Patterns of Linear Growth in Rural Guatemalan Adolescents and Children[1,2]

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ABSTRACT Length and weight data from a longitudinal study of rural Guatemalan subjects birth to 7 y of age and height and weight data from a cross-sectional study of the same subjects when they were 11–24.9 y old are compared to reference data for the USA general population and for Mexican-Americans. At birth, the median length of Guatemalan children is at ~ the 16th percentile of the USA reference or ~2 cm shorter. By 6 mo of age, Guatemalan children are shorter, on average, than the 5th percentile of the reference curves and, in absolute terms, are ~5 cm below the median; by 3 y, the difference increases to ~10 cm. As adults, Guatemalans have about the same absolute level of deficit (~13 cm) as they did at age 3 y. If the general USA population is used for comparison, Guatemalans can be said to grow as expected during adolescence, neither recuperating the growth retardation of early childhood nor falling further behind in size. If the Mexican-American sample is selected instead, it would appear that some catch-up in growth occurs in Guatemalan adolescents. Regardless of the choice of reference population, growth is markedly retarded only in early childhood; adolescence is not a period when growth is significantly constrained. J. Nutr. 125: 1060S–1067S, 1995.

INDEXING KEY WORDS:

- *growth* • *anthropometry* • *adolescence*
- *rural Guatemala*

While much is known in developing countries about growth in early childhood and the factors that shape its course, knowledge about growth during later childhood and adolescence is limited. Research to date indicates that growth failure and nutritional stress in poor children from developing countries are greatest in the first 2–3 y of life (Beaton et al. 1990). Growth during later childhood and adolescence in these same societies appears to be considerably less constrained, if at all (Martorell et al. 1994). Some argue that adolescence is a time when the growth retardation produced in early childhood may be recuperated (Delgado et al. 1987). However, the research to support the claim that catch-up growth can occur to a significant degree during adolescence is weak (Martorell et al. 1994). The objective of this paper is to compare patterns of growth of poor Guatemalans during childhood and adolescence to both a racially similar population of Mexican-Americans and a general USA reference. Several key questions guide the analyses: what are the periods in life in rural Guatemala when significant growth failure occurs? Specifically, is adolescence a time of constrained growth or instead, is it a period when some of the growth failure of earlier childhood is overcome by compensatory growth?

MATERIALS AND METHODS

The subjects included in this study were participants of a longitudinal study conducted by the Institute of Nutrition of Central America and Panama (INCAP) in four villages of eastern Guatemala. The study took

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place between 1969 and 1977 in four Ladino (i.e., Spanish speaking, mixed Spanish/Amerindian population) villages. The objectives of the study were to test the effects of improved nutrition achieved through food supplementation on physical growth and mental development. The groups under intensive monitoring were pregnant and lactating women and all children seven years of age and less. Details about the methods of this longitudinal study are found elsewhere (Martorell et al. 1995). Briefly, weight was measured on a beam scale to the nearest 10 g with children wearing a light shift, the weight of which was later subtracted. Supine lengths were measured using a standard measuring table to the nearest 0.1 cm; no standing heights were taken on children <7 y of age.

In 1988–89, a cross-sectional, follow-up study was carried out which included data on height and other measures of linear growth, weight, frame size, circumferences and skinfold thicknesses (Martorell et al. 1995). This article emphasizes the height and weight data. Standard measurement techniques were used (Lohman et al. 1988). Weight was measured to the nearest 100 g using a beam balance scale (Health O Meter). Subjects were given a light shift to wear and shoes were removed. A portable anthropometer in free-standing mode was used to measure height to the nearest 0.1 cm. The body mass index (BMI) was estimated as weight (kilograms) over height squared (meters^2).

The anthropometric data are compared with three reference populations. The first is the United States National Center for Health Statistics/World Health Organization (NCHS/WHO) reference, which is widely used by researchers throughout the world (WHO, 1983). For length data from birth to 36 mo, this reference is based on data collected from children from the Fels Research Institute's (Ohio) longitudinal study of 867 white, middle-class children (Dibley et al. 1987a, Hamill et al. 1979). Height data from 2 to 18 y are from national surveys carried out by NCHS. The appropriateness of these data as a reference (Dibley et al. 1987b) and their comparison with other references are discussed elsewhere (Stephenson et al. 1983).

For adolescents and young adults, a reference based on the first (1971–74) and second (1976–80) National Health and Nutrition Examination Survey (NHANES) published by Frisancho (1990) is used. The NHANES surveys included representative samples of subjects in the United States and as such, reflected the ethnic diversity of the country in the 1970s. For the most part, however, subjects included in these surveys were of European origin; in the combined data set used by Frisancho, 78% of subjects were Caucasian (Frisancho 1990). The reasons for using Frisancho's (1990) reference data for comparison are that percentile values are provided for adults and that additional anthropometric variables (e.g., BMI) are presented. For ages presented in both the Frisancho and NCHS/WHO references, values are very similar. This similarity is not unexpected because both include a common data source, NHANES I; also, average stature did not differ in NHANES I and II. The reason for not using only the NCHS/WHO (WHO 1983) curves is that they do not provide data after age 18 y or for variables other than height and weight. A disadvantage of Frisancho's curves is that the data were not smoothed and this may lead to some irregularity.

A reference population of similar ancestry as the study population is also used for comparison. The reference population selected for this purpose is that of Mexican-Americans measured in the Hispanic HANES of 1982–84 (Najjar and Kuczmarski 1989). Although poverty may have constrained growth, Mexican-Americans are undoubtedly much better off than rural Guatemalans. In fact, the growth patterns of Mexican-Americans are strikingly similar to those of well-to-do samples from the cities of Mexico and Guatemala (Johnston et al. 1973, Johnston et al. 1976, Martorell et al. 1989, Ramos-Galván 1975).

Subjects from all four villages included in the original study are pooled in the analysis because the purpose is to describe general differences in linear growth with respect to the reference populations selected. Differences between Guatemalans and the reference populations are overwhelmingly larger than intervillage differences (see Rivera et al. 1995 for examination of these differences). For the later ages, the study also combines, for the same reason, migrants and nonmigrants (Martorell et al. 1995). The follow-up study was able to collect data on 73% of former participants; coverage was greater for village residents (89%) than for migrants (41%).

For the analyses of child growth, data on 1232 boys and 1160 girls are included in this paper. Because of the longitudinal nature of the earlier study, individual subjects may be represented at more than one age interval.

In 1988–89, the subjects ranged from 11 to 27 y of age (born between 1962 and 1977). Presented in this paper are data for 786 males and 719 females 11.0–24.9 y in age; subjects 25–27 y are excluded to conform with the Frisancho's age groupings (1990), which were yearly to 17 y (e.g., 17.0–17.9), and at longer intervals thereafter (i.e., 18.0–24.9 y, for which we have subjects in the entire age range; 25.0–29.9 y, for which we lack subjects 28–29.9 y).

Mean and median values by age and sex are given in tabular form in this paper only for the rural Guatemalan sample. Medians for Guatemalan and Mexican-American samples are plotted relative to the percentile distribution in the USA reference population. Results of formal statistical tests are not presented because the differences of interest in this study are extremely large and often statistically significant. Rather, readers are encouraged to assess the magnitude of differences relative to the percentile distribution.

TABLE 1

Length or height[1] (cm) of Guatemalan children, adolescents and young adults

	Males				Females			
Age (y)	*n*	Median	x̄	SD	*n*	Median	x̄	SD
0.04[2]	453	50.4	50.2	2.5	409	49.5	49.3	2.3
0.25	507	58.2	58.0	2.5	461	56.7	56.5	2.4
0.5	508	63.5	63.4	2.5	448	62.0	61.8	2.3
0.75	511	67.0	66.7	2.7	450	65.3	65.1	2.5
1.0	504	69.7	69.4	3.0	453	68.0	67.8	2.8
1.5	494	74.4	73.9	3.4	429	72.5	72.4	3.1
2.0	492	78.5	78.2	3.6	427	76.8	76.6	3.4
2.5	466	82.5	82.4	3.7	428	81.0	80.6	4.2
3.0	472	86.4	86.2	3.9	407	85.2	84.7	4.0
3.5	472	89.0	88.9	3.9	391	87.7	87.7	4.1
4.0	466	92.5	92.4	4.1	398	91.2	91.1	4.3
5.0	407	99.0	98.6	4.2	384	97.5	97.6	4.6
6.0	370	104.8	104.4	4.3	357	103.5	103.4	4.5
7.0	339	110.0	110.0	4.2	326	109.0	109.0	4.7
11.0–11.9	61	132.8	132.6	5.6	64	135.0	135.7	7.7
12.0–12.9	72	135.8	137.1	6.9	55	141.3	139.5	5.8
13.0–13.9	67	141.5	142.9	7.9	71	145.6	145.3	5.6
14.0–14.9	62	149.2	147.6	8.1	68	146.6	146.1	5.6
15.0–15.9	58	156.9	155.5	9.4	58	149.8	149.7	5.6
16.0–16.9	82	161.1	159.6	7.6	64	149.3	149.5	4.8
17.0–17.9	64	160.2	160.2	5.3	62	149.4	149.6	5.2
18.0–24.9	281	162.6	162.5	5.6	318	150.4	150.4	5.7

[1] Supine length was measured until 7 y of age; 1 cm was subtracted from length values in children ≥24 mo to approximate height values used in the reference population. Standing height was measured at 11–25 y. Measurement before age 7 y was at exact ages.
[2] Measured at 15 days of life.

RESULTS

Data for length or height, weight and BMI for the Guatemalan sample are given in **Tables 1–3**, respectively. Median lengths or heights by age for the Guatemalan and Mexican American populations are plotted together with the 5th, 50th and 95th percentile values for the USA reference population in **Figures 1** and **2** for children 0–36 mo and subjects 11–25 y old, respectively. At 15 days, the median length of Guatemalan males is at ~ the 16th percentile of the NCHS/WHO reference, declining to less than the 5th percentile by nine months of age and to less than the 3rd percentile by 36 mo. Values remain at the same relative position at ages 3–7 y of age (not shown). Mexican-American boys, on the other hand, are at the 50th percentile at 9 mo (measures at younger ages not available), maintaining this level throughout childhood.

During adolescence, the median height of Guatemalan males remains at below the fifth percentile of the USA reference population. The median height of Mexican-American males is still near the 50th percentile during early adolescence but declines to around the 25th percentile in adulthood. Patterns are similar for females at all ages and for both the Guatemalan and Mexican-American populations.

Absolute differences in length among the populations are shown in **Figure 3** for 0- to 36-mo-old males and females. Differences between Guatemalan and the NCHS reference (noted as Guat-NCHS in the legend) are 2.2 cm at 15 days, ~6.5 and 8 cm by 12 mo and ~10 and 11.5 cm by 36 mo for males and females, respectively. Differences between the Mexican-American population and the NCHS/WHO reference (noted as Mex-NCHS) are negligible throughout young childhood. At 11 y of age, the difference between the Guatemalan and USA samples (Guat-USA) is at ~12.5 and 13.5 cm for males and females, respectively, only slightly greater than it was at 3 y (**Figure 4**). For males, differences increase between ages 13 and 15, but are at ~13 cm again by adulthood for both sexes. Differences in height during adolescence and adulthood between Mexican-American and USA medians (Mex-USA) suggest a different pattern (Figure 4). For both males and females, differences are minimal at 11 to 13 y of age, but increase thereafter so that at adulthood Mexican-Americans are ~6 cm shorter.

Patterns of growth for other anthropometric dimensions also have been examined. In terms of sitting height and bone diameters, patterns generally follow those observed for length and height. However, for bicristal breadth, there is substantial catch-up in late adolescence, particularly in females. On the whole, rural Guatemalans have smaller limb circumferences and reduced skinfold thicknesses than the reference

TABLE 2

Weight (kg) of Guatemalan children, adolescents and young adults

Age (y)	Males			Females		
	Median	x̄	SD	Median	x̄	SD
0.04[1]	3.4	3.4	0.5	3.2	3.3	0.5
0.25	5.7	5.6	0.8	5.2	5.2	0.7
0.5	7.0	7.0	1.0	6.5	6.5	0.9
0.75	7.7	7.6	1.0	7.2	7.1	1.0
1.0	8.1	8.1	1.1	7.5	7.5	1.0
1.5	8.9	9.0	1.1	8.5	8.4	1.0
2.0	10.0	10.0	1.1	9.4	9.4	1.1
2.5	11.1	11.1	1.2	10.5	10.5	1.3
3.0	12.1	12.1	1.3	11.4	11.5	1.4
3.5	13.0	13.1	1.4	12.4	12.5	1.4
4.0	13.9	13.9	1.4	13.1	13.3	1.5
5.0	15.4	15.4	1.6	14.7	14.9	1.6
6.0	16.9	16.9	1.7	16.2	16.2	1.7
7.0	18.7	18.8	1.8	17.9	18.2	2.0
11.0–11.9	29.0	28.9	3.5	30.4	31.0	5.9
12.0–12.9	31.0	31.5	4.6	34.1	33.8	5.3
13.0–13.9	34.4	35.1	5.5	39.6	40.1	6.4
14.0–14.9	39.1	38.6	6.0	41.6	41.1	6.2
15.0–15.9	46.2	45.7	7.1	45.2	46.0	5.6
16.0–16.9	50.0	49.4	6.1	48.0	48.5	6.1
17.0–17.9	52.2	51.7	5.6	48.2	49.5	6.8
18.0–24.9	55.4	56.3	6.5	49.2	50.4	7.9

[1] Measured at 15 days of life.

populations, particularly in males. Median BMI values by age are shown for adolescent and adult Mexican-Americans and Guatemalans relative to USA percentiles in **Figure 5** and **6** for males and females, respectively. The Guatemalan population, particularly in the case of males, is the leanest. Guatemalan males have values that are between the 50th and 5th percentiles. Older Guatemalan female adolescents and young women, on the other hand, have BMI values which are near the 50th percentile of the US population. Mexican-Americans of both sexes have values which are at or slightly above the 50th percentile.

DISCUSSION

A major consideration in any discussion of the results presented above is the choice of reference population. The ideal population to use would be one with similar growth potential as the Guatemalan population but living in an environment that does not constrain growth. Whether the Mexican-American population is the appropriate choice is not entirely clear. Just as Guatemalans, Mexican-Americans are of Spanish-Indian ancestry, though differences may exist in the proportions of admixture. Mexican-Americans are one of the tallest Hispanic populations reported in the literature (Martorell et al. 1989) and are as tall as well-to-do populations from Guatemala (Johnston et al. 1973, Johnston et al. 1976) and Mexico City (Ramos-Galván 1975). Before adolescence, Mexican-Americans are as tall as the general USA population suggesting unconstrained growth but important differences are observed during adolescence (Figure 2). One explanation might be that differences are due to genetic factors that lead to a faster growth tempo in Mexican-Americans and, hence, to a shorter duration of the adolescent growth phase. On the other hand, sexual maturation data for Mexican-Americans from HHANES do not suggest precociousness relative to patterns observed in European longitudinal studies (Villareal et al. 1989). But, data of this type are notoriously difficult to collect reliably and cross-study comparisons may be flawed. Also, the lack of USA reference data for sexual maturation is a serious limitation.

Two of the sets of reference data (i.e., NCHS/WHO, Frisancho) used in this report are derived from cross-sectional data and are subject to biases introduced by cohort effects. Periodic surveys reveal that average heights in the general US population have not changed for some time and hence these biases are unlikely to be important in the US data of Frisancho (1990). In the case of Mexican-Americans, marked changes in stature have occurred over time (Martorell et al. 1989). It is not clear whether future national surveys will reveal differences with respect to HHANES data, now 8–10

TABLE 3

Body mass index (kg/m²) of Guatemalan children, adolescents and young adults

Age (y)	Males			Females		
	Median	x̄	SD	Median	x̄	SD
Birth	13.4	13.4	1.4	13.3	13.3	1.5
0.25	16.6	16.5	1.8	16.2	16.1	1.7
0.5	17.4	17.3	1.8	17.0	17.0	1.6
0.75	17.0	17.1	1.6	16.7	16.8	1.5
1.0	16.7	16.7	1.5	16.4	16.4	1.4
1.5	16.4	16.3	1.3	16.0	16.0	1.3
2.0	16.3	16.4	1.1	16.0	16.0	1.2
2.5	16.3	16.3	1.2	16.0	16.1	1.4
3.0	16.2	16.3	1.2	15.9	16.0	1.2
3.5	16.4	16.5	1.2	16.1	16.2	1.3
4.0	16.2	16.3	1.1	15.8	16.0	1.2
5.0	15.7	15.8	1.1	15.5	15.6	1.2
6.0	15.5	15.5	1.0	15.2	15.3	1.0
7.0	15.6	15.5	1.0	15.2	15.3	1.0
11.0–11.9	16.2	16.4	1.4	16.5	16.7	1.8
12.0–12.9	16.6	16.7	1.3	17.2	17.2	1.8
13.0–13.9	17.2	17.1	1.2	18.8	18.9	2.3
14.0–14.9	17.6	17.6	1.4	19.3	19.2	2.5
15.0–15.9	18.5	18.8	1.5	20.2	20.5	1.7
16.0–16.9	19.3	19.4	1.5	21.6	21.7	2.4
17.0–17.9	20.2	20.1	1.6	21.8	22.1	2.6
18.0–24.9	20.9	21.3	2.1	21.8	22.3	3.2

[1] Measured at 15 days of life.

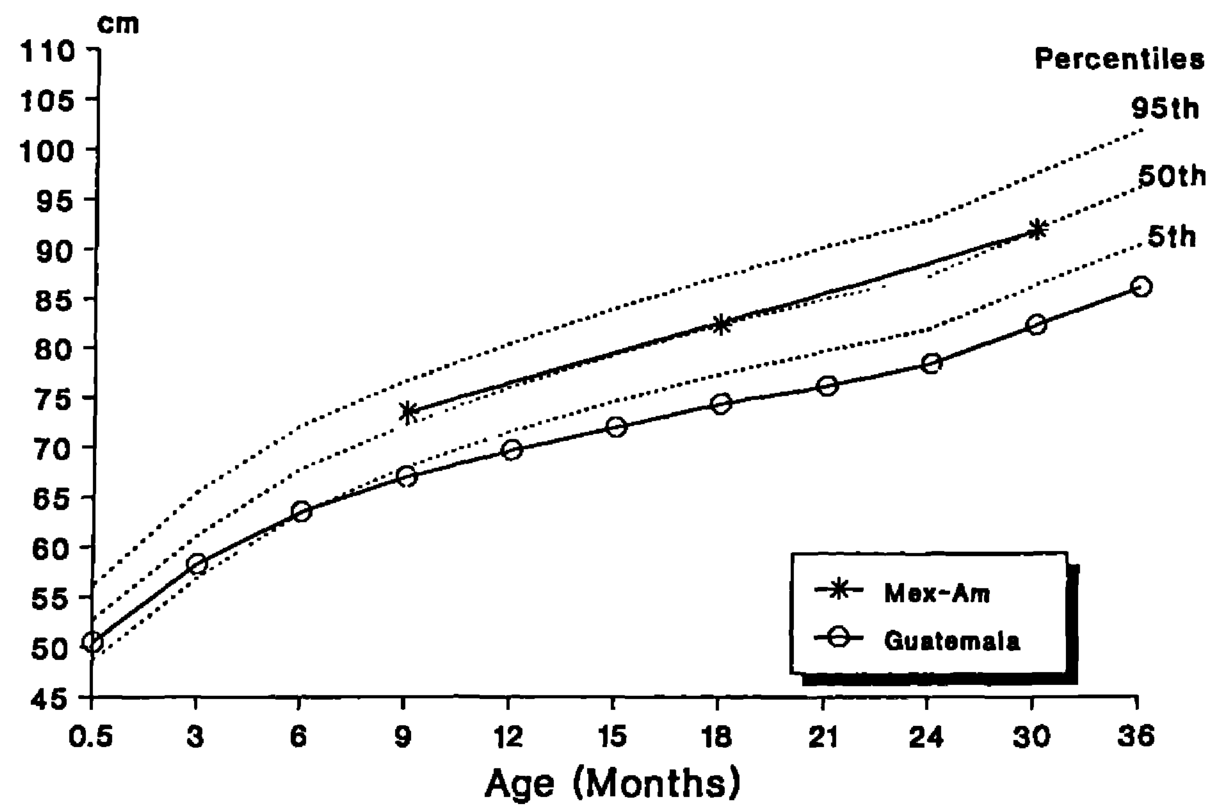

FIGURE 1 Median length in males 0.5–36 mo old: rural Guatemalans and Mexican-Americans compared with reference population [United States National Center for Health Statistics/World Health Organization (NCHS/WHO) 1983].

y old. Cohort effects could invalidate conclusions about growth during adolescence that are derived from cross-sectional studies, as in this case. Suppose that Mexican-American adolescents examined in HHANES grew poorly in early childhood because of poor diets and infection. Also, suppose that conditions changed such that young Mexican-American children measured in HHANES were not constrained in their growth. If these conditions apply, the patterns of adolescent growth that are inferred from the HHANES cross-sectional data would be erroneous. Adolescents would be short, not because of poor growth during adolescence, but because of early childhood retardation and estimates of age at peak height velocity would be biased downward. The same concern applies to the studies of well-to-do populations in Guatemala (Johnston et al. 1973, Johnston et al. 1976) and Mexico City (Ramos-Galván 1975), particularly in view of the fact that the data were collected at least two decades ago. Cohort-like effects also may be produced by migration patterns. The Mexican-American data set includes an unknown proportion of Mexican-born children. If immigration rates were greater for adolescents than for young children, the pattern shown in Figure 4 also could be produced under certain conditions (e.g., if adolescents born in Mexico were subjected to greater nutritional stress and growth retardation than native born adolescents). However, we have no evidence for differential immigration by age.

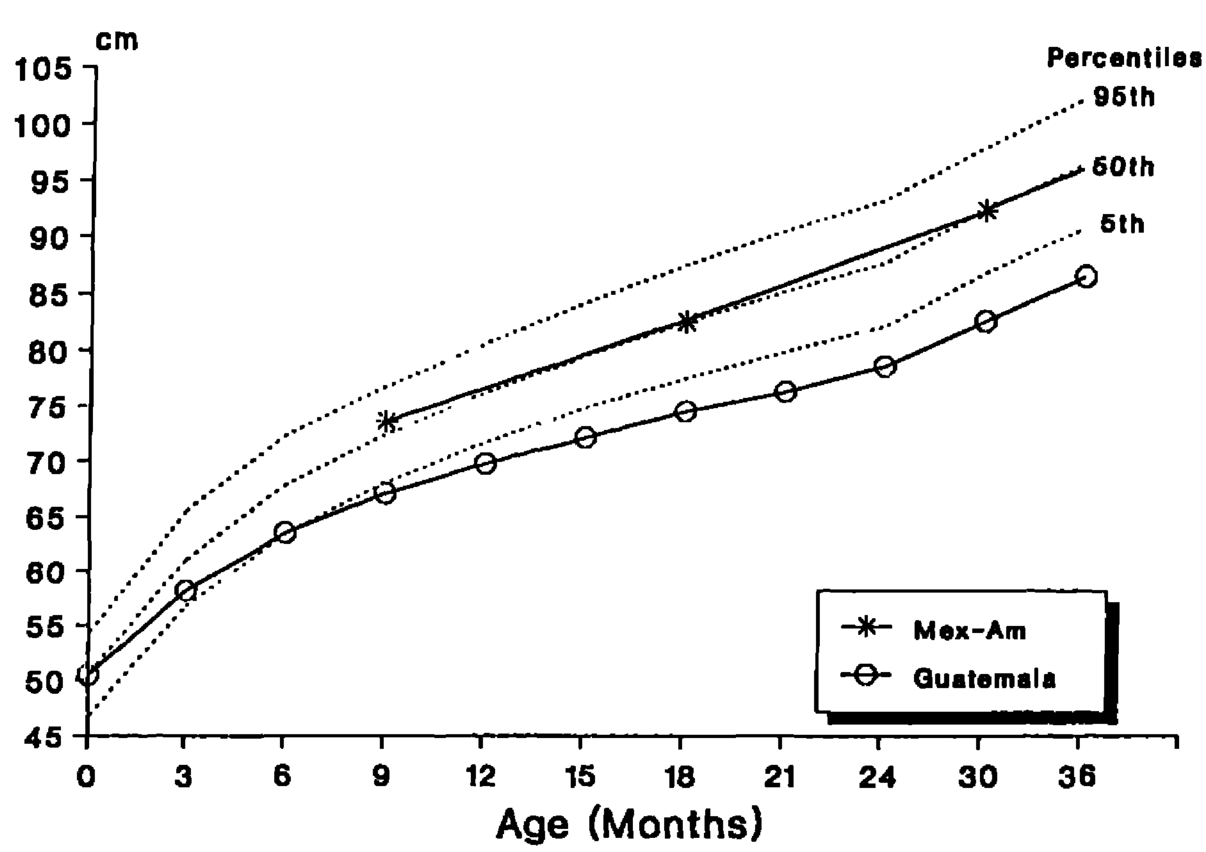

FIGURE 2 Median height in males 11–25 y old: rural Guatemalans and Mexican-American compared with USA reference population (Frisancho 1990).

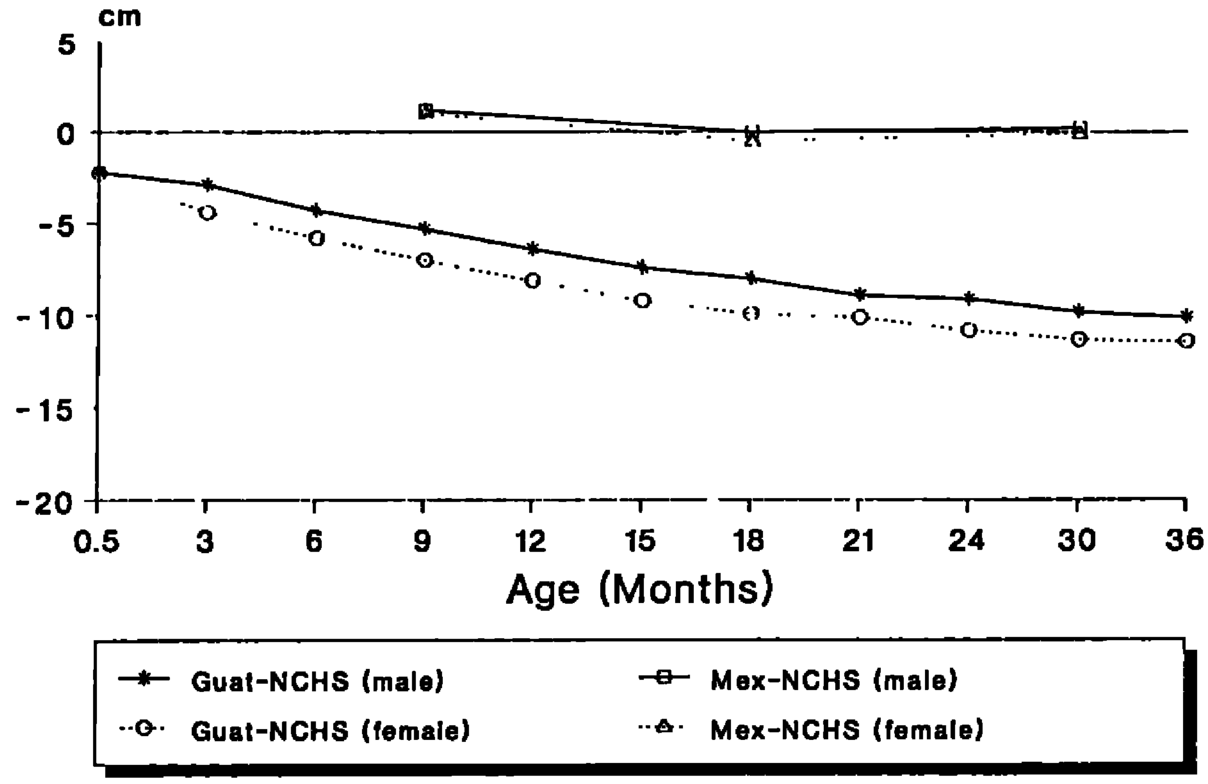

FIGURE 3 Differences in median length by age and sex for 0.5-to 36-mo olds.

At this time, it is not clear which of the two reference populations is most appropriate for assessment of the growth of rural Guatemalans. For assessment of growth during childhood, either reference may be used because patterns exhibited by Mexican-Americans are nearly identical to those of the general US population. Guatemalan children are born retarded in length and begin experiencing additional retardation shortly after birth. Both feeding practices as well as increased frequency of illness are the likely proximate determinants for this further decline. Though breastfeeding is nearly universal in this population, *exclusive* breastfeeding, clearly shown to reduce the risk of infectious illness (Brown et al. 1989), is rarely practiced. In addition, during the second half of infancy, complementary foods are generally inadequate in both quantity and quality to meet requirements.

The infant-feeding practices of the populations upon which the references are based should also be considered. Even under industrialized country conditions, growth patterns differ between breast-fed and bottle-fed infants with bottle-fed infants showing generally greater growth, more so in weight than in length, compared to exclusively breastfed infants (Waterlow 1988). Notably, the Fels children were primarily bottle fed with 85% completely weaned by 3 mo of age (Roche et al. 1989).

In the adolescent period, it is less clear whether Guatemalan growth patterns should be compared with the Mexican-American or USA general reference. If

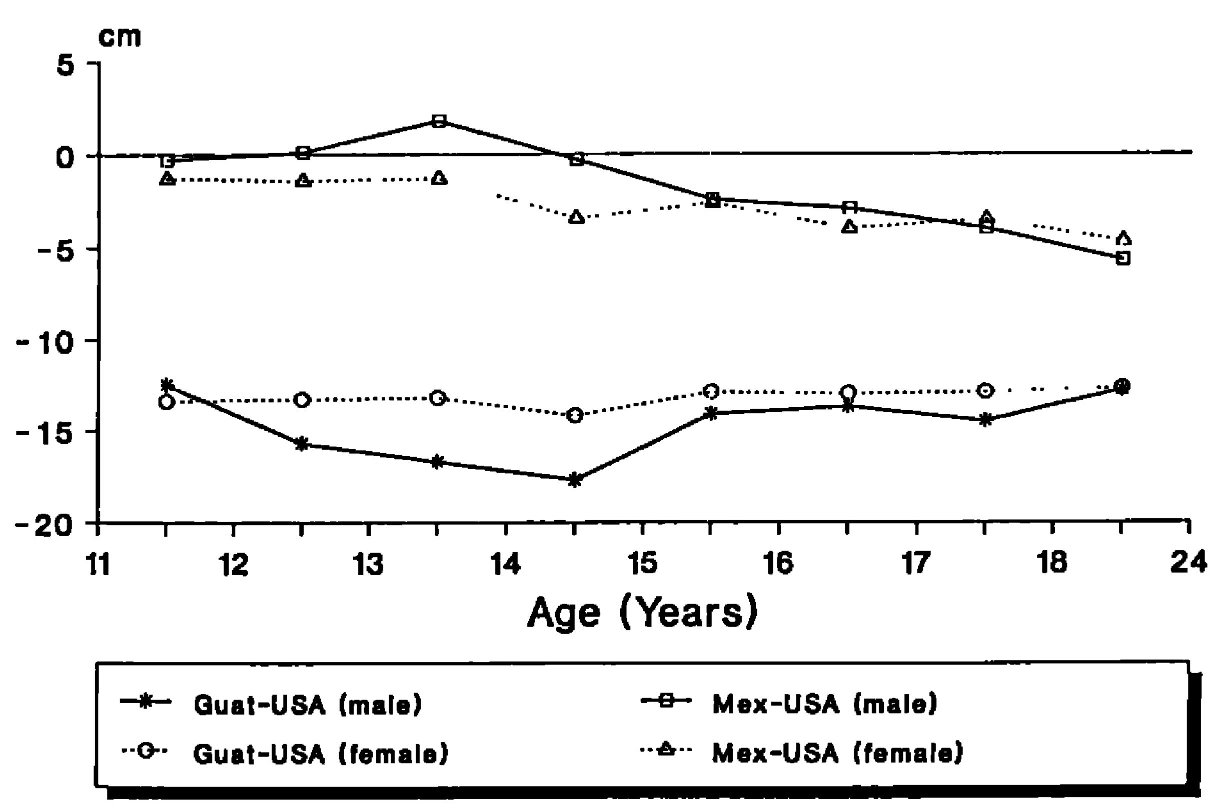

FIGURE 4 Differences in median height by age and sex for 11-to 25-y olds.

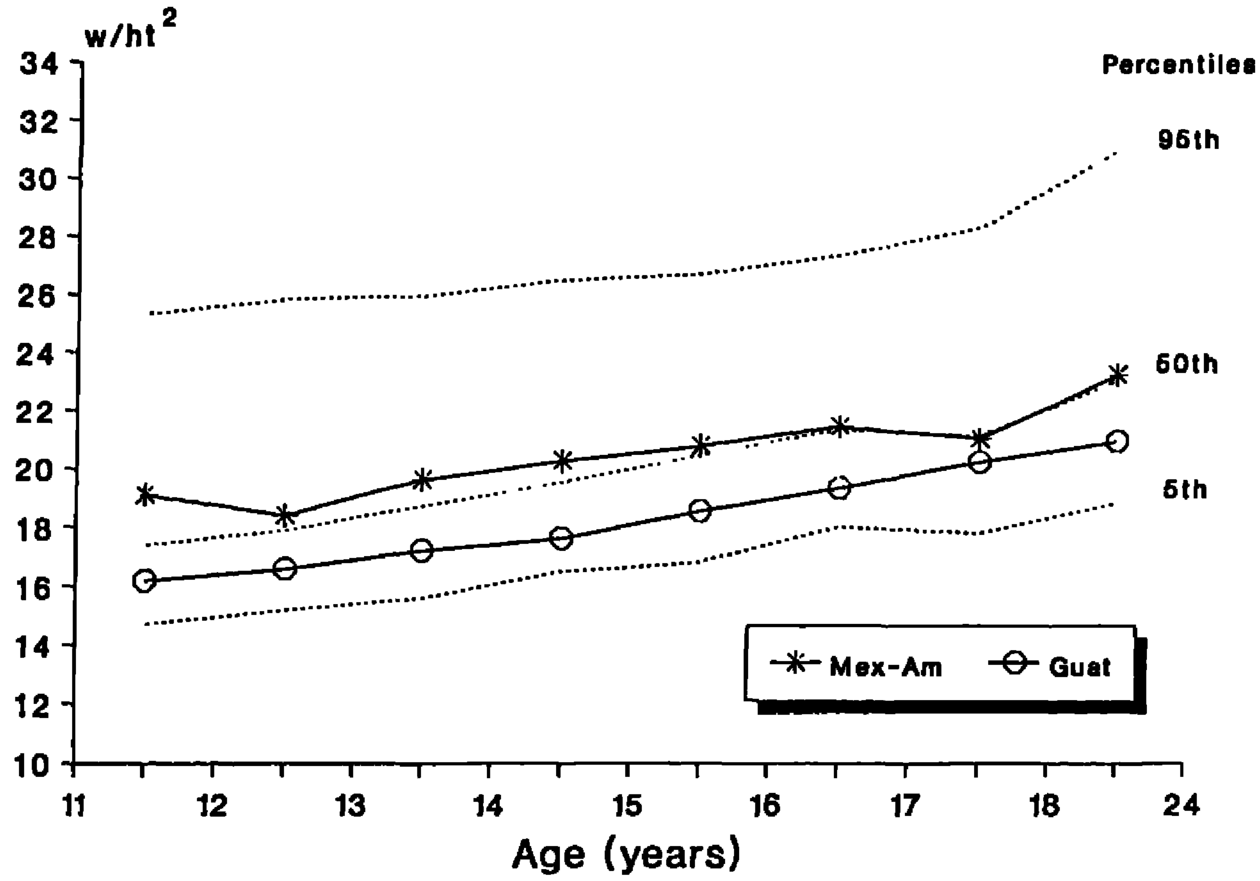

FIGURE 5 Median body mass index in males: rural Guatemalans and Mexican-Americans compared with USA reference population (Frisancho 1990).

the USA data are used as the reference population, one would conclude that absolute linear growth during adolescence is as expected. If Mexican-American data are more appropriate as a reference population, one would be further impressed by the extent to which some of the losses in early childhood are made up during adolescence, perhaps through delayed maturation and longer growth periods (see Martorell et al. 1994 for a discussion of this mechanism). Whether nutrition interventions aimed at adolescents might be helpful in promoting even greater compensatory growth is not clear because these efforts also may accelerate maturation with the unwanted result of reducing growth potential (Proos et al. 1991).

Regardless of the choice of reference population, it is clear that growth is markedly retarded in rural Guatemalans only in early childhood. Adolescence is certainly not a period in life when growth is constrained to a significant degree. In poor Guatemalans, therefore, stature in older children and adults indicates the degree to which growth was constrained in early childhood. Referring to height for age as an indicator of "chronic malnutrition" has brought about much confusion because it may be taken to mean that the process is still

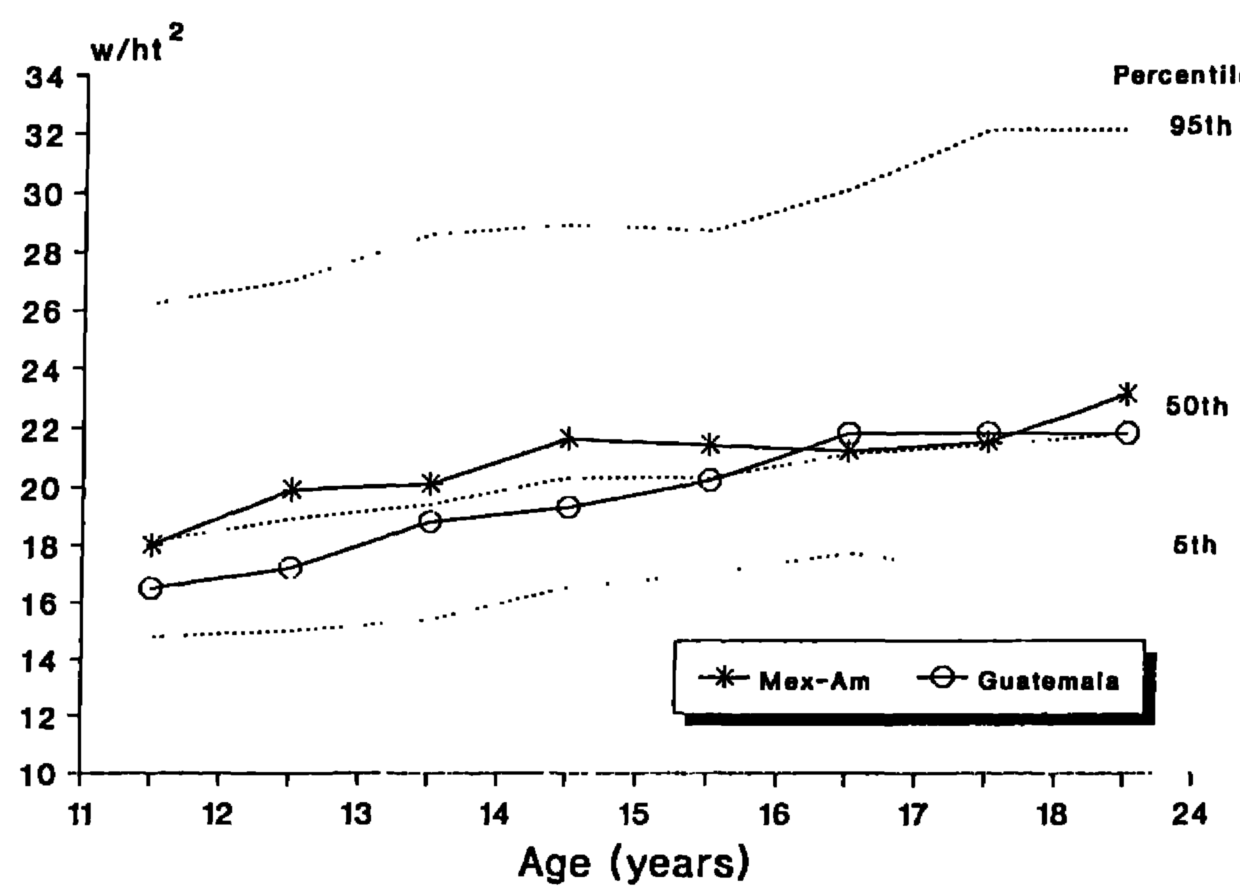

FIGURE 6 Median body mass index in females: rural Guatemalans and Mexican-Americans compared with USA reference population (Frisancho 1990).

continuing. Rather, as noted by Beaton et al. (1990), length for age in the first 2–3 y of life can be said to mark the state of "failing to grow" in early childhood, particularly if repeated measures are taken, whereas in older subjects, height for age marks the state of having "failed to grow". Height for age data at school entry, for example, would be a useful but lagged indicator of nutritional status, in that it reflects conditions at about 4 or more y previously (i.e., when the children were <3 y old).

The patterns of linear growth observed in Guatemala may differ from those common to other areas of the developing world. Skeletal age assessments, made relative to British reference data, indicate a delay of ~1.2 y in boys 11–14 y but none in girls of the same age (Pickett et al. 1995). This may explain the pattern shown in Figure 4; differences in girls with respect to the reference do not vary much with age. In boys however, differences increase temporarily at ages 12–14 y, which suggests earlier ages at peak height velocity in the reference population than in the study sample. Growth in height appears to continue to 19–20 y of age in males (analysis not shown) but little growth takes place in females after 15 y of age.

Menarche occurs at 13.7 y in the study sample, a year or so delayed when compared with US values (Khan et al. 1995). Thus, there is an apparent contradiction between the skeletal age (no delay) and menarche (1-y delay) results in girls but it is important to point out that both assessments of maturation indicate that delays are not severe. In other areas of the world, maturation may be more delayed and a prolonged period of linear growth, for example, might allow for substantial recuperation of the height retardation incurred in early childhood (Martorell et al. 1994).

Our relative ignorance of growth during adolescence in developing countries reflects the long-standing focus of attention on young children, who are at greatest risk of malnutrition. Although the priority remains unchanged, particularly for public health measures, greater attention needs to be given to research on adolescence, if only to understand the full impact of malnutrition in early childhood.

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