

Role of Genetic and Environmental Factors in the Increased Blood Pressures of Bolivian Blacks

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ABSTRACT The tendency toward hypertension or higher blood pressure is more common in blacks than whites. The factors that account for these differences are attributed to both environmental and genetic factors. To clarify this issue, an anthropological study of black and nonblack populations in the lowland village of Chicaloma, northeastern Bolivia at a midaltitude of 1,800 m was conducted. The study included 159 subjects, of which 79 were black and 80 were nonblack, 17–78 years. The study suggests the following: (1) the socioeconomic status of blacks as measured by an ownership index is greater than that of nonblacks, (2) blacks had higher average systolic and diastolic blood pressures than nonblacks and showed an age-associated increase in blood pressures, (3) the prevalence of hypertension was higher for blacks (7–6%) than nonblacks (1.3%), but three times lower than among blacks in the United States, (4) skin reflectance is inversely related to blood pressures so that contrary to what has been suggested the darker the skin color, the higher the blood pressures even at comparable levels of affluence. These findings together suggest that genetic factors predispose black individuals to increased blood pressures, but the expression of clinical hypertension is influenced by adverse unaccounted environmental factors. *Am. J. Hum. Biol.* 11:489–498, 1999. © 1999 Wiley-Liss, Inc.

INTRODUCTION

In general, African-American blacks have higher blood pressure than nonblacks. At the individual level, variability in blood pressure is determined by the interplay of blood volume and arteriolar constriction so that high blood volume associated with vasoconstriction results in high blood pressure. Since sodium produces both intravascular volume expansion and vasoconstriction, variability in either intake or retention of salt would influence blood pressure. The factors that account for these differences are attributed to both environmental and genetic factors.

Experimental and clinical studies have

shown that blacks in the United States have an enhanced sodium retention and a greater increase in blood pressure in response to Na⁺ intake than whites (Luft, 1977; Aviv et al., 1990; Hall, 1990). Similarly, epidemiological studies indicate that blacks ingest similar amounts of dietary salt than non-

Contract grant sponsor: NIH-Fogarty Minority International Research Training grant; Contract grant number: IT3700035 (to the Center for Human Growth).

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Received 27 January 1998; Revision received 22 May 1998; Accepted 26 May 1998

blacks (Frisancho and Leonard, 1984). It has been postulated that the genetic tendency to maintain higher blood pressure in blacks is the result of high retention of salt that might have evolved as an adaptation to the hot tropical climate of Africa and/or as result of selection during the transport of slaves from Africa to America (Gleibermann, 1973, 1975; Grim et al., 1980).

In contrast, the environmental hypothesis postulates that the environmental stresses of poverty and low socioeconomic status to which blacks are generally exposed are the main factors involved in high blood pressure. This hypothesis is based on evidence that the prevalence of hypertension in African-Americans is higher than that in the Caribbean and Brazilian black populations (Johnson and Remington, 1961; Johnson et al., 1975; Ribeiro et al., 1981; Coronihuntley et al., 1989; Dressler, 1987, 1991; James et al., 1991; Saunders, 1991). As inferred from current reviews (Dressler, 1987, 1991; James et al., 1991; Moorman et al., 1991; Calhoun, 1992; Williams, 1992), the increasing incidence of hypertension in developing nations is related to socioeconomic and behavioral traits associated with urban environments. It has been hypothesized that high blood pressure among U.S. blacks is related to socio-cultural stress resulting from the struggle of individuals of dark skin color to establish and maintain a middle-class life style (Dressier, 1990, 1991; Moorman et al., 1991; Calhoun, 1992; Williams, 1992).

In summary, it is not clear the extent to which the observed higher tendency toward hypertension or higher blood pressure in African-American blacks is related to socio-cultural stress in populations where skin color is not an important criterion of social class as it is the United States. Similarly, if the increased frequency of hypertension is related to genetic factors, it is not known whether it is expressed under conditions where blacks are of equal socioeconomic condition as nonblacks. For this reason, an anthropological study of black and nonblack populations living in the lowland village of Chicaloma, northeastern Bolivia at a mid-altitude of 1,800 m, was conducted.

MATERIALS AND METHODS

Sample

The analysis is based upon a sample of 159 subjects ranging in age from 17 to 78

years. The subjects were classified as either black or nonblack using: (1) individual self-identification, each participant being asked whether he/she considers him/herself as black or mestizo, (2) individual surname, last names being traced as of Aymara, Quechua, or Spanish ancestry, and (3) anthroposcopic observation by the principal investigator (ARF). Through these procedures, 92 subjects were classified as black and 67 were classified as nonblack. The latter included individuals of predominantly Aymara or Aymara mixed with Spanish ancestry. The sample represented 50% of the total adult populations of the village of Chicaloma in June 1995. The protocol for the study was approved by a Human Subjects Review Committee at the University of Michigan and the Bolivian Institute of Biology and Altitude (IBBA).

Study population

In geographic terms, the town of Chicaloma where the study was conducted, at a mid-altitude of 1,800 m, belongs to a subtropical region. Because of the semitropical and Andean location, there are no clear differences between the full seasons aside from the two defined seasons of summer (December through April) and winter (May through November). Summer is characterized by high temperatures and humidity with an average temperature of 95°F and 80% humidity, whereas winter is characterized by mild temperatures averaging 75°F and 50% humidity.

Until the 1960s, the economic base of the population was the cultivation of coffee, cacao, and tropical fruits, such as oranges, bananas, and tangerines. In the past 20 years, the economy of the population has shifted primarily to the cultivation of coca leaves. Because the cocoa plant is easy to produce and there is a high demand for coca leaves, their cultivation has become the main occupation of the population. The high economic return of coca plants has attracted other nonblack populations to the area. Therefore, in Chicaloma there are black and nonblack populations dedicated to the cultivation and trade of coca leaves. In general, land ownership tends to be more in the hands of blacks than nonblacks because blacks were the first colonizers of the area. Hence, the socioeconomic status of the blacks is higher than that of the nonblacks.

Origin of black population in Chicaloma and Bolivia

According to historical accounts, the black population of Bolivia came from the Spanish slave trade practiced prior to independence. Most of the black slaves during Spanish colonization were brought from West Africa to the ports of Buenos Aires, Argentina, and Lima, Peru (Crespo, 1977; Portugal, 1978; Criales, 1992). From there, the black slaves were taken to work as laborers in the land holdings of the Spaniards. Others were sold to work in the silver mines of Bolivia and Peru. It is estimated that ~1,000 slaves were transported to work in the silver mines of Potosi, located at an altitude above 4,500 m (15,114 ft) in the northeastern region of Bolivia. As a consequence of the harsh working conditions and extreme altitude, a large percentage of the black population died. Some of the surviving slaves escaped to the tropical lowlands, whereas others were sold to landowners in the lowlands (Criales, 1992). Since then, the black population has inhabited various areas of the tropical and subtropical regions of northeastern Bolivia. At present, there are ~6,000 members of this population living in the eastern tropical region of Bolivia known as the Yungas.

In 1953, the agrarian reform of Bolivia began and granted ownership of the land to the slaves. As a consequence, black slaves and other non-black settlers became small landowners. Other recent migrants or recent colonizers, such as mestizos, Aymaras, and Quechuas, have become tenants of both black and nonblack earlier settlers. Prior to the demand for coca leaves, the subsistence economy of the populations in the subtropical regions, referred to as the Yungas, was based on the agriculture of traditional products, such as coffee, cacao, sugar, and fruits. However, when the drug trade of cocaine increased, the demand for coca leaves also increased, causing a shift to coca cultivation almost entirely. Therefore, in recent times, the major cash crop of the Yungas and of the Chicaloma population has been the cultivation of coca leaves.

Measurements and analysis

The study includes measurements of socioeconomic status, anthropometric estimates of body composition, blood pressures, genetic markers, serum lipids, and dietary

practices. It should be noted that due to logistic difficulties the sample sizes were not the same for every measurement. Hence, the number of subjects are given for every variable included in the analysis.

Socioeconomic status

Language and level of education. Information on level of education and language spoken were obtained from questionnaires administered to the heads of the households. The questionnaires gathered information about: (1) level of education (questions ranging from literacy level to level of completed Bolivian education) and (2) language knowledge (whether the individual spoke Quechua, Aymara, or Spanish). The level of education was similar in both ethnic groups (Woodill, 1996). Although there are no differences between blacks and nonblacks in the number of people who speak Spanish, a significantly greater number of nonblacks speak Aymara.

Economic status. Information about economic traits were obtained from questionnaires administered to the heads of households. The questionnaires gathered information about: (1) house ownership, number of rooms in the house (other than the kitchen), (2) type of roof and floor, (3) type of walls in the house, (4) bathroom facilities (outside, latrine, washroom), (5) access to electricity, and (6) household items such as radio, tape recorder, sewing machine, bicycle, blender, refrigerator, car or motorcycle, upholstered furniture, and television set.

Anthropometric dimensions

The anthropometric data include height, weight, sitting height, and skinfold thicknesses measured at triceps, subscapular, midaxillary, suprailiac, thigh, and calf (Lohman et al., 1988; Frisancho, 1990). The body mass index (BMI), midupper arm muscle area, arm area, arm fat index, and sitting height index were calculated (Frisancho, 1990).

Measurements of whole body resistance were obtained with a bioelectrical impedance analyzer (Valhalla Scientific, San Diego, CA). Subjects assumed a supine position with arms and feet spread apart and shoes and socks removed. The detecting electrodes were placed on the dorsal aspect of the right wrist midway between the ra-

TABLE 1. Socioeconomic characteristics of Chicaloma sample and subsamples of blacks and nonblacks

Item	Chicaloma	Black	Nonblack
Years of education ¹	5.17 (n = 143)	5.18 (n = 80)	5.17 (n = 63)
Able to read (%) ¹	81.8 (n = 143)	85.0 (n = 80)†	77.8 (n = 63)
Speaks Aymara (%) ¹	25.9 (n = 143)	10.0 (n = 80)†	46.0 (n = 63)
Speaks Quechua (%) ¹	8.2 (n = 143)	2.8 (n = 80)†	15.0 (n = 63)
Speaks Spanish (%) ¹	98.0 (n = 143)	100.0 (n = 80)	95.2 (n = 63)
Owens house (%) ²	84.1 (n = 157)	87.8 (n = 90)†	79.1 (n = 67)
Has access to electricity (%) ²	83.4 (n = 157)	88.9 (n = 90)†	76.1 (n = 67)
Owens refrigerator (%) ²	25.5 (n = 157)	28.9 (n = 90)†	20.9 (n = 67)
Owens television set (%) ²	54.8 (n = 157)	63.3 (n = 90)†	43.3 (n = 67)

¹Adapted from Woodill (1996) based on partial sampler.

²Based on a more complete sample.

†P < 0.05 by Chi-square test.

dial and lunar processes and the anterior aspect of the right ankle midway between the tibia and fibia's malleoli.

Lean body mass was calculated using the equation of Kushner et al. (1992) for estimating total body water which was modified to provide a new population-specific equation for estimating lean body mass:

$$\text{Lean body mass (kg)} = 2.395 + (0.864 \times (H^2/R) - (0.009 \times E)),$$

where H = Height, squared, R = resistance from bioelectric impedance, E = ethnicity: 1 = black, 2 = nonblack.

Measurements of skin reflectance were made with a Photovolt Reflectometer, Model 575. Reflectance readings were made following the same procedures used in a previous study (Frisancho et al., 1981). This included measurements with two filters identified as triamber and trigreen. These filters have transmission peaks of ~600 nm (triamber), and 550 nm (trigreen) (Conway and Baker, 1972; Frisancho et al., 1981). At least two readings on the inner arm distal to the axillary region were obtained on each participant. The readings on the inner arm with the triamber and green filters were averaged.

Because of nonnormal distributions, the sum of skinfolds and mean skin reflectance were log₁₀ transformed.

Blood pressures

Blood pressures were measured in a sitting position. Systolic and diastolic blood pressures were obtained on three occasions: during the initial anthropometric evaluation, during specific health evaluation, and at the end of the examination. The results of the three readings were averaged. Each

reading was done using both a manual sphygmomanometer and a battery operated blood pressure monitor and was taken after the subject rested quietly for at least 5 min. The advantage of using automated equipment eliminated the observer bias and/or reading preference and minimized training time.

Serum lipids

At the examinations in Chicaloma blood was drawn into tubes with 0.1 g EDTA as anticoagulant after a 12–14 h overnight fast. Blood tubes were immediately placed on ice, and plasma was separated by centrifugation at 1,000 × g for 20 min at 4° C within 4 h. The analysis of cholesterol, high density lipoproteins (HDL), low density lipoproteins (LDL), and triglycerides were done at the Biochemistry Laboratory at the Instituto Boliviano de Altura (IBBA) following standard procedures (Friedewald et al., 1972):

$$\text{LDL cholesterol (mmol/L)} = \frac{[\text{total cholesterol (mmol/L)} - \text{HDL cholesterol (mmol/L)} - \text{triglyceride (mmol/L)}]}{2.18}.$$

RESULTS

General characteristics

As noted earlier, there are no differences between blacks and nonblacks in the number of people who speak Spanish, but a significantly greater number of nonblacks speak Aymara as described by Woodill (1996). About 84% of Chicaloma subjects own their house, 83% have access to electricity, 26% own refrigerators, and 55% own a television set (Table 1). Further, a significantly greater percentage of blacks own their house (87.8% for blacks and 79.1% for nonblacks). Moreover, a significantly

TABLE 2. Comparison of ownership index (OI) of blacks and nonblacks samples in Chicaloma

Item	N	Black		Nonblack		P
		Mean ± SE	N	Mean ± SE	N	
House ownership	90	0.91 ± 0.05	67	0.71 ± 0.08	67	<0.05
Electricity	90	1.10 ± 0.04	67	0.90 ± 0.06	67	<0.05
Refrigerator	90	1.10 ± 0.20	67	0.80 ± 0.20	67	<0.01
Television	90	1.20 ± 0.09	67	0.80 ± 0.11	67	<0.01
Ownership index (OI)	90	4.30 ± 0.3	67	3.30 ± 0.31	67	<0.01

greater percentage of blacks have access to electricity (88.9% for blacks and 76.1% for nonblacks), own a refrigerator (28.9% of blacks and 20.9% of nonblacks) own a television set (63.3% of blacks and 43.3% for nonblacks). Overall, blacks have a higher economic status than nonblack samples.

To investigate the relationship between socioeconomic status and blood pressures, an ownership index (OI) was calculated. The index is based on population reciprocals for the frequencies of (1) home ownership, (2) access to electricity, (3) possession of a television set, and (4) possession of a re-

frigerator. For example, the OI for house ownership in the population as a whole would equal 1.19 (1/84.1×100=1.19), 1.20 for access to electricity (1/83.4×100=1.20), 3.92 for ownership of refrigerator (1/25.5×100=3.92), and 1.82 for ownership of a television set (1/54.8×100=1.82). In this manner, each household was accorded an OI depending on whether or not it owned its home, had access to electricity, owned a television set, and a refrigerator. The use of reciprocals gave the greatest weighting to the least frequently owned of these four amenities.

TABLE 3. Anthropometric characteristics and skin reflectance of blacks and nonblacks in Chicaloma

Variable	Black		Nonblack		F-test
	N	Mean ± SE	N	Mean ± SE	
Males					
Age (yr)	37	39.2 ± 2.1	25	39.3 ± 2.6	n.s.
Height (cm)	37	165.8 ± 1.2	25	159.4 ± 1.6	P < 0.01
Weight (kg)	37	63.1 ± 0.9	25	59.3 ± 1.8	P < 0.01
BMI (kg/m ²)	37	22.9 ± 0.3	25	23.2 ± 0.4	n.s.
St. height (cm)	37	83.6 ± 0.6	24	84.8 ± 0.8	n.s.
St. height index (%)	37	50.5 ± 0.4	24	53.0 ± 0.3	P < 0.01
Sum skin folds (mm)	37	33.9 ± 1.7	25	42.1 ± 3.4	P < 0.01
Midupper arm muscle (cm ²)	37	50.5 ± 1.2	25	46.4 ± 1.1	P < 0.05
Arm fat index (%)	37	16.7 ± 1.1	25	18.0 ± 1.2	n.s.
Bioimpedance (Ω)	37	451.4 ± 6.4	24	469.4 ± 10.9	n.s.
Height ² /R (Ω)	37	61.5 ± 1.2	24	55.5 ± 1.8	P < 0.01
Lean body mass (kg) ¹	37	55.5 ± 1.1	24	50.3 ± 1.6	P < 0.01
Body fat (kg) ¹	37	7.6 ± 0.7	24	9.7 ± 1.0	n.s.
Body fat (%) ¹	37	12.1 ± 1.1	24	16.0 ± 1.6	P < 0.015
Mean skin reflectance (%)	36	14.6 ± 0.8	25	21.5 ± 0.6	P < 0.01
Females					
Age (yr)	55	39.0 ± 1.9	42	36.8 ± 2.3	n.s.
Height (cm)	55	154.1 ± 0.9	42	148.6 ± 0.8	P < 0.01
Weight (kg)	55	56.7 ± 1.2	42	52.9 ± 1.1	P < 0.01
BMI (kg/m ²)	55	24.0 ± 0.5	42	24.0 ± 0.5	n.s.
St. height (cm)	52	78.1 ± 0.4	40	77.7 ± 0.5	n.s.
St. height index (%)	52	50.7 ± 0.3	40	52.2 ± 0.3	P < 0.01
Sum skin folds (mm)	54	62.2 ± 3.7	41	68.3 ± 4.5	n.s.
Midupper arm muscle (cm ²)	54	36.8 ± 0.9	41	34.5 ± 1.2	n.s.
Arm fat index (%)	54	33.0 ± 1.4	41	36.9 ± 1.5	n.s.
Bioimpedance (Ω)	47	502.9 ± 7.1	36	528.0 ± 7.1	P < 0.01
Height ² /R (Ω)	47	61.5 ± 1.2	36	55.5 ± 1.8	P < 0.01
Lean body mass (kg)	47	43.5 ± 0.7	36	39.0 ± 0.9	P < 0.01
Body fat (kg)	47	12.2 ± 0.9	36	13.0 ± 0.9	n.s.
Body fat (%)	47	21.3 ± 1.2	36	24.6 ± 1.3	P < 0.01
Mean skin reflectance (%)	51	17.1 ± 0.6	38	23.6 ± 0.6	P < 0.01

n.s. = not significant.

TABLE 4. Blood pressures and serum lipids of blacks and nonblacks in Chicaloma.

Variable	N	Black		Nonblack		F-test
		Mean ± SE	N	Mean ± SE	N	
Males						
Systolic blood pressure (mmHg)	35	123.7 ± 3.1	25	107.4 ± 2.2		<i>P</i> < 0.01
Diastolic blood pressure (mmHg)	35	73.9 ± 2.1	25	65.7 ± 1.8		<i>P</i> < 0.01
Cholesterol (mg)	32	168.9 ± 11.3	17	176.2 ± 13.2		n.s.
High density lipoprotein (mg)	32	40.0 ± 1.7	17	43.0 ± 34.9		n.s.
Low density lipoprotein (mg) ¹	32	104.2 ± 6.5	17	135.3 ± 19.9		n.s.
Triglycerides (mg)	32	79.6 ± 9.8	17	103.05 ± 18.9		n.s.
Hemoglobin (mg/100ml)	27	14.6 ± 0.3	15	14.9 ± 0.4		n.s.
Hematocrit (%)	27	43.3 ± 0.6	15	42.3 ± 1.0		n.s.
Females						
Systolic blood pressure (mmHg)	54	119.2 ± 2.8	42	102.7 ± 2.2		<i>P</i> < 0.01
Diastolic blood pressure (mmHg)	54	72.9 ± 2.1	42	64.2 ± 1.8		<i>P</i> < 0.01
Cholesterol (mg)	51	171.9 ± 6.9	36	173.9 ± 8.7		n.s.
High density lipoprotein (mg)	51	48.7 ± 1.7	36	43.9 ± 2.3		n.s.
Low density lipoprotein (mg) ¹	51	111.7 ± 6.5	36	117.2 ± 7.5		n.s.
Triglycerides (mg)	51	71.9 ± 4.6	36	80.3 ± 8.4		n.s.
Hemoglobin (mg/100ml)	50	12.5 ± 0.2	36	12.3 ± 0.3		n.s.
Hematocrit (%)	50	38.2 ± 0.5	36	36.5 ± 0.5		n.s.

¹Low density lipoprotein (mg) = total cholesterol – high density lipoprotein – (Triglycerides × 0.16).
n.s. = not significant.

Results of this analysis indicate that blacks have a higher OI index than nonblacks (Table 2).

In terms of body size and body composition, blacks are significantly taller and heavier and have a greater midupper arm muscle area and higher lean body mass than nonblacks (Table 3). The mean skin reflectance is significantly lower in blacks than in nonblacks.

Blood pressures and cholesterol

Black males have significantly higher systolic and diastolic blood pressures, but lower serum cholesterols than nonblacks (Table 4). Similarly, black females have higher systolic and diastolic blood pressures than nonblacks, but have similar values of cholesterol, serum lipids, hemoglobin, and hematocrit concentrations (Table 4). The prevalence of hypertension (Table 5) is higher for blacks (7.9% for systolic and 5.9% for diastolic pressures) than nonblacks (1.3%). Among black males and females, systolic and diastolic blood pressures increase with age, whereas among nonblacks there are no age-associated increases (Figs. 1 and 2).

Multiple regression analyses were conducted with blood pressures as the dependent variable and age, sex, weight, BMI, sum of skinfold thicknesses, lean body mass, fat weight, percent fat weight, OI, and skin reflectance as independent vari-

ables. A series of regression analyses were run whereby the least important variables were excluded and only the important variables were included in the final equation. The results indicate that skin reflectance, age, and ethnicity are the most important predictors of variability in blood pressures (Table 6). However, OI, weight, BMI, sum of skinfolds, lean body mass, body fat (kg), body fat (%) have the least influence on blood pressures. Figure 3 shows that skin reflectance in the Chicaloma sample is inversely related to blood pressures so that the darker the skin reflectance the higher the blood pressures. As inferred from the correlations ($r = -0.43$ to -0.49 for systolic blood pressure and $r = -0.30$ to -0.47 for diastolic blood pressure), ~9–24% of the variability in blood pressure is related to variability in skin color. Serum cholesterol in Chicaloma is significantly influenced

TABLE 5. Frequency of hypertension among blacks and nonblacks in Chicaloma, with comparative data for U.S. blacks

	Chicaloma, Bolivia Nonblack (%)	Black (%)	U.S. ¹ Black
Systolic blood pressure > 160 mm Hg			
Males	0.0	7.3	30.1
Females	2.3	8.3	31.2
Total	1.3	7.9	30.5
Diastolic blood pressure > 95 mm Hg			
Males	0.0	2.4	31.2
Females	2.3	8.3	31.2
Total	1.3	5.9	30.5

¹National Center for Health Statistics (1977).

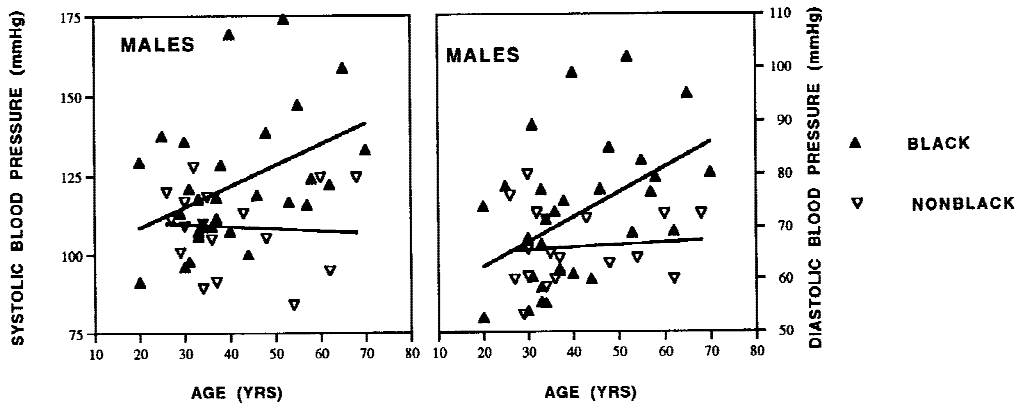


Fig. 1. Relationship of blood pressure and age among Chicaloma male samples. Note that among blacks, both systolic and diastolic blood pressures increase with age, whereas among nonblacks, they remain constant throughout all ages.

only by body fat. Similarly, the ratio of low density lipids to cholesterol is significantly related to material ownership and ethnicity. The remaining variables have a nonsignificant influence on variability of serum lipids.

DISCUSSION

The frequency of hypertension among Chicaloma blacks is much lower than that observed among U.S. blacks. These findings are similar to those reported in previous studies, in which the prevalence of hypertension in African-Americans is higher than that in Caribbean and Brazilian black populations (Johnson and Remington, 1961; Johnson et al., 1975; Rubeiro et al., 1981; Coroni-Huntsley et al., 1989; James et al.,

1991; Saunders, 1991). Various studies have hypothesized that high blood pressure among U.S. blacks is related to socio-cultural stress related to the establishment and maintenance of a middle-class life style in dark compared to light skin individuals (Dressler, 1990, 1991; Moorman et al., 1991; Calhoun, 1992; Williams, 1992). According to this hypothesis, the important issue is the status ascribed to the darker phenotype irrespective of the achievement of any given status level, i.e., the stresses associated with darker skin color have to do with the contribution that skin color per se makes to status attainment. In the population of Chicaloma, "blackness" is not associated with any negative status. In fact, the opposite oc-

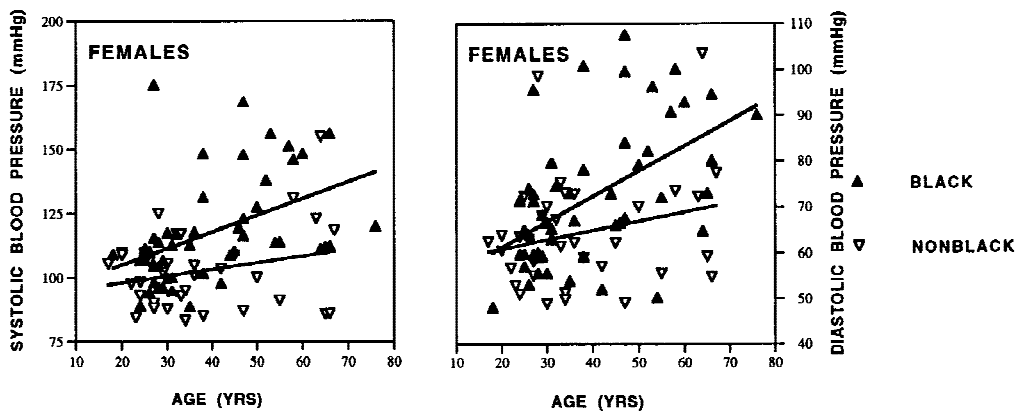


Fig. 2. Relationship of blood pressure and age among Chicaloma female samples. Note that among blacks, both systolic and diastolic blood pressures increase with age, whereas among nonblacks, they remain constant throughout all ages.

TABLE 6. Results of multivariate regression analyses of the best predictors of blood pressures and serum lipids for the sample of Chicaloma

Variable	R
Systolic blood pressure	
$Y = 166.64 - (45.67 \times \text{skin reflectance}) + (0.38 \times \text{age}) - (9.30 \times \text{ethnicity})$ (best predictor)	0.55
Not included in equation (poor predictors)	
OI, weight, BMI, sum of skinfolds, lean body mass, body fat (kg), body fat (%)	
Diastolic blood pressure	
$Y = 91.10 - (27.94 \times \text{skin reflectance}) + (0.38 \times \text{age})$ (best predictor)	0.46
Not included in equation (poor predictors)	
OI, weight, BMI, sum of skinfolds, lean body mass, body fat (kg), body fat (%), ethnicity	
Serum cholesterol	
$Y = 144.72 - (248 \times \text{body fat, kg})$ (best predictor)	0.26
Not included in equation (poor predictors)	
Age, weight, BMI, sum of skinfolds, lean body mass, body fat (%), OI, skin reflectance, ethnicity	
Ratio of low density lipid to cholesterol	
$Y = 54.08 + (1.16 \times \text{OI}) + (4.18 \times \text{ethnicity})$ (best predictor)	0.32
Not included in equation (poor predictors)	
Age, weight, BMI, sum of skinfolds, lean body mass, body fat (%), skin reflectance	

curs in that the principal local authorities are black. Because they are the major producers of the cash crop of the village, blacks have a higher or equal socioeconomic status as nonblacks. As indicated by material OI, blacks enjoy better economic conditions than nonblacks. Analyses of growth status and dietary intakes indicate that black children also have a higher standard of living than nonblacks (Woodill, 1996). These findings together suggest that the tendency toward high blood pressures among blacks from Chicaloma cannot be explained solely due to the influence of socio-cultural factors. However, it is possible that the tendency toward high blood pressures of blacks reflects the effects of transition from lower to higher socioeconomic status. In developing societies, a direct association between socioeconomic status and blood pressures emerges

first. At later stages of economic development, the association changes to the inverse pattern observed in industrialized nations. If this is the case, the increased tendency toward higher blood pressures of blacks would be related to the transition from a rural to urban environment.

It is also possible that blacks are predisposed to increased blood pressures due to the influence of genetic factors. Genetic studies among blacks from the islands of Barbados and La Desirade indicate that individuals having the largest proportion of African mitochondrial DNA have a higher mean systolic blood pressure and higher hypertension prevalence than those of non-African lineage (Darlu et al., 1990). Studies on the alpha 2-adrenergic receptor gene polymorphism among hypertensive and normotensive U.S. black and white subjects in-

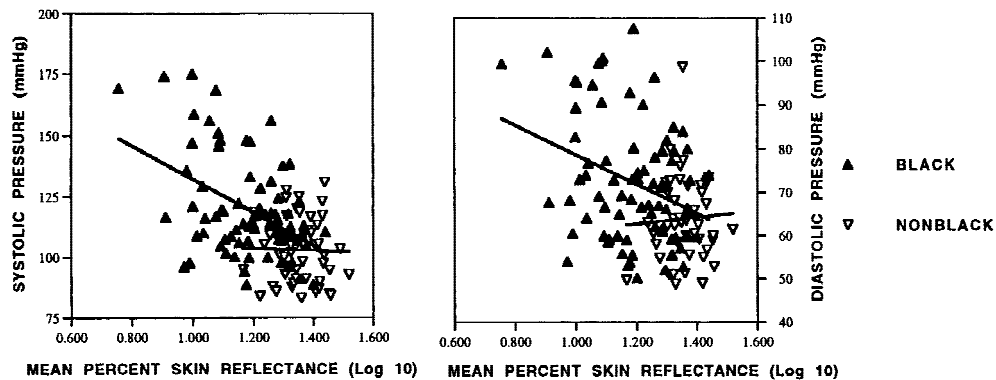


Fig. 3. Relationship of skin reflectance and blood pressures among Chicaloma samples. Note that among blacks, both systolic and diastolic blood pressures are significantly and inversely related to skin color, whereas among nonblacks, there is no relationship between skin color and blood pressure.

dicates that hypertensive blacks have a higher proportion of the abnormal short allele of alpha 2-adrenergic receptor gene than their normotensive counterparts (Freeman et al., 1995). In this study, 15.9% (13 out of 82) of the black hypertensives were homozygous for the short abnormal allele of alpha 2-adrenergic receptor gene polymorphism, but only 3% (2 out of 59) normotensive blacks and none of the (0 out of 25) white hypertensive subjects, were homozygous for the shorter allele. Comparative studies indicate that 80–90% of black Nigerians had a mutant allele, which is thought to influence the renin-angiotensin system, but 47% of hypertensive whites in Paris and Salt Lake City, Utah, also had a mutant allele (Cooper, 1997). These studies together suggest that there are genetic differences associated with the increased frequency of hypertension in blacks.

Several studies indicate that variability in skin color reflectance is the result of the additive effects of 3–5 loci (Byard, 1981) and that ~50–70% of the variability in skin reflectance is due to a heritable additive genetic component (Post and Rao, 1977; Frisancho et al., 1981). In the present study, skin reflectance per se accounts for ~9–24% ($r = -0.46$ for systolic pressure and $r = -0.32$ for diastolic pressure) of the variability in blood pressures. Similarly, multivariate regression analyses indicate that skin reflectance and age are the most important predictors of variability in blood pressures, whereas the material OI had the least effect on blood pressures and serum lipids. Thus, contrary to what has been suggested, the darker the skin color the higher the blood pressure, even at comparable levels of affluence.

In summary, the data suggest that genetic factors, as inferred from the association between blood pressures and skin reflectance, play a role, albeit small, in the risk to increased blood pressures. These findings suggest that genetic factors may predispose black individuals to increased blood pressures, but that the expression of clinical hypertension is under the influence of adverse unaccounted environmental factors.

ACKNOWLEDGMENTS

We thank Sanitarian Mr. Daniel Barra, for his enthusiastic assistance, the members

of the city council, schoolteachers, and all the families of Chicaloma, Bolivia, that participated in the study. We are also grateful to Stanley M. Garn for his suggestions and comments, and to Patricia Juliao for her assistance in revising this manuscript. This study was supported in part by NIH-Fogarty Minority International Research Training grant IT3700035 to the Center for Human Growth.

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