed that 30 per cent of cases of "essential hypertension," excluding those beginning at older ages, were due to renal causes. From the conflicting opinions voiced in the discussion of the paper by Schroeder (50), it is still impossible to make an accurate estimate of the frequency with which hypertension is preceded and possibly caused by diffuse renal disease.

Diseases associated with abnormally low blood pressure are either so infrequent or so severe in their disabling effects that they are unlikely to be encountered in a population sample living at home. Hypotension as a specific disease syndrome very likely does not exist. Its lack of importance may be indicated by the fact that in a recent text-book of internal medicine (51) the term appears only once in the index and then in connection with coarctation of the aorta. It is unlikely that the various conditions associated with low blood pressure could influence the findings in the present study.

The question may well be asked: what conditions are responsible for the observed range of blood pressure reported in this study? Certainly much of the variation is normal, for there is no reason to believe that normal subjects should be any less variable with respect to blood pressure than they are in regard to pulse rates, body temperature or body build. Not only are there normal variations from person to person, but also within an individual subject from time to time, depending on physiological and psychological conditions. Diseases producing a lowering of blood pressure are so uncommon that they will have little or no influence on the frequency distributions. Those associated with elevation of blood pressure are much more frequent, especially essential hypertension, atherosclerosis, chronic glomerulonephritis and chronic pyelonephritis. It seems likely that these disease conditions are responsible for most of the higher blood pressure values which have been observed, and for the skewness of the frequency distributions toward the high side of the scale.

To this point, the problem of defining the normal range of blood pressure has been handled by begging the question. Arriving at a suitable definition of normal would be simple if there were a definite limit beyond which morbidity or mortality were clearly increased, and within which no such increase was observed. While numerous clinical and actuarial observations have shown a definite increase of disability and death with increasing blood pressure levels, no clearcut dividing line can be ascertained, and frequent exceptions to the general rule have been observed. Consequently, although one can state with conviction that the prognosis associated with high blood pressure is poorer than that associated with normal or low blood pressure, it is impossible to state just where normal stops and abnormal begins.

Nor is the statistical approach to a definition any more fruitful. The frequency distributions of blood pressures for various race-sex-age groups give no satisfactory suggestion that there are two overlapping distributions, one representing the normal range and the other the abnormal. In the light of present-day treatment for hypertensive disease, one is tempted to agree with Pickering (31) and Master, Garfield and Walters (17) that the most satisfactory definition of normal is based on a sliding scale which increases with age, since it is only the more striking elevations in each age group which seem to indicate the need for treatment with any degree of reliability.

However, although this pragmatic approach has considerable appeal, it does not seem logical to assume that the proportion of persons with abnormal blood pressures remains constant throughout life. Certainly, the prevalence of most other chronic diseases increases with age. Diabetes mellitus affords a good example of this age trend, and provides an analogy with hypertensive disease in that hyperglycemia may be considered to bear the same relationship to diabetes as does hypertension to hypertensive disease. It is entirely feasible to set an arbitrary limit for blood sugar levels above which further diagnostic studies, particularly glucose tolerance tests, are indicated. If these are also abnormal, it may be taken for granted that treatment by diet, insulin or both will be advised.

The fundamental differences in our understanding of diabetes and hypertensive disease lie in the fact that enough is known of the abnormal physiology of diabetes to have resulted in the discovery of a diagnostic test and specific therapy, whereas for hypertensive disease, diagnosis depends on clinical examination, and treatment is largely symptomatic. Because of the fairly definite diagnostic procedures for diabetes, the dividing line between normal blood sugar levels and hyperglycemia, while still arbitrary, can be placed accurately enough for practical application in screening procedures. Because of the availability of specific therapy, we do not hesitate to make the diagnosis of diabetes and recommend treatment even when the disease is asymptomatic.

If it were possible to differentiate hypertensive disease from inconsequential elevations of blood pressure as satisfactorily as diabetes can be diagnosed among persons with hyperglycemia, and if a drug were to be discovered which could control hypertensive disease as well as insulin controls diabetes, it is reasonable to believe that the dividing line between normal blood pressure and hypertension would be placed for screening purposes at about the level beyond which mortality begins to be increased. The work of Dublin, Lotka and Spiegelman (52) suggests that this level is in the neighborhood of 130/85. The goal of treatment for hypertensive disease would undoubtedly include the maintenance of blood pressure at or near this level. Furthermore, it seems likely that there would then be general agreement that the prevalence of hypertension and hypertensive disease does increase with age.

If one accepts the concept that the blood pressure level may be only one of several indications of hypertensive disease, it becomes much easier to be reconciled to the current inability to draw a definite line between normal and abnormal blood pressure levels. Until such a demarcation can be made with reasonable certainty, it seems desirable to report blood pressure observations on groups of persons not only as the mean systolic and diastolic pressures, but also to give some indication of the spread of the individual values, preferably the standard deviation. With these parameters, it is possible to make much more meaningful comparisons between various studies than is possible when the results are reported only as the proportion exceeding an arbitrary value, particularly when various authors are unlikely to agree on the same upper limits of normal. The extent of this disagreement is indicated by a recent review of the literature pertaining to the prevalence of hypertension. This review lists 32 studies in which 12 different criteria for hypertension were utilized (11).

In screening programs, an arbitrary level must be selected with the full realization that values above that level need not necessarily indicate disease, nor all below it normality. Just where the line should be drawn will depend on the degree of specificity and sensitivity desired under the circumstances of the particular screening program. It is likely that as sensitivity is increased, specificity will be decreased, as was found by Kurlander, Hill and Enterline (53) to be the situation for various combinations of diagnostic tests for hypertension and heart disease. It also seems logical for screening purposes to use an upper limit for normal blood pressure which is increased with age. The decision where to set this limit will depend on the characteristics of the population being examined, the medical resources available for diagnostic studies, and the purposes of the screening program.

A unique value of the present study lies in the fact that it is the first to report blood pressure levels in a representative sample of Negroes under conditions which make it possible to compare blood pressures in Negroes and whites in the same community, and under similar circumstances. The results are in agreement with previous impressions (11, 24, 26, 54, 55), and show that at all ages after adolescence Negroes have higher mean systolic and diastolic pressures than do whites. This finding is also in keeping with a previous study from Muscogee County, Georgia (56), in which it is shown that the prevalence of abnormal cardiovascular shadows in chest photofluorograms was higher among Negroes than among whites, and that this increased prevalence was largely due to hypertensive cardiovascular disease.

Why Negroes in the United States have higher blood pressure levels than whites is not known. The assumption has been rather general that high blood pressure in the American Negro is somehow related to living conditions in this country, since it is claimed that native African Negroes have mean blood pressures lower than those for whites. Bays and Scrimshaw (10) have pointed out that the only acceptable study on blood pressures among African natives is that of Donnison (28), which was done in Kenya. Most American Negroes came from West Africa, an area from which scattered reports have indicated that hypertension is not uncommon (10). Until there is adequate knowledge regarding blood pressure among native Africans, it is decidedly premature to speculate that hypertension among American Negroes must be related to environmental conditions.

This is not to deny that environmental factors may play a role in determining the observed differences in blood pressure between whites and Negroes. Certainly there are marked differences in living conditions between the two races even within the same county, and it cannot be assumed that the observed differences between whites and Negroes are necessarily racial in character. An investigation into the relationship to blood pressure levels of the environmental conditions which are known to be different for the two races might well yield valuable information regarding the pathogenesis of hypertension.

Summary

Blood pressure levels in a representative sample of the 1946 population of Muscogee County, Georgia, have been reported. In order to obtain blood pressure readings under normal conditions, the subjects were examined in their homes insofar as this was possible. Considerable care was taken to insure that the readings were accurate and that the findings of different observers were comparable. The examined population was composed of persons 8 years of age and older, and included whites and Negroes of both sexes.

There was a general tendency for the mean blood pressures to increase with age. This was more marked for systolic than for diastolic pressures. Mean systolic pressures were higher among Negroes than whites at all ages, except for Negro males under 15 years of age. For both races there was a rather marked rise from the age group 8 through 14 to 15 through 24, least marked among white females. In young adult life, females had lower mean systolic pressures than males, whereas among older persons males had lower systolic pressures. This reversal of the relationship occurred at age 45 for whites, and at age 35 for Negroes.

The lowest mean diastolic pressures were those for white females. Negroes had the highest mean diastolic pressures, with no appreciable differences between the sexes in this respect. Mean diastolic pressures for white males occupied an intermediate position.

The frequency distributions of blood pressures showed a shift toward higher levels with advancing age, and also a flattening of the distributions. These changes were more marked for systolic than for diastolic pressures, and for each age group, more marked among Negroes than among whites.

Negroes with syphilis in 1946 had higher systolic and diastolic pressures in 1954, than did those classified as negative for syphilis in 1946. No explana-

tion for this association of syphilis and high blood pressure was afforded by the present study. Too few white persons had evidence of syphilis in the 1946 survey to make a similar analysis possible among whites.

Previous reports that blood pressure tends to rise during the day could not be confirmed. Blood pressures taken at home tended to be lower than those taken elsewhere, although the over-all differences were not marked.

The problem of defining normal and abnormal blood pressure was discussed. Although it appeared logical to assume that the proportion of persons with hypertension increases with age as is the case with most chronic disorders, there was no definite evidence in this study or in previous reports which allowed a satisfactory demarcation of normal from abnormal levels. From a pragmatic point of view, taking into consideration the present paucity of satisfactory diagnostic and therapeutic procedures for hypertensive disease, it seemed reasonable to accept an arbitrary upper limit of normal blood pressure which is increased with age. The decision where to set this limit will vary according to the characteristics of the population being examined, the medical resources available for diagnostic studies, and the purposes of the screening procedure.

References

1. Commonwealth of Massachusetts Recess Commission on Hypertension. Proceedings of a Symposium on Essential Hypertension. Wright and Potter, Boston, 1951.
2. Clark, E. G., and Morsell, J. A. An epidemiologic approach to the study of high blood pressure. Amer. Jour. Pub. Health, 1952, *42:* 542–548.
3. Clark, E. G. Modern concepts of epidemiology. Jour. Chron. Dis., 1955, *2:* 593–596.
4. Bordley, J., III, Connor, C. A. R., Hamilton, W. F., Kerr, W. J., and Wiggers, C. J. Recommendations for human blood pressure determinations by sphygmomanometers. Jour. Amer. Med. Ass'n, 1951, *147:* 632–636.
5. Ragan, C., and Bordley, J., III. The accuracy of clinical measurements of arterial blood pressure, with a note on the auscultatory gap. Bull. Johns Hopkins Hosp., 1941, *69:* 504–528.
6. Roberts, L. N., Smiley, J. R., and Manning, G. W. A comparison of direct and indirect blood-pressure determinations. Circulation, 1953, *8:* 232–242.
7. Van Bergen, F. H., Weatherhead, D. S., Treloar, A. E., Dobkin, A. B., and Buckley, J. J. Comparison of indirect and direct methods of measuring arterial blood pressure. Circulation, 1954, *10:* 481–490.
8. Alvarez, W. C. Blood pressure in fifteen thousand university freshmen. Arch. Int. Med., 1923, *32:* 17–30.
9. Kean, B. H., and Hammill, J. F. Anthropathology of arterial tension. Arch. Int. Med., 1949, *83:* 355–362.
10. Bays, R. P., and Scrimshaw, N. S. Facts and fallacies regarding the blood pressure of different regional and racial groups. Circulation, 1953, *8:* 655–663.
11. Morsell, J. A. The problem of hypertension. A critical review of the literature dealing with its extent. *In* Proceedings of a Symposium on Essential Hypertension. Commonwealth of Massachusetts, Recess Committee on Hypertension, Wright and Potter, Boston, 1951. P. 26.
12. Adams, J. M. Some racial differences in blood pressures and morbidity in a group of white and colored workmen. Amer. Jour. Med. Sci., 1932, *184:* 342–350.
13. Wetherby, M. A. Comparison of blood pressure in men and women. A statistical study of 5,540 individuals. Ann. Int. Med., 1932, *6:* 754–770.
14. Reed, L. J., and Love, A. G. Biometric studies on U. S. Army officers—somatological norms, correlations, and changes with age. Human Biol., 1932, *4:* 509–524.
15. Jenss, R. M. Age variations of systolic blood pressure in U. S. Army officers. Amer. Jour. Hyg., 1934, *20:* 574–603.
16. Robinson, S. C., and Brucer, M. Range of normal blood pressure. A statistical and

clinical study of 11,383 persons. Arch. Int. Med., 1939, *64:* 409–444.

17. Master, A. M., Garfield, C. I., and Walters, M. B. Normal Blood Pressure and Hypertension. Lea and Febiger, Philadelphia, 1952.
18. Hamilton, M., Pickering, G. W., Fraser Roberts, J. A., and Sowry, G. S. C. The aetiology of essential hypertension. I. The arterial pressure in the general population. Clin. Sci., 1954, *13:* 11–35.
19. Master, A. M., Dublin, L. I., and Marks, H. H. The normal blood pressure range and its clinical implications. Jour. Amer. Med. Ass'n, 1950, *143:* 1464–1470.
20. Burke, M. H., Schenck, H. C., and Thrash, J. A. Tuberculosis studies in Muscogee County, Georgia. II. X-ray findings in a community-wide survey and its coverage as determined by a population census. Pub. Health Rep., 1949, *64:* 263–290.
21. Feller, W. An Introduction to Probability Theory and its Applications. Vol. I, pp. 69–74, John Wiley and Sons, Inc., New York.
22. Diehl, H. S., and Lees, H. D. The variability of blood pressure. II. A study of systolic pressure at five minute intervals. Arch. Int. Med., 1929, *44:* 229–237.
23. Walker, H. M. Studies in the History of Statistical Method. Williams and Wilkins, Baltimore, 1929. P. 104.
24. Kesilman, M. The incidence of essential hypertension in white and Negro males. Med. Record, 1941, *154:* 16–19.
25 Orenstein, L. L. Hypertension in young Negroes. War Med., 1943, *4:* 422–424.
26. Reisinger, J. A. Study of hypertension in veterans. Ann. Int. Med., 1937, *10:* 1371–1389.
27. Symonds, B. The blood pressure of healthy men and women. Jour. Amer. Med. Ass'n, 1923, *80:* 232–236.
28. Donnison, C. P. Blood pressure in the African native. Its bearing upon the aetiology of hyperpiesia and arterio-sclerosis. Lancet, 1929, *1:* 6–7.
29. Nye, L. J. J. Blood pressure in the Australian aboriginal, with a consideration of possible aetiological factors in hyperpiesia and its relation to civilization. Med. Jour. Australia, 1937, *2:* 1000–1001.
30. Fishberg, A. M. Hypertension and Nephritis. 4th ed. Lea and Febiger, Philadelphia, 1939. a) p. 691; b) 611.
31. Pickering, G. W. The concept of essential hypertension. Ann. Int. Med., 1955, *43:* 1153–1160.
32. Pickering, G. W. High Blood Pressure. Grune and Stratton, New York. a) pp. 8–17; b) pp. 45–47; c) pp. 122–130; d) pp. 32–33, 1955.
33. Stoll, H. F. The role of syphilis in hypertensive cardiovascular disease. Amer. Jour. Med. Sci., 1915, *150:* 178–195.
34. Smith, D. T., Martin, D. S., et al. Zinsser's Textbook of Bacteriology. 9th ed, Appleton-Century-Crofts, Inc., New York, 1948. P. 608.
35. Horine, E. F., and Weiss, M. M. The relation of syphilis to hypertension (statistical study). Amer. Heart Jour., 1930, *6:* 121–127.
36. Harris, H. C. A study of syphilis as an etiological factor in arteriosclerosis and arterial hypertension. Mil. Surgeon, 1941, *88:* 642–659.
37. Allen, F. P. Cardiovascular impairment among one thousand Negro factory workers. Jour. Indust. Hyg., 1931, *13:* 164–168.
38. Deibert, A. V., and Bruyere, M. C. Untreated syphilis in the Negro male. III. Evidence of cardiovascular abnormalities and other forms of morbidity. Jour. Vener. Dis. Inform., 1946, *27:* 301–314.
39. Pesare, P. J., Bauer, T. J., and Gleeson, G. A. Untreated syphilis in the Negro male. Observation of abnormalities over sixteen years. Amer. Jour. Syphilis, Gonorrhea, and Vener. Dis., 1950, *34:* 201–213.
40. Brooks, H., and Carroll, J. H. A clinical study of the effects of sleep and rest on blood-pressure. Arch. Int. Med., 1912, *10:* 97–102.
41. Diehl, H. S. The variability of blood pressure. Morning and evening studies. Arch. Int. Med., 1929, *43:* 835–845.
42. Erlanger, J., and Hooker, D. R. An experimental study of blood-pressure and of pulse-pressure in man. Johns Hopkins Hosp. Reports, 1904, *12:* 145–378.
43. Mueller, S. C., and Brown, G. E. Hourly rhythms in blood pressure in persons with normal and elevated pressures. Ann. Int. Med., 1930, *3:* 1190–1200.

44. Ayman, D., and Goldshine, A. D. Blood pressure determinations by patients with essential hypertension. I. The difference between clinic and home readings before treatment. Amer. Jour. Med. Sci., 1940, *200:* 465–474.
45. Corcoran, A. C., Dustan, H. P., and Page, I. H. The evaluation of antihypertensive procedures, with particular reference to their effects on blood pressure. Ann. Int. Med., 1955, *43:* 1161–1177.
46. Freis, E. D. The discrepancy between home and office recordings of blood pressure in patients under treatment with pentapyrrolidinium. Importance of home recordings in adjusting dosages. Med. Ann. Dist. Col., 1954, *23:* 363–367; 414.
47. Pickering, G. W., Fraser Roberts, J. A., and Sowry, G. S. C. The aetiology of essential hypertension. 3. The effect of correcting for arm circumference on the growth rate of arterial pressure with age. Clin. Sci., 1954, *13:* 267–271.
48. Division of Special Health Services, Bureau of State Services, U. S. Public Health Service. Estimated prevalence of overweight in the United States. Pub. Health Rep. 1954, *69:* 1084–1086.
49. Smith, H. W. Hypertension and urologic disease. Amer. Jour. Med., 1948, *4:* 724–743.
50. Schroeder, H. A. The evidence that essential hypertension is not a single disease entity. *In:* Proceedings of a Symposium on Hypertension, p. 123, Commonwealth of Massachusetts, Recess Commission on Hypertension, Wright and Potter, Boston, 1951.
51. Harrison, T. R., Editor-in-Chief. Principles of Internal Medicine. The Blakiston Co., Philadelphia, 1950.
52. Dublin, L. I., Lotka, A. J., and Spiegelman, M. Length of Life. A Study of the Life Table. Rev. ed., p. 197, Ronald Press, New York, 1949.
53. Kurlander, A. B., Hill, E. H., and Enterline, P. E. An evaluation of some commonly used screening tests for heart disease and hypertension. Jour. Chronic Dis., 1955, *2:* 427–439.
54. Stone, C. T., and Vanzant, F. R. Heart disease as seen in a southern clinic. A clinical and pathologic survey. Jour. Amer. Med. Ass'n, 1927, *89:* 1473–1477.
55. Taylor, C. E. The racial distribution of nephritis and hypertension in Panama. Amer. Jour. Path., 1945, *21:* 1031–1046.
56. Comstock, G. W. Mortality of persons with photofluorograms suggestive of cardiovascular disease. New England Jour. Med., 1953, *248:* 1045–1050.

APPENDIX

TABLE 1

Participation in 1946 survey by 1946 census population, and by 1954 sample and examined population, by race and sex

Race and sex	1946 census			1954 sample			Examined population		
	Total	Participants		Total	Participants		Total	Participants	
		Number	Per cent		Number	Per cent		Number	Per cent
Total	95,638*	40,435	42.3	1,912	823	43.0	1,162	550	47.3
White male	31,848	9,970	31.2	620	216	34.8	331	130	39.3
White female	35,070	12,611	36.0	708	270	38.2	437	192	44.0
Negro male	12,846	7,881	61.3	261	142	54.4	168	93	55.3
Negro female	15,860	9,972	62.9	323	195	60.4	226	135	59.7

* Includes 14 persons with race or sex not stated.

TABLE 2

Persons with photofluorograms classified as suspected tuberculosis or cardiovascular disease among survey participants in 1946 census population, and in 1954 sample and examined populations, by race and sex

Race and sex	1946 census			1954 sample			Examined population		
	Number surveyed	Per cent classified as		Number surveyed	Per cent classified as		Number surveyed	Per cent classified as	
		TB*	CV†		TB*	CV†		TB*	CV†
Totals	51,940	3.6	1.7	823	3.6	1.7	550	4.0	1.5
White male	13,601	4.5	0.5 (white male and white female combined)	216	4.2	0	130	4.6	0
White female	16,711	3.7		270	3.7	0	192	4.2	0
Negro male	10,062	3.1	3.4 (Negro male and Negro female combined)	142	3.5	4.2	93	2.2	2.2
Negro female	11,566	2.9		195	3.1	4.1	135	4.4	4.4

* Comprises persons with photofluorograms classified as suspected tuberculosis by one or both survey film readers.

† Comprises persons with photofluorograms classified as suspected cardiovascular disease by first survey film reader only.

TABLE 3

Persons examined among 1954 sample population, by rental status and socioeconomic index in 1946

Rental and socioeconomic status in 1946	1954 Sample		
	Total	Examined	
		Number	Per cent
Rental status:			
Total*	1,885	1,144	60.7
Owned home	646	403	62.4
Monthly rent $10	216	156	72.2
$10–19	531	354	66.7
$20–29	181	108	59.7
$30+	311	123	39.5
Socioeconomic index†			
Total*	1,910	1,155	60.5
0	70	53	75.7
I	145	101	69.7
II	207	140	67.6
III	233	148	63.5
IV	239	140	58.6
V	279	149	53.4
VI	645	371	57.5
VII	92	53	57.6

* Totals do not agree with others because persons for whom this information is not available are omitted.

† See text. Socioeconomic status improves with increasing size of index number.

TABLE 4

Terminal digits of initial blood pressure observations

Terminal digit of observations	Systolic pressure		Diastolic pressure	
	Number	Per cent	Number	Per cent
Totals	1,162	100.0	1,162	100.0
0	363	31.2	424	36.5
2	166	14.3	148	12.7
4	225	19.4	214	18.4
5	1	0.1	3	0.3
6	140	12.0	131	11.3
8	267	23.0	242	20.8

TABLE 5

Selection of zero as terminal digit in two studies, by height of blood pressure

Source	Systolic pressure			Diastolic pressure		
	Total	<140 mm.	140 mm.+	Total	<100 mm.	100 mm.+
Muscogee County sample						
Totals	1,162	852	310	1,162	1,053	109
No. ending in "0"	363	245	118	424	359	65
Per cent ending in "0"	31.2	28.8	38.1	36.5	34.1	59.6
Master et al. (1952)						
Totals	15,711	12,810	2,901	15,711	15,056	655
No. ending in "0"	7,201	5,426	1,784	8,036	7,536	500
Per cent ending in "0"	45.9	42.3	61.5	51.1	50.0	76.4

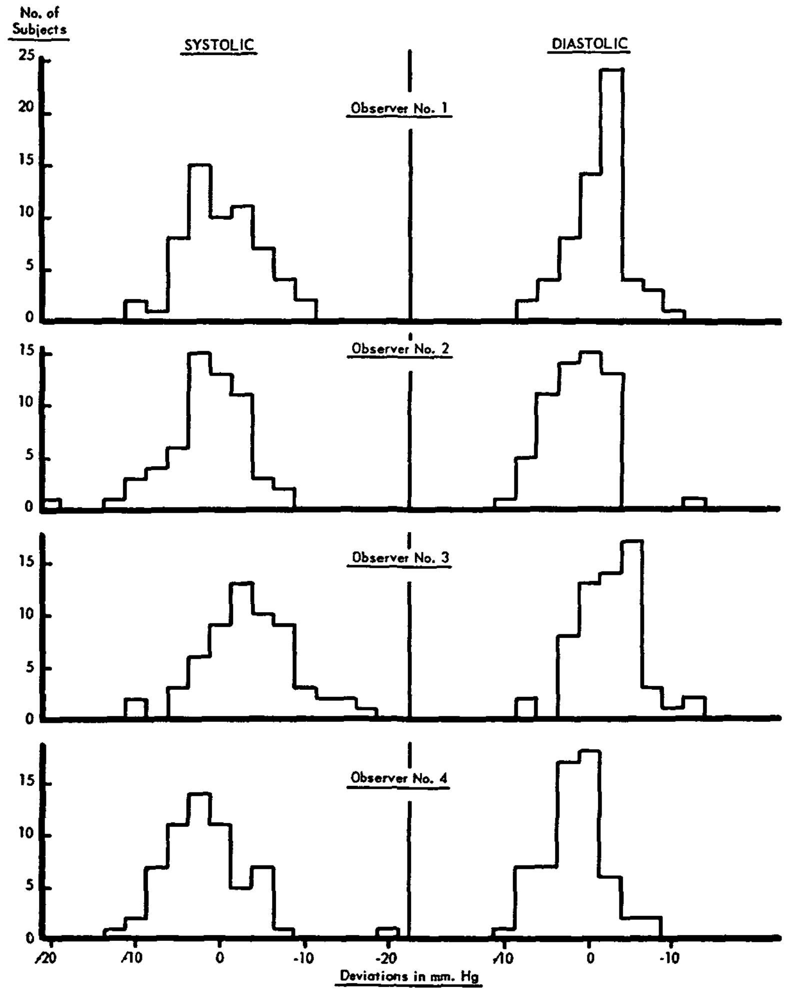

FIGURE 1. Distributions of deviations of individual blood pressure readings from mean readings for group, for each of 4 observers.

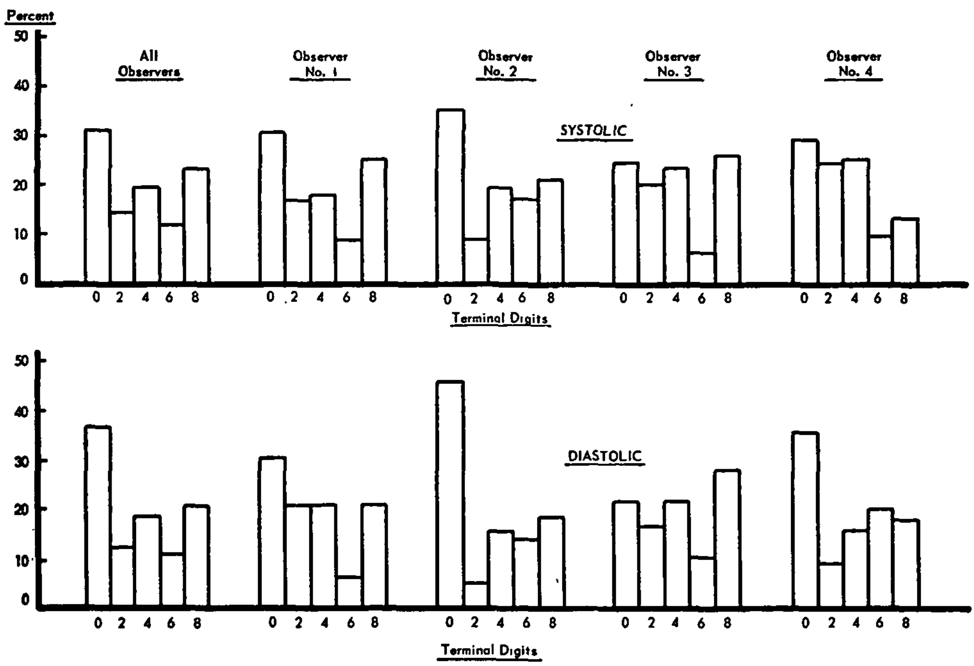

FIGURE 2. Distribution of initial blood pressure readings by terminal digit and observers.

TABLE 6

Frequency distribution of systolic blood pressure, by race, sex and age, Muscogee County, Georgia, 1954

Age	Number of subjects with stated blood pressure (mm Hg)														
	75–84	85–94	95–104	105–114	115–124	125–134	135–144	145–154	155–164	165–174	175–184	185–194	195–204	205–214	As stated
								White males							
8–14	2	5	16	19	13	6	2								
15–24			1	8	16	14	5								
25–34			2	10	14	10	1	3							
35–44		1	2	11	24	17	6	2		2					
45–54			2	13	11	11	8	5	3	5					(232)
55–64			1	2	6	7	9	2	4	5		1			(220) (230)
65–74					4	3		1	3		1	2			
75+						2	1	2	1			1			
								White females							
8–14	2	8	10	15	7	3									
15–24		1	12	24	12	5	1	1							
25–34	1	2	11	39	25	7		2							
35–44		3	7	28	28	15	9	3	1	2					
45–54			1	9	15	12	9	6	3	2	2	2			(220)
55–64				3	6	9	9	9	1		2	3	2	1	(218)
65–74					2	3	4	8	2	7	2		1	1	(240)
75+			1	1			3	2	2	3		1	1		
								Negro males							
8–14	2	6	9	7	3	3			1						
15–24			2	7	10	12	2	3		1					
25–34				1	7	7	2	2		2					
35–44				1	5	7	5	10	3	1		1	1		
45–54				1	4	3	4	4	2	3	2			1	(218)
55–64					2	1	2	1	1	1	2	3	1		(230)
65–74						2	1				1				
75+									1						
								Negro females							
8–14		2	11	11	4	2	1	2							
15–24			2	12	7	7	3	2	2	1	1				
25–34			5	10	7	13	5	2	1			1			
35–44			1	6	6	7	6	9	2	3	1	1	2		(220) (228) (234)
45–54			2		4	4	2	5	2	3	2	3	2	2	(230)
55–64					1	1	3	2	1	3	1	2	1		(220) (248)
65–74					1			1	1	1	3				
75+					1			2	1		3			1	(244)

TABLE 7

Frequency distribution of diastolic blood pressure, by race, sex and age, Muscogee County, Georgia, 1954

Age	Number of subjects with stated blood pressure (mm Hg)												
	5–14	35–44	45–54	55–64	65–74	75–84	85–94	95–104	105–114	115–124	125–134	135–144	145–154
White males													
8–14		1	8	29	16	7	2						
15–24			2	5	19	12	6						
25–34			1	5	10	8	15	1					
35–44				2	12	25	19	5	2				
45–54				2	13	16	14	8	5				1
55–64				2	8	11	8	7	2		1		
65–74				2	1	3	3	4	1				
75+					2	3	1	1					
White females													
8–14		1	4	15	15	9	1						
15–24	1		5	14	28	6	2						
25–34			2	17	41	17	9	1					
35–44				9	35	38	13		1				
45–54					25	14	11	8	3	1			
55–64				4	11	12	13	3	2		1		
65–74			1	3	9	6	8	2	2				
75+				2	2	4	4		1	1			
Negro males													
8–14		1	3	11	14	1	1						
15–24			3	16	9	6	3						
25–34			1	5	7	7		1					
35–44				2	12	6	9	2	3				
45–54				3	3	7	4	5	1	2			
55–64				1	3	2	4	3	2				
65–74				1	2			1					
75+				1									
Negro females													
8–14			1	8	17	3	4						
15–24			1	4	20	2	5	2	2	1			
25–34				3	16	12	9	2	1		1		
35–44				2	12	10	7	3	6	5		2	
45–54					4	6	6	7	8	1			
55–65					1	3	5	4	1		3		
65–74						3	3		1				
75+					2	2	3		1	1			