Age and Blood Pressure Changes
A 20-Year Follow-up Study in Nuns in a Secluded Order

MARIO TIMIO, PAOLO VERDECCHIA, SANDRO VENANZI,
SIMONETTA GENTILI, MAURIZIO RONCONI, BIANCA FRANCUCCI,
MAURO MONTANARI, AND ETTORE BICCHISA

SUMMARY In a prospective study, 144 white nuns belonging to a secluded monastic order and 138 white control laywomen were followed for 20 years to investigate whether living for a long time in a stress-free environment influences the effect of aging on blood pressure. Silence, meditation, and isolation from society are the distinctive features of the life-style examined. At study entry, blood pressure was not dissimilar in the nuns and the control group, but it increased over time only in the controls, with a mean slope of the regression line (β coefficient) of 0.089 mm Hg in the nuns (NS) and 2.171 in the controls (p < 0.0001) for systolic blood pressure and of 0.054 in the nuns (NS) and 0.742 in the controls (p < 0.0001) for diastolic blood pressure. Weight and body mass index increased similarly over time in the two groups. Family history of hypertension was not dissimilar between the groups. Serum cholesterol and triglycerides, higher at study entry in the nuns, increased similarly over time in the two groups. Twenty-four-hour urinary sodium excretion, collected randomly in both groups, did not differ over time between nuns and controls. None of the women smoked or used oral contraceptives. Educational level was higher in the control group, but subgroups of 48 nuns and 52 laywomen of comparable educational level maintained the same difference in the blood pressure trend over time as in the main cohort. Parity affected the increase of systolic, but not of diastolic, blood pressure with age among the laywomen, but nuns and no-childbirth controls maintained a significantly different blood pressure trend over time. Our longitudinal study suggests that the increase in blood pressure in women over 20 years may be avoided by living in a stress-free monastic environment characterized by silence, meditation, and isolation from society. The basic mechanisms of this phenomenon remain unexplained. (Hypertension 12: 457–461, 1988)

KEY WORDS • age • blood pressure • stress • life-style

THE progressive increase in blood pressure with age, which is the rule in the westernized world, is a complex and poorly defined phenomenon that may reflect "a cumulative dose of environmental factors interacting over a long period with hereditary susceptibility." In some primitive hunter-gatherer populations blood pressure does not increase with age except in subjects migrating or becoming acculturated, thus suggesting that hereditary factors may not be determinative, but only permissive, concerning age-related blood pressure regulation processes.2 3 Psychosocial stresses could affect the blood pressure rise with age, but the possible mechanisms involved are difficult to identify and standardize.4 5 Low blood pressure populations, although differing in race, habitat, and diet,6–11 share the feature of living in nonurban areas; conversely, subjects living in high stress areas with marked socioeconomic problems may show higher pressure levels in comparison with subjects living in low stress areas.12, 13 We previously reported preliminary data showing negligible changes in systolic and diastolic blood pressure with age in a group of white nuns in a secluded order, followed up prospectively for about 20 years.14 Secluded nuns may be a good model of a white urban group living in prolonged isolation in a very low stress environment. In this report we present a detailed analysis of some familial, anthropometric, humoral, and life-style correlates of blood pressure in the secluded nuns and in a control group of laywomen, both followed up prospectively for 20 years.

Subjects and Methods

The purpose of the study was to investigate the effect of aging on blood pressure in a group of 144 white nuns living in a secluded order in Umbria,
Italy, who represent a human model of life differing in many aspects from the standard in westernized societies. The main differences are in the levels of 1) anxiety for their earthly future; 2) drive, competition, and human expectations; 3) economic and familial stress; 4) social and political tensions; and 5) exposure to noise and pollution. The monastic environment, modeled on Saint Benedict's dictum, "ora et labora" (pray and work), is characterized by strict daily observance of alternate periods of meditation, prayer, worship, religious celebration, domestic chores, handcrafts, gardening, and husbandry. All activities are performed in strict isolation from urban life and, according to the monastic rule, in nearly absolute silence.

The survey included a clinical examination, anthropometric and blood pressure measurements, humoral investigation, and questionnaires. The nuns were asked about their demographic data, familial and personal medical history, level of education, and personal hygiene. Blood samples were drawn for determination of cholesterol and triglycerides; a 24-hour urine collection was made randomly for sodium measurement in a group of 72 nuns and 67 control laywomen.

The control group was composed of 138 laywomen living in communities surrounding the nunneries. Subjects from both groups were enrolled consecutively in the absence of selection parameters.

Investigation began in January 1964, enrollment finished in December 1968, and follow-up continued for about 20 years. Medical history was focused mainly on familial hypertension and was later controlled by objective ascertainment. Information about hygiene included tobacco and alcohol consumption, oral contraceptive use, and dietary pattern. Anthropometric measurements, physical examination, and blood pressure determinations were performed every 6 months. Height was measured in centimeters to the nearest 0.5 cm below, and weight was measured in kilograms to the nearest 0.5 kg below. Body mass was computed using the body mass index (weight/height²). Blood pressure was always taken by the same observer using a standard mercury sphygmomanometer on the right arm of the subject, who was seated comfortably in a chair after at least 10 minutes of rest. Korotkoff phases I and V were used to analyze systolic and diastolic blood pressure. Three consecutive readings were averaged. Blood samples drawn into Vacutainers were centrifuged within 1 hour; serum was separated promptly and stored at +4 °C. Twenty-four-hour urine collections were made in bottles stored at +4 °C. The storage period for serum and urine did not exceed 7 days. Total serum cholesterol and triglycerides were assayed by a single laboratory according to methods reported elsewhere.15, 16 Urinary sodium concentration was determined by flame photometry.

Comparison of categorical data between the two groups at entry was performed using one-way analysis of variance (ANOVA) and nonparametric tests when appropriate. Regression equations were obtained and comparisons between the two groups, using the slope of the regression line (β coefficient), were performed according to standard methods. Repeated-measure ANOVA was also used to compare the groups over time based on parametric values. The log-rank test was used to compare the groups for all-cause mortality over the 20-year observational period.

Results

Comparability at Entry

Table 1 provides detailed demographic, anthropometric, and clinical data of the two study groups at entry. The two groups, both white, were similar in ethnic background, region of birth, and area of familial settlement. None of the study subjects changed their residence over the study period. Educational levels were generally higher in the controls than in the nuns: 3.6% of controls were high school graduates versus 1.3% of the nuns and 13.8% had learned a trade or qualified for teaching or a technical profession versus 3.4% of the nuns. There was no significant difference between the two groups in family history of hypertension (18.7% among nuns, 15.9% among controls). No woman smoked or was taking oral contraceptives. A similar proportion of nuns and controls reported low consumption of tea and coffee. Two of 144 nuns and eight of 138 controls did not use alcohol (NS). Among those who did, mean weekly alcohol consumption was 189 g in the nuns and 196 g in the controls (NS). No appreciable difference was detected between nuns and controls with respect to height, weight, and body mass index. Blood pressure values in the nuns were not dissimilar from those in controls. Mean 24-hour urine sodium excretion was not dissimilar in the two groups. Only

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nuns</th>
<th>Laywomen</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 144)</td>
<td>(n = 138)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>38.2 ± 5.7</td>
<td>34.7 ± 4.8</td>
</tr>
<tr>
<td>Age range (yr)</td>
<td>22–58</td>
<td>25–46</td>
</tr>
<tr>
<td>Age at menarche (yr)</td>
<td>14.3 ± 2.1</td>
<td>13.2 ± 2.7</td>
</tr>
<tr>
<td>Family history of hypertension</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>159.1 ± 6.3</td>
<td>161.7 ± 5.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.7 ± 3.4</td>
<td>58.3 ± 4.6</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.4 ± 0.3</td>
<td>22.3 ± 0.2</td>
</tr>
<tr>
<td>Supine blood pressure (mm Hg)</td>
<td>125.6 ± 5.9</td>
<td>128.2 ± 7.4</td>
</tr>
<tr>
<td>Systolic</td>
<td>79.1 ± 4.1</td>
<td>81.0 ± 4.4</td>
</tr>
<tr>
<td>Diastolic</td>
<td>201.1 ± 13</td>
<td>187.6 ± 17</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>135.4 ± 16</td>
<td>123.2 ± 22</td>
</tr>
<tr>
<td>Triglycerides (mg/dl)</td>
<td>144.3 ± 7.7</td>
<td>138.2 ± 9.9</td>
</tr>
<tr>
<td>Urinary sodium excretion (mEq/24 hr)</td>
<td>144.3 ± 7.7</td>
<td>138.2 ± 9.9</td>
</tr>
</tbody>
</table>

Values are means ± SD (except for age range and family history of hypertension).
TABLE 2 Follow-up Measurements of Weight, Body Mass Index, and 24-Hour Urinary Sodium Output in the Nuns and Laywomen 4, 8, 12, 16, and 20 Years After Entry

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nuns</th>
<th>Laywomen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>BMI (kg/m²)</td>
</tr>
<tr>
<td>Year 4</td>
<td>59.9 ±4.4</td>
<td>23.4 ±0.2</td>
</tr>
<tr>
<td>Year 8</td>
<td>61.2 ±3.5</td>
<td>24.2 ±0.4</td>
</tr>
<tr>
<td>Year 12</td>
<td>63.1 ±5.0</td>
<td>25.0 ±0.7</td>
</tr>
<tr>
<td>Year 16</td>
<td>65.1 ±5.5</td>
<td>25.7 ±0.5</td>
</tr>
<tr>
<td>Year 20</td>
<td>66.1 ±5.3</td>
<td>26.1 ±0.8</td>
</tr>
</tbody>
</table>

Values are means ± SD. BMI = body mass index; UN.V = urinary sodium excretion.

Serum cholesterol and triglycerides were higher in the nuns than in the control groups (both \( p < 0.01 \)).

Follow-up Period

Four, 8, 12, 16, and 20 years after entry, the group of nuns was composed of 138, 138, 138, 136, and 95 subjects, respectively. At the same time, the control group was composed of 126, 126, 126, 124, and 113 women, respectively. Both groups showed similar increases in body weight and body mass index over the 20-year period (Table 2). Mean menopausal age was not dissimilar between the nuns (44 ± 6 [SD] years) and the controls (47 ± 3 years).

Systolic and diastolic blood pressure values recorded every 4 years in the nuns and controls are reported in Figure 1. The two groups showed a highly significant difference (\( p < 0.001 \)) in both systolic and diastolic values. Regression equations of systolic and diastolic blood pressure on age in nuns and controls by age at study entry (21–30, 31–40, 41–50 years) are shown in Table 3. For each of the three age groups, the slope of the systolic, as well as of the diastolic, pressure increase with age was significantly higher in the controls than in the nuns (all \( p < 0.0001 \)). In the nuns, the slope generally approximated the zero level.

Mean values of total serum cholesterol and triglycerides in the 4th, 8th, 12th, 16th, and 20th year after entry are reported in Figures 2 and 3, respectively. Their values increased in parallel with age, but the baseline difference between the two groups persisted nearly unchanged over the entire study period. Random estimates of urinary sodium excretion were not dissimilar in the nuns compared with those in controls at any time (see Table 2). Regression equations of systolic and diastolic blood pressure on age among the laywomen in relation to childbirth are reported in Table 4. While diastolic blood pressure increased similarly with age in child-bearing and no-childbirth laywomen, systolic blood pressure increased with age significantly more in the women with at least one child than in the no-childbirth women (\( \beta \) coefficient, 1.142 and 1.053, respectively; \( p < 0.01 \)). However, both systolic and diastolic blood pressure increased with age significantly more in the no-childbirth control women than in the nuns (all \( p < 0.001 \)).

There were six deaths (five of cardiovascular causes, one of cancer) among the nuns and 12 deaths (10 of cardiovascular causes, two of cancer) among the laywomen. Although all-cause and cardiovascular mortality were both slightly higher in the controls than in the nuns, the log-rank test did not show any statistical difference between the groups, probably because of the small numbers.

Discussion

The lack of blood pressure increase with age in nuns living in a secluded order resembles what may be observed in some unacculturated societies, such as the Melanesian Gaus of Fiji17, natives of New Guinea18 and the Solomon islands,1 and Brazilian Indian tribes,19 in which systolic and diastolic blood pressure levels remain constant or tend to decrease with age. In our subjects blood pressure at entry was not dissimilar between nuns and laywomen, but it increased over two decades of observation only in the latter group. The nuns did not show any pressure increase with age, and none of them manifested arterial hypertension. According to the Epstein and Eckoff20 scheme for classifying age-related blood pressure by level and slope, the trend remains at low levels of intercept and slope 0, which is not dissimilar to the pattern in low blood pressure populations.

The main question is why blood pressure did not tend to increase with age in the nuns. At study
entry, nuns and controls were not dissimilar with respect to blood pressure levels, age, race, ethnic background, age at menarche, family history of hypertension, and body mass index. Among the large number of life-style variables that might be implicated in differentiating blood pressure pattern with age between the two groups, use of alcohol, tobacco, coffee, tea, and oral contraceptives can be excluded because use of these products was absent or equally distributed between nuns and controls. Even the increase in weight and body mass index over time was not dissimilar in the two groups, suggesting that pressure levels and anthropometric pattern, which are usually assumed to be related, may not necessarily be related.

Salt intake probably did not influence the different blood pressure trend with age in the two groups, since 24-hour urinary sodium excretion, although taken only in a random sample from both groups, was similar between the groups. The possible causal relation between sodium and blood pressure is a controversial topic. Our findings, in accordance with others, do not support a role for sodium as a possible link between weight gain and blood pressure increase. Serum cholesterol and triglycerides, although not directly implicated in age-related blood pressure trends, were higher in the nuns than in the control group, perhaps as a consequence of a generally lipid-rich diet with low physical activity in the nunneries.

Although there is no evidence that menarche and menopause significantly affect blood pressure, they occurred at comparable ages in the two groups of women. Educational levels, generally higher in the control group, may affect the increase in blood pressure with age, but subgroups of nuns (n = 48) and laywomen (n = 53) of comparable educational level at entry maintained strongly different blood pressure trends over time. This finding confirms results of other studies showing that educational level may have little effect on age-related blood pressure changes.

Childbirth did not have a definite role in differentiating the blood pressure trend between nuns and controls. In fact, although systolic blood pressure alone increased with age more in the laywomen who had experienced childbirth than in those who had not, the mean slope of the regression line of both systolic and diastolic blood pressure versus age remained significantly higher in the no-childbirth control women than in the nuns.
Therefore, the main factor differentiating the two groups of women seems to be life-style, although the possible role of other dietary (e.g., calcium and potassium) or nondietary factors in differentiating the two groups was not investigated. The habitat of secluded nunneries is virtually devoid of conflict, aggression, and competition for power and money. Silence, meditation, and isolation from society are the main features. Although living for 20 years in such a low stress environment appeared to prevent the increase of blood pressure with age in the women studied, the basic mechanisms of this phenomenon remain unknown.

References


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**TABLE 4. Regression Equations of Systolic and Diastolic Blood Pressure on Age in Childbearing and No-Childbirth Laywomen**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intercept</th>
<th>$\beta$ slope</th>
<th>SE ($\beta$)</th>
<th>$t$ value</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childbirth</td>
<td>123.77</td>
<td>1.142</td>
<td>0.0202</td>
<td>55.78</td>
<td>1.102</td>
<td>1.183</td>
</tr>
<tr>
<td>No childbirth</td>
<td>125.73</td>
<td>1.053</td>
<td>0.0117</td>
<td>89.85</td>
<td>1.030</td>
<td>1.076</td>
</tr>
<tr>
<td>Dystolic BP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childbirth</td>
<td>80.45</td>
<td>0.356</td>
<td>0.0094</td>
<td>37.95</td>
<td>0.338</td>
<td>0.374</td>
</tr>
<tr>
<td>No childbirth</td>
<td>80.36</td>
<td>0.378</td>
<td>0.0054</td>
<td>69.71</td>
<td>0.367</td>
<td>0.388</td>
</tr>
</tbody>
</table>

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