Blood Pressure in Four Remote Populations in the INTERSALT Study


Four remote population samples (Yanomamo and Xingu Indians of Brazil and rural populations in Kenya and Papua New Guinea) had the lowest average blood pressures among all 52 populations studied in INTERSALT, an international cooperative investigation of electrolytes and blood pressure. Average systolic blood pressure was 103 versus 120 mm Hg in the remaining INTERSALT centers; diastolic blood pressure in these four population samples averaged 63 versus 74 mm Hg in the 48 other centers. There was little or no upward slope of blood pressure with age; hypertension was present in only 5% of the rural Kenyan sample and virtually absent in the other three centers. Also in marked contrast with the rest of the centers was level of daily salt intake, as estimated by 24-hour urinary sodium excretion. Median salt intake ranged from under 1 g to 3 g daily versus more than 9 g in the rest of INTERSALT populations. Average body weight was also low in these four centers, with no or low average alcohol intake, again unlike the other centers. The association within these four centers between the above variables and blood pressure was low, possibly reflecting their limited variability. While several other INTERSALT centers also had low average body weight or low prevalence of alcohol drinking, when this was accompanied by much higher salt intake (7–12 g salt or 120–210 mmol sodium daily), hypertension prevalence ranged from 8% to 19%. These findings confirm previous reports that in populations with a low salt intake, there is little or no hypertension or rise of blood pressure with age. While the contributory role of other characteristics of these populations must also be considered, the results are consistent with the view that a certain minimum salt intake is essential for rise in blood pressure with age in adults and a high frequency of hypertension in populations. (Hypertension 1989;14:238–246)

Individual epidemiological studies in several isolated populations have, over many years, reported low average blood pressures and little variation in blood pressure with age.1–13 An opportunity to assess these observations in simultaneous investigations using standardized methods, as well as to investigate possible explanatory factors, was provided by the INTERSALT study. INTERSALT, a multicenter international cooperative cross-sectional study focusing on relations between electrolytes and blood pressure, was comprised of 52 samples from 32 countries in North and South America, Europe, Africa, Asia, and the Pacific.14 Four remote population samples (Yanomamo and Xingu Indians of Brazil, rural populations in Kenya and Papua New Guinea) had the lowest average blood pressures among all populations studied in INTERSALT, as well as little or no increase of blood pressure with age.

The present report describes the blood pressure pattern and other characteristics of each of these samples.
four samples, including urinary electrolytes, body mass index (BMI), pulse, and alcohol.

Participants and Methods

Population Samples

The Yanomamo sample was composed of all adults from three villages located on the Surucucu plateau in northern Brazil. These villages were 8 hours walking distance from a Government Health Station in the area. The Yanomamo Indians are one of the most unacculturated native tribes in South America and possibly in the world. They live in an area of about 200,000 km² located along the border of Brazil and Venezuela. The total population consists of approximately 18,000 individuals, scattered throughout the Amazon rain forest in 200 or so villages composed of 40 to 250 people each. The Yanomamo are generally seminomadic, slash-and-burn agriculturalists who live on a diet of locally produced crops and game supplemented by wild fruits and insects. Dietary staples consist of cooked banana and manioc (cassava). In most villages there is little if any access to salt, refined sugar, alcohol, milk, or other dairy products.

The Xingu sample was obtained by random sampling from 10 native Indian tribes in the "Parque Indigena do Xingu" (PIX). The PIX occupies an area of 22,000 km² in the central region of Brazil. The 10 Indian tribes involved in the study have their own villages of approximately 150 inhabitants each. Each tribe still preserves its own language and, although less isolated than the Yanomamo, do not maintain regular contact with non-Indians. The diet of Xingu Indians is principally based on manioc (cassava) and fish. The consumption of meat from game animals is free in some tribes and restricted by taboos in others. The diet also includes, to a lesser extent, corn, sweet potatoes, cara, peanuts, bananas, and wild fruit. Salt and other foods sold in stores are not used regularly.

The sample from Papua New Guinea was obtained by random sampling from the rural villages of Kamus and Gimisave in the Asaro Valley of the Eastern Highlands Province of Papua New Guinea. The Kamus group consists of 569 persons living in five small hamlets that are approximately a 60-minute walk from the highlands highway and are located at altitudes ranging from 6,000 to 6,600 feet above sea level. The economy is based on small-holder coffee gardens and subsistence agriculture to provide food. The main staple is the sweet potato. Health services and a school for primary education are provided in another village at a 30-minute walking distance. Of the two groups, the Kamus are more traditional than the Gimisave; they rely more on subsistence agriculture and have fewer men in paid jobs and fewer women who have attended school. The Gimisave villages (population 594) are closer to the highway and the inhabitants have greater contact with a more modern lifestyle. There is less reliance on subsistence agriculture, consumption of "store" foods, beer, and cigarettes is higher, and betel nut chewing is more common than among the Kamus group.

The Kenyan sample was obtained by random selection of households. The population from which the sample was drawn consisted of the 1,500 inhabitants and 320 households in the rural villages of Rambugu and Ndori, which are located just north of Lake Victoria in western Kenya. About 85% of adults engage in subsistence farming and are exclusively from the Luo tribe.

Each center was asked to recruit 200 men and women aged 20–59 years, 25 in each of eight age and sex groups. In each center a number of participants were excluded, most due to incomplete urine collection (based on self-reported incompleteness or because total urine volume was less than 250 ml). A small number were excluded because of pregnancy.

Data Collection

The Study's two Coordinating Centers, in London and Chicago, were responsible for development of standardized procedures and training local investigators. Details of INTERSALT methods have been published.15 Standardized techniques were used for blood pressure measurement and for collection of 24-hour and casual urine samples.

For these four centers, interviews were conducted with the help of interpreters. Where participants did not know their ages, criteria for estimation of age were physical appearance, number and age of children, personal knowledge of the interpreters, and calendars of local events. Two blood pressure measurements were made, with the participant in a sitting position, by observers previously trained and certified in INTERSALT procedures. A random zero sphygmomanometer and the bell of a Littmann stethoscope were used. The mean of the two readings was the blood pressure of record. Participants refrained from strenuous activity or eating for at least 30 minutes before measurement; they emptied their bladders and then sat quietly for 5 minutes. A range of blood pressure cuffs was available to allow for differences in arm circumference. Systolic blood pressure (SBP) was recorded as the appearance of sound and diastolic blood pressure (DBP) as the disappearance of sound. Height and weight were also measured twice, using a stadiometer and a portable scale, calibrated daily.

For the 24-hour urine collection, standard 1 liter, wide-mouthed plastic jars, containing boric acid as preservative, were supplied (along with a funnel for women). Participants were carefully instructed on the need to collect all urine passed during 24 hours. Aliquots of urine samples were refrigerated at 4°C within 24 hours and frozen at -20°C within 7 days. During transportation and shipment to the Central Laboratory in Belgium the aliquots of urine were maintained frozen inside styrofoam boxes containing dry ice.
TABLE 1. Blood Pressure Patterns by Sex in Four Remote INTERSALT Populations

<table>
<thead>
<tr>
<th>BP variable by sex</th>
<th>Yanomamo (n=195)</th>
<th>Xingu (n=198)</th>
<th>Papua New Guinea (n=162)</th>
<th>Kenya (n=176)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic (mm Hg)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>101.3 (9.3)</td>
<td>103.3 (12.0)</td>
<td>109.6 (11.6)</td>
<td>114.3 (14.5)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>90.6 (7.8)</td>
<td>96.2 (9.0)</td>
<td>106.4 (12.1)</td>
<td>107.9 (15.7)</td>
</tr>
<tr>
<td>Diastolic (mm Hg)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>64.7 (8.5)</td>
<td>65.2 (7.7)</td>
<td>64.4 (9.6)</td>
<td>67.0 (15.2)</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>56.5 (7.5)</td>
<td>59.2 (7.8)</td>
<td>61.0 (10.3)</td>
<td>64.7 (15.1)</td>
</tr>
<tr>
<td>Percent hypertensive†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>0.0</td>
<td>1.0</td>
<td>0.8</td>
<td>5.0</td>
</tr>
<tr>
<td>Diastolic</td>
<td>+0.6</td>
<td>-0.4</td>
<td>-0.4</td>
<td>+1.3</td>
</tr>
</tbody>
</table>

*Values are mean±SD. BP, blood pressure.
†Hypertension defined as systolic blood pressure ≥140 or diastolic blood pressure ≥90 mm Hg.
‡Corrected for body mass index and sex.

All electrolyte analyses were carried out by the Central Laboratory, Department of Epidemiology, St. Rafael University, Leuven, Belgium. Sodium and potassium were analyzed by emission flame photometry, chloride by the Cotlove method, calcium and magnesium by atomic absorption flame photometry, and creatinine by the Jaffe method. In addition to internal laboratory controls, quality control was also monitored in the London Coordinating Center by comparison of results on anonymous split samples.

Individual electrolyte excretion was computed as the product of electrolyte concentration in the urine and urinary volume corrected to 24 hours. BMI was calculated as weight (kg) divided by height² (m²).

Results

Descriptive Statistics

Blood pressure. Mean SBPs were low in all four centers, particularly among the two Indian population samples in Brazil (101 and 103 mm Hg in men, 91 and 96 mm Hg in women) (Table 1). The combined average for the four centers was 103 mm Hg. In contrast, mean SBP in the remaining 48 INTERSALT centers was 120 mm Hg. Mean DBPs were also low in all four centers (57–67 mm Hg) (Table 1). Again, these levels were considerably lower than the average observed in other INTERSALT samples (74 mm Hg). In all four samples, with average age approximately 39 years, mean levels for men were higher than for women in both systolic and diastolic pressure.

Hypertension, defined as SBP 140 mm Hg or greater or DBP 90 mm Hg or greater, was completely absent among the Yanomamo, virtually absent among the Xingu and Papua New Guineans (0.8–1.0%) and low among the Kenyans (5%) (Table 1). The distribution of blood pressure values was similar among the four centers (Figure 1), except that in the Kenya sample, this distribution was shifted upward compared with the others and, as noted, there were a few persons (nine) in that

![FIGURE 1. Line graph of blood pressure distributions in the four populations; percent at given levels of diastolic and systolic pressure.](http://hyper.ahajournals.org/DownloadedFrom)
sample at hypertensive levels. Variation in blood pressure values, as reflected both in the magnitude of the standard deviations (Table 1) and the shape of the distribution curves (Figure 1), was generally smaller than observed in the 48 other INTERSALT centers.14 Again, variation in the Kenya sample was smaller than observed in the 48 other INTERSALT centers. The level in the Xingu sample (mean of 166 and median of 51.3) was higher than in the other three small-village population samples, it was still only about a third of the average level in the rest of the INTERSALT sample, the positive slope with age was smaller than the average for the remaining INTERSALT centers (close to 4 mm Hg).

**Urinary electrolytes.** Mean 24-hour urinary sodium in the Yanomamo sample (0.8 mmol in men and 1.0 mmol in women) was at the lower limit of measurability by the flame photometer (Table 2). Only nine persons in that sample had values higher than 5 mmol (the maximum was 27 mmol), and median output was 0.2 mmol. The Xingu also had very low mean 24-hour sodium excretion (11 mmol for women and 14 mmol for men) as did the Papua New Guinean sample (32 mmol for women, 43 mmol for men). Median levels were 5.8 and 26.8 mmol in these two samples. Although daily sodium excretion in Kenya (means of 53 and 60 mmol and median of 51.3) was higher than in the other three small-village population samples, it was still only about a third of the average level in the rest of the INTERSALT sample (mean of 166 and median of 160 mmol/24 hr).14

Urinary potassium excretion in three of the centers was relatively high (60–96 mmol/24 hr) (Table 2). These levels exceeded the mean potassium value of 54 mmol observed in the 48 other INTERSALT centers and used here for comparison. The level in Kenya, 32 mmol in men and 35 mmol in women,

**TABLE 2.** Urinary Variables in Four Remote INTERSALT Populations

<table>
<thead>
<tr>
<th>Variables</th>
<th>Yanomamo (n=195)</th>
<th>Xingu (n=196)</th>
<th>Papua New Guinea (n=162)</th>
<th>Kenya (n=176)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men (n=99)</td>
<td>Women (n=96)</td>
<td>Men (n=99)</td>
<td>Women (n=99)</td>
</tr>
<tr>
<td>Urinary Na (mmol/24 hr)</td>
<td>0.8 (1.8)</td>
<td>1.0 (3.1)</td>
<td>13.6 (25.2)</td>
<td>11.0 (17.0)</td>
</tr>
<tr>
<td>Urinary K (mmol/24 hr)</td>
<td>66.9 (35.4)</td>
<td>59.7 (28.1)</td>
<td>95.6 (40.8)</td>
<td>78.5 (46.0)</td>
</tr>
<tr>
<td>Urinary Na/K ratio</td>
<td>0.02 (0.03)</td>
<td>0.02 (0.01)</td>
<td>0.20 (0.53)</td>
<td>0.19 (0.31)</td>
</tr>
<tr>
<td>Urinary Cl (mmol/24 hr)</td>
<td>6.9 (7.4)</td>
<td>5.5 (4.8)</td>
<td>31.1 (31.6)</td>
<td>24.6 (29.9)</td>
</tr>
<tr>
<td>Urinary Ca (mmol/24 hr)</td>
<td>0.5 (0.1)</td>
<td>0.4 (0.5)</td>
<td>1.6 (1.2)</td>
<td>0.9 (0.9)</td>
</tr>
<tr>
<td>Urinary Mg (mmol/24 hr)</td>
<td>3.3 (1.9)</td>
<td>3.3 (1.7)</td>
<td>5.6 (2.3)</td>
<td>4.0 (1.9)</td>
</tr>
<tr>
<td>Urinary Cr (mg/24 hr)</td>
<td>4.5 (2.3)</td>
<td>4.0 (2.0)</td>
<td>11.6 (3.3)</td>
<td>7.2 (2.8)</td>
</tr>
<tr>
<td>Urinary vol (1/24 hr)</td>
<td>1.41 (0.60)</td>
<td>0.73 (0.22)</td>
<td>1.86 (0.77)</td>
<td>1.30 (0.77)</td>
</tr>
</tbody>
</table>

Values are mean±(SD). Cr, creatine; vol, volume.
was below that of the other remote population samples and of the average INTERSALT value for potassium.

Reflecting the generally low level of sodium and high level of potassium excretion (except for Kenya), the sodium/potassium ratio was low (Table 2). In three of these centers, the ratio was below 1.0. In no other INTERSALT center was a ratio less than 1.0 observed. In Kenya, this ratio was approximately 1.9; in the remaining 48 centers, mean sodium/potassium ratio was 3.4.

Levels of urinary chloride were similar to those of sodium: lowest in the Yanomamo (about 6 mmol), highest in the Kenya sample (58 and 68 mmol) (Table 2), but all lower than the mean level found in the remaining 48 samples (171 mmol). Excretion of calcium and magnesium was also low. Urinary creatinine was lower than in almost all other centers, and was lowest in the Yanomamo who are generally of small body build. In the Xingu and Kenya samples and among Yanomamo men, urinary volume was similar to that of other centers, but was lower than average in Papua New Guinea and among Yanomamo women. This could reflect low fluid intake, sweat loss, or incomplete collections in some individuals.

In almost all urinary measurements, values in women were lower than those among men.

**Body mass index, pulse, and alcohol.** Mean BMI was low in all groups (20.6–22.6) except for Xingu men (24.2) (Table 3). In the remaining 48 centers, mean BMI was 25.2, markedly higher than in three of the small-village centers. Even among the shorter Yanomamo, very low body weight (42–50 kg) resulted in a low BMI. Except for Kenya, mean BMI was higher in men than in women. Mean pulse, however, was higher in women in all four samples.

In regard to alcohol (not shown), neither the Yanomamo nor the Xingu drink alcoholic beverages, and the proportions of individuals reporting consumption of alcohol were low in the Papua New Guinea (8.7%) and Kenya samples (30.7%). In the remaining INTERSALT centers, 53% reported consumption of alcohol. Among drinkers, the median reported intake was 85 ml alcohol/wk in Papua New Guineans; among Kenyan consumers of alcohol, median weekly intake was 122 ml alcohol, not very different from the median level among drinkers in the remaining centers (131 ml).14

**Relation of Sodium Excretion to Blood Pressure**

In view of the limited variation in both mean sodium excretion and blood pressure, it was not likely that there would be a significant association within each center between the two variables. Although the confidence intervals around the regression coefficients for these centers generally included the value of the overall INTERSALT coefficient, only a low-order association was seen in regression analysis between sodium and blood pressure when controlled for age-sex or alcohol, BMI, and potassium. However, when the blood pressure means in these four small-village samples were plotted against the centers’ mean 24-hour urinary sodium excretions, blood pressure increased in a pattern consistent with increased sodium means, being lowest in the Yanomamo and highest in the Kenya sample (Figure 3). This relation was stronger for systolic than diastolic pressure. The Kenya sample, highest in sodium and lowest in potassium, also showed a significant association between the sodium/potassium ratio of individuals and their systolic pressure.

**Relation of Other Factors to Blood Pressure**

Within these centers, BMI was positively associated with blood pressure in seven of the eight analyses (i.e., of SBP and DBP in the four centers), significantly so in the Yanomamo (both SBP and DBP) and Kenyans (DBP). Pulse, like BMI, was positively associated with blood pressure (in all eight analyses), significantly so in the Yanomamo and also in the Xingu sample (DBP). Alcohol, low or not used in these centers, was not associated significantly with blood pressure.

Regression coefficients of blood pressure on urinary potassium were negative in seven of the eight within-center analyses, significantly so only for DBP in the Yanomamo. All remaining coefficients of blood pressure with urinary electrolytes...
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populations. villages consumed virtually no salt, while the Xingu

... was lower, and alcohol intake, if any, was also lower than in other centers. However, among INTERSALT samples overall, low body weight was not in itself observed to be a sufficient assurance of low prevalence of hypertension; several other INTERSALT centers (e.g., Colombia, South Korea, Taiwan, and six of the eight centers in Japan, China, and India) with low mean BMI similar to those in the four remote population samples (20.0–23.1) but with high salt intake (8–12 g daily) had prevalence rates of hypertension of 8–18%. Nor was low alcohol intake, in itself, a sufficient assurance against hypertension; five INTERSALT centers reported prevalence of drinking at or lower than the proportion in Kenya (30.7%, highest among the remote population samples). However, these five centers also had salt intake of 7–12 g daily and prevalence rates of hypertension of 8–19%.

The conclusion from the overall INTERSALT study, as well as from the findings in the present report, that habitual high salt intake is a critical environmental factor contributing to rise in blood pressure and high prevalence rates of hypertension in populations, is supported by data from other research methodologies. These include animal experimentation with hypertension induction by high salt feeding, early trials on severe sodium restriction in hypertensive patients, and more recent trials with more moderate salt restriction.24–30

Overall in the INTERSALT study, a significant positive association within centers was found between 24-hour urinary sodium excretion, BMI, excess alcohol intake, and systolic blood pressure of individuals and a significant negative association of urinary potassium with blood pressure. Within the four isolated centers, such significant associations were generally not found; it is the authors’ judgment that this could be a consequence of the small variation within the centers both in the characteristics reflecting lifestyle and in blood pressure. In these populations, therefore, the role of such factors as low sodium intake, high potassium intake, low alcohol, and low body weight is chiefly shown in the ecological finding of little or no hypertension and little or no rise in blood pressure with age. This is not the first observation of these patterns of blood pressure in such populations,1–13 but the standardized methods used across all INTERSALT centers and the ability to compare contemporaneous measurements over a wide range of the variables studied add strength and depth to the earlier findings. It may well be that other factors not measured in this study also have relevance to the blood pressure

(chloride, calcium, magnesium) were small and nonsignificant.

Discussion

In the INTERSALT study, it was possible to examine patterns of blood pressure and the factors possibly associated with these patterns in four remote populations and to compare them with other population samples examined contemporaneously and using the same methods. The key findings in the four remote population samples were low average blood pressures, absence or near absence of hypertension or rise of blood pressure with age. These patterns were in marked contrast with findings in the remaining 48 INTERSALT centers.

Also in marked contrast was the level of sodium intake, as assessed in carefully timed 24-hour urine collections. When the sodium values are converted to salt, those individuals studied in the Yanomamo villages consumed virtually no salt, while the Xingu Indians had a median intake of about one third gram salt daily. Those in the sample from Papua New Guinea had a median consumption of 1.5 g salt daily. The highest consumers among these four populations, the Kenya sample, had a median intake under 3 g/day. This contrasts with the median level of more than 9 g salt in the rest of INTERSALT.

In Kenya, where migration to the cities has an increasing impact on those remaining in the rural communities,12 intake of sodium was much higher than in the other three remote population samples, potassium was lower, and the sodium/potassium ratio was markedly greater. Parallel with these differences were the differences in blood pressure in the Kenya sample: higher mean levels of SBP and DBP, wider variation in the distribution, 5% with
findings. These four have other characteristics that may also relate to blood pressure level: high intake of fiber, low intake of saturated and total fats, and relatively high level of physical activity. Their social structure and daily life patterns are also distinctive. The findings of Page et al may have relevance here: in comparing blood pressure levels among six Solomon Islands populations similar in such aspects of lifestyle, they found that hypertension was virtually absent in all but the one population using salty inlet water for cooking.

Some investigators have suggested that the absence of blood pressure rise in such populations may be due to chronic disease or malnutrition. However, adults in the four remote population samples were physically active and generally appeared healthy, and no physical signs of evident malnutrition or protein deficiency were found. Truswell et al and Page et al also found generally good nutritional status among similar populations with little or no hypertension or rise of pressure with age.

Based on the study of these four centers and in their comparison with the remaining 48 centers, we conclude that, with a habitual low salt intake over the life span, there is little or no hypertension or rise of blood pressure with age. Although other characteristics of these four populations may have also played a contributory role, the findings in these centers are consistent with the view that a certain minimum intake of salt is required to produce a high frequency of hypertension in populations. As reported earlier, in the remaining 48 INTERSALT centers with higher salt intake, a positive association was found between sodium excretion and blood pressure of individuals, as well as rise of pressure with age. Those overall findings indicate the potential for lower average population pressure with lowered salt intake, even where such intake is above that of the four very low sodium populations reported on here.

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C. Westbrook; United States (Goodman, two cen-
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Members of the Chicago Coordinating Center were:
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Members of the Central Laboratory (Leuven)
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