# IMPLICATIONS OF THE RELATION BETWEEN BLOOD PRESSURE AND AGE

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When the etiology of a chronic disorder is unknown and its treatment unsatisfactory, it will tend to progress. The progression of the disorder takes time. When the condition manifests itself in middle age and becomes so common that in some populations it affects the majority of old people, the temptation to attribute it to aging becomes almost irresistible.

That blood pressure levels, particularly those for systolic pressure, are higher on average for old people than for young people is one of the facts of cardiovascular epidemiology that few would dispute, but all epidemiologic studies have shown a proportion of old people who have the arterial pressures of young adults. This proportion seems to vary from population to population. Stamler, *et al.*,[1] estimated it to be about 30 per cent of males in the 20-year follow-up of the utility company in Chicago. Data for Wales[2] and those of the Bergen survey in Norway[3] suggest considerably smaller proportions in Europe. But some cross-sectional studies of total populations appear to show no increase of pressure with age. Maddocks[4] and Lovell[5] have both reported total populations of Melanesians and Micronesians in the Pacific islands that fail to show the usual pattern of increasing pressure with age; Shaper[6] has reported similar findings in certain Nomadic tribes in Kenya, and the Amish—a somewhat isolated and intermarried sect in the United States—are also believed to manifest this phenomenon.[7]

Aging, therefore, does not necessarily cause blood pressure levels to rise, and realization of this posed the question whether aging, per se, is the factor responsible for the higher pressures in the elderly. This paper reports attempts to try to answer this question.

## METHODS

Longitudinal studies of general populations provide the only satisfactory opportunities to investigate the factors influencing the natural history of such conditions as hypertension. Two studies in South Wales —one of a mining community, the other of a neighboring agricultural area, with respectively ten-year and 8.5-year periods of follow-up between 1954 and 1964—were used for analyses of factors influencing the changes of arterial pressure that occurred during these intervals.[8] Together the studies provided long-term follow-up blood pressure data for over 2,000 subjects.

Those who have attempted the longitudinal analysis of any biologic characteristic that fluctuates are well aware of the problem of "regression toward the mean." Subjects with atypically high or low measurements at the original examination tend to reveal their more normal values on remeasurement. It is therefore misleading to relate the change to the initial value. This difficulty can be overcome in several

FIGURE I. MEAN CHANGE OF SYSTOLIC PRESSURE IN TEN YEARS ACCORDING TO MEAN SYSTOLIC PRESSURE AND AGE, RHONDDA FEMALES

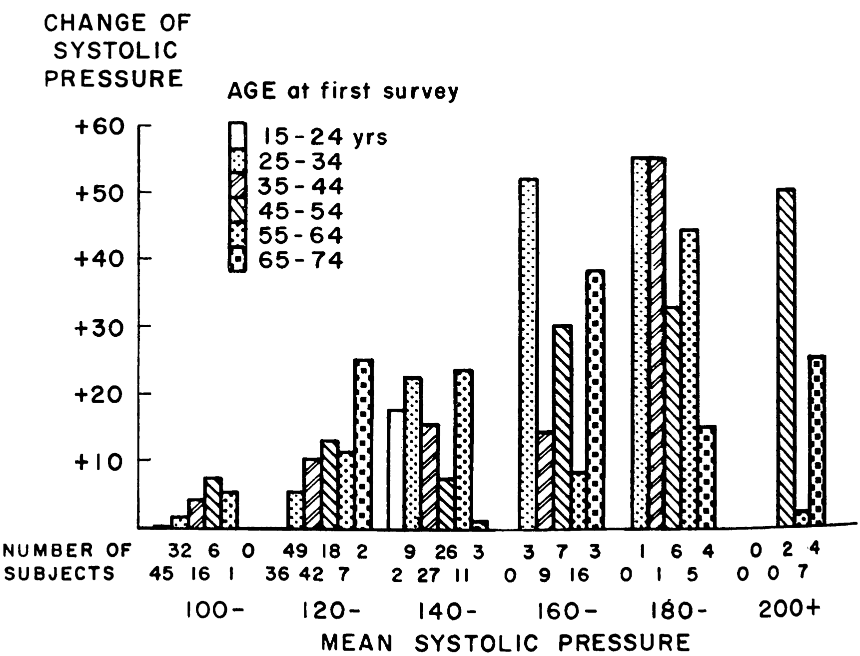


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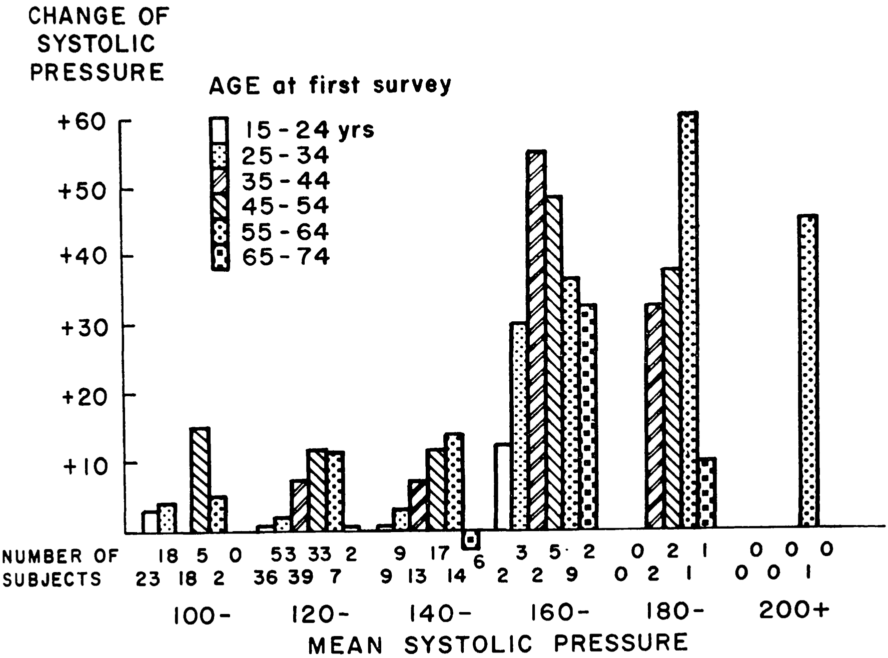
FIGURE 2. MEAN CHANGE OF SYSTOLIC PRESSURE IN TEN YEARS ACCORDING TO MEAN SYSTOLIC PRESSURE AND AGE, RHONDDA MALES

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ways. In this study the changes in pressure during these prolonged intervals were related to the mean of the first and the final readings.

## RESULTS

Tables showing the distributions of the changes in pressure during this period according to the mean pressure were compiled for each ten-year age-sex group. The results, illustrated for systolic pressure in females and males in the mining valley in Figures 1 and 2, suggested that the changes in pressure were more closely related to the pressure attained than they were to age. To investigate the relations statistically the method of multiple regression analysis was used to allow the simultaneous examination of the relative contributions of age and attained pressure in predicting changes of pressure.

The data were analyzed in ten-year age groups. Table 1 illustrates the findings in the agricultural population. Though the coefficients varied from age to age, nearly all the mean pressure coefficients were

TABLE I. MULTIPLE REGRESSION COEFFICIENTS FOR CHANGE OF PRESSURE ON MEAN PRESSURE AND AGE, AGRICULTURAL POPULATION

| | *Systolic Change* | | | | *Diastolic Change* | | | |
|---|---|---|---|---|---|---|---|---|
| | *Males* | | *Females* | | *Males* | | *Females* | |
| *Age at First Survey* | *Mean B.P.* | *Age* | *Mean B.P.* | *Age* | *Mean B.P.* | *Age* | *Mean B.P.* | *Age* |
| 5 | +0.47*** | −1.59** | +0.24 | −2.53*** | +0.32* | −0.51 | +0.19 | −0.98** |
| 15 | 0.00 | −1.30 | +0.34 | −0.64 | +0.09 | −0.72 | +0.51*** | −0.19 |
| 25 | +0.22** | +0.45 | +0.59 | −0.15 | +0.04 | +0.61* | +0.32*** | +0.01 |
| 35 | +0.37*** | −0.15 | +0.27 | +0.68 | +0.29** | −0.51 | +0.20* | −0.12 |
| 45 | +0.45*** | −0.21 | +0.24 | −1.33 | +0.50*** | −0.41 | +0.22* | −0.35 |
| 55 | +0.01 | +0.11 | +0.04 | −1.00 | +0.06 | +0.82 | +0.14 | +0.46 |
| 65 | −0.01 | −1.04 | +0.32 | −0.29 | +0.07 | −0.05 | +0.17 | +0.09 |

* Significant at the 5 per cent level.
** Significant at the 1 per cent level.
*** Significant at the 0.1 per cent level.

TABLE 2. MULTIPLE REGRESSION COEFFICIENTS FOR CHANGE OF PRESSURE ON MEAN PRESSURE AND AGE, MINING AND AGRICULTURAL POPULATIONS

| | *Systolic Change* | | *Diastolic Change* | |
|---|---|---|---|---|
| | *Mean B.P.* | *Age* | *Mean B.P.* | *Age* |
| Males | | | | |
| Mining population | +0.358** | +0.145 | +0.256** | −0.052 |
| Agricultural population | +0.243** | −0.056 | +0.198** | −0.054 |
| Females | | | | |
| Mining population | +0.220** | +0.145 | +0.123** | −0.025 |
| Agricultural population | +0.235** | −0.107 | +0.243** | −0.081* |

* Significant at the 5 per cent level.
** Significant at the 0.1 per cent level.

positive and many highly significantly so, whereas the age coefficients were frequently negative; only two (in the youngest age groups) were significant and each was negative. Among adults of either sex, and in both surveys, age seemed to play no significant role in determining change of pressure within ten-year age groups. Therefore, all adult age-groups were pooled and the analysis was repeated in the belief that if age were involved it should then be revealed by positive and significant age components.

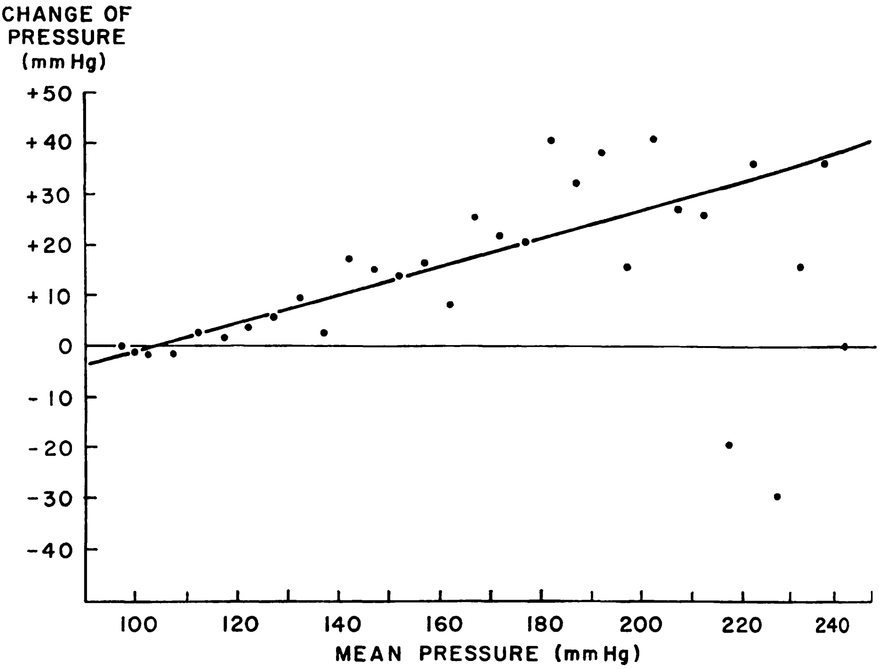
The results (Table 2) showed mean pressure coefficients that were all positive and all statistically significant in both sexes, both populations and for both systolic and diastolic pressures, but the age coefficients were again insignificant, with one exception. The exception, significant at the five per cent level, was negative. The relation between the change of pressure in ten years and attained pressure, ignoring age, was found not to deviate significantly from a rectilinear regression —the higher the attained pressure the greater the rate of increase. This is illustrated for women from the mining population in Figure 3.

## DISCUSSION

From these analyses it was concluded that age was only indirectly involved and did not itself determine the rate of change of pressure. It appeared to do so because blood pressure changes are on average positive, increase with higher pressures and take time to occur.

Few previous analyses have been undertaken to try to elucidate this particular problem, and none have used the same techniques. Harlan *et al.*,[9] in their analysis of the 18-year follow-up of United States

FIGURE 3. MEAN CHANGE OF SYSTOLIC PRESSURE IN TEN YEARS ACCORDING TO MEAN SYSTOLIC PRESSURE, RHONDDA FACH, FEMALES

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Navy flying personnel, concluded that age alone did not appear to have a significant influence on blood pressure after the effects of other variables known to affect pressure had been removed, but their study was of a cohort of young adult males over a period during which apparent changes of pressure with age are small.

Feinleib [10] has pointed out that multiple regression analyses involving two characteristics whose variances change in a systematically different manner—as do the variances of mean attained pressure and age with the passage of time—will emphasize the significance of the component with the increasing variance. He recently used a different technique to analyze the long-term follow-up data from the Framingham study. By classifying subjects according to their pressures at the third of a series of biannual surveys and then examining the changes in pressure during the six-year period from surveys four to seven he believed he had overcome the problem of regression toward the mean. The changes in pressure over this six-year interval showed the same phenomenon as did those in Wales: the higher the pressure the greater the rate of change; but an effect of age was still apparent in those with low initial pressures (see Table 3). Whether this was caused by incomplete removal of the phenomenon of regression toward the norm, whether caused by the secular changes in pressure present in the Framingham data as in all others, or by the different analytic techniques used remains to be seen and is currently under investigation.

One possible hypothesis to account for the findings, if they are confirmed, would be that the pressure itself determines its own subsequent rate of increase by causing structural changes in the vessels. Such an idea is not original. It is accepted in the case of malignant hypertension, and would accord with the known facts at lower levels of pressure.

The implications of such a hypothesis are, first, that some trigger mechanism would be necessary to initiate the vicious cycle. Any cause of minor but sustained increases in pressure could presumably act in this way. Longitudinal studies such as the Framingham project,[11] the 1,000-aviator study[12] or the study in Wales[13] show that changes in weight are positively correlated with changes in pressure. In the Welsh data, changes in body weight are not positively correlated with changes in blood pressure beyond age 40. They do not, therefore, account for the increases in pressure that, beyond that age, are becoming more prevalent, and this seems to accord with the hypothesis that body weight could be acting as one possible trigger mechanism that raises pressure to a level at which the pressure itself has deleterious effects.

TABLE 3. MEAN CHANGES OF SYSTOLIC PRESSURE IN 10 YEARS IN THE FRAMINGHAM PROJECT (FROM SURVEYS 2 TO 7) ACCORDING TO PRESSURE AS MEASURED AT SURVEY 3

| | *Systolic Pressure at Survey 3* | | | |
|---|---|---|---|---|
| *Age at Survey 3* | *<120* | *120* | *140* | *160+* |
| Males, excluding treated hypertensives | | | | |
| 35–44 | +1.4 | + 3.9 | + 4.3 | + 8.5 |
| 45–54 | +5.9 | + 6.3 | + 9.3 | +16.9 |
| 55–64 | +6.9 | + 8.8 | +11.7 | + 8.6 |
| Females, excluding treated hypertensives | | | | |
| 35–44 | +7.5 | +11.5 | +10.8 | +23.0 |
| 45–54 | +6.2 | + 7.9 | + 6.4 | +13.3 |
| 55–64 | +7.3 | + 7.1 | + 9.6 | + 5.8 |

Data kindly provided by Dr. M. Feinleib, National Heart Institute.

Presumably many other such causes could be found—including psychological ones—and it would be reasonable to postulate that genetic factors play a role in determining the response to them.

A second implication, and one that clearly could be put to experimental test, would be that effective treatment of hypertension at a stage before vascular changes became irreversible might break the vicious circle. When hypertension caused by some specific fault has been present for a long time, removing that fault may not lower the pressure, but some subjects, after their pressures have been reduced for a long period by drugs, do not revert back to hypertensive levels.

The hypothesis suggested to account for the relationship found is certainly not the only possible one. Some underlying humoral or other factor could explain equally well the relation found between change of pressure and pressure attained, and the lack of a direct relation between change of pressure and age.

Aging is a relentless process. It is therefore encouraging to have some suggestion that the development of hypertension can be dissociated from it. As Paul and Ostfeld[14] said "it is as unnecessary to assume that the blood pressure 'normally' rises with age as it is to conclude that those rises as are seen are completely benign."

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