Original Research Article

Nutritional Status of Maya Children, Their Mothers, and Their Grandmothers Residing in the City of Merida, Mexico: Revisiting the Leg-Length Hypothesis

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Objectives: To test the hypothesis that leg length-relative-to-stature is a more sensitive indicator of nutrition and health than is total height (HT) or sitting height (SH) in a sample of 109 triads of urban Maya children (6.0–8.99 years), their mothers, and maternal grandmothers from Merida, Mexico.

Methods: From September 2011 to June 2012, the following factors were obtained from all participants: (1) HT, SH, and leg length (LL); (2) the sitting height ratio (SHR = [SH × 100]/HT), relative leg length index (RLLI = [LL × 100]/height), and percentiles and *z*-scores of HT, SH, and LL were calculated; and (3) the percentages of stunting for children or very short ZHT for the adults, short ZSH, and short ZLL: HT-for-age, SH-for-age, or LL-for-age below the 5th percentile of the reference were calculated. Correlations were performed to examine the association between *z*-scores of HT, SH, and LL among three generations.

Results: Stunting in children was 11% (short ZLL = 29%, short ZSH = 7%). Short ZHT was present in 71% of mothers (short ZLL = 54%, short ZSH = 50%) and 90% of grandmothers (short ZLL = 69%, short ZSH = 83%). Significant correlations in ZHT, ZSH, and ZLL were found in mother-to-child and grandmother-to-mother, with the strongest correlations for ZLL.

Conclusions: These findings support the hypothesis for children and mothers. Based on ZLL, there is evidence that childhood and nutrition have improved somewhat for each younger generation. Persistent environmental adversity during growth resulted in growth deficits for LL and SH for the mothers and grandmothers. Am. J. Hum. Biol. 25:659–665, 2013.

This study focuses on a sample of contemporary Maya people from Mexico, especially on their biological status in terms of nutrition and physical growth. The Maya in Mexico have experienced more than 500 years of oppression and exploitation (Montejo, 1999), resulting in chronic poverty and marginalization, restricted access to education, limited health services, and an inadequate nutritional supply (Bogin, 2012; Bracamonte, 2007; Bracamonte and Lizama, 2006).

Currently, rural-to-urban migration, economic change, and cultural globalization have been modifying the lifestyle of the Maya (Azcorra et al., 2009; Bracamonte, 2007; Dickinson et al., 1993; Gurri and Balam, 1992; Gurri et al., 2001; Leatherman and Goodman, 2005; Leatherman et al., 2010; Salazar Pastrana, 2012; Varela-Silva et al., 2009).

Merida City, the capital of Yucatan State, became an important destination of rural-to-urban Maya migrants during the last decades. The growth of commerce, construction, manufacturing, services, and industry in Merida is a source of employment and has attracted the Maya population into the region (Bracamonte and Lizama, 2006). By 2010, there were around 74,827 Maya speakers in Merida, representing 9% of the population (INEGI, 2012a). Maya migrants have historically settled in the southern part of the city, an area that has been marginalized from economic development and is the most deprived (Dickinson et al., 1999; Fuentes, 2005). It is likely that these long-term levels of deprivation are reflected in the health and nutritional status of the Maya.

The first goal of this study is to document the persistence of poor nutritional and growth status across three generations of Maya living in Merida, Mexico: Maya grandmothers, their daughters, and the daughters' children (boys and girls). Our second goal is to test the hypothesis that relative leg length in proportion to total stature is a more sensitive indicator of nutritional status and health than is total stature or sitting height.

The rationale for using leg length as a biomarker for early life nutrition and health is based on the fact that between birth and puberty the legs grow relatively faster than the upper body, a pattern called the cephalo-caudal gradient in growth. We should expect, therefore, leg length to be relatively longer in populations that live under more advantaged circumstances, because better nutrition and health will allow for more rapid leg growth in the early years of life. This was first demonstrated to be the case by studies of child growth in Europe following World War II (Leitch, 1951). The association of leg length with nutrition and health conditions during the first decade after birth has since been replicated in many studies. Much of the research on use of leg length in human

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biology and epidemiology is reviewed in Bogin and Varela-Silva (2010). Many of these same studies find that leg length is a better predictor of adult health and risk for mortality than are total height or sitting height. Equally important, leg length tends to remain more constant from adulthood until death—it does not "shrink" as much with age as do total stature and sitting height—due to compression of vertebral discs and other joints. A more recent study of the United States population also supports the use of leg length relative to total body length as a biomarker of health and environmental quality for people between birth and 8 years (Bogin and Baker, 2012).

METHODS

A cross-sectional and intergenerational study was undertaken from September 2011 to June 2012 on 109 urban Maya triads (grandmothers, mothers, and children) resident in the southern, western, and eastern parts of Merida. Inclusion was based on the following criteria: (1) the presence of a child whose age ranged between 6.0 and 8.99 years attending a public school, (2) the mother was the biological mother of the child, and (3) the grandmother was the biological mother of the mother. We focused on 6- to 8-year-old children, because in terms of height and weight gain, this age range corresponds to the late childhood and early juvenile stages of growth. Infancy and early childhood are sensitive periods for growth in terms of the influence of the nutrition and health environment (Cameron and Demerath, 2002) due, in part, to relative rapid growth velocity. Between 6.0 years and puberty, skeletal growth rate tends to be stable or decelerating, and there are few skeletal maturation differences between girls and boys. In contrast, after 8.99 years and puberty, growth rate accelerates relatively rapidly, and maturational differences between the sexes and between early, average, and late maturers become quite marked (Bogin, 1999). Previous research with Maya samples found that by the late childhood and early juvenile stages, it was relatively easy to detect environmental influences on human height, weight, and body proportions (Bogin and MacVean, 1982; Bogin et al., 2002).

An additional requirement for inclusion in the sample was that each member of a triad had to have at least a maternal Maya surname, as opposed to a Spanish or other non-Maya surname. In Mexico, each person inherits and formally uses a patronymic and a matronymic. Surnames can be used as a genetic proxy and a means to identify ethnic groups (Chakraborty et al., 1989; Colantonio et al., 2003; Relethford, 1995).

Sample

The number of triads needed for statistical analysis (sample size) was calculated through a power analysis calculation. Setting the significance level at $\alpha = 0.05$, the power at 0.80, with a medium size error of 0.15 and eight independent variables in a multiple regression model, we found that a sample of 107 children, 107 mothers, and 107 grandmothers was required. For our analysis, a triad was considered complete when all variables were available for each child, mother, and grandmother.

Information about location and distribution of people according to their surnames is not available in Mexico. Therefore, the selection of the schools was done following two indicators: (1) the location and concentration of Maya language speakers in the city and (2) the location and concentration of people with the lowest level of income in the city (below the value of two times the minimum wage for Mexico, which was about US$8.91 per day in 2011). Maya language use and low income characterize urban people with Maya ancestry (Bracamonte and Lizama, 2006). Using datasets from the Ministry of Education (*Secretaria de Educación de Yucatán*), the National Institute of Statistics and Geography of Mexico (*Instituto Nacional de Estadística y Geografía*), and López-Falfán (2008), we grouped geographically all primary schools ($n = 357$) of Merida in four strata. Stratum 1 included schools in which we expected to find the largest number of children with Maya surnames and parents with low income. Most of these schools were located in the southern part and the others in the western and eastern parts of the town. We expected that, as we moved to Strata 2 and 3, we would find fewer children with Maya surnames and more children belonging to families with relatively higher incomes. Private schools were included in the Stratum 4. In Merida, most of the private schools are concentrated in the northern part, and people who attend them tend to come from families of very high income and of non-Maya ethnicity. Unpublished results of a study completed in 2011 carried out by one of the coauthors of this article (F.D.) show that in a sample of 993 students of public and private schools in Merida, there was not a single case of a child with two Maya surnames attending private schools. Strata 1, 2, and 3 consisted of 91, 61, and 89 public schools, respectively. Stratum 4 consisted of 116 private schools. For this study, we focused only on the schools that belong to Stratum 1. Of the 91 schools of Stratum 1, we selected randomly 20 of them, or 25% of the total, from which the participants were recruited.

To meet the required sample size and to allow for maximum geographic and socioeconomic variability to the sample, we selected no more than 10 children from each school. In those schools where more than 10 children met the inclusion criteria, 10 were selected randomly.

Recruitment

Participant's recruitment was made at the selected primary schools. In Mexico, primary education is compulsory, and in Yucatan State, 97% of the children attend school (INEGI, 2012b). In urban settings, such as Merida, this figure is higher. Prior to recruitment, we obtained approval from the Ministry of Education of Yucatan. Children and mothers with the required Maya surnames were identified through birth certificates provided by the directors of each primary school. Information about the grandmothers was obtained through informative meetings conducted at the schools to which mothers were invited. Mothers and grandmothers who met the inclusion criteria were formally invited to participate in the research. Those women who accepted to participate provided us with their address and phone number to make an appointment to begin the process of obtaining data.

After the review of the birth certificates and the informative meetings, we found 212 triads of child-mother-grandmother who met the inclusion criteria. Of these, 109 mothers and grandmothers accepted to participate. We recruited 60% of the triads from schools located in the southern part of the city and the remaining 40% from schools in the western and eastern parts.

Measurements

Current nutritional status of children, mothers, and grandmothers was assessed by anthropometry. Height (HT), sitting height (SH), weight (WT), and waist circumference (WC) were taken following standardized methods (Lohman et al., 1988).

The sitting height ratio (SHR = SH × 100/height), leg length (LL = height − SH), and relative leg length index (RLLI = LL × 100/height) were calculated for all participants. Percentiles and z-scores by age and sex of HT (HAZ), SH (SHZ), and LL (LLZ) for age were calculated for children and adults using growth reference values published by Frisancho (2008). Stunting, short trunk, and short legs were assessed for all participants. We defined these conditions on the basis of a HAZ, SHZ, and LLZ below the 5th percentile of the reference, respectively. We also calculated body mass index [BMI = weight (kg)/stature (m^2)] in children. The International Obesity Task Force (IOTF) guideline (Cole et al., 2000, 2007) was used to classify children as overweight, obese, and thin. WC $\geq$ 88 was used to classify adult women with abdominal obesity. This cutoff value was justified in a previous article based on a study of another Maya sample from Merida. This analysis also found that BMI had no predictive validity for obesity in Maya women (Wilson et al., 2011).

Additionally, mothers and grandmothers were asked if they suffered from noncommunicable diseases, such as diabetes mellitus, hypertension, hypercholesterolemia, and hypertriglyceridemia.

Ethical concerns

The research was approved by the Bioethics Committee for the Study of Human Beings (Comité de Bioética para el Estudio con Seres Humanos) of the Cinvestav (Center for Research and Advanced Studies of the National Polytechnic Institute, Unit Merida). It was also approved by the Loughborough University Advisory Ethical Committee. The mothers signed consent forms for themselves and on behalf of their children. For ethical reasons, adult women were measured only by women of the research team. In those cases where a woman could not read, then the consent form was read in her presence. Some of the grandmothers could not sign their name, in which case a fingerprint of the grandmother was obtained as proof of consent.

TABLE 1. Age and sex distribution of children sample

Age interval (years)	Boys		Girls		All	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
6.00–6.99	17	6.59 (0.23)	20	6.54 (0.21)	37	6.56 (0.22)
7.00–7.99	21	7.40 (0.28)	20	7.41 (0.30)	41	7.40 (0.29)
8.00–8.99	15	8.65 (0.25)	16	8.38 (0.26)	31	8.51 (0.29)
Total	53	7.49 (0.85)	56	7.39 (0.78)	109	7.43 (0.81)

Statistical analysis

Entry, cleaning, and analysis of data were done using Stata/IC 11.1 for Windows statistics package (StataCorp LP, 2010). Relationships between categorical variables were analyzed with χ^2 tests. Unpaired t-tests were applied to determine the differences between boys and girls for the continuous variables. Bivariate and partial correlations were calculated to examine the association in z-scores of height, SH, and LL between grandmothers and children and mothers and children. For the purpose of this study, squared partial correlations allowed us to estimate the proportion of variance of children's z-score values of HT, SH, and LL attributed to maternal predictors controlling the variance from grand-maternal predictors and vice versa (Kleinbaum et al., 2008). In all analyses, the significance level was set at $\alpha = 0.05$.

RESULTS

The age and sex distribution of the children's sample is given Table 1. There were no significant differences in the proportions of boys and girls by age group ($\chi^2 = 0.22$, $P > 0.05$). The age of the mothers ranged from 22.37 to 49.88 years (mean = 32.75 ± 5.67), and grandmothers ranged in age from 43.42 to 77.98 years (mean = 59.39 ± 8.41).

Anthropometry and nutritional status of children

Descriptive statistics of the measured and derived anthropometric variables of children by age and sex are given in Table 2. First, we tested for differences by sex for each variable and found no significant mean differences in HT, SH, SHR, LL, and RLLI ($P > 0.05$, Student's t-test). Girls, as a group, showed significantly higher values of SHZ (mean = −0.09 ± 0.73 vs. mean = −0.68 ± 0.78; $P < 0.05$, Student's t-test) and LLZ (mean = −0.79 ± 0.77 vs. mean = −1.47 ± 0.89; $P < 0.05$, Student's t-test) than boys.

Second, we assessed the degree for stunting for the children based on the z-scores. The HAZ values ranged from

TABLE 2. Descriptive statistics of measured and derived anthropometric variables of children by age and sex

Age (years)	N	Height (cm)		HAZ		SH (cm)		SHZ		SHR (%)		LL (cm)		LLZ		RLLI (%)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Boys, all	53	119.71	6.30	−0.78	0.66	64.29	2.89	−0.68	0.79	53.74	1.35	55.42	4.00	−1.47	0.89	46.26	1.35
6	17	116.01	5.55	−0.56	0.99	62.71	2.92	−0.38	0.92	54.07	1.37	53.30	3.38	−1.18	0.94	45.93	1.37
7	21	118.30	4.25	−0.97	0.75	63.83	2.35	−0.76	0.74	53.98	1.32	54.46	2.85	−1.68	0.79	46.02	1.33
8	15	125.91	5.08	−0.78	0.82	66.74	1.90	−0.91	0.62	53.04	1.16	59.17	3.57	−1.49	0.92	46.96	1.16
Girls, all	56	119.08	5.49	−0.55	0.72	63.64	2.73	−0.09	0.82	53.47	1.28	55.43	3.43	−0.80	0.77	46.53	1.28
6	20	115.05	3.60	−0.37	0.63	61.99	1.52	0.12	0.55	53.91	1.50	53.06	3.11	−0.69	0.87	46.09	1.50
7	20	119.44	4.30	−0.49	0.78	63.55	2.49	−0.12	0.85	53.20	1.13	55.90	2.59	−0.68	0.75	46.80	1.13
8	16	123.66	5.12	−0.86	0.67	65.84	2.79	−0.33	0.74	53.35	1.06	57.83	2.92	−1.08	0.64	46.75	1.06
Total	109	119.39	5.88	−0.66	0.79	63.96	2.82	−0.38	0.81	53.60	1.31	55.43	3.70	−1.12	0.89	46.40	1.31

HAZ: z-score for height; SH: sitting height; SHZ: z-score for SH; SHR: sitting height ratio (sitting height × 100/height); LL: leg length (height − sitting height); LLZ: z-score for leg length; RLLI: relative leg length index (leg length × 100/height).

TABLE 3. Growth characteristics of boys, girls, mothers, and grandmothers

	Boys		Girls			Mothers		Grandmothers	
Characteristic	*N*	%	*N*	%	χ^2	*N*	%	*N*	%
Short height	8	15	4	7	1.76	77	71	97	90
Short trunk	6	11	2	4	2.40	54	50	91	83
Short legs	23	43	9	16	9.80[a]	59	54	75	69

[a]$P < 0.05$.

TABLE 4. Descriptive statistics of measured and derived maternal and grand-maternal anthropometric variables

	Mothers		Grandmothers	
Variable	Mean	SD	Mean	SD
Age (years)	32.75	5.67	59.00	8.41
Height (cm)	147.91	4.84	143.08	4.77
HAZ	−2.01	0.75	−2.64	0.77
SH (cm)	79.30	2.35	75.85	2.95
SHZ	−1.65	0.74	−2.49	0.90
SHR (%)	53.64	1.20	53.01	1.29
LL (cm)	68.52	3.64	67.23	3.06
LLZ	−1.70	0.86	−2.04	0.76
RLLI (%)	46.31	1.37	46.99	1.29

HAZ: *z*-score of height; SH: sitting height; SHZ: *z*-score of SH; SHR: sitting height ratio (SH × 100/height); LL: leg length (height − SH); LLZ: *z*-score of LL; RLLI: relative leg length index (LL × 100/height).

TABLE 5. Bivariate and partial correlations coefficients of the child's linear growth variables with the mother's and grandmother's growth variable

	Z-height		Z-sitting height		Z-Leg length	
	r	Partial *r*	*r*	Partial *r*	*r*	Partial *r*
	Child's growth variables					
Mother	0.3987[a]	0.3838[a]	0.2141[a]	0.1994[a]	0.3558[a]	0.3554[a]
Grandmother	0.1176	−0.0114	0.0866	0.0346	0.0637	0.0611
	Mother's growth variables					
Grandmother	0.3197[a]	–	0.2514[a]	–	0.3303[a]	–

[a]$P < 0.05$.

−2.66 to 1.1 (mean = −0.66 ± 0.79) with 11% of the children meeting the criteria for stunting. Values of SHZ range from −2.01 to 1.44 (mean = −0.38 ± 0.81), and LLZ values range from −3.91 to −1.12 (mean = −1.12 ± 0.89). Only 7% of children presented short SHZ; however, 29% showed short LLZ for their age. There were no significant mean differences in HAZ by sex ($P > 0.05$, Student's *t*-test), and there were no significant differences in the proportions of stunted boys and girls ($\chi^2 = 1.76$, $P > 0.05$). The proportion of boys and girls with short LLZ was significantly different ($\chi^2 = 9.80$, $P < 0.05$), with boys being more leg stunted than girls (Table 3).

Using the IOTF references for BMI, we found that 36% of children (both sexes) exceeded the age- and sex-specific percentile for "healthy BMI"; 24% of them being overweight and 12% obese. Only 3% met the criteria for thinness.

Anthropometry and nutritional status of mothers and grandmothers

Descriptive statistics of observed and derived anthropometric variables of mothers and grandmothers are given in Table 4. In general, *z*-score values of HT, SH, and LL were low. When compared with the references, 71% of the mothers were below the 5th percentile for ZHT, classified as short stature or adult stunting. The deficit on growth was slightly more severe in ZLL (54%) than in ZSH (50%). On average, ZLL of mothers corresponded to 46.31% (±1.37) of the total height, which correspond to the 5th percentile of the references. In contrast, the mean of SHR was 53.63 (±1.20), which corresponds to 67th percentile of the reference.

Fifty-five percent of the mothers presented abdominal obesity. A diagnosis of chronic disease was reported by 18% of the mothers. The types of disease are as follows: 20% hypertension, 15% Type 2 diabetes mellitus, 15% hypercholesterolemia and hypertriglyceridemia, and 10% asthma.

The height of grandmothers was in general very low, ranging from 131.50 to 159.20 cm (mean = 143.08 ± 4.77). Mean ZHT, ZSH, and ZLL were all below −2.0. Ninety percent of grandmothers were below the 5th percentile of ZHT; however, unlike the mothers, the deficit of growth was more severe in SH than in LL (short ZSH = 83% vs. short ZLL = 69%). Values of RLLI of grandmothers ranged from 43.10 to 49.96 (mean = 46.99 ± 1.29).

Eighty-three percent of the grandmothers showed abdominal obesity. A chronic disease diagnosis was reported by 55% of grandmothers. Type 2 diabetes mellitus (21%) and hypertension (28%) were the most prevalent, followed by 16% hypercholesterolemia and 12% hypertriglyceridemia. The coexistence of two or more diagnosis was reported, with 6% of Maya grandmothers reporting to have been diagnosed with diabetes and hypertension and 11% with the coexistence of hypercholesterolemia and hypertriglyceridemia.

Correlations of growth scores between generations

Bivariate and partial correlations for HAZ, SHZ, and LLZ between grandmothers and children were weak and not significant (Table 5). In contrast, mother and child growth indicators correlated significantly. Correlation coefficients between mothers and children were stronger in leg length than in sitting height (LLZ partial $r = 0.3554$ vs. SHZ partial $r = 0.1994$). In addition, partial correlation coefficients show that the association between mothers and children remained significant after the exclusion of grand-maternal association. There were significant correlations for all variables between grandmothers and mothers. As for the children, the association was stronger in ZLL than ZSH.

DISCUSSION

The growth and nutritional status of children, mothers, and grandmothers shown in this study reflect, in general, the chronic poverty experienced by this sample of Maya people.

Nutritional status of children

Clinical stunting was found for 11% of children. Values of HAZ, SHZ, and LLZ were in general low, with 28% and 23% of children were below 15th percentile of height-for-age and sitting height-for-age, respectively. Growth deficits are most pronounced for the legs, with 48% of children below 15th percentile of leg length-for-age.

Our results provide further support to the hypothesis that leg length is often more sensitive to the quality of the environment than is total height. Two studies most relevant to our Mexican-Maya research include one by Frisancho et al. (2001), who found for a sample of 2,985 Mexican Americans aged 2–17 years, that participants with a poverty income ratio (PIR) below the median had significantly shorter leg length relative to their height than participants with PIR values above the median. There were no significant differences in sitting height by PIR values. Another study by Bogin et al. (2002) found that children (5–12 years) of Guatemala-Maya families who migrated to the United States were 11.54 cm taller, on average, than Maya children of the same ages living in Guatemala. Moreover, 60% of the mean height increment (6.83 cm) was explained by the differences in leg length. The authors noted that improvements in the living conditions in the United States, such as the use of safe drinking water, the availability and access to health care, and school breakfast and lunch programs, were some of the main factors that could explain the differences between studied groups.

Available evidence suggests that stunted children usually grow to be stunted adults (Bogin et al., 1992; Martorell et al., 1994). Reviews of longitudinal studies show that stunting during childhood is strongly linked to short stature and reduced lean body mass, reduced cognitive ability, less schooling, and lower income during adulthood (Black et al., 2008; Victoria et al., 2008; Walker et al., 2007).

Significant improvements in the environmental conditions are needed for a recovery from a growth deficit in early postnatal life. Unfortunately, it is very common that familial conditions surrounding an undernourished child do not change during the years of growth. Indeed, growth deficits usually increase as Bogin et al. (1992) reported that Guatemalan Maya children grow during the juvenile and adolescent stages of life. This is particularly true for social groups who experience transgenerational adverse socioeconomic conditions, such as the Maya. Several studies find that the height of adult Maya in Yucatan and Guatemala declined significantly following the European Conquest of 1500 CE (Bogin and Keep, 1999) and has not increased markedly since the end of the colonial period (McCollough, 1982; Siniarska and Wolanski, 1999). Overweight is the other end of the malnutrition spectrum for the Maya children studied here. Our findings of 36% with overweight/obesity are consistent with the results of national surveys of Mexico, which reported that for Yucatan in 2006, the rate of excess of weight in school children aged 5–11 years was 36.3% in urban population (INSP-SSP, 2007).

Nutritional status of mothers and grandmothers

A deficit in growth in adult women was evident in total HT, SH, and LL. To better understand the nature of these deficits, we reviewed the findings of the Longitudinal Study of Adolescent Growth of Leeds, which measured healthy children from schools in Leeds, England (Buckler, 1990). The findings of the Leeds Study show that the growth pattern of the legs and the upper body during the childhood and adolescent stages of development are different. Before puberty and the onset of the adolescent growth, height increments are relatively greater for growth of the legs than for the upper body. After puberty, the acceleration of growth is much more evident in sitting height than in leg length. Once the velocity peaks for both legs and trunk have passed, the growth of legs declines more rapidly than trunk. On average, in girls, the growth of trunk finishes at ~17 years when compared with ~15 years for the termination of growth of the legs. In light of the Leeds Study, results for the Maya mothers and grandmothers suggest that they suffered growth deficits during both their childhood and adolescence. These adult women were characterized by approximate equal deficits for sitting height and leg length. We interpret this to mean that adverse living condition experienced by these Maya women were present during all growth periods and across both generations.

Short stature in adults is strongly correlated with high morbidity and mortality rates. Particularly, cross-sectional and longitudinal studies show that height is inversely related to respiratory diseases, such as bronchitis, coronary heart disease, and stroke (Barker et al., 1990; Forsen et al., 2000; Leon et al., 1995). In addition, women with short legs have greater risk for higher body fat percentages, greater insulin resistance, and higher prevalence of Type 2 diabetes mellitus (Asao et al., 2006; López-Alvarenga et al., 2003).

Correlations between generations

Our analysis of the associations of growth scores between generations suggest that (1) the intergenerational associations between mothers-children and grandmothers-mothers are stronger for total height and lower limbs than for sitting height, and (2) significant associations in growth scores are present between grandmother-to-mother and mother-to-child, but not between the grandmother-to-child. The first of these findings support the hypothesis that leg length relative to total stature is a more sensitive indicator of the quality of the environment for nutritional and health status than is sitting height. This seems to be true across the three generations.

A limiting factor to the study of intergenerational patterns of growth is the decrement in stature of adults. In general, after 40 years, total height is reduced by about 1 cm per decade, and this decline may accelerate after 70 years (Minaker, 2011). The reduction in stature affects the upper body relatively more than the legs (Chumlea et al., 1985). These age changes may influence the correlations in measurements between generations. We believe that this limitation is reduced through the use of z-score values of growth measurements, as the z-scores are standardized for both sex and age. However, it is possible that the US NHANES III growth references include women in better health than the Maya. If this is true, then it is also possible that the Maya grandmothers experienced greater reduction in sitting height as they aged, inflating the percentage of Maya grandmothers with short ZSH.

Finally, our findings indicate that the future health and social capital of the children is compromised. Historically, the Maya have been a social group with the lowest level of wage-earning employment, the lowest wages when they are employed in the formal sector, and the lowest access to quality education and the health system. Our findings suggest that the political–economic system of the Merida region has severe negative effects on the biology of the Maya. Using the perspective proposed by Wells (2012), the economics and politics of a society are capable of shaping both extremes of malnutrition, stunting, and obesity, in the same economically disadvantaged group. The present-day Maya people continue dealing with the biological burden of the past 500 years and with an uncertain future.

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