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# Blood pressure variation among Ethiopians on the Simien Plateau

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**Summary.** This report presents information on determinants of blood pressure variation in a rural sample of 263 Ethiopian highlanders 14–86 years of age, resident at 3530 m on the Simien Plateau. Mean systolic and diastolic blood pressures for males and females were 109/75 and 106/73, respectively, and there were no age differences. These findings confirmed that men and women can have low normal blood pressure throughout adulthood. Blood pressures increased with increasing body mass index (BMI) among adult males, although the mean BMI of 19·1 $kg/m^2$ was low compared with US values. This illustrates that BMI variation may be associated with blood pressure variation in men even at low mean values of both. Blood pressure did not vary with adult haemoglobin concentration.

## 1. Introduction

An age-related increase in blood pressure is so widespread in Western industrial populations that it is considered a part of the usual ageing process and considered remarkable when a few individuals escape (Finch 1990). However, data from over 36 populations in which blood pressure does not change with age illustrate that it is not an inevitable concomitant of the passage of time (James and Baker 1995). These populations also offer a natural experimental situation in which to evaluate the independent influence of other sources of variation such as body mass index (BMI). Furthermore, many of these populations reside in tropical or high-altitude environments, and their physiological adaptations may influence blood pressure variation. The purpose of this report is to present information on determinants of blood pressure variation in a sample of 263 Ethiopian rural agropastoralists 14–86 years of age and resident at 3530 m on the Simien Plateau. Mean systolic and diastolic blood pressures for males and females were low, and did not increase with age or haemoglobin concentration. Blood pressure increased with BMI among adult males.

## 2. Materials and methods

### *2.1. Population and sample*

Data were collected in December 1995 from 314 males and females 14 years of age and older, native to, and residing around, 3530 m in the Ambaras Region of the Simien Mountains National Park, North Gondar, Ethiopia. The rural population farms barley and herds sheep, goats and cattle for sale and consumption. The sample is about 18% of the resident population in the relevant age range in the two Peasant Associations from which the study sample was drawn.

### *2.2. Measurements*

An Ethiopian physician (A.G.) collected from each participant a brief health history that focused on cardiopulmonary signs and symptoms. Blood pressure was taken with a sphygmomanometer and stethoscope by an American member of the

research team (M.D.) after the study participant had been seated for a few minutes while other measurements were obtained. Systolic and diastolic blood pressures were recorded as the appearance (phase 1) and disappearance (phase V) of sounds. Three measurements were taken and averaged for analysis. If one measurement were more than 100 mmHg different from another, then a fourth measurement was made immediately, and the outlier was discarded. This was usually the individual's first experience with blood pressure measurement. Measurements were taken in an open-air field laboratory in the presence of other villagers. Measurements of height, weight and a venepuncture blood sample for immediate determination of haemoglobin concentration were also obtained.

*2.3. Analysis*

The analysis was limited to 263 healthy, non-pregnant villagers. Forty-two people were excluded because of acute or chronic illness, and seven were excluded because of pregnancy. The sample was homogeneous for many lifestyle characteristics. All drank locally brewed barley beer daily and were non-smokers, 260 drank coffee, 252 were full-time agropastoralists, 249 had no education. Table 1A describes the morphological characteristics of the study sample. Because height, weight and BMI increased during the teens, mean values of these variables are given separately for those under 21 years of age and for adults. Reported ages were approximate: 54% gave ages that ended in zero or five. However, reported ages were consistent with life cycle stage revealed by genealogies collected from study participants. For example, only those claiming ages of 50 years or older reported adult children and grandchildren, while those claiming ages in their 20s and 30s reported only young children.

BMI was calculated as weight divided by height squared ($kg/m^2$). Blood pressure was classified as normal (systolic $< 130$ and diastolic $< 85$ mmHg), high normal (systolic 130–139 and diastolic 85–89), stage 1 hypertension (systolic 140–159 and diastolic 90–99), stage 2 hypertension (systolic 160–179 and diastolic 100–109), stage 3 hypertension (systolic 180–209 and diastolic 110–119) or stage 4 hypertension (systolic $\geq 210$ and diastolic $\geq 120$) (Joint National Committee V 1993). When systolic and diastolic pressures fell in different categories the higher category was used. Means and standard errors are reported. Correlation, partial correlation and multiple regression analyses describe the relationship between blood pressure and other variables. A significance level of 0·05 is used.

## 3. Results

Mean systolic and diastolic blood pressures for males and females were 109/75 and 106/73 mmHg, respectively (Table 1B). Figure 1 demonstrates that systolic and diastolic blood pressures remained stable across adulthood in this sample ($r_{\text{systolic-age}} = -0{\cdot}08$ and $r_{\text{diastolic-age}} = -0{\cdot}16$ for men; $r_{\text{systolic-age}} = +0{\cdot}08$ and $r_{\text{diastolic-age}} = 0$ for women, all $p > 0{\cdot}05$). The mean male systolic blood pressure was significantly higher than female ($t = 2{\cdot}1$, $p < 0{\cdot}05$). There were no sex differences in mean diastolic blood pressure ($t = 1{\cdot}5$, $p > 0{\cdot}05$); 95·7% of males and 97·6% of females had normal or high normal blood pressure (table 2). Figure 2 demonstrates that adult male blood pressures increased slightly with increasing BMI ($r_{\text{systolic-BMI}} = r_{\text{diastolic-BMI}} = +0{\cdot}25$, $p < 0{\cdot}05$ for men; $r_{\text{systolic-BMI}} = +0{\cdot}07$ and $r_{\text{diastolic-BMI}} = +0{\cdot}17$ for women, $p > 0{\cdot}05$). Figure 3 demonstrates that adult blood pressures did not vary with haemoglobin concentration in this high-altitude population ($r_{\text{systolic-hb}} = +0{\cdot}15$ and $r_{\text{diastolic-hb}} = +0{\cdot}12$ for men and $r_{\text{systolic-hb}} =$

Table 1. Characteristics of Ambaras, Ethiopia blood pressure sample.

| | All males ($n = 139$), $X \pm$ SEM | Males under 21 ($n = 23$) | | Males 21+ ($n = 113$), $X \pm$ SEM | All females ($n = 124$), $X \pm$ SEM | Females under 21 ($n = 28$) | | Females 21+ ($n = 96$) $X \pm$ SEM |
|---|---|---|---|---|---|---|---|---|
| | | Range | $X \pm$ SEM | | | Range | $X \pm$ SEM | |
| *A: General* | | | | | | | | |
| Age (years) | 38 ± 1·5 | 14–86 | 17 ± 0·4 | 42 ± 1·5 | 35 ± 1·3 | 14–80 | 17 ± 0·4 | 40 ± 1·3 |
| Height (cm)† | 162 ± 0.7 | 138–176 | 151 ± 1·9 | 164 ± 0·5 | 151 ± 0·5 | 136–165 | 148 ± 1·3 | 152 ± 0·5 |
| Weight (kg) | 49 ± 0·7 | 29–67 | 38 ± 1·7 | 51 ± 0·5 | 43 ± 0·5 | 30–66 | 39 ± 1·3 | 45 ± 0·6 |
| BMI (kg/m$^2$) | 18·6 ± 0·2 | 13·3–26·1 | 16·6 ± 0·4 | 19·1 ± 0·15 | 18·8 ± 0·2 | 14·0–26·4 | 17·6 ± 0·4 | 19·2 ± 0·2 |
| Haemoglobin concentration (g/dl)† | 15·9 ± 0·1 | 12·9–19·1 | – | – | 15·0 ± 0·1 | 12–18·4 | – | – |
| Percentage oxygen saturation of arterial haemoglobin | 95·7 ± 0·2 | 84–99 | – | – | 94·8 ± 0·2 | 83–99 | – | – |
| *B: Blood pressure* | | | | | | | | |
| Systolic (mmHg) | 109 ± 1·1 | 79–134 | – | – | 106 ± 1·1 | 82–141 | – | – |
| Diastolic (mmHg) | 75 ± 0·8 | 55–101 | – | – | 73 ± 0·7 | 56–91 | – | – |
| Pulse (f/min) | 70 ± 0·9 | 44–104 | – | – | 83 ± 1·0 | 60–124 | – | – |

† Female height sample is 123 because height was not measurable in one woman. Haemoglobin concentration sample sizes (limited to iron-sufficient individuals) are 136 for males and 117 for females.

$+0{\cdot}06$ and $r_{\text{diastolic-hb}} = +0{\cdot}14$ for women; all $p > 0{\cdot}05$). BMI did not vary with age among adults ($r = -0{\cdot}14$ for men and $r = -0{\cdot}18$ for women, $p > 0{\cdot}05$). Haemoglobin concentration decreased with age among men ($r = -0{\cdot}36$, $p < 0{\cdot}05$), but not women ($r = +0{\cdot}05$, $p > 0{\cdot}05$). Multiple-regression analyses confirmed that BMI is the only one of the three variables that explains significant variation in systolic and diastolic blood pressures (table 3). There were no significant interactions among the three variables (analyses not shown).

## 4. Discussion

Mean blood pressure was low, and there were no age differences in systolic or diastolic blood pressure in this cross-sectional sample of Ethiopian highlanders 14–86 years of age. Longitudinal studies will be required to determine whether blood pressure remains stable throughout adulthood in this population. These studies would yield accurate information on the passage of time (important in the absence of birth certificates verifying age), and consider possible alternative explanations to the apparent blood pressure stability. The possibility that an adult decrease in BMI accounts for the apparent adult blood pressure stability is discounted by the lack of association between adult age and BMI. The possibility that a secular trend towards higher blood pressure among young adults accounts for the apparent stability seems unlikely, in light of reported mean blood pressure of 121/80 for a sample of 22 males of unreported age studied in a nearby area during the mid-1960s (Harrison, Kuchemann, Moore, Boyce, Baju, Mourant, Godber, Glasgow, Kopec, Tills and Clegg 1969). A re-analysis of those data reported that blood pressure was negatively correlated with age, and suggested that this was due to selective elimination of blood pressures above average (Clegg, Jeffries and Harrison 1976). It is not possible to

Table 2. Blood pressure classification of Ambaras sample.

| | Males | | Females | |
|---|---|---|---|---|
| | *n* | Percentage | *n* | Percentage |
| Normal | 116 | 83·5 | 115 | 92·0 |
| High normal | 17 | 12·1 | 7 | 5·6 |
| Hypertension, stage 1 | 5 | 3·6 | 3 | 2·4 |
| Hypertension, stage 2 | 1 | 0·7 | 0 | 0 |
| Hypertension, stage 3 | 0 | – | 0 | – |
| Hypertension, stage 4 | 0 | – | 0 | – |

Table 3. Sets of beta weights and multiple correlation coefficients of adult systolic and diastolic blood pressure.

| | Multiple *R* | Age | BMI | Haemoglobin concentration |
|---|---|---|---|---|
| Male | | | | |
| Systolic | +0·257* | −0·06 | +0·20 | +0·09 |
| Diastolic | +0·286** | −0·14 | +0·21 | +0·02 |
| Female | | | | |
| Systolic | +0·126 | +0·07 | +0·10 | +0·06 |
| Diastolic | +0·234 | −0·09 | +0·15 | +0·15 |

$* p = 0{\cdot}06$; $** p < 0{\cdot}05$.

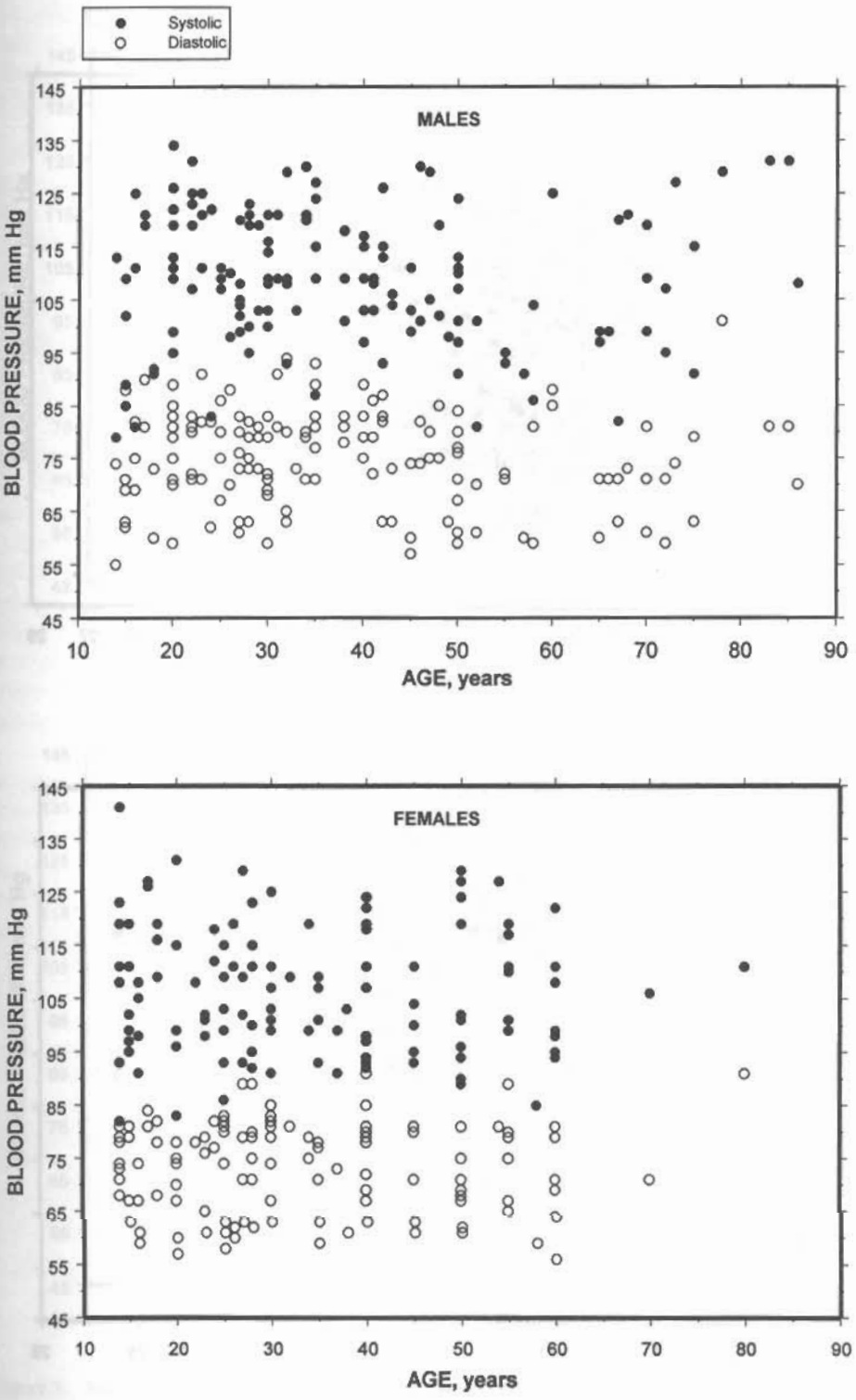


Figure 1. Scatterplot of male and female systolic and diastolic blood pressures with age.

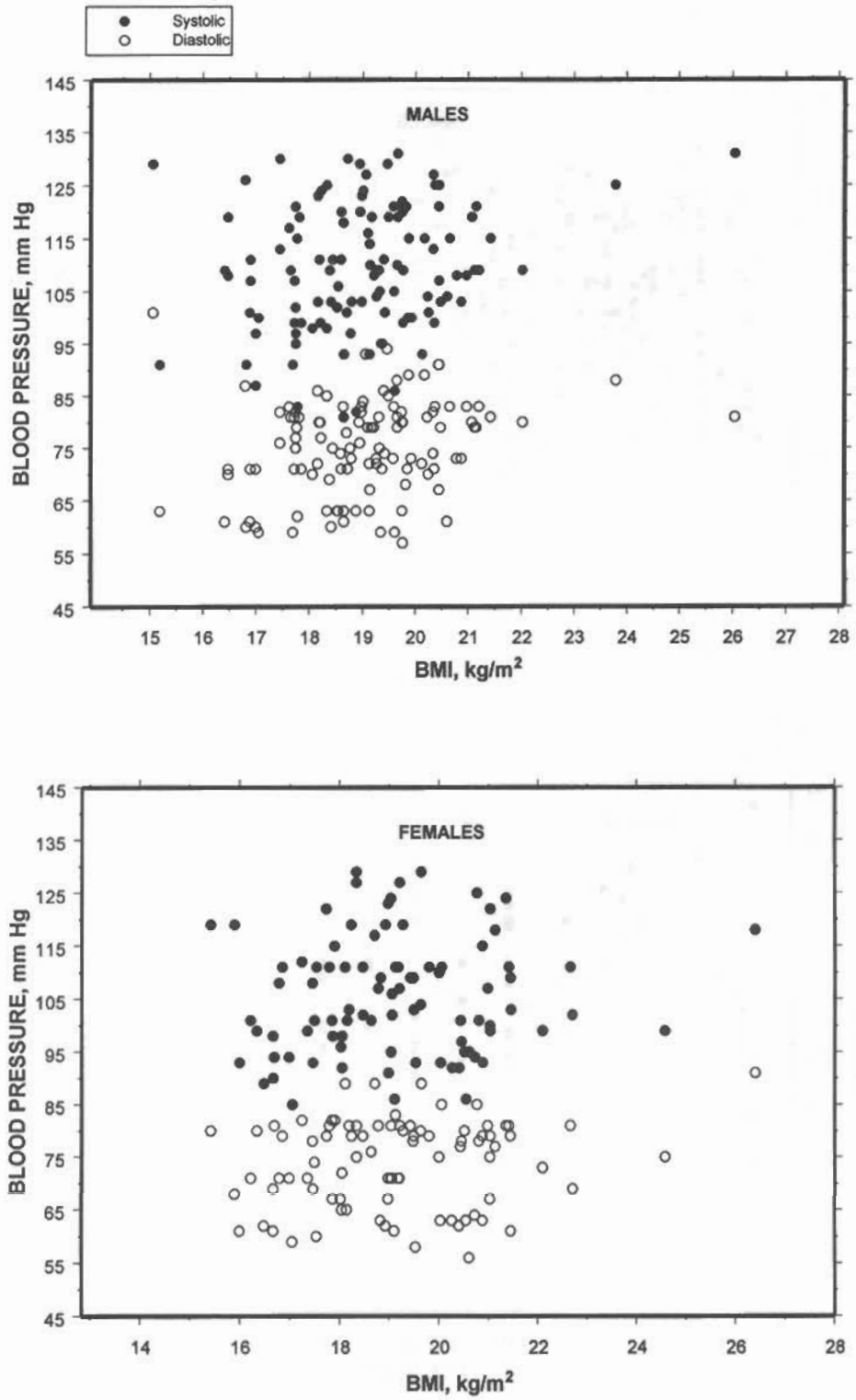


Figure 2. Scatterplot of adult male and female systolic and diastolic blood pressures with BMI.

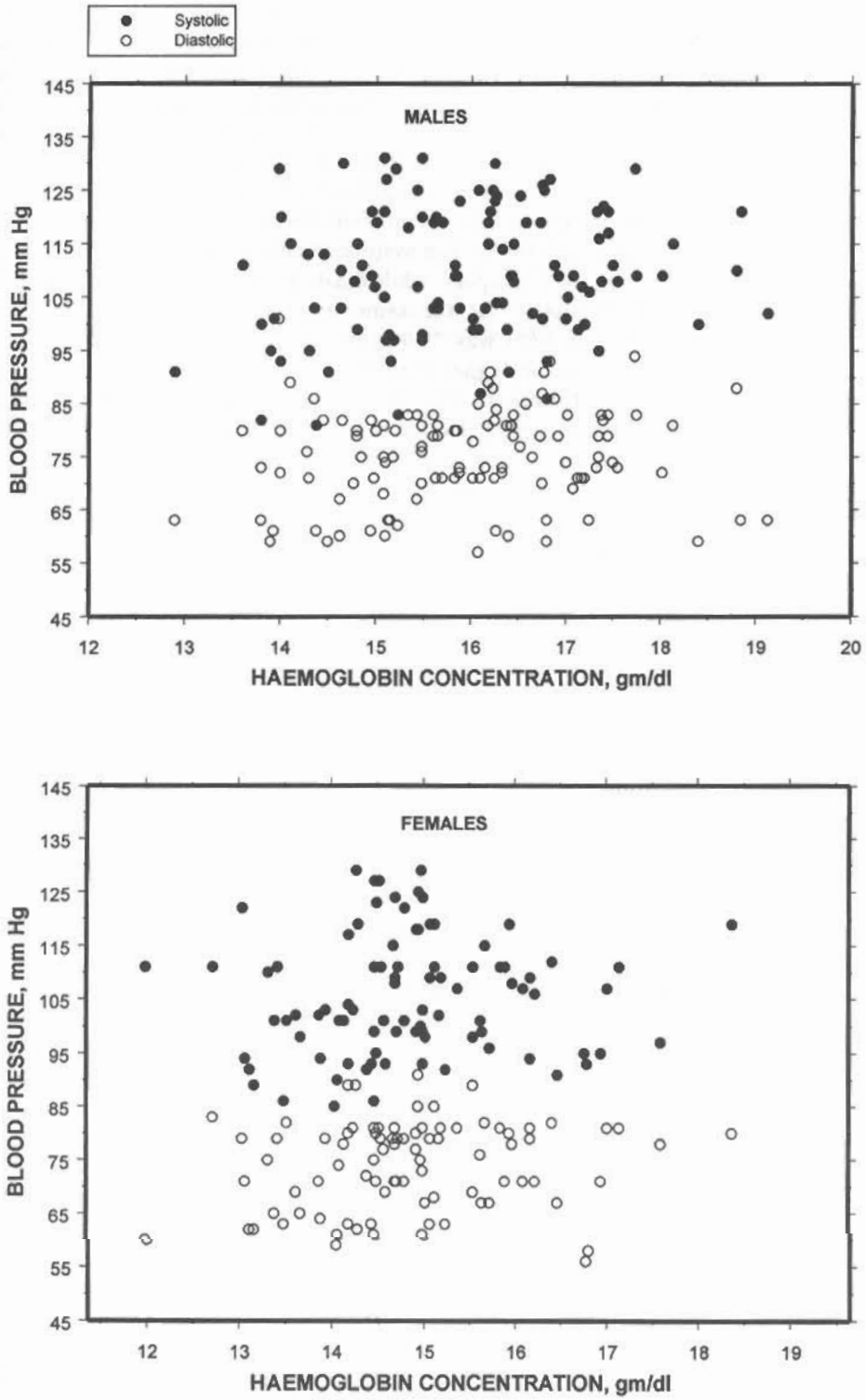


Figure 3. Scatterplot of adult male and female systolic and diastolic blood pressures with haemoglobin concentration.

determine whether there is a substantive difference between those results indicating a decrease in blood pressure with age and those of the present study indicating no change in blood pressure with age, because information on age, and on the distribution of blood pressures throughout adulthood, was not presented in the earlier study. The findings of the present study do indicate that adults in Ambaras have sufficient arterial elasticity to have low blood pressures throughout the life cycle.

Ambaras blood pressures and BMI were substantially lower than US values. For example, US males had means of 129/81 and females of 123/77 in the late 1970s (Drizd, Dannenberg and Engel 1986). The systolic means were about one US standard deviation higher than the Ethiopian, while diastolic means were about one-half a US standard deviation higher. At the same time, US mean male BMI was 25·3 $kg/m^2$ and mean female BMI was 25·0 $kg/m^2$ (Najjar and Rowland 1987) or about one US standard deviation higher than the Ambaras sample. Thirty-five per cent of the Ambaras BMI were in the adult chronic energy deficiency range (BMI < 18·5). This has been reported elsewhere in Ethiopia (Ferro-Luzzi, Sette, Franklin and James 1992). However, even though blood pressures and BMI were low relative to Western populations, BMI variation explained a small, but significant, 6% of the male pressure variation. Males with BMI two standard deviations above the mean had predicted systolic and diastolic blood pressures 7 and 5 mm higher than the average. The re-analysis of the small Ethiopian male sample studied during the 1960s reported a positive relationship between blood pressures and ponderal index (stature/weight$^{1/3}$) (Clegg *et al.* 1976). The actual ponderal index was not reported, so it is not known whether that sample was as lean as the present sample. While attention usually focuses on overweight and hypertension (e.g. Krieger and Landsberg 1995), the present Ethiopian findings suggest that the general relationship between BMI and blood pressures also exists at the low end of the normal range, at least among men.

A possible association with haemoglobin concentration was investigated because blood pressure increases with increased red cell mass at sea level (Eschbach and Davidson 1995) and because haemoglobin concentration might be elevated adaptively in this population resident at 3530 m. Haemoglobin concentration variation was not associated with variation in blood pressure. This may be because there were few high haemoglobin concentration values among healthy, iron-sufficient Ambaras residents (Beall, Gebremedhin, Brittenham, Decker and Shamebo 1996). Many studies of high-altitude native populations report low blood pressure (reviewed in James and Baker 1995), although there are notable exceptions (e.g. Sun 1986). Lifestyle factors such as the absence of smoking are probably relevant to the low blood pressures of the present high-altitude sample.

In conclusion, these findings from a sample of Ethiopians native to, and resident around, 3530 m on the Simien Plateau in Ambaras, North Gondar, Ethiopia, confirmed that men and women can have low normal blood pressure throughout adulthood. They showed no blood pressure association with haemoglobin concentration. Finally, they illustrated that BMI variation was associated with blood pressure variation in a sample of males with low BMI and blood pressures.

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**Zusammenfassung.** In der vorliegenden Studie werden Informationen über Determinanten der Variation des Blutdrucks bei einer ländlichen Stichprobe von 263 Bewohnern des äthiopischen Hochlandes im Alter von 14–86 Jahren vorgestellt. Die Probanden leben auf dem Simien Plateau des äthiopischen Hochlandes in einer Höhe von 3530 Meter. Systolischer und diastolischer Blutdruck betrugen im Mittel 109/75 bei Männern und 106/73 bei Frauen, Altersunterschiede lagen nicht vor. Diese Beobachtungen bestätigen, dass Männer und Frauen im gesamten Erwachsenenalter geringe Blutdruckwerte aufweisen können. Bei erwachsenen Männern stieg der Blutdruck mit ansteigendem Body Mass Index (BMI) an, obwohl der BMI mit 19·1 kg/m$^2$ im Vergleich zu US-Werten gering war. Dies belegt, dass bei Männern Variationen im BMI mit Variationen im Blutdruck sogar bei geringen Werten für beide Merkmale assoziiert sein können. Der Blutdruck variierte nicht mit der adulten Hämoglobinkonzentration.

**Résumé.** On présente des informations sur les déterminants de la variation de la pression sanguine dans un échantillon rural de 263 montagnards éthiopiens âgés de 14 à 86 ans, résidant à 3530 m d'altitude sur le plateau Simien. Les pressions systolique et diastolique moyennes pour les hommes et pour les femmes,

étaient respectivement 109/75 et 106/73 et dépourvues de différences d'âge. Ces résultats confirment que ces hommes et ces femmes ont une pression sanguine normale basse tout au long de la vie adulte. Les pressions sanguines augmentent avec l'accroissement de l'indice de masse corporelle (IMC) chez les adultes masculins, bien que l'IMC moyen de 19·1 $kg/m^2$ soit faible comparé aux valeurs des Etats-Unis. Ceci montre que la variation d'IMC peut être associée à celle de la pression sanguine chez les hommes, même à valeur moyenne basse des deux caractéristiques. La pression sanguine ne variait pas avec la concentration en hémoglobine chez l'adulte.