Determinants of Hypertension in West Africa: Contribution of Anthropometric and Dietary Factors to Urban-Rural and Socioeconomic Gradients

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The determinants of hypertension in West Africa have not been well defined. The authors sampled 598 participants aged 45 years or more from a recent population-based survey in southwest Nigeria (190 rural men and women, 205 urban poor men and women, and 203 retired railway workmen). The estimated mean age was 61 (10) years. Mean pressures were low relative to westernized societies: systolic blood pressure = 124 (24) mmHg, diastolic blood pressure = 72 (13) mmHg. Both men and women were remarkably lean: body mass index = 21.3 (3.6) and 23.0 (5.2) kg/m^2, respectively. Hypertension prevalence increased across the gradient from rural farmers to urban poor to railway workers: 14, 25, and 29 percent, respectively, had a blood pressure of 140/90 mmHg or greater, and 3, 11, and 14 percent, respectively, had a blood pressure of 160/95 mmHg or greater (p for trend < 0.01 for both cutpoints). On the basis of a 24-hour urine sample, daily electrolyte excretion was 110 (57) mEq of sodium and 46 (24) mEq of potassium. Mean sodium:potassium ratio was 2.6 (1.0) and was higher among the urban residents (p < 0.01) and correlated with systolic and diastolic pressures (r = 0.16–0.18, p < 0.01). These findings provide quantitative estimates of the impact of known hypertension risk factors in West Africa and demonstrate the basis for increased prevalence with urbanization and associated economic and dietary change. These results also provide support for recommendations for prevention in West Africa and provide a benchmark against which to compare populations in the African diaspora. *Am J Epidemiol* 1996;143:1203–18.

blacks; blood pressure; hypertension; potassium; sodium; social class

Cardiovascular diseases, particularly stroke, renal failure, and heart failure, account for a considerable proportion of the chronic disease burden among adults in sub-Saharan Africa (1–3), even though the prevalence of hypertension remains substantially lower than in industrialized societies (4–7). Previous studies have observed lower blood pressures and prevalence of hypertension in rural compared with urban populations in Africa (8–11), and positive gradients in blood pressure have been identified as a function of education, occupational rank, or other measures of socioeconomic position (12–14). This pattern contrasts with findings in the United States, however, where the highest prevalence of hypertension has been observed

among blacks in the rural South (15–17). Furthermore, in industrialized societies, the relation between socioeconomic position and blood pressure is usually inverse (18–22). International comparisons have suggested that this inverse association is the more common pattern *within* societies (23), although a positive association between blood pressure and level of industrialization appears to hold *across* societies (24, 25).

The socioeconomic gradient must therefore be understood as antecedent to a set of more proximate risk factors, as its relation to blood pressure varies from positive to negative in different settings depending on the specific distribution of these factors across the gradient. Because there is likely to be a smaller set of such factors operating in the West African setting, it may be an environment that is well suited to studies designed to identify these proximate factors. Risk factors associated with blood pressure change that may potentially play a role in West Africa include dietary sodium (26–28), potassium (29, 30), sodium:potassium ratio (31, 32), obesity (33–38), ambient temperature (39, 40), pulse rate (12, 41), alcohol in-

take (42, 43), and migration status (44–48). Sex differentials in blood pressure levels have also been examined in West Africa, but with conflicting results (13, 14, 49–51). Psychosocial stress, another important determinant of hypertension, has been studied little in Africa.

Given the difficulty of long-term drug treatment in low-income countries, primary prevention assumes a greater public health importance (52, 53). The basis for a prevention strategy lies in precise estimates of the impact of causal risk factors. Although some evidence exists that the pattern of risk in Africa is similar to that found in other regions, few studies are available from West Africa that include population samples representative of the major social strata.

In this research, we examined the influence of the known social and environmental risk factors for hypertension in three population subgroups drawn from among the Yoruba-speaking people of southwestern Nigeria. The objective was to estimate the quantitative impact of the risk factors within the population and their potential contribution to urban versus rural and social class differences in hypertension prevalence. More than 90 percent of the Nigerian population, including those in rural areas as well as the urban poor, are relatively homogeneous with respect to socioeconomic position (54). The remainder of the population includes ethnic minorities characterized by a persistently high degree of isolation (55) and a very small elite whose lifestyle has become almost fully westernized (56). Our strategy was to avoid the extremes of this distribution and to attempt to depict the circumstances for the 90 percent in the middle.

The data collected in this survey were also intended to serve as a baseline against which prevalence of hypertension and the impact of risk factors may be assessed in populations of the African diaspora. The prevalence of hypertension among blacks in the United States is among the highest in the world (17), and this increased risk has led to widespread speculation about unique, presumably genetic, characteristics of this population (57–61). This perspective has been associated with a tendency, apparent for many years, to conclude that hypertension is surprisingly common in West Africa (13, 62, 63). In addition, it has been proposed that the impact of dietary sodium is atypical in these populations (58, 64–66). This investigation therefore represents one component of our attempt to examine these issues within the context of an international collaborative study designed to estimate the gradient in hypertension prevalence and the impact of known risk factors in Africa, the Caribbean, and the United States (67, 68).

MATERIALS AND METHODS

Study setting

Three sites were chosen to represent the basic socioeconomic groupings within the Nigerian population. Residents of the village of Idere, located in the Ibarapa District of Western Oyo State, comprised the rural sample. The 6,000 inhabitants of this village cultivate individual allotments of communal land apportioned on the basis of family lineage (69). These subjects will be referred to as "Rural Farmers."

The other two study sites were located within Ibadan, an indigenous Yoruba city of approximately three million people. The community of Idikan, a high-density section of the old city, includes about 7,000 inhabitants who are engaged primarily in trade or craftsmanship. Although the community is urban, very few in this community have access to regular wage labor and are characterized most accurately as informal sector workers, designated here as the "Urban Poor."

Pensioners of the Nigerian Railway Corporation in Ibadan were selected as the third subgroup. The majority of these subjects spent their entire adult lives as salaried employees of the colonial and federal governments. Because very few women were employed in this manner, recruitment was limited to men. Participants in all sites were aged 45 years or older to ensure sufficient disease risk.

Sampling scheme

The Rural Farmer and Urban Poor were selected as random subsets of participants who had been examined in 1992–1993 for the International Collaborative Study on Hypertension in Blacks (67, 68). The Study sampling strategy was based on probability proportionate to size cluster sampling (70), as described in detail elsewhere (68). This method involved random selection of clusters from an enumeration of all possible clusters in the geographic area of interest. From the age-eligible subjects, 300 names (150 men and 150 women) in each of the two sites were randomly generated for this substudy, with the goal of recontacting 100 men and 100 women in each site.

For the sample of Railway Workers, we attempted to enroll all age-eligible members of the Nigerian Railway Pensioners' Union resident in Ibadan by contacting members during union meetings. Participants were asked about other pensioners who did not attend meetings, and an interviewer contacted these individuals and encouraged them to come to a meeting to be enrolled. Lindsay (71) investigated a random sample of employee records of the same group at the archive maintained by the Nigerian Railway Corporation.

Mean values for demographic characteristics, including age, number of children, years of education, number of wives, religion, and state of origin, did not differ between the sample of employee records and our participants.

Blood pressure measurement

Blood pressure was measured with the procedures developed for the International Collaborative Study on Hypertension in Blacks (68). Briefly, after emptying their bladder, participants were seated for 5–10 minutes and during this period were queried about consumption of food, alcohol, coffee, or cigarettes within the previous 30 minutes. The ambient temperature was recorded, the arm circumference at the midpoint was measured, and an appropriate cuff was selected. The radial pulse was located, the pulse obliteration pressure was estimated, and 30 mmHg was added to this value to serve as the maximum inflation point. Systolic and diastolic blood pressures were measured with a standard mercury manometer three times as the first- and fifth-phase Korotkoff sounds. Examiners were trained to deflate the mercury at a rate of 2-mm per second and record values to the closest even integer. Thirty-second pulse was counted before each of the three readings. Virtually all previously diagnosed hypertensives were found to be either unmedicated or, if taking medication, were doing so with great irregularity or in doses insufficient to reduce blood pressure. For this reason, medication status was not included in the case definition. Participants with readings of 160/95 mmHg or greater were referred for care and provided a 1-year supply of medication.

Anthropometric measurements

Weight was recorded to the nearest 0.1 kg by using an electronic digital scale after participants removed shoes and any heavy clothing. Height was determined in meters with a rigid measure against a vertical wall. Two measurements of waist and hip circumference were made for each participant. For measurement of waist circumference, participants stood erect with their abdomen relaxed, arms at their side, and heels of their feet together. The tape was positioned at the level of the natural waist, which was considered to be the narrowest part of the torso as seen from the front. If a subject had a large amount of abdominal fat, the tape was positioned at the point midway between the bottom of the rib cage and the top of the iliac crest (approximately 2 cm above the iliac crest). For the measurement of hip circumference, the measurer squatted at the right side of the subject so that the point of maximum extension of the buttocks could be seen,

and the recorder checked to be certain that the tape was horizontal by standing on the opposite side of the participant's body. Measurement were recorded to the nearest 0.1 cm. If there was a difference of 0.5 cm or more between the two readings, measurements were repeated, and all three readings were recorded. The mean of two or all three readings was used as the value for analysis.

Certification procedures

Six field workers were recruited and trained; all were young adults native to Ibadan, and two were residents of Idikan. Field staff were at least bilingual (Yoruba and English), and one was also conversant in Pidgin, a dialect of English spoken as a second language in many parts of West Africa.

Since a primary objective of this study was cross-site comparison, careful attention was devoted to training and quality control. All field staff first passed a videotaped examination (Shared Care, Inc., Torrance, California). Training involved taking readings using a double-headed (i.e., "Y" terminal) stethoscope, and formal certification included a series of three consecutive blood pressure readings on two practice subjects. If the trainer's mean readings differed by more than 3 mmHg from those of the trainee for either systolic or diastolic pressure, a third practice subject was measured.

A Dinamap Portable Vital Signs Monitor (Model 8100, Critikon Inc., Tampa, Florida) was also used for certification. On each practice subject, Dinamap readings were taken after the second and third manual blood pressure readings. The examiners had to match the trainer's mean readings within 3 mmHg; given the well-described difference between oscillometric devices and human readings (72, 73), the trainee had to match the mean Dinamap reading within only 8 mmHg for both systolic and diastolic pressures.

The accuracy of blood pressure measurement was high, as assessed by three outcome measures. First, digit preference was limited. For readings ending in zero, two, four, six, and eight, the following distribution was observed for systolic pressure: 18.3, 21.2, 19.3, 19.6, and 21.6 percent. The corresponding distribution of terminal digits for diastolic pressure was 21.5, 20.4, 20.4, 16.5, and 21.2 percent. The highest use of zero for any single observer was 26.3 percent. Second, the correlation of the examiner's values and the Dinamap readings was 0.96 for systolic pressure and 0.90 for diastolic pressure, based on a subsample of 67 subjects who had Dinamap readings taken after both the second and third manual readings. When modeled in regression equations, the slopes of the relation between manual and automated readings did

not differ from 1.0, and the intercepts did not differ significantly from zero. Third, repeat measures on a set of 23 individuals taken on separate days by the same observers yielded a correlation of 0.84 and a within-person standard deviation of 7 mmHg.

Two field workers gathered data only in Idikan, while the other four collected data in all sites. Analysis of variance showed that observer means for blood pressure do not differ independently of site effects ($p > 0.20$) and thus do not contribute to cross-site variation.

Subjects chose their language of response; 95.5 percent answered in Yoruba, 4.1 percent chose English, and two subjects opted for Pidgin English. The interview instrument was translated from English into Yoruba and back-translated for purposes of verification (74). Interviewers collected questionnaire information on marital and family status, alcohol and cigarette consumption, occupation, religion, migration status, educational level, age, previous diagnosis of hypertension, and other variables. Ages were estimated or missing in many cases, however, especially in the Rural Farmers and Urban Poor, where the majority of participants did not know their exact date of birth. A technique for estimating age in the rural area (based on a list of historical events) was applied; however, since ages as reported are considered to be less than completely accurate, subjects were stratified into two age categories, 45–54 and 55 or more years.

Collection of 24-hour urine samples

Because of refrigeration and transportation constraints, 24-hour urine samples were collected for 100 percent of the Urban Poor, for random subsets of 50 percent of the Rural Farmers, and for 10 percent of the Railway Workers. After careful instruction, participants chosen for urine collection were given jars containing boric acid as a preservative. Subjects returned to the clinic the following morning or were met in their home. When the samples were collected on the following day, the times that the collection began and ended were recorded, and participants were asked about completeness of the collection.

Two aliquots of urine were stored for each subject. One aliquot was analyzed at the Department of Chemical Pathology of the University College Hospital, Ibadan, Nigeria, using a flame photometer. Samples were reanalyzed for sodium and potassium at Loyola Medical School, Maywood, Illinois; the correlations for sodium, potassium, and sodium:potassium ratio between the analysis values of the two laboratories were all greater than 0.92, and the values obtained in Nigeria were used in the analysis.

Statistical methods

Data were entered into Epi-Info Version 5 (75), and analysis was carried out with statistical programs available on the Statistical Analysis System (SAS) Version 6 (76). Group differences were assessed with t tests; the conservative Cochran and Cox approximation for the p value was used in the case of unequal variances (77). Site differences among the men were assessed by using analysis of variance, χ^2 tests, and Mantel-Haenszel trend tests, and bivariate relations of continuous variables were examined with correlation analysis. Hierarchic modeling was used to determine the best predictors of mean blood pressure. Given the uncertainty about body mass index (BMI) as a predictor at the low levels of obesity observed here (78), different models were evaluated, including height and weight separately. Overall BMI appeared to capture explanatory information equal to, but not greater than, weight and was included in the final models to facilitate comparisons with other studies.

The effect of the "regression-dilution" effect on the relation between urinary electrolytes was estimated with repeat 24-hour collection in a subsample of participants (79). Although a correction factor was estimated, the primary emphasis for these analyses remained on the raw values.

RESULTS

Descriptive findings

Demographic characteristics of the sample are shown in table 1, stratified by sex, and further separated by socioeconomic group for men. Women are not stratified by socioeconomic group because few significant differences were observed between the two sites in which they were sampled. Statistics comparing group means appear at the right side of data stratified by site for men. The site p value corresponds to tests for differences by socioeconomic group among men only, since women were not included in the Railway Workers subgroup. The last column provides p values from t tests for the difference between means for men and women.

On the basis of reported age, Railway Workers were significantly younger than other men, and women were younger than men. As noted above, however, ages were estimated in many cases, especially in the Rural Farmer and Urban Poor groups, and subjects were therefore classified into two age categories, 45–54 and 55 or more years. There were no differences in the proportions of subjects in these two age strata. Dramatic differences in level of education existed between men and women and for men between socioeconomic groups (table 1). Use of alcohol was

TABLE 1. Demographic characteristics of the sample, stratified by site and sex, age ≥45 years, Nigeria, 1994

| | Men | | | | | | Site (p value)* | Total men (n = 386) | | Total women (n = 212) | | Total sample (n = 598) | | Sex t test p value |
| | Rural farmers (n = 108) | | Urban poor (n = 75) | | Railway workers (n = 203) | | | | | | | | | |
	Mean	(SD†)	Mean	(SD)	Mean	(SD)		Mean	(SD)	Mean	(SD)	Mean	(SD)	
Age (years)	63.0	(12.6)	65.2	(11.0)	60.2	(8.5)	0.00	61.8	(10.4)	60.0	(9.9)	61.1	(10.3)	0.03
Current no. of wives	1.5	(0.9)	1.6	(1.1)	1.4	(0.7)	0.14	1.4	(0.9)	NA†		NA		NA
Current no. of children	5.9	(3.2)	7.1	(3.6)	6.3	(2.5)	0.03	6.3	(3.0)	4.0	(1.8)	5.5	(2.9)	0.00
Proportion with some education	0.28		0.45		0.86		0.00	0.62		0.08		0.43		0.00
Proportion aged ≥55 years	0.70		0.83		0.75		0.17	0.75		0.72		0.74		0.40
Proportion currently married	0.90		0.95		0.96		0.09	0.94		0.83		0.90		0.00
Proportion born where now living	0.95		0.80		0.15		0.00	0.51		0.51		0.51		0.97
Proportion smoking cigarettes	0.29		0.32		0.31		0.88	0.30		0.00		0.17		0.00
Proportion drinking alcohol	0.45		0.20		0.22		0.00	0.31		0.02		0.18		0.00

* Site group means compared with $F_{(2, n-3)}$ statistics, proportions compared with $\chi^2_{(2)}$ statistics.
† SD, standard deviation; NA, not applicable.

most common for males in the Rural Farmers group, a result of the availability of palm wine and other non-commercial beverages.

Diastolic pressure was higher in men than in women, and a gradient was apparent from Rural Farmers to Railway Workers, with Urban Poor intermediate between the two (table 2). This pattern was also significant for prevalence of hypertension, as measured by either of the two common criteria, but not for systolic pressure. Significant differences in the levels of several established risk factors for blood pressure elevation were observed, including waist circumference and hip circumference, with the Rural Farmers having the lowest values. While height did not vary for men, weight increased along the expected gradient, leading to a significant trend in mean BMI. Women had a higher BMI, a lower waist-to-hip ratio, and a higher pulse.

On the basis of 24-hour urine collection, sodium and potassium excretion did not differ significantly between men and women or between socioeconomic groups among the men (table 3). Sodium:potassium ratio, however, showed a significant trend across the socioeconomic groups, mirroring the pattern for hypertension prevalence (figure 1).

For men, both 24-hour sodium and sodium: potassium ratio were positively and significantly correlated with both systolic and diastolic pressures (table 4). For women, only the correlation between sodium: potassium ratio and diastolic pressure was significantly different from zero. The strongest correlations were observed for male Rural Farmers ($r = 0.3-0.5$).

Urinary electrolytes were not significantly correlated with reported age for all men combined, although women did demonstrate an inverse correlation between age and 24-hour sodium excretion ($r = -0.18$, 95 percent confidence interval (CI) -0.33 to -0.03). Men, on the other hand, showed strong positive correlations between BMI and sodium excretion ($r = 0.20$, 95 percent CI 0.04 to 0.35) and also between waist-to-hip ratio and sodium excretion ($r = 0.23$, 95 percent CI 0.07 to 0.38). These correlations were particularly strong for men in the Urban Poor group ($r_{sodium:BMI} = 0.30$, 95 percent CI 0.08 to 0.52 and $r_{sodium:waist-to-hip} = 0.25$, 95 percent CI 0.03 to 0.48).

Univariate comparison of hypertensives and normotensives

Hypertensives as a group excreted significantly more sodium and had significantly higher sodium: potassium ratios than did normotensives (table 5). They were also older and had higher pulse rates, BMI values, and waist-to-hip ratios. Alcohol consumption showed no relation to hypertension (data not shown).

TABLE 2. Cardiovascular characteristics of the sample, stratified by site and sex, age ≥45 years, Nigeria, 1994

| | Men | | | | | | | | Total men (n = 386) | | Total women (n = 212) | | Total sample (n = 598) | | Sex t test p value |
| | Rural farmers (n = 108) | | Urban poor (n = 75) | | Railway workers (n = 203) | | Site (p value)* | | | | | | | | |
	Mean	(SD†)	Mean	(SD)	Mean	(SD)			Mean	(SD)	Mean	(SD)	Mean	(SD)	
Systolic blood pressure (mmHg)	121.1	(17.9)	125.6	(27.3)	127.0	(24.2)	0.10		125.1	(23.4)	122.6	(24.5)	124.2	(23.8)	0.23
Diastolic blood pressure (mmHg)	70.6	(10.9)	72.4	(14.0)	76.1	(13.5)	0.00		73.8	(13.2)	69.8	(12.1)	72.4	(12.9)	0.00
Body mass index (kg/m²)	20.4	(2.8)	21.4	(4.5)	21.8	(3.6)	0.00		21.3	(3.6)	23.0	(5.2)	21.9	(4.3)	0.00
Waist-to-hip ratio	0.92	(0.05)	0.92	(0.05)	0.91	(0.05)	0.10		0.91	(0.06)	0.88	(0.07)	0.90	(0.06)	0.00
Weight (kg)	57.6	(8.6)	61.0	(12.7)	61.9	(11.4)	0.01		60.5	(11.1)	56.8	(13.9)	59.2	(12.3)	0.00
Height (cm)	168.1	(6.0)	168.7	(6.2)	168.3	(6.9)	0.82		168.4	(6.5)	157.2	(5.9)	164.4	(8.2)	0.00
Waist circumference (cm)	79.4	(7.6)	83.1	(11.4)	82.4	(10.3)	0.01		81.7	(9.9)	83.8	(11.6)	82.4	(10.6)	0.02
Hip circumference (cm)	86.2	(6.4)	90.3	(8.2)	90.6	(7.8)	0.00		89.3	(7.7)	95.9	(11.4)	91.7	(9.7)	0.00
Pulse rate (beats/minute)	75.1	(10.2)	75.0	(13.5)	75.8	(10.6)	0.82		75.5	(11.1)	77.9	(10.8)	76.3	(11.1)	0.01
Proportion with mean blood pressure ≥140/90 mmHg	0.14		0.25		0.29		0.01		0.24		0.23		0.24		0.79
Proportion with mean blood pressure ≥160/95 mmHg‡	0.03		0.11		0.14		0.01		0.10		0.09		0.10		0.46

* Site group means compared with $F_{(2, n-3)}$ statistics, proportions compared with $\chi^2_{(2)}$ statistics.
† SD, standard deviation.
‡ World Health Organization Criteria.

TABLE 3. Twenty-four-hour urine characteristics of the sample, stratified by site and sex, age ≥45 years, Nigeria, 1994

	Sodium (mEq/24 hours)			Potassium (mEq/24 hours)			Sodium:potassium ratio			Urine volume (ml/24 hours)		
	No.	Mean	(SD*)	No.	Mean	(SD)	No.	Mean	(SD)	No.	Mean	(SD)
Men												
Rural farmers	53	110.8	(56.7)	53	54.9	(27.5)	53	2.20	(1.09)	54	1,166.6	(544.7)
Urban poor	73	110.6	(50.6)	73	45.2	(22.4)	73	2.61	(0.96)	74	1,448.6	(678.7)
Railway workers	18	118.3	(58.1)	18	44.7	(16.5)	18	2.74	(1.12)	19	1,403.1	(452.7)
Site p value†	0.85			0.06			0.04			0.03		
Total men	144	111.6	(53.6)	144	48.7	(24.1)	144	2.48	(1.04)	147	1,339.1	(617.1)
Total women	178	108.8	(60.0)	178	43.8	(23.6)	178	2.63	(1.02)	180	1,393.4	(685.8)
Total sample	322	110.0	(57.1)	322	46.0	(23.9)	322	2.56	(1.03)	327	1,369.0	(655.4)
Sex t test p value	0.66			0.07			0.18			0.46		

* SD, standard deviation.
† Site group means compared with $F_{(2, n-3)}$ statistics.

Multivariate relations

Results of modeling blood pressure of the men as a linear function of selected covariates are shown in tables 6 and 7. Separate models were considered for each of the three socioeconomic groups, although Railway Workers were omitted from table 7 because of insufficient urinary electrolyte data. Models that excluded sodium:potassium ratio accounted for 8–26 percent of the variation in blood pressure. The effect of temperature was uniformly negative and significant in all three sites. BMI was a predictor of blood pressure for both the Rural Farmers and Railway Workers, although men in the Urban Poor group did not show this relation and instead had a consistent effect of waist circumference on blood pressure.

In models that included sodium:potassium ratio, 13–48 percent of the variance in blood pressure was accounted for by the selected covariates (table 7). The adjusted effect of sodium:potassium ratio was uniformly positive for both systolic (range β_{ratio}: 4.19–6.58) and diastolic (range β_{ratio}: 2.11–2.46) blood pressures.

Similar models based on a larger set of predictors for all men and all women are shown in table 8. Age category was positively associated with systolic pressure for both men and women. Anthropometric measures were significant predictors of systolic and diastolic pressures for men, but not for women. Women, however, showed an effect of the number of children, with more offspring being associated with lower systolic pressure.

After sodium:potassium was added to the set of predictors in these models, the percentage of variance accounted for by the models ranged from 7 to 23 percent. The pattern of effects remained similar, although the reduced sample size resulted in a loss of some precision for the coefficient estimates. Only the number of children remained a strong predictor of systolic pressure for women ($\beta = -3.55$), while pulse rate and sodium:potassium ratio showed modest effects for diastolic pressure ($\beta_{pulse} = 0.31$, $\beta_{ratio} = 1.55$). Sodium:potassium ratio showed a strong positive relation to both systolic ($\beta = 6.35$) and diastolic ($\beta = 2.93$) pressures for men, however.

Assessment of attenuation of the relation between blood pressure and sodium:potassium ratio

A subset of participants was asked to collect 24-hour urine samples on multiple days to estimate the within-person variability of electrolyte excretion. Data were available for two to three 24-hour collections in
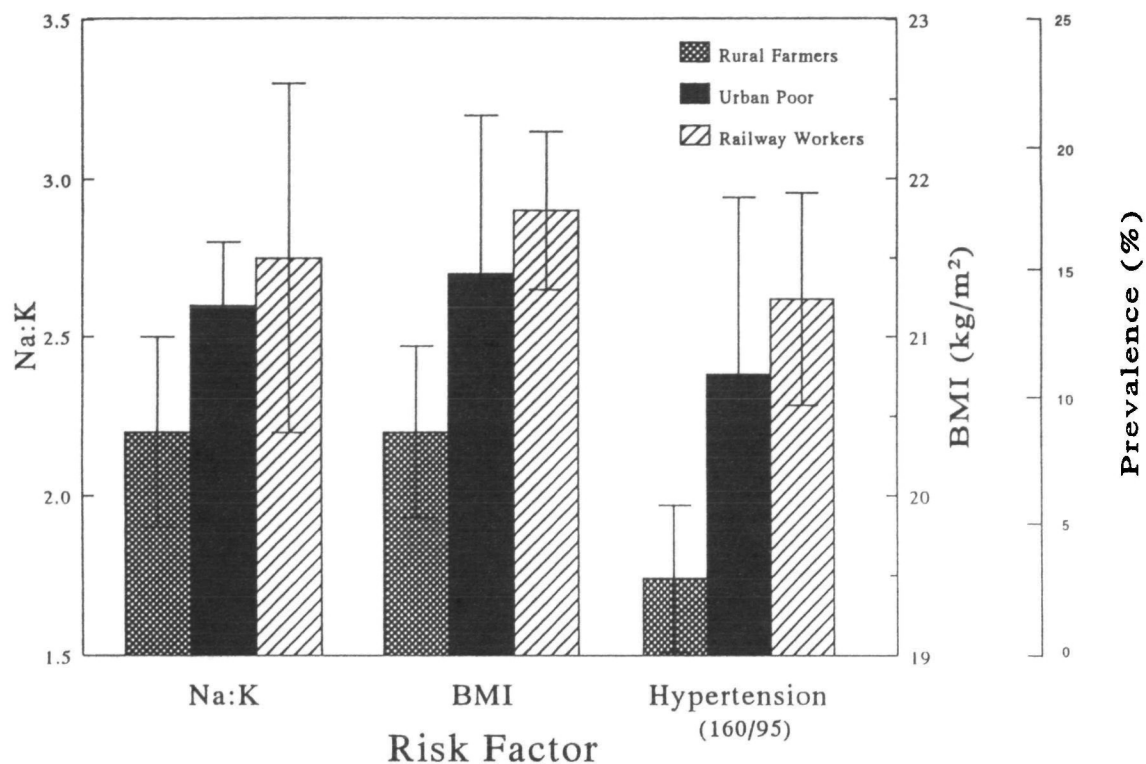
FIGURE 1. Socioeconomic gradient (mean, 95 percent confidence interval) in the prevalence of hypertension, body mass index (BMI), and sodium:potassium ratio, Nigeria, men, 1994. BMI site effect, $p < 0.01$; sodium:potassium ratio site effect, $p < 0.05$; hypertension, 160/95 mmHg; test of trend, $p < 0.01$.

a single week for 23 individuals, for a total of 63 specimens. The intraclass correlations were 0.37 for sodium, 0.48 for potassium, and 0.37 for sodium:potassium ratio, suggesting only a moderate level of within-person variability in this community. The intraclass correlation for both systolic and diastolic pressures was 0.84. In this subsample, the observed correlation between the 3-day mean of the sodium:potassium ratio and the 3-day mean of blood pressure was 0.41 for systolic pressure and 0.34 for diastolic pressure, which may be taken to represent a reasonable estimate of the upper bound of this relation. As a result of within-person variability, a single 24-hour collection would have underestimated the "true" correlation between systolic pressure and sodium:potassium ratio by 64 percent, while blood pressure measurement on only a single day would reduce the observed correlation between these two variables by 9 percent (80). "Correction" for the regression-dilution effect in the measurement of sodium:potassium ratio and blood pressure in the total sample thus increases the correlation from 0.16 to 0.28; i.e., 1.64 (the correction factor for sodium:potassium ratio) × 1.09 (correction factor for systolic pressure × 0.16 (the observed correlation coefficient).

DISCUSSION

The findings of this study demonstrate that while hypertension exists in West Africa, the prevalence is considerably lower than that typically observed in industrialized societies (81). Approximately one in four individuals over age 45 years was found to have a blood pressure greater than 140/90 mmHg, while about one in 10 had values greater than 160/95 mmHg. The associated disease burden may be substantial, however; given the virtual absence of effective pharmacologic treatment in the current social and economic environment (82), persons with severe hypertension are clearly at significant risk of cardiovascular complications (1). Approximately 15 percent of the deaths among adults in sub-Saharan Africa are attributable to cardiovascular causes, half of which are secondary to hypertension (2, 83).

The forces apparently driving the emergence of hypertension as a mass disease through the lifestyle changes associated with urbanization and economic transition are portrayed in the findings of this study. The gradient from Rural Farmers to Urban Poor to Railway Workers is seen both in the important risk factors and in the outcomes (figure 1). For both hypertension criteria, the test of linear trend across so-

TABLE 4. Correlations and 95 percent confidence intervals between blood pressure and urinary electrolytes, stratified by site and sex, age ≥45 years, Nigeria, 1994

	Men						Total men		Total women		Total women	
	Rural farmers		Urban poor		Railway workers							
	r	95% CI*	r	95% CI	r	95% CI	r	95% CI	r	95% CI	r	95% CI
	(n=53)		(n=73)		(n=18)		(n=144)		(n=178)		(n=322)	
Systolic blood pressure												
Sodium	0.41	0.16 to 0.61	0.13	−0.10 to 0.35	0.11	−0.38 to 0.55	0.20	0.04 to 0.35	0.03	−0.12 to 0.18	0.11	0.00 to 0.22
Potassium	−0.08	−0.34 to 0.19	−0.04	−0.27 to 0.19	−0.18	−0.60 to 0.31	−0.10	−0.26 to 0.06	−0.06	−0.21 to 0.09	−0.07	−0.18 to 0.04
Ratio†	0.51	0.28 to 0.69	0.13	−0.10 to 0.35	0.10	−0.38 to 0.54	0.25	0.09 to 0.40	0.10	−0.05 to 0.24	0.16	0.05 to 0.26
	(n=53)		(n=73)		(n=18)		(n=144)		(n=177)		(n=321)	
Diastolic blood pressure												
Sodium	0.33	0.07 to 0.55	0.19	−0.04 to 0.40	0.23	−0.27 to 0.63	0.24	0.08 to 0.39	0.12	−0.03 to 0.26	0.18	0.07 to 0.28
Potassium	0.03	−0.24 to 0.30	0.05	−0.18 to 0.28	−0.16	−0.58 to 0.33	−0.00	−0.16 to 0.16	0.02	−0.13 to 0.17	0.02	−0.09 to 0.13
Ratio†	0.32	0.05 to 0.54	0.17	−0.06 to 0.39	0.26	−0.24 to 0.65	0.25	0.09 to 0.40	0.15	0.00 to 0.29	0.18	0.07 to 0.28

* CI, confidence interval.
† Ratio = sodium:potassium ratio.

cioeconomic sites was significant ($p < 0.01$), and this trend persisted after adjustment for age and temperature differences between sites (not shown). At the same time, it should be recognized that hypertension prevalence is low in all groups, despite sodium intake of over 100 mEq/day, strongly arguing against the presence of exaggerated "salt sensitivity" at the population level, as suggested by some authors (57, 64–66).

We propose that the gradient in risk factors between sites is the consequence of their differing socioeconomic foundations: subsistence agriculture for the Rural Farmers, trade and craftwork for the Urban Poor, and wage labor for the Railway Workers. When these three groups are considered, it is important to recognize the relatively elite status of the Railway Workers as wage laborers in an economy not yet truly capitalistic, but merely "articulated" by capitalism (84). More than 70 percent of the Nigerian population are still engaged in subsistence agriculture (54), and wage earners make up less than 4 percent of the adult population (85). In large, urban areas such as Ibadan, up to one fifth of the adult population may be wage earners, while in the remainder of the country less than 2 percent receive regular wages. Of those working for wages, 67 percent are in the public sector (e.g., civil servants, teachers, Railway Workers, etc.) (86).

While wage laborers may not be "richer" than farmers or traders in terms of value of goods or currency acquired during a given year, their involvement in a wage-labor economy has a significant impact on social organization and lifestyle factors, and their access to regular cash payments, however small, sets them apart as a distinct social group. The changes in lifestyle and behavior, as well as social and family structure, afforded by this involvement with wage economy, however, appear to be associated with greater opportunity for cardiovascular risk, including increased weight, increased sodium:potassium ratio, and decreased social integration (51). This trend is analogous to published findings of increased blood pressure or hypertension prevalence as a function of occupational grade, educational level, or status within given study populations (12–14).

While the vast majority of Nigerians are not integrated into a wage economy, few previous studies in the region provide a basis for comparison with the Rural Farmer and Urban Poor groups presented here. Several studies have investigated blood pressure among urban (12–14, 63, 87) and rural (50, 88) wage-earning populations, as well as among children (89, 90) and university students (91, 92), but few have addressed the majority population of urban and rural adults engaged in non-wage-earning labor and in sub-

TABLE 5. Mean values for normotensive and hypertensive* participants, age ≥45 years, Nigeria, 1994

| | Normotensives | | | Hypertensives | | | t test |
	Mean	(SD†)	No.	Mean	(SD)	No.	p value
Sodium (mEq/24 hours)	107.1	(56.4)	247	119.7	(59.0)	75	0.04
Potassium (mEq/24 hours)	46.6	(25.2)	247	43.8	(19.1)	75	0.15
Sodium:potassium ratio	2.48	(0.99)	247	2.84	(1.12)	75	0.00
Age (years)	60.3	(10.3)	377	63.5	(9.8)	124	0.00
Waist:hip ratio	0.89	(0.06)	456	0.91	(0.06)	140	0.00
Body mass index (kg/m²)	21.7	(4.4)	455	22.7	(4.2)	141	0.01
Pulse (beats/minute)	75.6	(10.3)	454	78.8	(13.0)	142	0.00

* Hypertensive = mean pressure ≥ 140/90 mmHg.
† SD, standard deviation.

TABLE 6. Regression coefficients from linear models† predicting mean blood pressure in three socioeconomic environments as a function of a set of covariates, men aged ≥45 years only, Nigeria, 1994

	Intercept	Age ≥55 years	Temperature (°C)	BMI‡ (kg/m²)	Waist (cm)	Hip (cm)	Pulse (minute)	F	R²
Systolic blood pressure									
Rural farmers (n = 108)	87.02**	6.06	−1.31**	2.25**	−0.02	−0.40	1.31**	5.37**	0.24
Urban poor (n = 75)	202.04**	−0.01	−2.63	−1.09	0.91*	−0.59	0.14	1.31	0.10
Railway workers (n = 183)	104.22**	5.54	−1.35*	1.47**	−0.13	−0.02	1.08**	4.93**	0.14
Diastolic blood pressure									
Rural farmers (n = 108)	68.09**	0.36	−0.85**	1.45**	0.18	−0.54**	0.55**	6.07**	0.26
Urban poor (n = 75)	122.92**	−6.86	−2.19*	−0.04	0.46*	−0.22	0.13	2.19*	0.16
Railway workers (n = 183)	50.62**	1.33	−0.12	0.75*	0.04	−0.16	0.53**	2.70*	0.08

* $p < 0.05$ [for H_0: $\beta_n = 0$]; ** $p < 0.01$ [for H_0: $\beta_n = 0$].
† Mean pressure = $\beta_0 + \beta_1 \times$ AGE + $\beta_2 \times$ TEMP + ... + $\beta_6 \times$ PULSE + ε.
‡ BMI, body mass index.

TABLE 7. Regression coefficients from linear models† predicting mean blood pressure in two socioeconomic environments as a function of a set of covariates that includes sodium:potassium ratio, men aged ≥45 years only, Nigeria, 1994

	Intercept	Age ≥55 years	Temperature (°C)	BMI‡ (kg/m²)	Waist (cm)	Hip (cm)	Pulse (minute)	Sodium:potassium ratio	F	R²
Systolic blood pressure										
Rural farmers (n = 108)	96.55**	5.19	−1.48*	1.67	0.05	−0.39	1.05**	6.58**	4.74**	0.42
Urban poor (n = 75)	188.06**	0.11	−2.51	−1.08	0.93*	−0.69	0.25	4.19	1.34	0.13
Diastolic blood pressure										
Rural farmers (n = 108)	89.57**	0.83	−1.04**	1.85**	0.18	−0.88**	0.37	2.11	5.98**	0.48
Urban poor (n = 75)	118.33**	−6.91	−2.26*	−0.02	0.48*	−0.30	0.21	2.46	2.42*	0.21

* $p < 0.05$ [for H_0: $\beta_n = 0$]; ** $p < 0.01$ [for H_0: $\beta_n = 0$].
† Mean pressure = $\beta_0 + \beta_1 \times$ AGE + $\beta_2 \times$ TEMP + ... + $\beta_7 \times$ RATIO + ε.
‡ BMI, body mass index.

sistence farming. Johnson (93) completed a population survey of Lagos, Nigeria, residents, including blood pressure measurements on 1,392 subjects aged 10–102 years. Only 24 percent of male subjects had no schooling, and fully 43 percent were engaged in "skilled or professional" work, suggesting a population more thoroughly integrated into a wage economy than the Urban Poor group in our study. Not surprisingly, therefore, mean blood pressures and prevalence

of hypertension were considerably higher than among the Urban Poor group described here; 23 percent of men in the comparable age-sex group had a systolic pressure of 160 mmHg or more (93). Pobee et al. (94) conducted studies of hypertension prevalence among villagers in rural Ghana and found prevalences of 2–5 percent (diastolic pressure ≥ 95 mmHg), roughly comparable with the Rural Farmer group described here.

TABLE 8. Regression coefficients from linear models† predicting mean blood pressure in men and women as a function of a set of covariates, age ≥45 years, Nigeria, 1994

	Intercept	Age ≥55 years	Temperature (°C)	BMI‡ (kg/m²)	Waist (cm)	Hip (cm)	Pulse (minute)	Non-migrant§	No. of children	F	R²
Systolic blood pressure											
Men (n = 364)	108.00**	6.08*	−1.01**	0.90*	0.11	−0.14	0.88**	−6.95**	−0.20	5.74**	0.11
Women (n = 207)	108.74**	9.04	0.50	−0.56	0.13	0.23	−0.17	5.46	−3.46**	3.62**	0.13
Diastolic blood pressure											
Men (n = 364)	60.91**	−0.28	−0.28	0.69**	0.16*	−0.25*	0.41**	−5.14**	0.11	6.17**	0.12
Women (n = 207)	61.28**	−0.52	−0.18	0.30	−0.04	−0.01	0.31	1.33	−0.66	1.20	0.05

* $p < 0.05$ [for H_0: $\beta_n = 0$]; ** $p < 0.01$ [for H_0: $\beta_n = 0$].
† Mean pressure = $\beta_0 + \beta_1 \times$ AGE $+ \beta_2 \times$ TEMP $+ ... + \beta_7 \times$ RATIO $+ \varepsilon$.
‡ BMI, body mass index.
§ Nonmigrant = participant born in the same community in which he or she now lives.

While overall hypertension prevalence among the Railway Workers was found to be lower than in several previous studies of wage-earning populations in West Africa (13, 14, 63), differences in the characteristics of samples appear to account for the lower overall prevalence observed here (table 9). Bunker et al. (13), for example, studied civil servants in Benin City, a group that might at first seem comparable with the Railway Workers group, since both groups are made up of public sector wage laborers. For men between ages 45 and 64 years in the study by Bunker et al., however, mean BMI was 24.4, significantly higher ($p < 0.01$) than the value of 21.8 observed for men in the Railway Workers group (13). Furthermore, 65 percent of the male subjects in that study reported drinking alcohol, while the comparable percentage

among Railway Workers in the current study was 22 percent. In addition, fewer than 1 percent of the subjects in the study by Bunker et al. had zero years of education, compared with 14 percent of surveyed Railway Workers (13).

Two studies in West Africa in which the subjects may be roughly comparable with the Railway Workers group in the current study are those by Ogunlesi et al. (12) and Giles et al. (50). Ogunlesi et al. measured 404 male Nigerian factory workers aged 18–54 years and found a mean BMI of 21.6. Blood pressures and prevalence of hypertension were also roughly equivalent between these factory workers and the Railway Workers in the current study. Giles et al. surveyed 3,588 Liberian rubber plantation workers (age 20 years or more). Blood pressures in men of the same age range

TABLE 9. Comparison of findings between recent hypertension surveys of wage-earning populations in West Africa, 1987–1994

Study (reference)	Subjects	No.	Age range (years)	% ≥140/90 mmHg	% ≥160/95 mmHg	Mean systolic pressure (mmHg)	Mean diastolic pressure (mmHg)
Kaufman et al.*	Male railway workers	203	≥45	29.0	14.2	127	76
Idahosa (63)†	Male civil servants	521	20–62	33.6	8.8	134	75
		45	45–62	68.9	33.3	141	89
	Policemen	594	20–63	24.4	8.2	130	76
		34	45–63	58.8	41.2	144	89
Bunker et al. (13)*	Male civil servants	438	25–54	34.0	18.0	128	82
		102	45–54	52.0	26.0	136	87
Ekpo et al. (14)‡	Urban workers§	5,200	≥16	‖	8.1	‖	‖
		36	≥56	‖	27.8	‖	‖
Giles et al. (50)†	Male plantation workers	394	≥45	18.0	8.0	127	75
Ogunlesi et al. (12)¶	Male factory workers	404	18–54	20.3	‖	128	70
		141	35–54	27.0	11.0	128	73

* Blood pressure values = mean of second and third readings from standard mercury manometer and variously sized cuffs.
† Blood pressure values = second of two readings from an automated device and single cuff.
‡ Blood pressure values = second of two readings from standard mercury manometer and variously sized cuffs.
§ Subjects were predominantly (84.2%) male.
‖ Statistic not provided in published source.
¶ Blood pressure values = mean of three readings from automated device and variously sized cuffs.

as the Railway Workers in this study were roughly equivalent, while prevalence of hypertension in the similarly aged Liberian workers was slightly lower.

Although weight was a predictor of elevated blood pressure in our study, the effect was relatively small and was restricted to men, in contrast to some previous studies in Africa. Bunker et al. (13), for example, found correlations of BMI with systolic and diastolic pressures to be 0.33 and 0.32, respectively, for men, and 0.44 and 0.44, respectively, for women. Hypotheses to explain this disparity include the possibility that participants in our study were sufficiently lean to be near a threshold value for the effect of overweight or that BMI is not an accurate reflection of percent body fat in lean populations (78). Among Railway Workers, the group of men with the highest mean BMI, correlation with mean systolic pressure was 0.19 (95 percent CI 0.05 to 0.32), and that with mean diastolic pressure was 0.15 (95 percent CI 0.02 to 0.29). With an obesity cutpoint of BMI of 25.0 or greater, the adjusted odds ratio for hypertension (160/95 mmHg) among men was 2.34 (95 percent CI 1.05 to 5.22), yielding population attributable risk percents of 8.0, 17.7, and 18.7 among Rural Farmers, Urban Poor, and Railway Workers, respectively.

While the absence of a relation between BMI and blood pressure for women (whose mean BMI was significantly greater than that of men) is not consistent with most previous findings, it is commonly observed that the relation between BMI and blood pressure has a lower magnitude in women than in men (95). Furthermore, Walker et al. studied obese women (BMI $\geq$ 29.5) in South Africa and found that "in [a] low socioeconomic and low fat dietary context" (96, p. 101), obesity apparently conferred no additional risk of hypertension. The INTERSALT investigators observed significant positive correlations between BMI and blood pressure for women in only 27 of 52 sites (33). Finally, it is also possible that the sample size of 212 women in the our study simply did not provide sufficient power to identify a modest relation between BMI and blood pressure.

Sodium and potassium were found to be related to blood pressure, with hypertensives excreting approximately 10 percent more sodium than normotensives and both men and women showing positive correlations between sodium:potassium ratio and blood pressure. The absolute quantity of sodium excreted in 24 hours in this sample was moderate, i.e., higher than in the four INTERSALT low-blood pressure sites characterized by extremely low sodium excretion (<60 mEq/24 hours) (97), but lower than in all but one of the other 48 INTERSALT sites (81). Adjusted coefficients for the relation between sodium:potassium ratio

and blood pressure in our study were generally greater in magnitude than the INTERSALT values (31).

Relative to Western populations, the study population is characterized by low mean BMI, low levels of alcohol and cigarette consumption, high levels of physical activity, and moderate levels of sodium intake. Of the factors considered in this study, the relation between sodium and potassium appears to be the single most important predictor of hypertension from a public health standpoint (98). If the sodium:potassium ratio were to be modified, either by reduction of sodium or augmentation of potassium, from its observed mean value of 2.6 to a plausible target of 1.0, the data presented here predict that a 30–40 percent reduction in the prevalence of hypertension would be realized (figure 2). This recommendation is consistent with current public health guidelines in other countries (99) and may be more readily achievable in Nigeria, where discretionary use of sodium accounts for a greater percentage of intake than in westernized diets (100) and where natural sources of dietary potassium are abundant.

Of the variables considered here, only the number of children was a strong, consistent, and independent predictor of blood pressure for women. This is consistent with some previously published studies (14) and suggests that in this relatively low-risk environment, the important contributions of psychosocial and socioeconomic variables might come to the foreground, unobscured by the anthropometric and behavioral effects that capture most investigators' attention in studies of westernized populations. While socioeconomic status was examined here for men, no women in our study were wage laborers, but instead were primarily occupied as agricultural workers, traders, and craft workers. While Bunker at al. (13) observed that women in their sample of relatively elite urban workers took on the social status commensurate with their husbands' occupational grade, women in our study demonstrated a high degree of economic independence from their spouses and generally achieved status through active rather than passive means. Women achieved their status, for example, through successful small-business ventures and activity in community organizations, as well as through the number of children raised (69, 101). Further research should concentrate, however, on measures of social status, social and economic stress, and social integration that are relevant to women living in these social contexts, since established physiologic risk factors are apparently not highly predictive of disease status for this group.

The majority of existing studies of blood pressure in West Africa have been conducted in clinical settings or among other nonrepresentative populations such as
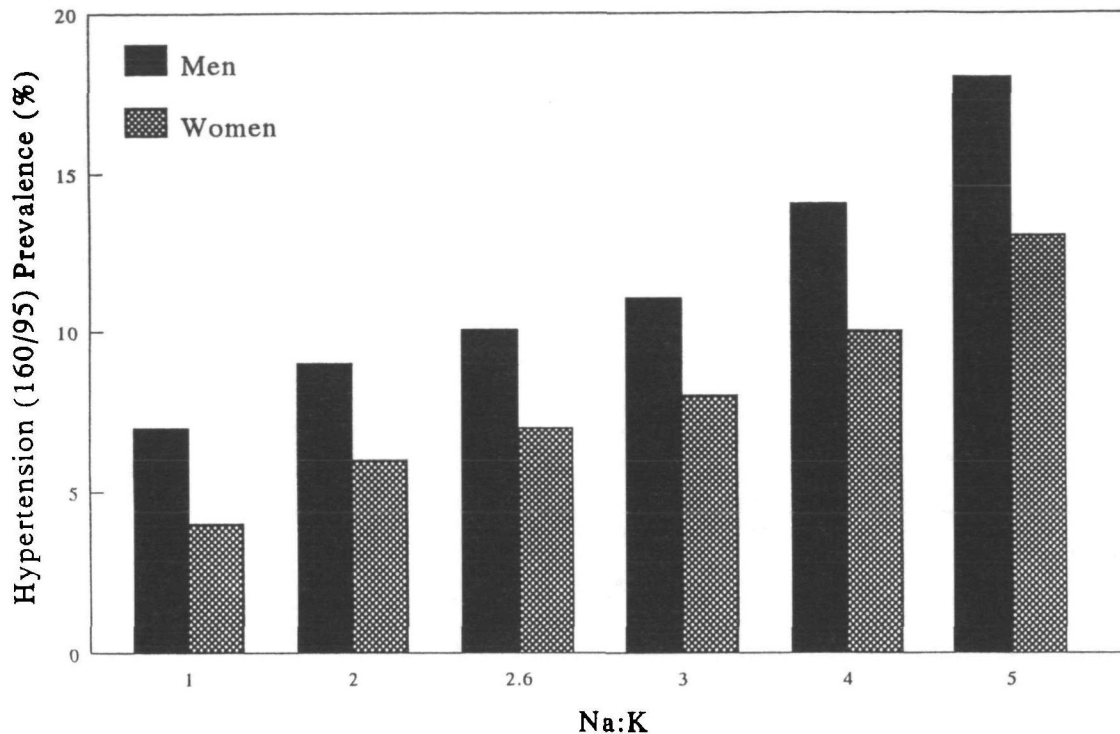
FIGURE 2. Predicted hypertension prevalence associated with change in sodium:potassium ratio, Nigeria, 1994.

wage workers or urban elites (4). An important strength of this study is therefore its potential to characterize accurately the population of West Africans. While the communities sampled are representative of the general population, however, a weakness of our study rests in the degree to which participants who were examined are representative of those who were sampled. The failure to recontact a significant portion of the previously sampled subjects in both the Rural Farmer and Urban Poor groups raises important concerns about the potential for nonresponse bias in this study. A comparison of demographic characteristics shows no significant differences between those who were recontacted and those who were not, but this does not rule out the possibility of differential follow-up.

The data presented here support the hypothesis that there is a continuous distribution of hypertension prevalence from lean, low-salt, high-physical-activity societies in which wage labor is uncommon or absent to high-BMI, high-salt, low-physical-activity populations in which wage labor is the norm (e.g., the United States and Europe) (24, 97). Social and economic transformations occurring in some segments of the contemporary West African population are apparently bringing hypertension prevalence values closer to those seen in Western societies (13, 63), but these data suggest that hypertension prevalence in the general

population in West Africa, while significant from a public health standpoint, is still considerably less than that seen industrialized societies.

Contrary to some previous speculation (64–66), there appears to be no evidence that unique processes are operating in the etiology of hypertension in this population. Rather, the same risk factors that are important in industrialized societies can be identified in West Africa. Where those risk factors are largely absent, the prevalence of the disease remains low, and where those risk factors become more common, prevalence rises pari passu. This is consistent with previous findings that different racial or ethnic groups, when observed under conditions of relatively equal social position and equal prevalence of common risk factors, demonstrate similar patterns of disease (102). This study is therefore consistent with the general hypothesis that human populations are essentially uniform in their mean susceptibility to hypertension and that observed differences in disease distributions result from differential exposure to established risk factors (103).

REFERENCES

1. Mensah GA, Barkey NL, Cooper RS. Spectrum of hypertensive target organ damage in Africa: a review of published studies. J Hum Hypertens 1994;8:799–808.
2. Cooper RS, Rotimi C. Establishing the epidemiologic basis for prevention of cardiovascular diseases in Africa. Ethn Dis 1993;3 (Suppl.):S13–23.
3. Pobee JOM. Community-based high blood pressure programs in sub-Saharan Africa. Ethn Dis 1993:3 (Suppl): S38–45.
4. Kaufman J, Barkey N. Hypertension in Africa: an overview of prevalence rates and causal risk factors. Ethn Dis 1993;3 (Suppl):S83–101.
5. Ashcroft MT. Prevalence of hypertension and associated electrocardiographic abnormalities in Jamaica and West Africa. West Indian Med J 1977;26:24–33.
6. Vaughan JP, Miall WE. A comparison of cardiovascular measurements in the Gambia, Jamaica and the United Republic of Tanzania. Bull World Health Organ 1979;57: 281–9.
7. Wilson TW, Hollifield LR, Grim CE. Systolic blood pressure levels in black populations in sub-Sahara Africa, the West Indies and the United States: a meta-analysis. Hypertension 1991;18 (3 Suppl):I87–91.
8. Simmons D, Barbour G, Congleton J, et al. Blood pressure and salt intake in Malawi: an urban-rural study. J Epidemiol Community Health 1986;40:188–92.
9. Seedat YK, Seedat MA, Hackland DBT. Prevalence of hypertension in the urban and rural Zulu. J Epidemiol Community Health 1982;36:256–61.
10. Seedat YK, Seedat MA, Hackland DBT. Biosocial factors and hypertension in urban and rural Zulus. S African Med J 1982;61:999–1002.
11. Poulter N, Khaw KT, Hopwood BEC, et al. Blood pressure and its correlates in an African tribe in urban and rural environments. J Epidemiol Community Health 1984;38: 181–5.
12. Ogunlesi A, Osotimehin B, Abbiyessuku F, et al. Blood pressure and educational level among factory workers in Ibadan, Nigeria. J Hum Hypertens 1991;5:375–80.
13. Bunker CH, Ukoli FA, Nwankwo MU, et al. Factors associated with hypertension in Nigerian civil servants. Prev Med 1992;21:710–22.
14. Ekpo EB, Udofia O, Eshiet NF, et al. Demographic, life-style and anthropometric correlates of blood pressure of Nigerian urban civil servants, factory and plantation workers. J Hum Hypertens 1992;6:275–80.
15. McDonough JR, Garrison GE, Hames CG. Blood pressure and hypertensive disease among Negroes and whites. Ann Intern Med 1964;6:208–28.
16. Schoenberger JA, Carter M, Eckenfels EJ, et al. Hypertension in Holmes County, Mississippi. In: Paul O, ed. Epidemiology and control of hypertension. Miami, FL: Symposia Specialists, 1975:485–502.
17. Prineas RJ, Gillum RF. U.S. epidemiology of hypertension in blacks. In: Hall WD, Saunders E, Shulman NB, eds. Hypertension in blacks: epidemiology, pathophysiology and treatment. Chicago, IL: Year Book Medical Publishers, Inc., 1985:17–37.
18. Fouriaud C, Jacquinet-Salord MC, Degoulet P, et al. Influence of socioprofessional conditions on blood pressure levels and hypertension control: epidemiologic study of 6,665 subjects in the Paris district. Am J Epidemiol 1984;120:72–86.
19. Keil JE, Tyroler HA, Sandifer SH, et al. Hypertension: effects of social class and racial admixture. Am J Public Health 1977;67:634–9.
20. Moorman PG, Hames CG, Tyroler HA. Socioeconomic status and morbidity and mortality in hypertensive blacks. Cardiovasc Clin 1991;21:179–94.
21. Hypertension Detection and Follow-Up Program Cooperative Group. Race, education and prevalence of hypertension. Am J Epidemiol 1977;106:351–61.
22. Winkleby MA, Jatulis DE, Frank E, et al. Socioeconomic status and health: how education, income and occupation contribute to risk factors for cardiovascular disease. Am J Public Health 1992;82:816–20.
23. Stamler R, Shipley M, Elliot P, et al. Higher blood pressure in adults with less education: some explanations from INTERSALT. Hypertension 1992;19:237–41.
24. Waldron I, Nowotarski M, Freimer M, et al. Cross-cultural variation in blood pressure: a quantitative analysis of the relationships of blood pressure to cultural characteristics, salt consumption and body weight. Soc Sci Med 1982;16: 419–30.
25. INTERSALT Cooperative Research Group. Sodium, potassium, body mass, alcohol and blood pressure: The INTERSALT Study. J Hypertens Suppl 1988;6:S584–6.
26. Blaustein MP, Hamlyn JM. Pathogenesis of essential hypertension: a link between dietary salt and high blood pressure. Hypertension 1991;18 (Suppl.):III184–95.
27. Dustan HP. A perspective on the salt-blood pressure relation. Hypertension 1991;17(1 Suppl.):I166–9.
28. Elliott P. Observational studies of salt and blood pressure. Hypertension 1991;17(1 Suppl.):I3–8.
29. Langford HG. Dietary potassium and hypertension: epidemiologic data. Ann Intern Med 1983;98 (Part 2):770–2.
30. Linas SL. The role of potassium in the pathogenesis and treatment of hypertension. Kidney Int 1991;39:771–86.
31. Elliott P, Dyer A, Stamler R. The INTERSALT Study: results for 24-hour sodium and potassium, by age and sex. The INTERSALT Cooperative Research Group. J Hum Hypertens 1989;3:323–30.
32. Kesteloot H. Epidemiological studies on the relationship between sodium, potassium, calcium, and magnesium and arterial blood pressure. J Cardiovasc Pharmacol 1984;6 (Suppl. 1):S192–6.
33. Dyer AR, Elliot P. The INTERSALT study: relations of body mass index to blood pressure. J Hum Hypertens 1989;3: 299–308.
34. Gillum RF. The association of body fat distribution with hypertension, hypertensive heart disease, coronary heart disease, diabetes and cardiovascular risk factors in men and women aged 18–79 years. J Chronic Dis 1987;40:421–8.
35. Keenan NL, Strogatz DS, James SA, et al. Distribution and correlates of waist-to-hip ratio in black adults: The Pitt County Study. Am J Epidemiol 1992;135:678–84.
36. Neser WB, Thomas J, Semenya K, et al. Obesity and hypertension in a longitudinal study of black physicians: The Meharry Cohort Study. J Chronic Dis 1986;39:105–13.
37. Ng'andu NH. Blood pressure levels of Zambian rural adolescents and their relationship to age, sex, weight, height and three weight-for-height indices. Int J Epidemiol 1992;21: 246–52.
38. Selby JV, Friedman GD, Quesenberry CP Jr. Precursors of essential hypertension: the role of body fat distribution pat-

tern. Am J Epidemiol 1989;129:43–53.

39. Jenner DA, Puddey IB, Beilin LJ, et al. Lifestyle- and occupation-related changes in blood pressure over a six-year period in a cohort of working men. J Hypertens 1988;6 (Suppl. 4):S605–7.

40. Jenner DA, English DR, Vandongen R, et al. Environmental temperature and blood pressure in 9-year-old Australian children. J Hypertens 1987;5:683–6.

41. Liu K, Ballen C, Jacobs DR, et al. Ethnic differences in blood pressure, pulse rate, and related characteristics in young adults. The CARDIA Study. Hypertension 1989;14:218–26.

42. Touyz RM, Rathakrishnan S, Reinach SG, et al. Hypertension, alcohol and cations in urban black and colored South Africans. S Afr Med J 1989;75:109–13.

43. Gyntelberg F, Meyer J. Relationship between blood pressure and physical fitness, smoking and alcohol consumption in Copenhagen males aged 40–59. Acta Med Scand 1974;195:375–80.

44. He J, Klag MJ, Whelton PK, et al. Migration, blood pressure pattern, and hypertension: the Yi Migrant Study. Am J Epidemiol 1991;134:1085–101.

45. He J, Tell GS, Tang YC, et al. Effect of migration on blood pressure: the Yi People Study. Epidemiology 1991;2:88–97.

46. Poulter N, Khaw KT, Mugambi M, et al. Migration-induced changes in blood pressure: a controlled longitudinal study. Clin Exp Pharmacol Physiol 1985;12:211–16.

47. Salmond CE, Joseph JG, Prior IA, et al. Longitudinal analysis of the relationship between blood pressure and migration: the Tokelau Island Migrant Study. Am J Epidemiol 1985;122:291–301.

48. Salmond CE, Prior IA, Wessen AF. Blood pressure patterns and migration: a 14-year cohort study of adult Tokelauans. Am J Epidemiol 1989;130:37–52.

49. Astagneau P, Lang T, Delarocque E, et al. Arterial hypertension in urban Africa: an epidemiologic study on a representative sample of Dakar inhabitants in Senegal. J Hypertens 1992;10:1095–101.

50. Giles WH, Pacque M, Greene BM, et al. Prevalence of hypertension in rural West Africa. Am J Med Sci 1994;308:271–5.

51. Lang T, Pariente P, Salem G, et al. Social, professional conditions and arterial hypertension: an epidemiological study in Dakar, Senegal. J Hypertens 1988;6:271–6.

52. Muna WFT. The importance of cardiovascular research in Africa today. Ethn Dis 1993;3 (Suppl.):S8–12.

53. Nissinen A, Bothig S, Granroth H, et al. Hypertension in developing countries. World Health Stat Q 1988;41:141–54.

54. World Bank. Social indicators of development, 1990. Baltimore, MD: Johns Hopkins University Press, 1991:230.

55. Osaghae EE. Ethnic minorities and federalism in Nigeria. Afr Affairs 1991;90:237–58.

56. Imoagene O. A discordant ruling class. In: Imogene O, ed. The Nigerian class structure. Ibadan, Nigeria: Evans Brothers, 1989:40–63.

57. Wilson TW, Grim CE. Biohistory of slavery and blood pressure differences in blacks today: a hypothesis. Hypertension 1991;17(1 Suppl.):1122–8.

58. Grim CE, Wilson TW. Salt, slavery and survival: physiological principles underlying the evolutionary hypothesis of salt-sensitive hypertension in western hemisphere blacks. In: Fray JCS, Douglas JG, eds. Pathophysiology of hypertension in blacks, New York, NY: Oxford University Press, 1993:25–49.

59. Anonymous. Hypertension—in black and white. Lancet 1992;339:28–9.

60. Klahr S. The kidney in hypertension—villain and victim. N Engl J Med 1989;320:731–3.

61. Dustan H. Growth factors and racial differences in severity of hypertension and renal disease. Lancet 1992;339:1339–40.

62. White PD. Hypertension and atherosclerosis in the Congo and in Gabon. In: Stamler J, Stamler R, Pullman TM, eds.

The epidemiology of hypertension. New York, NY: Grune and Stratton, 1967:150–4.

63. Idahosa PE. Hypertension: an ongoing health hazard in Nigerian workers. Am J Epidemiol 1987;125:85–91.

64. Law MR, Frost CD, Wald NJ. By how much does dietary salt reduction lower blood pressure. I. Analysis of observational data among populations. Br Med J 1991;302:811–15.

65. Kaplan NM. Ethnic aspects of hypertension. Lancet 1994;344:450–2.

66. Campese VM, Parise M, Karubian F, et al. Abnormal renal hemodynamics in black salt-sensitive patients with hypertension. Hypertension 1991;18:805–12.

67. Ataman SL, Cooper R, Rotimi C, et al. Standardization of blood pressure measurement in an international comparative study. J Clin Epidemiol (In press).

68. Rotimi CN, Cooper RS, Ataman SL, et al. Distribution of anthropometric variables and the prevalence of obesity in populations of West African origin: The International Collaborative Study of Hypertension in Blacks (ICSHIB). Obesity Res 1995;3 (Suppl. 2):95S-105S.

69. Eades JS. The Yoruba today. Cambridge, England: Cambridge University Press, 1980:69.

70. Lemeshow S, Robinson D. Surveys to measure programme coverage and impact: a review of the methodology used by the Expanded Programme on Immunization. World Health Stat Q 1985;38:65–75.

71. Lindsay L. Putting the family on track: husbands, wives and work on the Nigerian Railway. Ph.D. dissertation, University of Michigan, Ann Arbor, MI, 1996.

72. Hasan MA, Thomas TA, Prys-Roberts C. Comparison of automatic oscillometric arterial pressure measurement with conventional auscultatory measurement in the labour ward. Br J Anaesth 1993;70:141–4.

73. Weaver MG, Park MK, Lee DH. Differences in blood pressure levels obtained by auscultatory and oscillometric methods. Am J Dis Child 1990;144:911–14.

74. Del Greco L, Walop W, Eastridge L. Questionnaire development 3: translation. Can Med Assoc J 1987;136:817–18.

75. Dean AG, Dean JA, Burton AH, et al. Epi-Info, Version 5: a word processing, database, and statistics program for epidemiology on microcomputers. Stone Mountain, GA: USD, Inc., 1990.

76. SAS Institute, Inc. SAS user's guide: statistics, version 6 ed. Cary, NC: SAS Institute, Inc., 1989.

77. Lee AFS, Gurland J. Size and power tests for equality of means of two normal populations with unequal variances. J Am Stat Assoc 1975;70:933–41.

78. Smalley KJ, Knerr AN, Kendrick ZV, et al. Reassessment of body mass indices. Am J Clin Nutr 1990;52:405–8.

79. MacMahon S, Peto R, Cutler J, et al. Blood pressure, stroke, and coronary heart disease. Part 1. Prolonged differences in blood pressure: prospective observational studies corrected for the regression dilution bias. Lancet 1990;335:765–74.

80. Dyer AR, Shipley M, Elliott P, for the INTERSALT Cooperative Research Group. Urinary electrolyte excretion in 24 hours and blood pressure in the INTERSALT Study. I. Estimates of reliability. Am J Epidemiol 1994;139:927–39.

81. INTERSALT Cooperative Research Group. Appendix tables: Centre-specific results by age and sex. J Hum Hypertens 1989;3:331–407.

82. Alubo S. Economic crisis, austerity, and health care in Nigeria. Nigerian J Pol Econ 1985;3:129–46.

83. Ghali J. Should cardiovascular disease be a health priority for developing countries? Ethn Dis 1991;1:379–93.

84. Cooper F. Africa and the world economy. Afr Stud Rev 1981;24:1–86.

85. Aina TA. Class structure and the economic development process in Nigeria. Odu J West Afr Stud 1986;29:17–36.

86. Fashoyin T. Industrial relations in Nigeria. London, England: Longman, 1980:13–14.

87. Oviasu VO, Okupa FE. Occupational factors in hypertension in the Nigerian African. J Epidemiol Community Health

1979;33:274–8.

88. Oviasu VO, Okupa FE. Arterial blood pressure and hypertension in Benin in the equatorial forest zone of Nigeria. Trop Geogr Med 1980;32:241–4.

89. Akinkugbe OO. School survey of arterial pressure and proteinuria in Ibadan, Nigeria. East Afr Med J 1969;46:258–61.

90. Akinkugbe OO, Akinkugbe FM, Ayeni O, et al. Biracial study of arterial pressures in the first and second decades of life. Br Med J 1977;1:1132–4.

91. Adams-Campbell LL, Nwankwo MU, Omene JA, et al. Assessment of cardiovascular risk factors in Nigerian students. Arteriosclerosis 1988;8:793–6.

92. Idahosa PE, Ilawole M. Towards Nigeria's first national blood pressure survey: a pilot study of arterial blood pressure in members of the National Youth Service Corps. J Hypertens 1984;2 (Suppl. 3):S209–11.

93. Johnson TO. Arterial blood pressures and hypertension in an urban African population sample. Br J Prev Med 1971;25:26–33.

94. Pobee JO, Larbi EB, Belcher DW, et al. Blood pressure distribution in a rural Ghanaian population. Trans R Soc Trop Med Hyg 1977;71:66–72.

95. He J, Klag MJ, Whelton PK, et al. Body mass and blood pressure in a lean population in southwestern China. Am J Epidemiol 1994;139:380–9.

96. Walker AR, Walker BF, Manetsi B, et al. Obesity in black women in Soweto, South Africa: minimal effects on hypertension, hyperlipidemia and hyperglycemia. J R Soc Health 1990;110:101–3.

97. Carvalho JJM, Baruzzi RG, Howard PF, et al. Blood pressure in four remote populations in the INTERSALT study. Hypertension 1989;14:238–46.

98. Langford HG. Sodium-potassium interaction in hypertension and hypertensive cardiovascular disease. Hypertension 1991; 17(1 Suppl.):I155–7.

99. Beard TC. Hypertension after INTERSALT: prospects for prevention. J Cardiovasc Pharmacol 1990;16 (Suppl. 7):S31–4.

100. Crocco SC. The role of sodium in food processing. J Am Diet Assoc 1982;80:36–9.

101. Fadipe NA. The sociology of the Yoruba. Ibadan, Nigeria: Ibadan University Press, 1970.

102. Cruickshank JK, Jackson SHD, Beevers DG, et al. Similarity of blood pressures in blacks, whites and Asians in England: the Birmingham Factory Study. J Hypertens 1985;3:365–71.

103. Cooper R, Rotimi C. Hypertension in populations of West African origin: is there a genetic predisposition? J Hypertens 1994;12:215–27.