Higher Blood Pressure in Adults With Less Education
Some Explanations From INTERSALT
Rose Stamler, Martin Shipley, Paul Elliott, Alan Dyer, Susana Sans, and Jeremiah Stamler
on behalf of the INTERSALT Cooperative Research Group

An inverse association between social class and disease has frequently been reported; education, an indicator of social class, was negatively related to blood pressure in several studies. Reasons are not clear. INTERSALT, an international study on electrolytes and blood pressure, obtained data on years of education for 10,079 adults in 52 centers in 32 countries. Data presented here are for 47 centers, omitting five where the population in the sample had no education or no differences in educational level. Regression coefficients were calculated for the education-blood pressure association in each center. An inverse association was found for men in 28 centers and for women in 38. Center coefficients were combined to give a studywide estimate of that association. When adjusted only for age, systolic pressure in men was 1.3 mm Hg higher for 10 fewer years of education (p<0.05) and for women 4.5 mm Hg higher (p<0.001). However, when adjusted also for five lifestyle factors (24-hour sodium and potassium excretion, body mass index, alcohol intake, and smoking), these estimates were reduced by about one half, and the inverse association was no longer significant for men. Similar findings were obtained for diastolic pressure. Those with less education had on average higher sodium excretion, lower potassium excretion, greater body mass, and higher alcohol intake, all factors tending to increase blood pressure. Improvement of these factors, which help explain the differences in blood pressure related to years of education, has the potential to reduce the blood pressure disadvantage associated with lower socioeconomic status.

(Key Words: population studies • blood pressure • educational status • socioeconomic status)

That persons in lower socioeconomic strata have higher rates of disease and mortality at all ages has been known quantitatively at least since public health records have been kept and known qualitatively for even longer.1-7 In recent years, several population studies have reported that persons of higher education tended, on average, to have lower blood pressure as well as lower prevalence rates of hypertension than those with less education.8-11 It is unlikely that the mere act of sitting in a classroom for more years would in itself produce lower average blood pressure; a more credible explanation is that education, a marker of socioeconomic status, is associated with habits of lifestyle that help account for differences in blood pressure. Certainly, in the past, differing patterns of nutrition, of sanitation, and of housing and work conditions were major contributors to social differentials in disease and health.1,12,13

Could lifestyle differences, particularly nutritional ones, also help explain the reported social differences in blood pressure levels? Is this social difference in blood pressure a common phenomenon shared by many populations? These two questions were examined using data from INTERSALT, an international collaborative study on the relation of electrolytes and other factors to blood pressure.

(Methods)
The methods and main findings of the INTERSALT study have been extensively reported.14-18 This cross-sectional study was the largest of its type; 10,079 men and women aged 20-59 years participated at 52 centers in 32 countries, covering a wide range of cultures and lifestyles, including dietary patterns. A detailed standardized protocol formed the basis of pre-study training of local investigators by the study's two coordinating centers (London and Chicago) and of ongoing quality control during the study. Electrolyte intake was assessed (with analysis in a central laboratory in Leuven, Belgium) through measurement of excretion in timed 24-hour urine collections. Blood pressure was measured...
with a random zero sphygmomanometer by trained and certified observers. The mean of two measurements was used for these analyses. Other variables likely to be related to blood pressure were also measured using standardized methods (e.g., alcohol intake in the previous 7 days ascertained through a questionnaire, and body mass index [kg/m²]). In addition, information on demographic and social factors was obtained from participants, including reported number of years of education completed, as an indicator of socioeconomic status.

Statistical Methods

The size and standardization of procedures in INTERSALT resulted in effect in 52 simultaneous studies, each of approximately 200 persons randomly selected from defined populations. These features permitted the analysis of relations both across populations and within populations. For the present report, linear regression analyses were performed within each center for the relation between blood pressure and years of education; age-adjusted coefficients were computed separately for men and women. To obtain a studywide estimate of the relation between individual pressure and education, the age-adjusted within-center coefficients were combined (pooled), with each center coefficient being weighted by the inverse of its variance, to reduce variance of the pooled coefficient. The standard error of the pooled coefficient was computed, and 95% confidence intervals (CI) were calculated. A z score (the ratio of the coefficient to its standard error) was calculated to test for statistical significance.

Partial correlations, adjusted for age, were used to assess the relation to education to several blood pressure–related lifestyle variables: body mass index, 24-hour urinary excretion of sodium and potassium, alcohol intake, and cigarette smoking. Within-center coefficients were then recalculated, adjusting for these variables. The within-center adjusted coefficients were then again pooled as above.

Analyses were done first with all participants included and then excluding those on antihypertensive treatment since their "true" pressures were unknown. Educational status of those on medication was compared with those not on medication to rule out any bias arising from this procedure. Data on education were obtained both as years of education completed and as school category (e.g., elementary, high school, college, university). The variable in the present analysis is years of education since using this continuous distribution requires fewer assumptions than equating categories of schooling in different countries. In five of the 52 centers, there was either no or almost no formal education (the Xingu and Yanomamo of Brazil, the Papua New Guinea highlanders, and in Ladakh, India) or little variation in the amount of education among the center's participants (New Delhi, India). Since these analyses are based on within-center differences in years of education, these five centers could not be included. Within and across the remaining 47 centers, there was considerable variation in number of years of education. Mean number of years ranged across centers from 2.6 to 17.4. Coefficients of variation within centers averaged 36.6% for men and 39.6% for women. The number of participants in the 47 centers totaled 9,125 when all persons were included in the analysis and 8,477 when those currently on antihypertensive medication were excluded.

Results

INTERSALT found an inverse association between years of education and both systolic and diastolic blood pressures in a majority of the populations studied (Table 1). Age-adjusted regression coefficients for the education–systolic blood pressure relation in men were negative in 28 of the 47 centers, significantly so in three of them. There were 19 centers where this coefficient was positive, with two of them significant. The within-center coefficients were pooled to give studywide estimates of the education–blood pressure association. The pooled coefficients for the relation of years of education to individual systolic pressure in men gave a significant studywide negative coefficient of -0.13 (95% CI, -0.25 to -0.01). This coefficient indicates that for every additional year of education, systolic pressure was approximately 0.13 mm Hg lower; when men on medication were excluded, this was reduced to 0.09 mm Hg lower, a difference no longer statistically significant. In women, the inverse association of education with systolic blood pressure was stronger than for men, with 38 of 47 centers having negative regression coefficients

### Table 1. Relation of Education to Blood Pressure in INTERSALT: Within-Center Regression of Blood Pressure on Years of Education, Adjusted for Age

<table>
<thead>
<tr>
<th>Centers and coefficients</th>
<th>Systolic BP</th>
<th>Diastolic BP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>Centers with negative coefficient (No.)</td>
<td>28 (38)</td>
<td>26 (28)</td>
</tr>
<tr>
<td>Centers with p&lt;0.05 (No.)</td>
<td>3 (9)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Pooled coefficient (standard error)</td>
<td>-0.130 (0.061)</td>
<td>-0.071 (0.046)</td>
</tr>
<tr>
<td>z=</td>
<td>-2.13*</td>
<td>-1.54</td>
</tr>
</tbody>
</table>

Values for coefficients and standard errors are millimeters of mercury per year of education. BP, blood pressure. *p<0.05, †p<0.01, ‡p<0.001.
In this multivariate analysis, although the negative education–blood pressure relation was still present, its magnitude was diminished (Table 3). The effect of these education-related lifestyle variables on the inverse education–blood pressure association is demonstrated in Table 4. The coefficients are expressed as the differences in blood pressure (in mm Hg) associated with 10 more years of education, first when adjusted only for age, and then also for the foregoing lifestyle variables. For the education–systolic blood pressure relation in men, with multivariate adjustment compared with adjustment for age only, the inverse association is reduced by almost one half and is no longer statistically significant. A reduction is also seen with multivariate adjustment among women, but there is still a significant inverse association of years of education and systolic blood pressure. For diastolic pressure, multivariate adjustment reduces the negative association for both sexes, and this association is not statistically significant for either sex.

To determine whether, in repeat analyses, exclusion of the 648 persons on antihypertensive medication introduced bias, their educational level was compared with the remaining 8,477. The age-adjusted difference in years of education in the treated versus untreated men and women was less than one third year (not significant) (data not shown).

**Discussion**

INTERSALT, based on a large population sample from 29 countries, found higher blood pressure for those with less education in a variety of social settings, including both highly industrialized and less industrialized populations. A key finding is that close to one half of the education-related differences in blood pressure can be explained by differences in lifestyle, particularly in nutrition and nutrition-related factors, along the gradient of educational level. Those with fewer years of education had, on average, higher intake of sodium, lower intake of potassium, greater body mass, and higher alcohol consumption. These factors help explain differences in blood pressure related to years of education.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index (kg/m²)</td>
<td>-0.036*</td>
<td>-0.137†</td>
</tr>
<tr>
<td>24-hr sodium excretion (mmol)</td>
<td>-0.037*</td>
<td>-0.068†</td>
</tr>
<tr>
<td>24-hr potassium excretion (mmol)</td>
<td>0.041†</td>
<td>0.030</td>
</tr>
<tr>
<td>Cigarette smoking (1=smoker, 0=non-smoker)</td>
<td>-0.116†</td>
<td>-0.062†</td>
</tr>
<tr>
<td>Alcohol (milliliters per week)</td>
<td>-0.066†</td>
<td>0.036*</td>
</tr>
</tbody>
</table>

*(p<0.05, †p<0.001).

(nine of them significant) and nine having positive regression coefficients (two significant). The combined studywide coefficient (−0.45, with 95% CI from −0.59 to −0.31) indicates that for each additional year of education, systolic pressure in women was 0.45 mm Hg lower. When women currently on antihypertensive medication were excluded, this coefficient was reduced (to −0.32) but remained significant (p<0.01). There was also an inverse association between years of education and diastolic pressure; this association was weaker than for systolic pressure.

Education was also found to be associated with several other variables previously reported in INTERSALT and in other studies to be related significantly to blood pressure: body mass, alcohol intake, 24-hour urinary sodium, and (inversely) potassium excretion. In the present age-adjusted analysis (Table 2), it was found that the higher the education, the lower the sodium excretion, body mass index, and alcohol intake (in men) and the higher the potassium excretion. These findings therefore made it important to determine the degree to which these lifestyle factors accounted for the inverse education–blood pressure association. The regression analyses were repeated with control not only for age but also for 24-hour urinary excretion of sodium and potassium, for body mass index, and for reported alcohol intake. To remove its possible confounding effect, smoking was also included in the multivariate analysis, since it too is related to education (inversely) (Table 2).

**TABLE 2. Partial Correlation Coefficients Between Lifestyle Variables and Years of Education, Age-Adjusted**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index (kg/m²)</td>
<td>-0.036*</td>
<td>-0.137†</td>
</tr>
<tr>
<td>24-hr sodium excretion (mmol)</td>
<td>-0.037*</td>
<td>-0.068†</td>
</tr>
<tr>
<td>24-hr potassium excretion (mmol)</td>
<td>0.041†</td>
<td>0.030</td>
</tr>
<tr>
<td>Cigarette smoking (1=smoker, 0=non-smoker)</td>
<td>-0.116†</td>
<td>-0.062†</td>
</tr>
<tr>
<td>Alcohol (milliliters per week)</td>
<td>-0.066†</td>
<td>0.036*</td>
</tr>
</tbody>
</table>

*(p<0.05, †p<0.001).

In this multivariate analysis, although the negative education–blood pressure relation was still present, its magnitude was diminished (Table 3). The effect of these education-related lifestyle variables on the inverse education–blood pressure association is demonstrated in Table 4. The coefficients are expressed as the differences in blood pressure (in mm Hg) associated with 10 more years of education, first when adjusted only for age, and then also for the foregoing lifestyle variables. For the education–systolic blood pressure relation in men, with multivariate adjustment compared with adjustment for age only, the inverse association is reduced by almost one half and is no longer statistically significant. A reduction is also seen with multivariate adjustment among women, but there is still a significant inverse association of years of education and systolic blood pressure. For diastolic pressure, multivariate adjustment reduces the negative association for both sexes, and this association is not statistically significant for either sex.

To determine whether, in repeat analyses, exclusion of the 648 persons on antihypertensive medication introduced bias, their educational level was compared with the remaining 8,477. The age-adjusted difference in years of education in the treated versus untreated men and women was less than one third year (not significant) (data not shown).
verse education-blood pressure association may lie with psychosocial) not measured in the study but related to
ences. It is also possible that other factors (e.g.,
fection of the observed remaining blood pressure differ-
macronutrients and micronutrients may add to explana-
frozen stored urine aliquots. For example, social differ-
other factors, particularly nutritional, not measured in
methodological reasons, and this too would tend to
pressure relation for such factors may be inadequate for
underestimate their contribution to that relation.21
Changes have occurred, particularly in those with higher pressure.
There are at least two possible explanations for the
inversely related blood pressure differential than was observed in
untreated persons. However, this could not account for
the main findings presented here since the same phe-
nomenon was observed with and without treated indi-
viduals, namely, when lifestyle factors were controlled
for, the inverse education-blood pressure association
was reduced.
Based on the current findings, a reasonable inference is that lower intake of sodium, less overweight, lower alcohol consumption, and higher potassium intake could narrow to some degree the education-related blood pressure differences. Long-term population studies have documented that differences in average population pressure are associated with measurable differences in mortality (e.g., a 2–3 mm Hg lower average population systolic pressure predicts a 4–6% lower coronary death rate and a 6–9% lower stroke death rate).18 Thus, improved nutrition has the potential to reduce the observed education-related differential in cardiovascular risk.

### Acknowledgments

INTERSALT was launched under the auspices of the Council on Epidemiology and Prevention of the International Society and Federation of Cardiology (ISFC). The members of the Executive Committee of INTERSALT are Professors Geoffrey Rose and Jeremiah Stamler (principal investigators), Professor Rose Stamler, Dr. Paul Elliott (coordinator), Professor Michael Marmot, Professor Kalevi Pyorala (Council on

<p>| Table 4. Differences in Blood Pressure Associated with 10 Years More Education: Pooled Within-Center Regression Coefficients for Blood Pressure of Individuals and Years of Education, Adjusted for Age Only and Adjusted for Multiple Variables |</p>
<table>
<thead>
<tr>
<th>Blood pressure variable</th>
<th>All persons</th>
<th>Excluding those on antihypertensive therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difference</td>
<td>(SE)</td>
</tr>
<tr>
<td><strong>Systolic BP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted</td>
<td>-1.30*</td>
<td>(0.61)</td>
</tr>
<tr>
<td>Multivariate adjusted</td>
<td>-0.69</td>
<td>(0.62)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted</td>
<td>-4.47†</td>
<td>(0.71)</td>
</tr>
<tr>
<td>Multivariate adjusted</td>
<td>-2.89†</td>
<td>(0.73)</td>
</tr>
<tr>
<td><strong>Diastolic BP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted</td>
<td>-0.71</td>
<td>(0.46)</td>
</tr>
<tr>
<td>Multivariate adjusted</td>
<td>-0.57</td>
<td>(0.47)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age adjusted</td>
<td>-1.62†</td>
<td>(0.48)</td>
</tr>
<tr>
<td>Multivariate adjusted</td>
<td>-0.74</td>
<td>(0.50)</td>
</tr>
</tbody>
</table>

Multivariate analyses are adjusted for age, body mass index, 24-hour excretion of sodium and potassium, smoking, and alcohol intake. Values for differences and standard errors are millimeters of mercury per 10 years of education (standard error of the difference). BP, blood pressure; SE, standard error of the difference.

*p<0.05, *p<0.01, tp<0.001.
Epidemiology and Prevention, ISFC), Professors Hugo Kesteloot and Josef Joossens (central laboratory), Professor Giuseppe Mancia (Council on Hypertension, ISFC), Professors Alan Dyer, Daan Kromhout, and Ulrich Laaser, and Dr. Susana Sans.

We gratefully acknowledge the work of the local INTERSALT investigators in 52 population samples in 32 countries worldwide. A full list of these investigators and key local staff members is published in the British Medical Journal 1988;297:327–328.

References
Higher blood pressure in adults with less education. Some explanations from INTERSALT.
R Stamler, M Shipley, P Elliott, A Dyer, S Sans and J Stamler

doi: 10.1161/01.HYP.19.3.237
Hypertension is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1992 American Heart Association, Inc. All rights reserved.
Print ISSN: 0194-911X. Online ISSN: 1524-4563

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://hyper.ahajournals.org/content/19/3/237

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Hypertension can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Hypertension is online at:
http://hyper.ahajournals.org/subscriptions/