Infant and Child Growth and Fatness and Fat Distribution in Guatemalan Adults

Dirk G. Schroeder,1 Reynaldo Martorell,1 and Rafael Flores2

To examine whether poor growth in utero or young childhood is associated with adult abdominal fatness in a developing country context, the authors analyzed prospectively collected data on 372 female and 161 male Guatemalans measured as children between 1969 and 1977 and remeasured as adults in 1988–1989 (men and women) and 1991–1994 (women only). Childhood stunting (height-for-age z score) was associated with a lower body mass index and percent body fat in men, while no associations were found in women. In both sexes, however, severely stunted children had significantly greater adult abdominal fatness (waist:hip ratio), once overall fatness and confounders were controlled. The adult waist:hip ratio (×100) was increased by 0.65 (95% confidence interval 0.10 to 1.20) in men and 0.29 (95% confidence interval −0.03 to 0.61) in women for each height-for-age z score less at age three. Migration to urban centers was significantly associated with an even greater waist:hip ratio in severely stunted females (p = 0.03). In a subsample of 137 women, short and thin newborns had significantly greater adult abdominal fatness compared with long and thin or short and fat newborns or children who became stunted postnatally. The adult waist:hip ratio (×100) was increased by 1.58 (95% confidence interval 0.35 to 2.81) for each kilogram less birth weight. The authors conclude that, in countries where maternal and child malnutrition exists alongside rapid economic development and urban migration, abdominal obesity and related chronic diseases are likely to increase. Am J Epidemiol 1999;149:177–85.

Overweight, particularly abdominal fatness, is a well-established risk factor for cardiovascular disease, adult-onset diabetes, stroke, and mortality (1–3). Malnutrition in utero or early childhood may cause fatness later in life (4). Animal studies find that rats that are malnourished in utero or during early infancy become overweight adults when put on unrestricted diets (5–8). In humans, exposure to famine during early pregnancy (9) and low birth weight (10, 11) have been associated with adult obesity and greater waist:hip ratio, respectively. Improvements in socioeconomic status and diet subsequent to childhood malnutrition are thought to strengthen these associations (12–14). The scientific evidence for these associations, however, is mixed. A number of human, epidemiologic studies have failed to find an association between early malnutrition and later adiposity (15–18).

Studies that have examined the relation between early growth and later fatness and fat patterning have been conducted almost exclusively in industrialized countries where malnutrition is relatively rare. In developing countries, intrauterine growth retardation (19) and poor linear growth during childhood (20) are common because of poor diets and high rates of infection. Malnourished children in these countries are increasingly exposed to Western diets and lifestyles as adults as a result of rapid economic development or migration from rural to urban settings. It has therefore been suggested that developing countries are on the verge of an epidemic of obesity-related cardiovascular disease (21–27). No long-term studies testing these associations in a developing country, however, have been published.

In this study, we tested the hypothesis that poor linear growth during childhood, as measured by stunting at 3 years of age, predicts fatness and high risk fat patterning of young Guatemalan adults. In addition, in a subsample of women, we examined the associations between indicators of intrauterine growth and adult abdominal fatness. Finally, we tested whether early nutritional supplementation or migration to urban settings modified these associations. The data used to test these hypotheses were collected during a supple-

MATERIALS AND METHODS

Subjects

The study population is drawn from 1,370 subjects who were measured as children in a longitudinal study conducted by the Institute of Nutrition of Central America and Panama (INCAP) and collaborating US universities between 1969 and 1977 in four villages in rural Guatemala (figure 1). Detailed descriptions of the sample, methods, and quality control of the original study have been published elsewhere (28). Briefly, four impoverished Ladino (i.e., Spanish speaking, mixed Spanish-Indian ancestry) villages were randomly allocated to receive either a high-protein, high-energy drink (atole) (two villages) or a low-energy, non-protein supplement (fresco) (two villages). Supplements were available daily at feeding centers to all members of the community. A preventive and curative health program was offered in all villages. Energy from supplementation by pregnant women was associated with significantly heavier babies (29), and consumption of atole by children was associated with better child growth (30).

Between 1988 and 1989 (men and women) and 1991 and 1994 (women only), follow-up studies located and reexamined 825 subjects who were measured as children in the 1969–1977 study, of which approximately 13 percent had migrated from the villages to a nearby town or Guatemala City, and who were adults at follow-up (figure 1) (31). Age cut-offs defining adulthood were based on skeletal age and maturity (32). Exposure to atole in childhood was significantly associated with greater height, weight, and fat-free mass but not with fat mass in young adulthood (33).

Measurements

All measurements were conducted by trained field workers in the communities using standard, previously published methods (28) and are therefore described only briefly. The quality of the data was closely monitored in both the 1969–1977 (34) and follow-up studies (31). Precision and reliability of all measurements were high (34, 35).

Infant anthropometry. Weight was measured at birth. Weight, supine length, and head circumference were measured at 15 days of age. Gestational age was estimated from the last menstrual period. Child linear growth. Supine length was measured at 24, 30, 36, 42, 48, and 60 months of age and converted to height-for-age z scores using the National Center for Health Statistics reference and the Epi Info computer program (Centers for Disease Control and Prevention, Atlanta, Georgia).

Adult fatness and distribution. Height, weight, skinfold measures, and circumferences were taken using standard techniques (28, 36). The percent body

<table>
<thead>
<tr>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured at least once aged 24-60 m in 1969-77</td>
<td>664</td>
</tr>
<tr>
<td>Measured aged 18+ y in 1988-89 (males) or 17+ y between 1988-89 or 1991-1994 (females)</td>
<td>525</td>
</tr>
<tr>
<td>Complete data on childhood and adult measures and potential confounders</td>
<td>372*</td>
</tr>
<tr>
<td>Complete data on birth anthropometry and gestational age.</td>
<td>137**</td>
</tr>
</tbody>
</table>

* Analytical sample used for results presented in Tables 1 and 2.
** Analytical sample used for results presented in Tables 3-5.

fat was calculated as a function of weight and fat-free mass. Fat-free mass was calculated from sex-specific prediction equations developed through a densitometric study of Guatemalans matched to the subjects on age, anthropometric measurements, and ethnic origin (37). The waist:hip ratio (×100) was used as an indicator of abdominal fatness.

Socioeconomic status. Two summary socioeconomic variables based on housing quality and family possessions in childhood (year, 1977) and adulthood (year, 1988) were created using a principal components analysis (33). Overall, the socioeconomic conditions changed little in these villages over these years (38).

Lifestyle. Information on smoking and alcohol consumption and parity (in women) was obtained through oral interview.

Physical activity. Men who worked as farmers or laborers were classified as having high physical activity. Occupation could not be used as a proxy for physical activity in women because over 95 percent stated their occupation as "housewife." Studies of energy expenditure in this same population find that, although women work long hours, they do so at very low levels of intensity (39).

Statistical analysis

Main analyses were confined to the 161 men measured between 1969 and 1977 and older than 18 years between 1988 and 1989 and to the 372 women older than 17 years with one or more nonpregnant measurements taken between 1988 and 1989 and/or 1991 and 1994 who also had complete data on all variables of interest (figure 1). Repeat anthropometry measurements collected on women between 1988 and 1994 were averaged. Subanalyses were done on 137 women who also had birth weight and anthropometry at 15 days of age; these analyses were limited to singleton, term infants between 37 and 43 weeks of gestational age.

Height-for-age at 36 months was used as a summary indicator of cumulative prenatal and early childhood nutrition; if unavailable (29 percent of sample), it was estimated using regression with data taken at 24, 30, 42, 48, or 60 months of age. Height-for-age z score in this population is highly stable after 24 months of age (40). Models that were restricted to subjects who had a height measurement taken at exactly 36 months of age gave results similar to those reported below.

Data for males and females were analyzed separately using multiple variable regression and analysis of covariance to determine associations between infant and child growth and adult fatness, while adjusting for potential confounding factors. The potential confounders that were included were age at which child height was taken and adult age, socioeconomic status, village of residence, smoking (men), alcohol (men), occupational physical activity (men), parity (women) and, in some models, body mass index or percent body fat. Analyses were done using SAS for Windows, version 6.11, software for microcomputers (Statistical Analysis System, Cary, North Carolina).

RESULTS

The sample of 372 women and 161 men was stunted by 3 years of age (mean, −2.57 z score). At follow-up, women were aged 17–28 years and were short (mean, 150.1 cm), but not thin (mean percent body fat, 26.2 percent). Men at follow-up were aged 18–24 years and were moderately lean (mean percent body fat, 12.8 percent). Compared with reference values (41), mean body mass indexes were at the 55th and 20th percentiles for women and men, respectively. In women, the waist:hip ratio was significantly correlated with the percent body fat (Pearson’s correlation coefficient (r) = 0.80, p < 0.0001), body mass index (r = 0.50, p < 0.0001), parity (r = 0.41, p < 0.0001), and age (r = 0.20, p < 0.0001). In men, the waist:hip ratio was significantly correlated with the percent body fat (r = 0.30, p < 0.0001) and body mass index (r = 0.30, p < 0.0001) and inversely correlated with high physical activity (r = −0.23, p < 0.005) and smoking (r = −0.15, p = 0.05).

Table 1 shows age-adjusted mean values for the fatness indicators examined by tertile of childhood height-for-age z scores and results of analyses in which childhood height-for-age was used as a continuous variable. Women and men who were stunted in childhood were shorter and lighter as adults. In men, stunting was associated with a lower body mass index and percent body fat; each z score decrease in height-for-age z score at 3 years was associated with a decrease in the percent body fat of 0.51 percent (95 percent confidence interval 0.11–0.91); no significant relation between body mass index or percent body fat and childhood stunting was found in women. In both sexes, the waist:hip ratio was significantly, positively associated with childhood stunting, controlling for the total percent body fat and confounders. Severe stunting in childhood was associated with waist:hip ratios (×100) of 0.7 (95 percent confidence interval 0.1 to 1.5) and 1.1 (95 percent confidence interval −0.3 to 2.4) greater for women and men, respectively, compared with mildly stunted counterparts (table 1). In regression models, each z score decrease in childhood height-for-age was associated with an increase in the
Birth anthropometry

The association between intrauterine growth and adult fatness was examined in 137 women who had complete data at birth, childhood, and adulthood (figure 1). Table 3 presents results of multiple regression analyses, with the anthropometric variable of interest entered separately along with potential confounders. Birth weight, ponderal index at 15 days of age, and weight-for-age z-score at 3 years were each significantly positively associated with the anthropometric variable of interest. For subjects with complete data, the association was significant (p < 0.05) for all three variables, with a 1,000 g less birth weight being associated with a 1.27% increase in adult fatness (95% confidence interval 0.12 to 2.44). Adult height was also significantly associated with adult fatness, with a 1.58 cm increase in height being associated with a 1.27% increase in adult fatness (95% confidence interval 0.12 to 2.44). The modifying effect of migration to urban settings on the relation between childhood stunting and adult waist:hip ratio was also explored. Within each level of stunting, migrants to urban settings generally had higher waist:hip ratios (table 2). In multivariable models, women who were severely stunted as children and moved to urban areas had significantly greater waist:hip ratios compared with all other women (p = 0.03). No statistically significant differences were observed between migrants and nonmigrants in males. For subjects remaining in the rural villages, improvement in socioeconomic status between childhood and adulthood did not modify the relation between childhood and adulthood fatness and adult fatness (results not shown). It should be noted that improvements in socioeconomic status for those who stayed in the rural communities were relatively mild compared with the improvements for those who moved to urban areas.

Supplementation, migration, and improvement in socioeconomic status

The potential modifying effect of early nutritional supplementation on the association between childhood stunting and adult waist:hip ratio (x100) of 0.45 (95% confidence interval 0.10 to 0.95) in males and 0.29 (95% confidence interval 0.03 to 0.60) in females.

<table>
<thead>
<tr>
<th>Stunting by child height-for-age z score</th>
<th>Women who migrated to town or city</th>
<th>Men who migrated to town or city</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe, &lt;-3</td>
<td>91.9 (117)†</td>
<td>90.6 (44)</td>
</tr>
<tr>
<td>Moderate, -3 to -2</td>
<td>90.5 (130)</td>
<td>89.4 (55)</td>
</tr>
<tr>
<td>Light, &gt;-2</td>
<td>90.3 (77)</td>
<td>89.2 (41)</td>
</tr>
</tbody>
</table>

* Adjusted for age childhood height was taken; adult age; village of residence; percent body fat; parity (none, any; females only); alcohol (none, any; males only); smoking (none, any; males only); and physical activity (heavy, light; males only).

† Numbers in parentheses, number of subjects.

The waist:hip ratio (x100) for subjects who were severely stunted and migrated to urban areas was significantly greater for women (p = 0.03) but not men (p = 0.28) compared with all other women and men, respectively.


<table>
<thead>
<tr>
<th>Model</th>
<th>Independent variables</th>
<th>Mean</th>
<th>% body fat*</th>
<th>95% Cl</th>
<th>p value</th>
<th>Waist:hip ratio†</th>
<th>Slope</th>
<th>95% Cl</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Birth weight (kg)</td>
<td>3.017 (0.41)$§</td>
<td>1.27</td>
<td>0.12 to 2.44</td>
<td>0.03</td>
<td>-1.58</td>
<td>-2.81 to -0.35</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Birth weight (z)</td>
<td>-0.32 (0.42)</td>
<td>0.56</td>
<td>0.05 to 1.07</td>
<td>0.03</td>
<td>-0.63</td>
<td>-1.16 to -0.10</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Length at 15 days (cm)</td>
<td>49.3 (1.92)</td>
<td>-0.03</td>
<td>-0.28 to 0.22</td>
<td>0.84</td>
<td>-0.19</td>
<td>-0.46 to 0.08</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Length-for-age at 15 days (z)</td>
<td>-1.11 (0.84)</td>
<td>-0.06</td>
<td>-0.65 to 0.53</td>
<td>0.84</td>
<td>-0.44</td>
<td>-1.07 to 0.09</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ponderal index at birth (g/cm$^3$ x 100)</td>
<td>2.52 (0.33)</td>
<td>2.28</td>
<td>0.67 to 3.89</td>
<td>0.007</td>
<td>-1.61</td>
<td>-3.41 to 0.19</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Head circumference at 15 days (cm)</td>
<td>34.8 (1.2)</td>
<td>0.09</td>
<td>-0.34 to 0.52</td>
<td>0.68</td>
<td>-0.47</td>
<td>-0.93 to -0.01</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Height-for-age at 3 years (z)</td>
<td>-2.49 (0.92)</td>
<td>0.17</td>
<td>-0.40 to 0.74</td>
<td>0.55</td>
<td>-0.37</td>
<td>-0.98 to 0.24</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Weight-for-age at 3 years (z)</td>
<td>-1.48 (0.81)</td>
<td>1.13</td>
<td>0.50 to 1.76</td>
<td>0.0007</td>
<td>-0.68</td>
<td>-1.41 to 0.05</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Length-for-age z score change from 15 days to 3 years (z)</td>
<td>-0.94 (1.25)</td>
<td>0.14</td>
<td>-0.29 to 0.57</td>
<td>0.53</td>
<td>-0.05</td>
<td>-0.50 to 0.40</td>
<td>0.84</td>
<td></td>
</tr>
</tbody>
</table>

* Each anthropometric independent variable was entered in a separate model along with gestational age, age when measure taken in childhood, village of residence, adult age, adult socioeconomic status, and parity.
† Each anthropometric independent variable entered in separate model along with gestational age, age when measure taken in childhood, village of residence, adult age, adult socioeconomic status, parity, and percent body fat.
§ CI, confidence interval.
$ Numbers in parentheses, standard deviation.

Proportionality at birth

Next, the relation between proportionality at birth and adult abdominal fatness was examined. In table 4, mean adjusted adult waist:hip ratios by length at 15 days and ponderal index at 15 days are presented by tertile. These results find that newborns who were shorter and thinner had significantly higher waist:hip ratios (mean, 92.5; 95 percent confidence interval 90.6 to 94.3) as adults than did those who were shorter and heavier (mean, 89.3; 95 percent confidence interval 88.0 to 90.7) or longer and thinner (mean, 89.4; 95 percent confidence interval 88.0 to 90.8) as newborns.

Prenatal versus postnatal growth

Finally, analyses in which perinatal and childhood anthropometric variables were entered simultaneously into multiple variable models suggested that prenatal growth was a stronger predictor of increased adult abdominal fatness than was postnatal growth. As seen in table 5, low birth weight is the variable most significantly and consistently associated with increased abdominal fatness, regardless of what combinations of other indicators of prenatal and postnatal growth are included in the models. Notably, once birth weight is in the model, stunting at 3 years contributes little to the model. This suggests that the associations between
TABLE 4. Adjusted* mean adult waist:hip ratio according to length at 15 days and ponderal index at 15
females only)

<table>
<thead>
<tr>
<th>Length at 15 days (cm)</th>
<th>&lt;2.67</th>
<th>2.67–2.84</th>
<th>&gt;2.84</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;48.4</td>
<td>92.5±† (10)†</td>
<td>90.1 (15)</td>
<td>89.3± (22)</td>
<td>90.6 (47)</td>
</tr>
<tr>
<td>48.4–50.2</td>
<td>91.2 (18)</td>
<td>89.5 (14)</td>
<td>89.7 (15)</td>
<td>90.1 (47)</td>
</tr>
<tr>
<td>&gt;50.2</td>
<td>89.4± (17)</td>
<td>89.7 (17)</td>
<td>89.2± (9)</td>
<td>89.4 (43)</td>
</tr>
<tr>
<td>All</td>
<td>91.0 (45)</td>
<td>89.8 (46)</td>
<td>89.4 (46)</td>
<td>90.2 (137)</td>
</tr>
</tbody>
</table>

* Adjusted for gestational age, age when measure taken in childhood, village of residence, adult age, adult socioeconomic status, parity, and percent body fat.
† Adjusted means with different letters differ significantly at p < 0.01.
‡ Numbers in parentheses, number of females.


<table>
<thead>
<tr>
<th>Model*</th>
<th>Independent variables</th>
<th>Waist:hip ratio (x100)</th>
<th>Slope</th>
<th>95% CI†</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Birth weight (kg) +</td>
<td></td>
<td>–1.49</td>
<td>–2.77 to –0.21</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Height-for-age at 3 years (z)</td>
<td></td>
<td>–0.24</td>
<td>–0.85 to 0.37</td>
<td>0.43</td>
</tr>
<tr>
<td>2</td>
<td>Length-for-age at 15 days (z) +</td>
<td></td>
<td>–0.34</td>
<td>–1.01 to 0.33</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Height-for-age at 3 years (z)</td>
<td></td>
<td>–0.26</td>
<td>–0.91 to 0.39</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>Birth weight (kg) +</td>
<td></td>
<td>–1.78</td>
<td>–3.09 to 0.47</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Length-for-age z score change from 15 days to 3 years (z)</td>
<td></td>
<td>–0.24</td>
<td>–0.72 to 0.24</td>
<td>0.32</td>
</tr>
<tr>
<td>4</td>
<td>Length-for-age at 15 days (z) +</td>
<td></td>
<td>–0.58</td>
<td>–1.29 to 0.13</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Length-for-age z score change, from 15 days to 3 years (z)</td>
<td></td>
<td>–0.24</td>
<td>–0.76 to 0.28</td>
<td>0.36</td>
</tr>
<tr>
<td>5</td>
<td>Birth weight (kg) +</td>
<td></td>
<td>–1.73</td>
<td>–3.21 to –0.25</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Height-for-age at 3 years (z) +</td>
<td></td>
<td>–0.07</td>
<td>–0.90 to 0.76</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>Length-for-age z score change from 15 days to 3 years (z)</td>
<td></td>
<td>–0.21</td>
<td>–0.87 to 0.45</td>
<td>0.54</td>
</tr>
<tr>
<td>6</td>
<td>Length-for-age at 15 days (z) +</td>
<td></td>
<td>–0.62</td>
<td>–1.94 to 0.70</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Height-for-age at 3 years (z) +</td>
<td></td>
<td>0.04</td>
<td>–1.35 to 1.43</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Length-for-age z score change from 15 days to 3 years (z)</td>
<td></td>
<td>–0.27</td>
<td>–1.39 to 0.85</td>
<td>0.63</td>
</tr>
</tbody>
</table>

* All models included gestational age, age when measure taken in childhood, village of residence, adult age, adult socioeconomic status, parity, and percent body fat.
† CI, confidence interval.

stunting at 3 years and abdominal fatness presented earlier in this paper are likely due to prior poor fetal growth of these short children.

DISCUSSION

In this population-based cohort study of Guatemalans who were born into deprived socioeconomic environments, poor linear growth (stunting) in childhood was associated with a lower body mass index and percent body fat in adult men, but there was no association with body mass index or percent body fat in adult women. In both sexes, however, childhood stunting was associated with increased abdominal fatness (as indicated by waist:hip ratio) when either body mass index or percent body fat was adjusted for. These associations were independent of adult age, village of residence, socioeconomic status, parity, and percent body fat.

This study is unique because it is the first to examine these associations in a large sample followed from birth to adulthood in a developing country. In addition, in contrast to other studies on this subject (10, 11), intrauterine and childhood malnutrition was common in this sample. Availability of perinatal anthropometric measures allowed examining the effect of proportionality at birth on later outcomes as hypothesized by Barker (42, 43) and others. Finally, the randomized exposure to a high-energy, high-protein or low-energy, low protein supplement in utero and/or early childhood growth...
and follow-up of migrants to urban centers allowed the examination of the potential modifying effects of these exposures.

The primary limitation of the study is the relative youth of our population. Approximately 54 percent of the women and 23 percent of the men who were measured in childhood were included in this analysis; the larger sample size in women is due to the fact that females only were measured between 1991 and 1994, prior to which time many subjects were still adolescents. A statistical comparison of childhood anthropometry and socioeconomic status found no differences between individuals who were originally measured and those who were included in the current analysis.

**Socioeconomic status and other confounders**

An inverse association between birth weight and waist:hip ratio, independent of overall adult body size, has been found in both men (10) and women (11) living in industrialized countries. The validity of such associations has been questioned, however, because of the difficulty in controlling for present-day social and economic conditions (44–46). In this study, adult socioeconomic status and male occupation were controlled for in all models. Occupation was not controlled for in women because nearly all women in the sample are homemakers. Other potential confounders of the examined relations are smoking, alcohol, parity, physical activity, and diet with all but the last of these controlled for in all analyses. Adult diet was not measured and therefore may be confounding the relations. The high degree of homogeneity of the diet consumed by this population, which is heavily dependent on maize tortilla and beans and uses high fat foods infrequently, however, makes this unlikely. In the analyses of birth and perinatal measures on later fatness, gestational age and the exact day of life the measures were taken were controlled for.

**Female-male differences**

Differences in overall fatness between the sexes may partially explain the differences in results between men and women. Women in this population had body mass index measures that were at approximately the 55th percentile of reference values (41), while men in this population were lean with body mass indexes at approximately the 20th percentile. A higher level of strenuous activity was seen in men compared with women in this population (39). For both men and women who were stunted as children, however, fat is concentrated in the abdominal region. Notably, associations between body mass index and cardiovascular risk factors (47) and between the waist:hip ratio and biochemical indicators of cardiovascular disease (48) have been found in other lean, developing country populations.

**Proportionality at birth**

Most previous studies of the long-term health effects of intrauterine malnutrition have used birth weight as the only indicator of fetal growth. It has recently been theorized that anthropometric disproportionality at birth (e.g., being long and thin) increases the risk for later cardiovascular disease while proportionate smallness does not (42, 43). In this analysis, we examined the relation between proportionality at birth and the waist:hip ratio in women. In our analysis, we found that the highest ratios were among women who were proportionately short and thin at birth and not among the disproportionally long and thin or short and fat as has been theorized (42, 43).

**Implications for developing and industrialized countries**

It has been suggested that, if the so-called fetal origins or programming hypothesis is correct, developing countries, in which malnutrition exists alongside rapid economic development and urban migration, are facing an epidemic of cardiovascular disease (21–27). The potential modifying effects of migration and change in socioeconomic status on the associations of interest were thus explicitly tested in this study. Results suggested that severely growth-retarded children whose socioeconomic conditions improved, albeit slightly, while they were living in the same rural environment were not at increased risk for higher abdominal fatness. On the other hand, migrants to urban centers had larger waist:hip ratios than did nonmigrants. In multivariable models, women who were severely stunted as children and migrated to urban areas had the greatest waist:hip ratio compared with all other women ($p = 0.03$) (table 2). Migrants were self-selected and may differ from nonmigrants, but no statistically significant differences in childhood anthropometry and socioeconomic status were found between migrants and nonmigrants. For industrialized countries, these findings may contribute to an understanding of the high rates of obesity and abdominal fatness seen among immigrant populations (49–51).

**Conclusion**

In conclusion, this population-based, prospective cohort study of rural Guatemalans found that the relation between childhood stunting and the percent body
fat in young adulthood differed by sex, with no association in women and a negative association in men. Controlling for overall body size or the percent body fat, however, this study provides additional evidence that poor growth in utero or childhood leads to increased adult abdominal adiposity, as measured by the waist:hip ratio. The data suggest that migration from rural to urban settings strengthens these associations, but that relatively minor improvements in socioeconomic status in those who remained in the rural communities and exposure to a high-energy, high-protein supplement do not. In a subset of women only, indicators of poor fetal growth were found to be even better predictors of higher adult abdominal adiposity than was poor postnatal growth; newborns that were lightweight because they were both short and thin at birth had the highest risk for abdominal fatness in young adulthood.

The statistically significant, though admittedly small, associations identified in this analysis are notable considering the relative youth of the study population at the time of measurement (range, 17–28 years) and the relatively minor improvements in socioeconomic status the majority had experienced. We are continuing to collect data on indicators of cardiovascular disease risk factors in this population. It is likely that the associations reported in this paper will only strengthen as the population ages and continues to adopt a lifestyle increasingly similar to that of Western industrialized countries. In sum, the results of this paper support the notion that, in countries where maternal and child malnutrition exists alongside rapid economic development and urban migration, abdominal obesity and related chronic diseases are likely to increase. The results also contribute to our understanding of the high rates of obesity and abdominal fatness seen among immigrants in Western, industrialized societies who came from poorer countries.

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