Age-Related Changes in Blood Pressure
STEN LANDAHL, CALLE BENGTSSON, JOHAN A. SIGURDSSON, ALVAR SVANBORG, AND KURT SVARDSUDD

SUMMARY This report is based on three different representative population samples of a total of 1304 men (50–79 years old) and 1246 women (38–79 years old) observed for up to 12 years. Subjects' consumption of antihypertensive drugs and blood pressure levels in subjects with and without such treatment are presented. The prevalence of treatment with antihypertensive drugs (including β-blockers and diuretics for other indications) increased from 2% at age 50 years to 37% at 79 years of age among the men and from 1% at 38 years to 61% at 79 years of age among the women. The mean systolic/diastolic blood pressure in untreated subjects increased from 138/91 mm Hg at age 50 years to 159/91 mm Hg at age 70 years in the men and from 123/79 mm Hg at age 38 years to 168/93 mm Hg at age 70 years in the women. At age 79 years the mean systolic/diastolic blood pressure was 155/83 mm Hg in the men and 161/85 mm Hg in the women. In a longitudinal follow-up of reexamined subjects, there was an increase in systolic blood pressure levels up to age 75 years and a reduction in diastolic blood pressure after age 75 years in both sexes. (Hypertension 8: 1044-1049, 1986)

KEY WORDS • blood pressure levels • antihypertensive treatment

SEVERAL previous studies from industrialized countries have reported age-associated changes in both systolic (SBP) and diastolic (DBP) blood pressures. These changes seem to be different for SBP and DBP and have also been reported to be different in male and female subjects. The majority of these studies have been performed on age groups below 60 to 65 years of age. Blood pressure measurements on representative groups of populations above these ages are lacking, although certain previous reports indicate that there is no further age-related rise in SBP or DBP at higher ages. Generally, reference values for arterial blood pressures are lacking for elderly people. At the same time, however, the prescription and consumption of antihypertensive drugs increase sharply at ages above 60 years.

This report is based on results from three different longitudinal population studies of men and women living in Göteborg and representing the age interval 38 to 79 years in women and 50 to 79 years in men. Göteborg is the second largest city in Sweden, with 450,000 inhabitants within the city borders and about 1 million in the metropolitan area. It has a considerable amount of industry, the biggest harbor in the country, and an advanced school and university system. Göteborg is located on the west coast and has a milder climate than the middle and northern parts of Sweden.

All three studies were designed to obtain samples representative of the general population, and reports of comparisons between responders and nonresponders are available. The aim of this report was to describe blood pressure levels studied both longitudinally over 9- to 12-year periods and cross-sectionally in the total sample population as well as in those without drugs influencing the blood pressure.
Study Populations and Methods

The number of participants at different ages is shown in Table 1. The study of men born in 1913 and 1923 \( ^{13} \) started in 1963 and included a sample of 973 men, all born in 1913. The response rate was 88%, and comparisons between responders and nonresponders have been described. \( ^{14,15} \) Certain differences in mean income, marital status, and alcoholism were observed. A total of 703 of the men have been observed for 10 years. Another 50-year-old cohort of 226 men (born in 1923) was included in the study 10 years later.

The study of women in Göteborg started in 1968–1969 with a sample of 1622 women born in 1930, 1922, 1918, 1914, and 1908. The response rate was 90%, and comparisons between responders and nonresponders have been reported. \( ^{16} \) The nonresponders were studied through telephone interviews and records from outpatient and inpatient departments. No differences were found with respect to place of birth, presence of heart disease, and blood pressure. This report deals with the women born in 1918 and examined at ages 38, 44, and 50 years and those born in 1930 and examined at 50, 56, and 62 years of age. Seventy-five percent of these women had been observed for 12 years.

The "70-year-old people in Göteborg" study started in 1971–1972 with 973 women and men examined out of a sample of 1148 persons born in 1901–1902 (a response rate of 85%). The representativity of this sample has been demonstrated previously. \( ^{17} \) The nonresponders (15%) did not differ with respect to such variables as income, marital status, or previous hospital care. Recent observations showed a similar mortality at age 79 years in responders and nonresponders (A. Svanborg, unpublished data, 1986). We were able to follow up 46% of the originally examined men (208) and 63% of the women (328) at age 79 years. Another 70-year-old cohort born in 1906–1907 (473 men and 561 women) was examined in 1976–1977.

Blood pressure was measured manually with the cuff method after the subjects had spent 5 minutes at rest in a sitting position and was registered to the nearest 5 mm Hg in every subject except for the women born in 1918 and 1930 and for the 60-year-old men, when the nearest 2 mm Hg was used. As far as DBP is concerned, Korotkoff's Phase IV and V were measured, but only Phase V data are used in this report, with the exception of the 50-year-old men examined in 1963, for whom only Phase IV was used.

The majority of antihypertensive drugs used in these populations included thiazide and thiazidilike diuretics, \( \beta \)-adrenergic receptor blocking agents, hydralazine, prazosin, calcium influx inhibitors, spironolactone, and \( \alpha \)-methylldopa.

Results

The use of antihypertensive drugs at the time of the analyses in subjects examined between 1963 and 1981 is shown in Table 2. The percentage treated was higher in women than in men, and the prevalence of such treatment was approximately doubled in both sexes for every decade above 50 years. Table 2 also shows the proportion treated because of hypertension, which was known for the age interval 70 to 79 years.

The mean SBP at various ages among the different cohorts is given in Table 3 and Figure 1. All persons examined on each occasion, except for those treated with antihypertensive drugs are included. There was an increase in the mean SBP up to age 70 years and a moderate decrease from age 70 to 75 years. The age-related increase in SBP was more pronounced in men than in women, and the prevalence of such treatment was approximately doubled in both sexes for every decade above 50 years. Table 2 also shows the proportion treated because of hypertension, which was known for the age interval 70 to 79 years.

The mean SBP at various ages among the different populations included thiazide and thiazidilike diuretics, \( \beta \)-adrenergic receptor blocking agents, hydralazine, prazosin, calcium influx inhibitors, spironolactone, and \( \alpha \)-methylldopa.

### Table 1. Number of Participants at Different Ages

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>—</td>
<td>372*</td>
</tr>
<tr>
<td>44</td>
<td>—</td>
<td>336*</td>
</tr>
<tr>
<td>50</td>
<td>855t</td>
<td>308*</td>
</tr>
<tr>
<td>54</td>
<td>792t</td>
<td>—</td>
</tr>
<tr>
<td>56</td>
<td>—</td>
<td>350†</td>
</tr>
<tr>
<td>60</td>
<td>718†</td>
<td>—</td>
</tr>
<tr>
<td>62</td>
<td>—</td>
<td>325‡</td>
</tr>
<tr>
<td>70</td>
<td>449§</td>
<td>524</td>
</tr>
<tr>
<td>75</td>
<td>329§</td>
<td>410</td>
</tr>
<tr>
<td>79</td>
<td>208§</td>
<td>328</td>
</tr>
</tbody>
</table>

*Women born in 1930.
†Women born in 1913.
‡Women born in 1918.
§Men born in 1901–1902.
¶Women born in 1901–1902.

### Table 2. Treatment with Blood Pressure-Lowering Drugs

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>44</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>54</td>
<td>6</td>
<td>—</td>
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<tr>
<td>56</td>
<td>—</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td>62</td>
<td>—</td>
<td>20</td>
</tr>
<tr>
<td>70</td>
<td>19 (13)</td>
<td>39 (30)</td>
</tr>
<tr>
<td>75</td>
<td>29 (17)</td>
<td>49 (39)</td>
</tr>
<tr>
<td>79</td>
<td>37 (19)</td>
<td>61 (39)</td>
</tr>
</tbody>
</table>

Numbers in parentheses indicate the percentage of subjects with a history of antihypertensive treatment.

*\( \beta \)-blockers, diuretics, and/or other antihypertensive drugs.
TABLE 3. Systolic Blood Pressure at Various Ages in Subjects Without Antihypertensive Treatment

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Men</th>
<th>SBP (mm Hg)</th>
<th>No.</th>
<th>Women</th>
<th>SBP (mm Hg)</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>123±14.4</td>
<td>369*</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>—</td>
<td>124±16.4</td>
<td>—</td>
<td>138±20.5</td>
<td>841†</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>138±20.5</td>
<td>841†</td>
<td>133±19.4</td>
<td>284*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>142±20.1</td>
<td>747†</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>—</td>
<td>—</td>
<td>134±18.8</td>
<td>298‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>144±22.2</td>
<td>643†</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>159±25.0</td>
<td>362§</td>
<td>168±25.5</td>
<td>321</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>158±24.5</td>
<td>234§</td>
<td>166±22.5</td>
<td>209</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>155±24.6</td>
<td>130§</td>
<td>161±22.1</td>
<td>127</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Systolic blood pressure (SBP) expressed as mean ± SD.

*Women born in 1930.
†Men born in 1913.
‡Women born in 1918.
§Men born in 1901–1902.
||Women born in 1901–1902.

than in those without treatment. However, the pattern of blood pressure change with age in the total population was identical to that among untreated subjects.

The mean DBP in women without antihypertensive treatment also increased with age up to 70 years (Table 4; see Figure 1). In men, however, no change in DBP was observed between 50 and 70 years of age. After age 70 to 75 years, the DBP decreased in both men and women. In the total study population (treated patients included), the mean DBP was 1 to 3 mm Hg higher in both sexes than among those with no antihypertensive treatment.

Table 5 shows the longitudinally observed changes in blood pressure observed in subjects without hypertensive drugs: women were examined at the age intervals 38 to 50, 50 to 62, and 70 to 79 years, and men were examined at 50 to 60 and 70 to 79 years. The SBP increased significantly in both sexes at least up to age 75 years. The lower value at the age interval 70 to 79 years compared with that at 70 to 75 years is due to a decrease in SBP between ages 75 and 79 years. The DBP in women still showed an increase at the age interval 50 to 62 years but showed a decline after age 75 years, and no change was noted in DBP in men until after age 75 years, when a significant decline was observed.

Table 6 shows the blood pressure levels in those probands born in 1901–1902 who were reexamined at both age 75 and 79 years. The DBP decreased after age 75 years in both sexes. The blood pressures were also lower in this group of survivors at ages 70 and 75 years than in the total study population. The longitudinal changes showed a unimodal distribution.

Discussion

Previous epidemiological studies of possible age-related changes in blood pressure are numerous (for a review, see References 1–12) and have yielded somewhat controversial results. To a great extent, the discrepancies are due to variations in population sampling procedures and the samples investigated, to differences in age-standardized morbidity and longevity be-
Tweed, for example, populations in developing and
developed countries, and to cultural and environmental
 differences. The Swedish population is presently
the oldest in the world, with no less than 17% aged
65 years or more. Compared with most other countries,
numeric and cultural differences between different age
groups are rather small.

The majority of epidemiological studies in countries
with high longevity indicate that the SBP rises with
age. This is obviously the case in Göteborg, as well as
in Framingham, Massachusetts, USA, and Glostrup,
Denmark,11 up to age 70 to 75 years. The age-related
rise indicated by both cross-sectional and longitudinal
comparisons was found to be faster in women than in men.
Cross-sectional comparison showed that the regres-
sion lines representing SBP versus age in the two
sexes cross each other at age 45 years in the Fra-
mingham study but not until age 60 to 70 years in the
present investigation. Available data indicate that in
the Japanese population the female line does not ap-
proach the male line until ages above 70 years.30 Long-
itudinal blood pressure measurement results from the
Framingham study indicate that, although the age-
related rise was faster in women than in men and the
female lines approach the male ones at about age 70
years, these lines never cross. The present results
showed a rate of change of about 1 mm Hg per year in
both men and women up to age 75 years longitudi-

nally, while the cross-sectional comparisons showed a
faster increase in women than in men. These findings
might either imply a higher selective mortality of
women with higher blood pressure than of men, or
result from the fact that the proportion of women treat-
ed with blood pressure—lowering drugs was much
higher (see Table 2), resulting in different sex distribu-
tions of the untreated groups. There are no data avail-
able in the Swedish mortality statistics indicating that
women below the age of 70 to 75 years have a higher
risk than men of having cardiovascular complications
due to hypertension. We therefore conclude from the
present results that available epidemiological data
indicate that the rate of age-related increase in SBP
is faster in women than in men and that at age 70 years,
a higher clinical reference value for SBP has to be
accepted in women than in men. How great such a
physiological difference should be accepted to be —
cross-sectionally women had blood pressure levels that
were 10 mm Hg higher — remains to be studied in
populations with a similar rate of treatment with
antihypertensive drugs.

The present report is based on three different popu-
lation studies in samples that obviously allow general-
izations to be made about the total population of Göte-
borg. Indirect evidence such as available information
on the consumption of antihypertensive drugs in differ-
ent areas of Sweden indicates that the present obser-
vations on age-related changes in SBP and DBP also
are relevant for the rest of the population in Sweden.

A comparison of the age-related change in DBP is
more difficult to make because of the proportionally
higher measurement error in relation to the age differ-
ences. The fact that Korotkoff's Phase IV was used in
the longitudinal analyses for men born in 1913 was
shown to be of minor importance, since the change

### Table 6. Systolic and Diastolic Blood Pressures in Subjects
70-79 Years of Age Who Attended All Three Examinations and
Received No Antihypertensive Treatment

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Men (n = 130)</th>
<th>Women (n = 127)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP (mm Hg)</td>
<td>DBP (mm Hg)</td>
</tr>
<tr>
<td>70</td>
<td>152 ± 19.8</td>
<td>88 ± 9.5</td>
</tr>
<tr>
<td>75</td>
<td>156 ± 22.4†</td>
<td>89 ± 10.4</td>
</tr>
<tr>
<td>79</td>
<td>155 ± 24.6</td>
<td>83 ± 11.3‡</td>
</tr>
</tbody>
</table>

Systolic (SBP) and diastolic (DBP) blood pressure expressed as mean ± SD.

* p < 0.05, † p < 0.001 (paired t test), compared with same-sex
SBP in 70-year-old age group; ‡ p < 0.001 (paired t test), compared
with same-sex DBP in 75-year-old age group.
between 54 and 60 years of age showed no difference compared with Phase V data. Also, the change in DBP between 70 to 75 and 79 years of age was similar for both phases. Most results were based on registration of blood pressure to the nearest 5 mm Hg, except for the two youngest female cohorts and the 60-year-old male cohort. This methodological difference is of minor importance as far as analyses of longitudinal changes within the different cohorts are concerned but may affect the comparison between the absolute blood pressure levels for different cohorts. In men, previous studies\(^1-^12\) have shown an age-related increase, at least up to age 50 to 60 years and thereafter a leveling off. The present study of men older than 50 years showed a further decline starting above age 70 to 75 years. There was a sex difference with a further rise also in DBP up to age 70 years in women, while both cross-sectional and longitudinal data showed a decline in the DBP of men and women after age 75 years, after which no sex differences in these age-related trends in blood pressure levels can be seen.

For ethical reasons all the participants in the population studies in Göteborg have had some medical intervention (e.g., the institution of antihypertensive treatment). From this point of view, the best cross-sectional comparison can be made between the “starting” ages (i.e., 38, 50, and 70 years) in the total study population. However, our main conclusions have been based on both the cross-sectional analysis and the results from longitudinal follow-ups in subjects without any drug treatment influencing the blood pressure. The decline in blood pressures during the age interval 75 to 79 years thus could not be due to any intervention given during this age interval. It is also important to bear in mind that the distribution of the blood pressure changes was close to normal with a slightly more pronounced decrease.

The reason for the blood pressure decline has not been addressed in this report. Other studies of the same sample\(^11\) have shown a marked change of body mass and body composition at these ages. Possible relationships between body mass, body cell mass, and blood pressure can be anticipated. However, it should be emphasized that similar changes in body mass and body composition also took place at the age interval 60 to 70 years, when there still was an increase in SBP in both sexes and in DBP in women. A marked decline in body height could also affect blood pressure, for instance, by changing the demand of blood pressure to ensure adequate cerebral blood flow. Selective mortality and observer bias may also be factors of some importance for this decline in blood pressure.

One reason for the increase of SBP up to age 70 to 75 years is a gradual deterioration of elastic filaments in the aorta and large arteries. This exchange of elastic filaments with stiffer collagen elements increases the “Windkessel” phenomenon in these vessels, leading to increased pulse pressure. A decreasing ability with age to handle exogenous blood pressure-affecting factors such as salt intake, extracellular volume, and serum proteins may also be of importance.\(^22\) Several previous studies\(^2-^29\) have investigated possible age-related changes in the production of catecholamines. The results are conflicting, but the majority of these studies conclude that increased norepinephrine levels are balanced by a decrease in receptor sensitivity. Plasma renin activity and renin concentrations have been reported to be lowered by increasing age, but similarly in hypertensive and normotensive elderly.\(^26,^30\) Also, plasma and urine aldosterone concentrations decrease with age.\(^31\)

The reason why the age-related SBP changes in women are more pronounced than in men is unknown. Neither do we know any reasons for the earlier leveling off of the DBP in men than in women. Possible relationships to hormonal changes causing, for example, differences in salt and water content of the body might be considered. Recent studies have shown a less pronounced blood pressure increase after age 50 years in women who are postmenopausal than in women who still menstruate.\(^32\)

References
Age-related changes in blood pressure.
S Landahl, C Bengtsson, J A Sigurdsson, A Svanborg and K Svärdsudd

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