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BLOOD PRESSURE IN UNIVERSITY FRESHMEN AND OFFICE PATIENTS *

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What is the average blood pressure for a man or woman of a given age? How common is hypertension in young people? What is its significance, particularly in early life? These are some of the questions which occurred to me after taking the blood pressures on 265 men called in the closing days of the second draft.¹ Although clinical experience had led me to expect a high incidence of hypertension in young men, it had not prepared me for the finding that in this particular series there were more with pressures over 130 mm. than under; and very many with pressures between 160 and 275. It was soon clear that this group did not represent a fair sampling from the community because so many were rejects from the recruiting offices; that is, most of the physically fit had gone to war and the unfit were left.

On turning to the available statistics, it was surprising to see that most of them must be objected to on this same score of previous selection. Thus Smith² studied 500 aviation recruits, Sorapure³ 796 soldiers, Goepp⁴ 9,996 accepted insurance cases, Fisher⁵ 12,647 accepted insurance cases, MacKenzie⁶ 31,934 accepted insurance cases, and Woley⁷ 1,000 insurance cases which remained after excluding those with histories or physical findings suggestive of cardiovascular abnormality. The insurance statistics would have much more value if they were based on the examination of all applicants; but even then

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1. Alvarez: California State J. M. **17**:367, 1919.

2. Smith, B.: J. A. M. A. **71**:171 (July 20) 1918.

3. Sorapure: Lancet **2**:841, 1918.

4. Goepp: Penn. M. J. **22**:295, 1919.

5. Fisher: Proc. Assoc. Life Ins. Med. Directors of America, N. Y., 394, 1912; 90 and 246, 1915; 203, 1917.

6. MacKenzie: Ibid, 221, 1917.

7. Woley: J. A. M. A. **55**:121 (July 5) 1910.

there would undoubtedly be a considerable amount of adverse selection because those with hypertension often have premonitions of future illness; and many seek insurance after discovering their defects.

The next question then is: how are we to get a fair sampling? An ideal way would be to examine every tenth individual passing a certain point on a busy street. Different strata of society might be sampled by choosing streets in different parts of the city and also by choosing different cities. Unfortunately, such methods are not practicable at present. The next best thing probably would be to study the young people gathered together in the public schools and colleges. Particularly in state universities where tuition is free it would seem that the student body should represent a fair sampling from the more intelligent part of the community. Fortunately, it is becoming more and more the custom in the leading schools to examine the incoming freshmen. Lee⁸ and Barach and Marks⁹ have already reported on the blood pressure readings in some 1,200 college students, but their groups were not large enough for analysis by age and sex.

During the last few years all the freshmen entering the University of California have been subjected to a physical examination which includes the measurement of the blood pressure. Under ordinary conditions this mass of data which has accumulated at the university infirmary would have been ideal for my purposes. Unfortunately, however, the war with its demands on the fittest of the young men, has made me uncertain of the sampling even in the ages below 21. In 1918 most of the men were gone; but some were enrolled in the S. A. T. C., and some probably remained on account of physical handicaps which turned them back from the recruiting offices. Certain it is that there is a big difference between the average pressures of the male entrants in 1919 and the pressures of those in the three preceding years. As would be expected, there is practically no difference in the figures for the corresponding groups of women (Fig. 5). I hope to clear up these uncertainties by getting more and better data in the next few years.

TECHNIC

Unfortunately, the methods of taking the pressures are not exactly the same for men and women. The men take a tepid shower before the examination and are then examined in the reclining position. They are more likely to stand around in negligé and get cold than are the women. The women's pressures are taken standing. The systolic pressure, the only one studied at this time, was taken by palpation. This is the more reliable method as it is less subject to wide variations.

8. Lee: Boston M. & S. J. **173**:541, 1915.

9. Barach and Marks: Arch. Int. Med. **13**:648 (May) 1914.

One aneroid (a large Tycos) and three mercury column instruments were used. The aneroid was checked at regular intervals against a mercury column. The records were taken off the cards and arranged as in Tables 1 and 2. This shows, first, that the data on the women are much better for statistical purposes than those on the men because the women examiners have read quite closely to the millimeter, while the men have had a strong tendency to read to the nearest multiple of ten. For practical purposes, and especially when measuring a value that often fluctuates from hour to hour, it is of little importance whether a pressure is 150 or 160 mm., but for statistical work and especially for drawing curves of frequency distribution, it is much better to have the data evenly distributed. It is useless to try and make the steps less than 2 mm. because that is the unit on most of the scales.

A glance at Table 1 shows that the lowest age is 16. There were 99 women and 34 men who entered the university at that age during the period covered. Three thousand, three hundred and thirty-three (3,333) entered between the ages of 18 and 19. The curves of frequency distribution for the different ages for the two sexes are shown in Figure 1. The abscissae represent the blood pressures by 5 mm. Stages. In these units "85" = 85 to 89, and "90" = 90 to 94. When 85 is made to include from 83 to 87 the only difference in the curves is one due to the exaggeration of the deformity brought about by the grouping of the data about the multiple of ten. The ordinates represent percentages at the different pressures.

A study of these curves shows several interesting things. In the first place, as Kilgore¹⁰ has pointed out, they are fairly symmetrical and correspond to the type "A" curve so well known to statisticians. It is the curve obtained when we chart the heights of a thousand men, the errors in 100 measurements of a meter bar, or the results of a thousand throws of dice. In all these studies of large groups of observation it has been found that most of the data will lie more or less closely about the average. Hence it is that the probability that small errors or deviations from the average will occur is larger than the probability that large errors or deviations will occur. Thus, in measuring a thousand men with an average height of 5 feet 6 inches, the probability of finding men 5 feet 5 inches, and 5 feet 7 inches in height is much greater than the probability of finding men 5 feet or 6 feet tall. There will be scores of the former to one or two of the latter. With the help of mathematical formulae we can calculate just how many of the data are likely to fall within certain limits measured on each side of the average. The divergences between the calculated

10. Kilgore: *Lancet* 2:236, 1918.

and the actual curves are often very slight as will be noted in Figures 2 and 3. A study of the differences which do appear is sometimes very helpful.

The simplest and shortest way in which to compare the curves is to plot the data on paper which has been ruled according to the theory of probability, with small spaces near the 50 per cent. mark and wide ones near the 0.01 and 99.99 per cent. marks. If the data follow the theory, they will plot out in a straight line. Those who have difficulty in following this part of the discussion would be much helped by reading Whipple's¹¹ and Rugg's¹² little books on applied statistics.

Figure 3 shows the data for 5,807 women and 2,930 men plotted on probability paper. It will be noted that the figures for the women between pressures of 110 and 130 lie along a straight line; as do those for the men between 90 and 140 mm. This suggests strongly that within those limits deviations from the average are due to various small errors subject to the law of chance. Deviations above and below these limits are probably due to pathologic factors. It will be noted also that the line for the women is more nearly vertical than that for the men. This demonstrates a fact which will be shown again later in other ways, and that is that the dispersion is less for the women: i. e., their readings are grouped more closely about the average. This is well shown in Figure 2 where we can compare the distribution curve for the women with that for the men. The women's curve is high and narrow; the men's is low and wide. The average for the women is 115 mm.; for the men 126.5 mm. If we get the average of the deviations from the average we find that for the women it is 8.0 mm., and for the men 10.8 mm. In Figure 2 the distribution curves have been smoothed so as to remove the humps which are seen in Figure 4. This smoothing is done by averaging the values of different points on the curve with the values of the two adjacent points (Rugg,¹² p. 184). The solid lines represent these smoothed curves. The lines of dots and dashes represent the probable curves secured by plotting the intersections of the two straight lines drawn through the data in Figure 3. The dotted lines represent the theoretical curves obtained mathematically, using the so-called standard deviation which for the women is 2.12 (of the 5 mm. abscissae units) and for the men, 2.98. Given these data it is easy to calculate the values of the ordinates corresponding to the different abscissae. The results of the graphic and mathematical methods are so close for the women that only one theoretical curve has been plotted.

11. Whipple: *Vital Statistics*, N. Y., 1919.

12. Rugg: *Statistical Methods Applied to Education*, Boston, 1917.

TABLE 1.—BLOOD PRESSURE OBSERVATIONS ON WOMEN STUDENTS

Pressure	Ages										Total	Percentage	Theoretical Percentage from Probability Paper	Theoretical Percentage Computed from Standard Deviation	Smoothed Curve in Percentages
	16	17	18	19	20	21	22	23	24	25 to 26	27 to 28	31 to 35	36 to 40		
80-84	1	2	3	4	5	1	1	1	1	2	2	1	1	4	0.07
85-89	1	1	2	3	4	1	2	3	1	2	1	1	1	14	0.24
90-94	4	13	34	83	12	13	12	7	8	7	10	7	7	32	0.34
95-99	4	34	111	233	48	39	36	28	14	33	41	24	19	157	1.13
100-104	19	62	104	110	64	55	38	31	18	27	56	67	25	613	0.55
105-109	14	95	281	223	118	122	61	49	56	61	75	67	25	1,217	0.86
110-114	12	74	161	221	145	109	82	40	40	49	54	45	21	1,879	3.56
115-119	20	94	221	188	103	97	60	45	26	52	72	57	23	1,058	8.85
120-124	12	65	135	108	54	39	26	27	16	18	37	19	12	568	12.00
125-129	5	45	89	63	41	31	24	11	16	18	27	22	11	403	17.00
130-134	1	10	22	17	7	3	7	4	3	5	5	1	2	157	18.30
135-139	1	3	8	3	1	1	1	3	1	1	1	1	1	92	15.40
140-144	1	1	1	1	1	1	1	1	1	1	1	1	1	4	6.94
145-149	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2.70
150-154	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1.59
155-159	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1.13
160-164	1	1	1	1	1	1	1	1	1	1	1	1	1	2	0.41
165-169	1	1	1	1	1	1	1	1	1	1	1	1	1	2	0.29
Total.....	99	512	1,214	1,014	579	503	317	259	201	277	383	302	150	5,807	0.07
Average....	115.8	117.2	116.5	116.2	116.2	115.7	116.5	115.4	115.4	114.7	115.4	117.3	118.3	115.0	0.07

Average deviation of the 5,807 = $1.6 \times 5 = 8$ mm.
Standard deviation = $2.12 \times 5 = 10.6$ mm.
Coefficient of variation $\frac{M}{\sigma} = \frac{115}{185}$

TABLE 2.—BLOOD PRESSURE OBSERVATIONS ON MEN STUDENTS

Pressure	Ages										Total	Percentage	Theoretical Percentage from Paper	Theoretical Percentage Computed from Standard Deviation	Smoothed Curve in Percentages
	16	17	18	19	20	21	22	23	24	25 to 26	27 to 30	31 to 35	36 to 40		
80-84			3	.....	.....	.....	.....	.....	.....	.....	3	.....	.....	0.06	0.10
85-89				3	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.20	0.31
90-94			3	11	17	11	10	.....	.....	.....	.....	.....	.....	0.60	0.91
95-99			13	17	11	11	9	.....	.....	.....	.....	.....	.....	1.70	1.33
100-104			13	11	13	7	5	.....	.....	.....	.....	.....	.....	4.00	2.10
105-109			13	11	41	27	14	.....	.....	.....	.....	.....	.....	8.00	3.76
110-114			35	54	42	35	30	19	13	18	.....	.....	.....	16.50	7.16
115-119			21	53	54	42	30	19	13	18	.....	.....	.....	39.50	11.78
120-124			107	91	59	64	40	31	15	21	23	9	6	50.00	13.77
125-129			63	80	33	43	27	34	14	20	10	8	2	54.00	14.39
130-134			24	63	80	33	43	30	19	34	16	15	6	68.00	13.34
135-139			29	89	83	70	55	38	30	19	7	7	6	80.00	10.26
140-144			35	48	43	26	30	17	11	10	9	7	5	88.50	7.49
145-149			23	40	48	40	24	22	20	13	6	3	3	90.00	4.83
150-154			15	24	17	13	6	7	.....	5	2	.....	.....	94.40	3.41
155-159			7	16	8	7	6	4	.....	1	1	.....	.....	97.40	2.25
160-164			1	11	6	3	4	.....	.....	1	1	.....	.....	98.00	1.07
165-169			2	3	1	3	.....	.....	.....	.....	.....	.....	.....	99.55	0.76
170-174			1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	99.90	0.43
175-179			1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	99.99	0.23
180															0.07
Total.....	34	212	560	545	362	330	233	178	113	139	117	66	40	2,690	
Average....	126.3	128.2	127.8	126.2	126.3	125.4	126.2	126.3	130.0	126.9	126.0	126.8	.....	126.8	

Average deviation of the 2,930 = $2.17 \times 5 = 10.85$ mm.

Standard deviation = $2.98 \times 5 = 14.90$ mm.

Coefficient of variation $\frac{100 \times \text{S.D.}}{M} = \frac{298}{126.5} = 2.35$

A glance at these curves shows that the agreement between the found and the theoretical data is close. The main difference is that the actual curves drop off a little too rapidly at first on the upper side and then later they do not drop off fast enough. This deformity of the curves suggests strongly that the figures over 137 mm. for the women and over 148 mm. for the men represent pathologic conditions. If we turn again to Figure 3, we see that according to the theory of probabilities only one man in 10,000 should have a pressure over 175. Actually there were eight in 2,930 or twenty-seven in 10,000. Similarly, there should have been only one woman in 10,000 with a pressure over 150; actually there were twenty-five in 5,807 or 43 in 10,000.

The higher figures are modified by the incidence of hypertension; the lower ones by fainting and perhaps by convalescence from acute infections. I threw out a number of records below 90 mm. on which fainting was definitely noted, but it is likely that many of the low records included might also have been removed for this reason. To be entirely consistent, I should probably have left these records in, just as I have left in the high records in cases where excitement may have been a disturbing factor.

In Figure 1 it will be noted that the modes or apices of the men's curves lie between 120 and 130; those of the women lie between 110 and 120. This difference of 10 mm. between the pressures of the two sexes has been noted by previous observers. It is remarkable that there is practically no change in the location of the mode between the ages of 18 and 40. That for the men is actually a little lower at 33 than at 17; and that for the women is lower at 38 than at 16.

There are some differences in the frequency polygons for the various age groups, but owing to inaccuracies in the readings, to the smallness of some of the groups and to uncertainties about the sampling we cannot lay much stress on them. The sexual difference is most marked at the age of 24. It is suggestive that the curve for the 16 year old boys resembles that for the women; and that for the women over 36 resembles that for the men. The possible significance of this finding will be discussed later.

THE AVERAGE BLOOD PRESSURE

Figure 4 shows the arithmetical means (averages) of the different age groups plotted on coordinate paper. It will be seen that the curve of average pressure not only does not rise steadily as it has been supposed to do, but actually drops from 17 to 25 in the women and from 17 to 21 in the men. This finding was so unexpected that every care has been taken to insure the accuracy of the figures. Ordinarily, such averages are obtained by grouping the data and then applying

short-cut methods. In this case no grouping was done, and the figures charted represent the means of the actual data as they were taken off the records. As there was considerable doubt about the reliability of the sampling in the men's group, I divided the data into two parts: those obtained in 1919, and those obtained before that. Figure 5 shows the average for the two groups separately and combined. Many of the ages are not represented because the number of readings was too small. In order to save time these averages were computed by the short-cut method. The dotted line is that of the more exact averages shown in Figure 4. These curves show the reliability of the sampling for the women. The 1919 women (between 17 and 22) average about 1.0 mm. higher than do those for the preceding years. This difference is so small and so consistent that it may be due to the personal equation of the examiners or to errors in their instruments. The trend of the average in both groups of women is downward during these years.

When we turn to the curves for the men we find differences so large that it would seem that they must be due to disturbances in the sampling. This difference ranges from 9 mm. at 18, to 3.5 mm. at 23; the 1919 men showing the higher figures. The average of the 1919 men falls from 18 to 23, while that of the pre-nineteen men rises from 18 to 24. No significance can be attached to the big rise in the combined average at 24 because it is not present in the pre-nineteen curve, unless it be that the rise at 23 there corresponds to the rise at 24 in the 1919 curve. It is hard to explain the big differences in the men's curves as we do not know enough about the ways in which the sampling was modified. Some might perhaps ascribe the increase in average pressure in 1919 to the strain of the War year, but that seems to me improbable.

There is little doubt about the drop from 17 to 25 in the women's curve as it appears in both the 1919 and the preceding groups. It appears also in the curve drawn from data secured on 1,000 of my office patients. This drop does not seem to have been described heretofore. The most extensive studies of the yearly average have been made by MacKenzie⁶ and Fisher.⁵ Their figures, for men only, when plotted on coordinate paper, lie in a practically straight line from 119 mm. at 17 to 140 mm. at 66. Unfortunately, these observations have little value to us; the line had to be straight because only those men were accepted who varied within prescribed limits from a prescribed standard.

After 25, the average curve for the women rises rapidly. In the series of office patients it was found to rise so much more rapidly than that for the men that it crossed over about the age of 40. After

Fig. 1.—Frequency distribution curves for men and women students at different ages. The abscissae are pressures in mm. and the ordinates are percentages. In order to shorten the chart the ordinates for different age groups are made to overlap.

that the women averaged higher than the men (Fig. 6.). What we need now is more information about the trend of these average curves below 17 and above 35. We must know where the sexual difference appears and when it disappears or becomes reversed. Work is now being done on this problem in the children's clinic at the Universities of California and Stanford.

Another feature of the frequency distribution curves in Figure 1 which requires comment is their apparent bimodality, i. e., their tendency to show two peaks. Exceptions are found in the men at 16, 19, 23, 24 and 25, and in the women at 20, 23, 24, 25 and 36. This peculiarity is due in most instances to the tendency of the examiners to read to the nearest multiple of 10 on the scale. That tendency, however, will not explain the bimodality of the men's curves at 17 and 31,

Fig. 2.—The solid lines represent smoothed frequency curves for 5,807 women and 2,930 men students from 16 to 40 years of age. The dotted lines represent the corresponding theoretical curves computed mathematically. The dash and dot lines represent theoretical curves obtained by plotting the straight lines in Figure 3. The ordinates are percentages and the abscissae, pressures.

and of the women's curve for 16, where modes fall on 105, 115, and 135 mm. Particularly in the case of the women, where the readings were made with great care, it is hard to understand why the sides of the graph should show so little evidence of deformity when the top is deeply notched. If we could be sure of the figures, the bimodality of the curves might lend support to my theory that there are perhaps two types or varieties of the human species: one in which hypertension will not develop, except perhaps in old age; and the other in which it, or allied disturbances, develop early on the basis of a congenital predisposition. Unfortunately for this argument, even when there

are two groups, if their modes are close together the fused curve will be unimodal. This is shown in Figure 7, where the solid line represents the distribution curve for all the women and men, taken together. Here we see how two groups with different modes can fuse so that

Fig. 3.—Shows the data for men and women students plotted on probability paper. The ordinates represent percentages; the abscissae, pressures. If the observations followed the law of probability exactly they would plot as a straight line.

the resultant curve is similar in form to the individual ones. If there had been equal numbers of men and women in the two groups the combined curve would have been like that in the corner of Figure 7.

That curve, with its mode at 120, probably comes pretty close to representing the distribution of blood pressures in Americans between 16 and 36.

DISCUSSION

Before entering on a discussion of the findings it might be well first to answer an objection which has been made by many of the friends who have seen these data during the last year, and which may be made again. These men felt that the higher figures should be disregarded because it is well known that the pressure in some people varies from hour to hour, and that it often goes up under excitement.¹³

Fig. 4.—Shows the curves of average pressure for men and women between the ages of 16 and 40.

While this is true, it must be remembered that all the students were examined in the same way so that all were equally subject to excitement; and yet one developed a pressure of 115 mm., another 155, and another a fainting spell with a pressure of 80. By examining the men with 155 and 80, day after day, we might, perhaps, get figures more nearly in accord with our ideas of what they should be, but such juggling of disturbing data is not permissible in a scientific study. If we are going to measure some over again we must measure them

13. O'Hare: *Am. J. M. Sc.* **159**:369, 1920.

all. On another day some of the high pressures would undoubtedly be lower, but some of the borderline ones and some even of the high ones would be found higher.

Unfortunately, I have not been able to measure these students over again, but I have taken a series of carefully recorded measure-

Fig. 5.—Showing differences in the averages in the different age groups, for 1919 and for 1916-1918. The ordinates are pressures and the abscissae, ages. The middle lines show averages for the combined data of 1916-1919. These averages were obtained after grouping the data by stages of 5 mm. The dotted lines are exact averages taken from Figure 4.

ment on 100 consecutive office patients, 50 women and 50 men, who were observed twice at varying intervals of time. In spite of the fact that many of these people took treatment: rest cures, etc., in the interims between the two measurements; and in spite of wide individual

variations, there was a difference of only 0.07 mm. between the first average and the second. On the second examination, the women averaged 1.94 lower, while the men averaged 2.08 mm. higher. These findings make me feel that if I could measure the students over and over again with great care, individual variations would probably balance each other so that the frequency polygons and averages would remain about the same. Furthermore, it must be remembered that not only can the excitement account for an increase in pressure but a tendency to hypertension will often account for the excitement. The phlegmatic individual with a normal pressure is perhaps bored by the proceeding, while the keen hypochondriac with an over sensitive

Fig. 6.—Shows yearly averages on 1,000 office patients. The abscissae represent age groups. The curve for the women is below that for the men before 40, and above it afterwards.

and erratic vasomotor system is afraid that serious organic lesions will be found; he gets nervous and his pressure goes up. It is not improbable also that it is the man with the hypertensive diathesis who is most likely to show the wide variations. One of the characteristic things about these people is their vasomotor instability; they blush, they blanch, they feel hot in one part of the body and cold in another. There is good reason, therefore, for expecting their blood pressures to be more variable than those of the people with good vasomotor control. Furthermore, we probably get a much better idea about a man's vasomotors and his blood pressure when he is under a little strain than

when he is under the most favorable conditions, just as we can judge better about a man's heart after exercise; about his pancreas after feeding sugar, and about his kidneys after feeding salt or urea. At any rate, the essential point is that if a thousand young people are examined on one day under the same conditions, with the same instruments and the same examiners, some will be found with low pressures, many with medium ones and a considerable number with high ones.

The next thing to do before we can discuss the incidence of hypertension in these students is to define the limits of normal. Such a

Fig. 7.—To show that a unimodal curve can conceal the fact that there are two groups present with modes at 115 and 125 mm. The solid line represents the distribution for 8,737 men and women together. The small curve in the corner shows this distribution as it would have been if there had been equal numbers of men and women.

definition will be of interest not only to the student but to the clinician and to the life insurance medical director. There are several ways in which we can approach this problem. We can find the average and take certain limits on each side of it; we can study the points of divergence of the actual from the theoretical frequency curve, and best of all, we can watch a large series of borderline cases to see which

ones have, or later develop, other signs of cardiovascular-renal peculiarity.

The arithmetical mean for the men is 126.5; for the women 115.0 mm. If we exclude the data below 100 and above 130 we get 120.3 for the men and 114.4 for the women. Figure 3 shows that the median or mid number of the men is 123.5; for the women it is 112.5. The median is often a good measure of central tendency because it is not so much affected by the widely divergent figures as is the mean. Mathematicians often estimate the "probable error" or limits within which the middle 50 per cent. of the data will lie. For the men these limits are 115-132.5 for the median and 116.5-136.5 for the mean. For the women the limits are 105-119 for the median and 107.8-122 for the mean. Judging by clinical experience, these figures do not seem to be very helpful. They suggest that the measures of central tendency are placed too high for the men. They show again very clearly the great difference in the dispersion of the data for men and women.

If we turn to Figure 3 we note that the data for the women follow the law of probability between limits of 100 and 130 mm.; the data for the men follow the law between 90 and 140 mm. That suggests strongly that between these limits variations from the average are due to many small errors attendant on the method of measurement, the condition of the subject, etc. Above and below these limits the divergence of the found from the expected would appear to be due to pathologic causes. This is shown still more clearly in the curves from office patients. See figure 8. In these, there can be no doubt but that the humps off to the right, in some instances entirely separate from the main polygon, represent pathologic cases.

Let us turn now to the limits which have been set by various writers in the past. One often hears it stated that the pressure for any age is roughly 100 plus the age. Figure 4 shows at a glance that that rule cannot be used in youth when the pressure is declining with age. The life insurance statistics show that it cannot be used even for older men. According to MacKenzie, the normal range for men between 15 and 39 is 26 mm. Taking our mean of 126.5, the limits would be 113.5 and 139.5. Fisher thinks 12 mm. above the average for the age is a permissible deviation. For the women this would make 127 the upper limit. Janeway¹⁴ was inclined at first to take 150 or 160 mm. as the upper limit of normal, but in 1915¹⁵ he said, "I am inclined to revise my former opinion and to agree with Cook and Lauder Brunton before him that over 135 mm. up to middle life,

14. Janeway: Arch. Int. Med. **12**:755 (Dec.) 1913.

15. Janeway: Bull. Johns Hopkins Hosp. **26**:341, 1915.

Fig. 8.—To show frequency distribution of blood pressures in 1,000 office patients at different ages, compared with the distribution of 6,508 students between 16 and 22. The changes in the women's curve after 40 is well shown.

and 145 to 150 mm. thereafter should be regarded as pathologic hypertension if found on repeated examinations." In a series of 7,872 office patients, he found 11.1 per cent. with pressures of 165 mm. or over. Lee,⁸ who studied Harvard freshmen, places the upper limit at 140 mm. In his series of cases he had 12.8 per cent. exceeding that figure; at the University of California there were 20.4 per cent.

It seems pretty clear from a study of the literature that with the passage of time and the accumulation of knowledge about the subject, the tendency is to lower the upper limit of normal. A few years ago I would have accepted 135 or 140 mm. as the upper limit of normal for young people, but I have seen so many men and women in whom pressures between 130 and 135 were associated with irritable, enlarged hearts, anginoid pain, dizziness, morning headache, cyanotic hands, transient albuminuria and other typical findings, that we feel that the upper limit for the men should be placed at 130. Theoretically the limit for the women should be 5 or 10 points lower, but practically it would seem to be a little higher, perhaps about 127. This may be because women often appear to tolerate hypertension better than the men do.

TABLE 3.—PERCENTAGES INCLUDING AND OVER THE DIFFERENT PRESSURES IN THE CALIFORNIA STUDENTS; IN THE STUDENTS STUDIED BY BARACH AND MARKS, AND BY LEE (SEE BIBLIOGRAPHY); IN ONE THOUSAND OFFICE PATIENTS, AND THIRTEEN THOUSAND SEVEN HUNDRED AND EIGHTY-NINE MIDDLE AGED MEN APPLYING FOR INSURANCE

Blood Pressure, Mm.	Univ. of California Students			Barach and Marks, 18-31 Years	Lee	Office Patients, 10-40 Years		13,789 Insurance Applicants, Men
	Men		Women			Men	Women	
	1916-1919	1916-1918	1916-1919					
130	46.0	36.0	12.0	47.0	....	53.0	38.0	
135	28.9	....	5.1					
140	20.4	12.0	2.4	24.0	12.8	26.0	21.0	
145	11.5	....	0.8					
150	5.6	4.7	0.4	9.4	....	14.0	12.0	9.0

According to Table 3, the 130 mm. limit seems reasonable enough so far as the women students are concerned; but it seems as if it must be too low for the men. It may be, of course, that the sampling was bad, and that in later years we will get figures even lower than those obtained in the years before 1919. It is interesting to see how much more frequently hypertension is found in women who go to a doctor's office than in women who go to college. The difference is not so marked for the men. At first sight these figures may seem incredible, but let us check them in several ways. At the office I have found that practically all of the men with pressures over 130 show other signs of cardio-vascular peculiarity. The insurance exam-

iners say that 83 per cent. of the applicants with pressures over 150 can be rejected for albuminuria, cardiac hypertrophy, etc. (1917, p. 252). Table 2 in my article on drafted men shows how rapidly the percentage of such abnormalities rises with the increase of blood pressure: from 54 per cent. at 130 mm. to 100 per cent. at 166 mm. Lee found other cardiovascular troubles in twenty-two out of the eighty-five students with pressures over 140 mm. In this group of 662, 5.1 per cent. had albuminuria. MacLean¹⁶ who studied 60,000 soldiers (already selected) found albuminuria in 12.6 per cent. after exercise. Unfortunately, the statistics of the provost marshal general on the draft do not help us much because so many of the men did not have a complete examination, but were dismissed as soon as some obvious disqualification such as an amputation, a stiff joint or a large hernia became apparent. Moreover, the work was done hurriedly; blood pressures were rarely taken and analyses of the urine were rarely made. In 1917, 2,521 of those passed into the army had almost immediately to be treated for valvular heart disease.¹⁷ Even among the carefully picked aviators, Whitney¹⁸ found 5 per cent. who had to be rejected on this score. Hence it is that the 13.1 per cent. rejected for heart disease by the local boards and induction examiners¹⁹ did not include all even of the obvious and striking cases of cardiac disease, let alone those with nephritis and hypertension. In some states, where the examination was probably conducted more carefully, the figure rose as high as 22.8 per cent. Under the circumstances, then, remembering how highly diluted these percentages are by the number of cases in which the heart was not examined, we must be impressed by the high incidence of cardio-vascular disease in the young men of the nation.

In the discussion on Dr. Fisher's paper, Dr. Van Wagenen pointed out that 40 per cent. of 17,500 deaths studied by his company were traceable to cardiovascular-renal disease in one form or another, (1917, p. 259). As he said, "It makes little difference to us whether a man begins the circle of disease with an apoplexy, a chronic heart trouble or kidney disease; if he lives long enough he will develop all those different troubles." As we know that many of those who come to their end on account of hypertension, arteriosclerosis, heart and kidney disease are reported as having died of pneumonia, acute dilatation of the stomach, etc., we must suspect that at least one-half of all deaths are attributable to chronic cardiovascular disease. If, as I believe, the

16. Maclean: *Brit. M. J.* **1**:94, 1919.

17. Second Report of the Provost Marshall General, Washington, 1919, p. 424.

18. Whitney: *J. A. M. A.* **71**:1389 (Oct. 26) 1918.

19. War Department Bull. 11, 1919, p. 84. Physical Exam. of the First Million Draft Recruits.

tendency towards these troubles often exists from birth, then, if we look carefully enough, we need not be surprised if we find slight hypertension or other related peculiarities in about 50 per cent. of young men. I shall discuss shortly a possible explanation for the fact that these defects show up so much later in the women.

The main hope in attempting to define an upper limit of normal is that we may be able later to say from experience that if a boy has a pressure above a certain figure he is going, if he lives long enough, to develop definite cardio-vascular disease. It may prove impossible to prophesy about those with low pressures because some, perhaps, will develop hypertension in middle life, while others will live on past 70 with remarkably good arteries and kidneys. We will have to follow for the next forty years a large series of young men with apparently normal cardiovascular systems before we can say how many develop the degenerative diseases late out of a clear sky, and how many appear to develop them late, but really have shown a few signs and symptoms from childhood. The insurance directors who re-examine and follow up their cases will undoubtedly be able later to answer many of these questions. In the meantime we can learn a great deal by taking very careful histories on those past middle age who come now with hypertension. Not infrequently I get histories of "heart trouble," "kidney trouble," polyuria, dyspnea, palpitation, anginoid pain and "nervous breakdowns" dating back into childhood or years before the patients discovered their hypertension. Naturally in many instances this history can be gotten only from the mother. She will recall diagnoses and symptoms which caused her great anxiety during trying periods of her child's development. A review of the literature shows that chronic nephritis is not so uncommon in childhood and in many of the reported cases no infectious or other cause could be found.²⁰ We must analyze a large series of these histories to see whether the children of people with cardio-vascular disease are more likely to develop endocarditis and nephritic infections after the exanthemata than are the children of those with good hearts and kidneys. The bacteriologists are now awaking to the fact that the virulence of organisms is not the only variable and the resistance of the guinea-pig a constant. They are beginning to suspect that particularly when studying susceptibility to chronic infections, they must have to develop pedigreed strains of animals whose reactions to disease will be uniformly high or uniformly low. It is unfortunate that his training makes the city specialist look at his patient as a lone man making a short "to a finish" fight with bacteria. In many instances what the physician sees is but one round

20. Hill: *Am. J. Dis. Child.* **14**:267 (Sept.) 1917.

Berkeley and Lee: *Am. J. Dis. Child.* **13**:354 (April) 1917.

Judson and Nicholson: *Am. J. Dis. Child.* **8**:257 (Sept.) 1914.

of a fight which began years before and which will drag on until old age appears on the scene. Moreover, the patient is not alone but is surrounded by the shades of many ancestors who are making the fight hopeless either for him or for the bacteria.

SEXUAL DIFFERENCE

We come now to a discussion of the big sexual difference in blood pressure. As I stated above, the distribution curves suggest strongly that if there are two types in the community, we may say that the women before the menopause appear to be composed almost entirely of the type endowed with a low pressure. This uniformity is seen also in the fact that half of their readings fall within limits of 7 mm. on each side of the average. The interesting thing is that after 35, the women's distribution curve widens out so that it comes to resemble that for the men. We know that this big increase in blood pressure often comes at the menopause when the ovaries atrophy. It suggests that in some way the ovary is able to cover up or hold latent the tendency to hypertension which we will presume the women inherit equally with the men. Another possibility is that hypertension is a defect linked up, as are some other well known defects, with sex chromosome. This might explain why it appears early in the males who have only one such chromosome. The females have two, one of which may be normal and able to neutralize the defect in the other. With the atrophy of the ovary at the menopause the defect may appear, much as the plumage of a cock appears sometimes in hens with diseased ovaries. Much in favor of these theories is the observation that hypertension often develops early in women who show signs of insufficient ovarian function, such as scanty and painful menstruation, sexual anesthesia, male distribution of body hair, infantile uterus, etc. We shall have to check these observations statistically to see whether or not the correlation is close enough to be significant. Careful studies will have to be made also on families to ascertain the incidence of hypertension (1) when neither parent has cardiovascular disease; (2) when one has it, and (3) when both have it. I have already collected some records which show that the incidence of hypertension in children is likely to be very high when both parents show the defect.

We must also study in childhood the beginning of the sexual difference in blood pressure. Unfortunately, although considerable work has been done on blood pressure studies in children, I can find no data so arranged that we can say when the divergence appears. Some writers give their impression that it appears about the age of puberty, which is just what we should expect. If this point is settled definitely we shall be able to associate hypertension very closely with the evolution of sex and thus with the glands of internal secretion. It is inter-

esting to note in Figure 8 that the big increase in the incidence of hypertension comes 10 years later in the men than in the women. Apparently, the strenuous life has less to do with this disease than has the quieting down of the sexual functions.

PROGNOSIS

What does slight hypertension mean in youth? Many will answer absolutely nothing. We know that these people can live out their three-score and ten and can work hard physically and mentally. I agree entirely with Sir James MacKenzie, Sutherland²¹ and others who decry the tendency on the part of many physicians to treat these young people with "functional" cardio-vascular disease energetically with drugs, restricted diets and restriction of activities. Until we know more about the causation of the trouble, it does not seem to me that we have the right to prescribe minutely or to threaten the patient with disaster if he does not follow our instructions. Many of these boys enjoy athletics and we have as yet no data to show that such exercise will shorten life. We have no data showing that a protein poor diet persisted in for forty years will lengthen life. About all we can say is that as these people often tend to break down nervously, they should live within their means of strength; they should get enough sleep and rest, and should avoid nervous strain.

Although the experience of men like MacKenzie who have watched young people with murmurs, tachycardias, extrasystoles, transient albuminurias, etc., for long periods of time shows that the prognosis is generally good as regards the immediate future, I cannot accept their statements that these things mean nothing at all. In one instance a patient expressed it very well. He was a well built athletic young man of 24, a nervous wreck on account of a slight hypertension associated with extrasystoles and palpitation. He said, "All doctors who see me tell me to forget it, that there is nothing the matter with me; but I know that my uncles all had this sort of thing and they all died young with myocarditis. Now, if I live long enough won't I go the same way?" The fact that some obscure infection took him off three months later suggests that his presentiments of impending dissolution were not so unfounded and neurotic as most of his physicians thought they were.

Although people with hypertension can round out fairly long lives, the statistics of the life insurance companies show that in the aggregate this disease definitely shortens the expectancy of life. This is shown convincingly in Table 4 made up from data embodied in Fisher's paper (1915). This shortening of life is the more striking when we remember that these deaths took place within a period of at most eight years following the application for insurance. It is also signi-

ficant that it was cardiovascular disease which took off at least 78 per cent. of the men with the high pressures.

TABLE 4.—LIFE EXPECTATION IN PERSONS WITH HYPERTENSION *

	Per Cent.
Percentage of expected deaths according to American Actuarial tables.....	100
Pressures of 105 and under.....	47
Pressures of 106 - 110.....	65
Usual experience in accepted cases.....	86
10-14 mm. over average for age.....	114
15-24 mm. over average for age.....	181
25-34 mm. over average for age.....	205
35-44 mm. over average for age.....	246
45-59 mm. over average for age.....	254
60 plus mm. over average for age.....	450

* 2,857 cases were observed for periods of time ranging up to eight years.

Perhaps, we may look at it in this way: half of us are to depart from this world on account of cardiovascular disease. An ignorant, insensitive laborer may discover it at 60 when he has a stroke, or an acute decompensation of the heart. A business man, careful of his health, has his handicap discovered about the age of 40. A still more careful man may, perhaps, recognize in the circulatory disturbances of his little children the fore-runner of the process which, later in life, is to cause trouble. Many will ask, what good can come out of such pessimistic views? Several advantages may accrue. In the first place, we may learn a great deal about this disease by following it, not for a few months, but for a life-time or through several generations. Secondly, if we ever find specific methods for combating the process, it will probably be helpful to begin early; and thirdly, if we find that these diseases run through a lifetime we may spare our patients endless annoyance and financial loss in attempts at cures through tooth pulling, tonsil removing, purgation, sweating, use of drugs, high frequency currents, etc. Much light might be thrown on the etiology of the disease by studying the nature of the inheritance. Thus, if it be shown that not infrequently a man with a "pure hypertension" can have a father with marked arteriosclerosis, a mother with myocarditis, an uncle with nephritis and children with orthostatic albuminuria, and "functional murmurs," we will be in a position to say that these manifestations are probably all related.

It is to be desired that in the future those who write on this subject will give not only a few averages, but tables of frequency distribution so that their data can be used again and studied in other ways by subsequent observers.

SUMMARY

A statistical analysis has been made of the blood pressures in 8,737 University of California freshmen and 1,000 office patients.

The mathematical treatment of these data suggests that pressures over 130 mm. for the women and over 140 mm. for the men are abnormal. The arithmetical mean for women between 16 and 40 was 115 mm.; for men, 126.5 mm.

The blood pressure in young women is much more uniform than in men. The range for the women was practically from 85 to 155; for the men it was from 90 to 175. Fifty per cent. of the women's readings fell between 105 and 119 mm.; 50 per cent. of the men's fell between 116.5 and 136.5 mm.

High blood pressure appears earlier and to a greater degree in young men than in young women.

The average blood pressure in the women rose from 16 to 17; then dropped to 25 and after that rose rapidly. Little can be said about the men's yearly averages on account of disturbances in sampling brought out by the world war. Averages from the office patients showed that the pressure for women drops from puberty to 25, after which it rises so rapidly that the women catch up with and pass the men after 40. Apparently changes in the gonads of men and women have more effect on the blood pressures than has the strenuous life.

It is suggested that hypertension is based on a hereditary peculiarity. Its manifestations appear to be suppressed in women as long as the ovaries function well.

From clinical experience it would seem that pressures over 127 in women, and over 130 in young men, are indicative of a hypertensive diathesis which is associated with many typical symptoms and findings.

Fifty out of a hundred men will die of cardiovascular disease. This makes its appearance at different ages in the different men. The writer believes that careful examination would show the beginnings of such disease in childhood and youth, even in those individuals who are to round out a fairly long life. He believes that a hereditary predisposition is the most important etiologic factor.

Suggestions are made for further work along the lines of these hypotheses.

I wish to thank Dr. Robert Legge and Dr. Ruby Cunningham for their cooperation and their kindness in giving me access to their excellent records.