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Well-Being Changes in Response to 30 Years of Regional Integration in Maya Populations From Yucatan, Mexico

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ABSTRACT Infant mortality rate (IMR), overall frequency of linear enamel hypoplasia (LEH), sexual dimorphism in LEH, age of onset of LEH, and age at menarche were used as indicators to test the hypothesis that the origin and development of the tourist industry and increased state participation on Maya subsistence agriculturists in the early 1970s had improved the well-being of the Maya. Two historical moments were inferred from the data. The first was derived from cheap and effective immunization and sanitation campaigns that reduced IMR from 143.4/1,000 live births in the early 1960s to 97.4 in the early 1970s. State participation broke the undernutrition–disease cycle enough to reduce LEH frequencies significantly (from 71.9% in individuals born before 1971 to 51.5% in those born in 1971 or after, $\chi^2 = 55.72$; 1 df; $\alpha = 0.00001$) and to eliminate the sex difference in LEH expression (from a 14.8% LEH difference between men and women before 1971 [Male/Female Odds Ratio = 0.45, α significant at 0.05] to a nonsignificant 2% difference). Improvement in overall living conditions reflected in a “modern stage” infant mortality regime and an almost disappearance of LEHs, resulted from gradual improvements in living conditions that did not become apparent until the 1980s. Trends in the age at menarche are not statistically significant, probably due to methodological limitations. However, if overall living conditions continue to improve or stay as they are today, accelerations in maturation should become noticeable. *Am. J. Hum. Biol.* 13:590–602, 2001. © 2001 Wiley-Liss, Inc.

Adult characteristics result from the interaction between the genotype and environmental conditions (Bogin, 1988; Lasker, 1969). In humans the greatest source of environmental phenotypic variability is related to the interactions among nutrition, disease, and socioeconomic conditions during growth (Eveleth and Tanner, 1990; Martorell, 1980, 1985; Waterlow, 1984). By studying the adult phenotype it is possible to infer the individual's growth environment, and by comparing generations it is possible to evaluate the impact of changing environmental conditions.

Not all phenotypic traits are equally plastic, nor do they respond similarly to environmental stimuli (Wolanski and Siniarska, 1984). In addition, population composition may vary through time. Therefore, the choice of physical characteristics in cross-sectional studies attempting to infer past or changing environmental conditions must be made considering any known interaction between the nature of the changes and the trait. Also, when comparing physical traits between past and present populations, it is important to make sure that population's characteristics are similar enough so that

major changes can be attributed to environmental interactions and not to demographic accidents.

In this paper, infant mortality frequency and age distribution of dental linear enamel hypoplasia (LEH), and age at menarche are used to test the hypothesis that the origin and development of the tourist industry and increased state participation on Maya subsistence agriculturists in the early 1970s improved the Maya's well-being. Improvements in well-being should be indicated by reductions in infant mortality, overall LEH frequencies, LEH sexual dimorphism, and age at menarche after regional integration.

BACKGROUND

The Maize Maya region of the state of Yucatan, Mexico, is located between the cities

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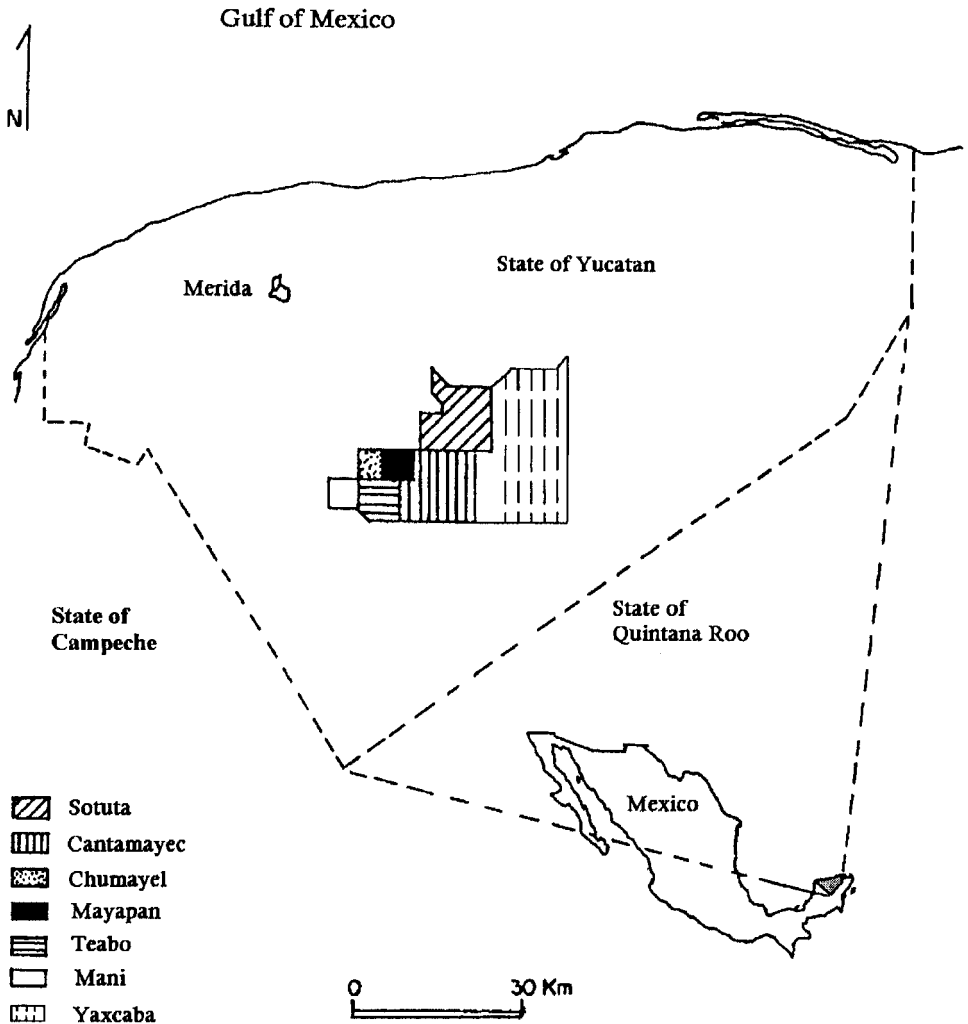


Fig. 1. Municipios from the Central Maize Region of the State of Yucatán, Mexico.

of Mérida and Cancun (Fig. 1). Since the agrarian reform in the 1920s, there have been few if any major population movements, and the ethnic composition of the population in the study area has remained the same for at least 100 years. Today, most migration is to the neighboring cities of Cancun, and Mérida, and it is circular (Gurri and Balam, 1992). Most household members in this study were born in the area, and could if needed be reached by the investigator.

In the late 1960s and early 1970s the

Mexican federal government and the State of Yucatán built a modern road connecting the central area of the state of Yucatán to the urban centers of Mérida and Cancun. This road increased the number of peasants seeking salaried work in the cities, which transformed the region's subsistence economy (Re Cruz, 1996; Villanueva, 1994) into a mixed economy.

While out migration was the rule in the 1970s (Terán and Rasmussen, 1994; Dalta-buit, 1992), population movements became circular in the 1980s and 1990s (Gurri and

TABLE 1. *Municipios and localities where data were collected for the present study in the central maize region of Yucatan*

Municipio	Locality	Project and data collection dates
Cantamayec	Cantamayec	INI (1992), NSF (1995–1997)
	Cholul	INI (1992), NSF (1995–1997)
Chumayel	Chumayel	INI (1992), NSF (1995–1997)
	Mani	INI (1992)
Mayapan	Tipikal	INI (1992)
	Mayapan	INI (1992), NSF (1995–1997)
Sotuta	Sotuta	INI (1992), NSF (1995–1997)
	Tabi	INI (1992)
	Tibolon	INI (1992)
	Zavala	INI (1992)
	Teabo	INI (1992)
Yaxcabá	Yaxcabá	State of Yucatan (1993)
	Kanacom	State of Yucatan (1993)
	Kankabdzonot	State of Yucatan (1993)
	Santa Maria	State of Yucatan (1993)
	Tahdzibichen	State of Yucatan (1993), NSF (1995–1997)
	Thiholop	State of Yucatan (1993)
	Tixcaaltuyub	State of Yucatan (1993), NSF (1995–1997)
	Yaxunah	State of Yucatan (1993)

Balam, 1992). Peasant households are placing more emphasis on wage labor and participation in the cash economy without abandoning slash and burn agriculture in their home communities (Gurri and Balam, 1992). The strategy followed by the Maya since the early 1980s has increased local population pressure on agricultural land, increased deforestation and reduced land yields (Sohn et al., 1999).

In addition, private and state provided sanitation and health services were incorporated into the area (INI, 1976). Today and since the early 1970s vaccination campaigns against diphtheria, whooping cough, tetanus polio and measles cover 100% of infants under 5 years of age (Gurri, 1997; Gurri and Balam, 1992). Malaria was eradicated in the early 1970s (INI, 1976). Access to primary health care became universal in health clinics and households throughout the area. In addition, several towns have well-equipped private pharmacies. Every one of the towns in this study, as do most towns in the study area, has running water and electricity.

MATERIALS AND METHODS

The data were collected in 19 localities of the central maize region of the state of Yucatan between 1992 and 1996 in three different research projects (Table 1). The first project was financed by the Instituto Nacional Indigenista (INI), and the data were collected in 1992. The second project was financed by the State of Yucatan, and was

carried out in eight communities of the municipio of Yaxcabá in 1993. The third and last project was financed by the National Science Foundation. The data for the third project were collected in the summer of 1995, winter of 1996, summer of 1996 and winter of 1997 field seasons in the municipios of Cantamayec, Chumayel, Mayapan, Sotuta, and Yaxcabá. Fieldwork was supervised in each of the projects by the first author. Anthropometric and dental data gathering techniques were the same for each project.

The samples were chosen to be representative of the maize region and large enough to detect nutritional status differences in children under 10 years of age between municipios. In every municipio the houses in each community were numbered sequentially and were selected at random with the help of a random number generator. Every individual present at the time of the visit was measured and the teeth of all individuals 10 years and older were examined.

Linear enamel hypoplasia (LEH) differences between generations of individuals 10 years and older were tested. Because it was obtained at random, the sample was considered representative of the maize region, and the adequacy of the sample size to make cohort comparisons was tested following the stratified sample size estimation for proportions described in Cochran (1977), using the sample variance as an estimate of σ^2 . An optimum sample size of 1136 was estimated, the total number was 1260.

TABLE 2. Regression equations utilized to determine age of LEH formation for each tooth^{a,b}

I^1 Age of LEH formation = $-(\text{Inv}(SI^1/4.5) \times D) + 4.5$
I_1 Age of LEH formation = $-(\text{Inv}(SI_1/4 \times D) + 4$
C_c Age of LEH formation = $-(\text{Inv}(SC_c/6) \times D) + 6.5$
C_c Age of LEH formation = $-(\text{Inv}(SC_c/4.17) \times D) + 4.5^*$
S = Size of tooth in millimeters
D = Distance from the CEJ to the lesion in millimeters
I^1 = Upper central incisor
I_1 = Lower central incisor
C_c = Lower canine

*Canine crown formation chronology from Anderson et al. (1976).

^aCrown formation chronology from Massler et al. (1941).

^bEquations from Goodman and Rose (1990).

The permanent upper central incisors, the lower central incisors and mandibular canines were examined for LEH in individuals 10 years and older. The first and the last have been recommended for population surveys as being the most hypoplastic teeth (Duray, 1992; Goodman and Armelagos, 1985; Goodman and Rose, 1990; Lanphear, 1990). The lower central incisors were also included because of the frequent loss of the upper central incisors in Yucatec populations. Inspection of these teeth was done under indirect sunlight next to the door of the house, and with the aid of a flash light held by an assistant. Tooth size and distance from the occlusal surface to the lesion were measured to the nearest millimeter with a plastic vernier calliper.

Differences in LEH frequency between age groups were tested using χ^2 , and frequencies of LEH were compared between men and women with the aid of the odds ratio (Agresti, 1990). Age of LEH formation was estimated using the regression method presented in Goodman and Rose (1990) (Table 2). Rate of enamel development was estimated by dividing the individual crown height by the standard time of crown formation in years, using the dental development standards of Massler et al. (1941). The standards of Anderson et al. (1976) were also used for the canines. These estimates are based on calcification (X ray), and the results are more consistent with those expected from the nutritional epidemiology of the children in the study area (Gurri and Balam, 1995). Differences in frequency distribution for each tooth were compared using Kolmogorov-Smirnov tests.

Age at menarche was estimated from the answers to complete fertility surveys collected during the summer of 1995. The status quo method was used to determine age

at menarche at the time of the survey for women between 10 and 19 years of age. For a better fitting model, a log 10 transformation was applied to the data, and a logit instead of a probit model (Aldrich and Nelson, 1984) was used.

The retrospective method was used to make inter-cohort comparisons. This is the only alternative to the "status quo" method when a large number of women in the sample are older than 19 or 20 years (Hediger and Stine, 1987). The method is subject to recall errors (Bean et al., 1979; Bergsten-Brucefors, 1976; Damon and Bajema, 1974). Nevertheless, Bean et al. (1979) reported that after an average of 34 years, 90% of the women they surveyed in the Minneapolis-St. Paul metropolitan area were able to repeat their previously reported age at menarche to within 1 year. In the maize region of Yucatan, recall may even be better. Beyene (1989) reports that only 35% of the women interviewed in Chichimila, Yucatan, knew about menarche before the event took place. Onset of first menses, according to Beyene (1989), was a psychologically stressful event, and Maya women were particularly conscious of the time of onset as well as of their menstrual cycle.

RESULTS

Overall, 471 households (11.2% of houses in the study area) were visited during the three projects, and a total of 1,762 individuals 10 years or older were measured. Only individuals with known age and at least one tooth in the mouth were used in the LEH analysis. The total sample was 1,260. Reproductive histories were collected from 348 women 10+ years of age during the third project.

Infant mortality rate (IMR) in the maize region followed the pattern of southern

TABLE 3. Infant mortality rates in southern Mexico and in the maize region of Yucatan

Dates	IMR in Southern México ^a	Dates	IMR Maize Region Yucatan	Dates	IMR Maize Region Yucatán ^d
1951-1961	92	1940	180.5 ^b		
1962-1966	147	1950	143.4 ^b		
1967-1971	93	1960	103 ^b		
1972-1976	112	1970	97.4 ^c	1970-1974	49.02
1977-1981	92	1971	82.1 ^c		
1982-1986	92	1972	88 ^c		
		1973	81 ^c		
		1974	89.4 ^c		
		1975	82.1 ^c		
		1980	80.9 ^c		
		1987	32.9 ^c		
		1988	38.2 ^c	1985-1989	42.33
		1990	34.7 ^c	1990-1995	41.67

^aSource 1987 National Fecundity and Health Survey for southern Mexico (Bobadilla and Langer, 1990).

^bSource Vital registries, Enciclopedia Yucatanense, vol XI:88 (1979).

^cSource Vital registries, SSA. (1997) Informes de Servicios Coordinados de Yucatán, Mérida Yuc., 1970-1996.

^d1995 ACT-CINVESTAV fertility survey of the Central Maize Region, this paper.

Mexico until the first half of the 1970s (Table 3). Mortality levels well above 100 were evident before 1960. By 1960, mortality levels decreased to a little over 100 in the maize region as well as in southern Mexico. While mortality levels remained high from 1962 to 1986 in southern Mexico, they declined in the maize region. The first important drop started in 1971 remaining more or less constant until the second half of the 1980s when it decreased from 80 to 32.9 per 1,000. The 1980 results were supported by the results of the fertility histories collected during this investigation.

A total of 1,260 individuals, 471 men and 789 women, were studied for presence or absence of LEH between 1992 and 1996. Individuals were divided into those whose enamel started to develop in 1971 and those whose enamel developed earlier. The first part of Table 4 shows frequencies of LEH for each group by sex. Frequencies of LEH were significantly different between those born prior to state integration and those born afterwards (71.9 vs. 51.5, respectively, $\chi^2 = 55.72$, 1 df, $\alpha < 0.00001$). In addition, men were significantly more likely to have hypoplasias before 1971 than women (odds ratio 0.45, $\alpha \leq 0.05$). The sexual dimorphism in LEH disappears after this date.

Closer comparison to IMR was done by analyzing frequencies of LEH by year of birth (Fig. 2). A tendency line was added to help the interpretation. There is a reduction in LEH in 1970 that marks the beginning of a downward trend, and a second and steeper trend starting around 1980. Because enamel development in the front teeth may

take up to six years, peaks in LEH frequency are difficult to interpret.

To eliminate year-to-year variation and to make statistical comparisons, the sample was grouped into five year cohorts by sex. In any one category, therefore, the older half of the individuals would have shared part of their growing environment with the older cohort, and the younger half with the younger cohort. Most individuals in a cohort, however, would have spent most of their enamel development time within their cohort so that frequency differences between cohorts should reflect changes in the growth environment through time. The cohorts were organized around 1973, which was taken as a midpoint so that all individuals whose enamel formation started during the beginning of the downward trend would be included in one category onward.

LEH differences through time and between men and women are shown graphically in Figure 3, in which the second part of Table 4 is plotted. LEHs from 1930 to 1970 are consistently high in men and women, but higher in men. These differences disappear in the 1971-1976 cohort due to a reduction in LEH of 18.6% in males. Subsequently, there is a significant reduction in overall LEH frequencies as shown by high negative standardized residuals in the youngest cohorts (-3.36 for the 1976-1980 cohort and -7.74 for the 1981-1986 cohort) and a significant χ^2 of 55.72. Except for the 1966-1970 cohort, however, none of the other five-year cohorts show significant odds ratios in LEH frequency by sex.

Distributions of ages of onset of LEH for

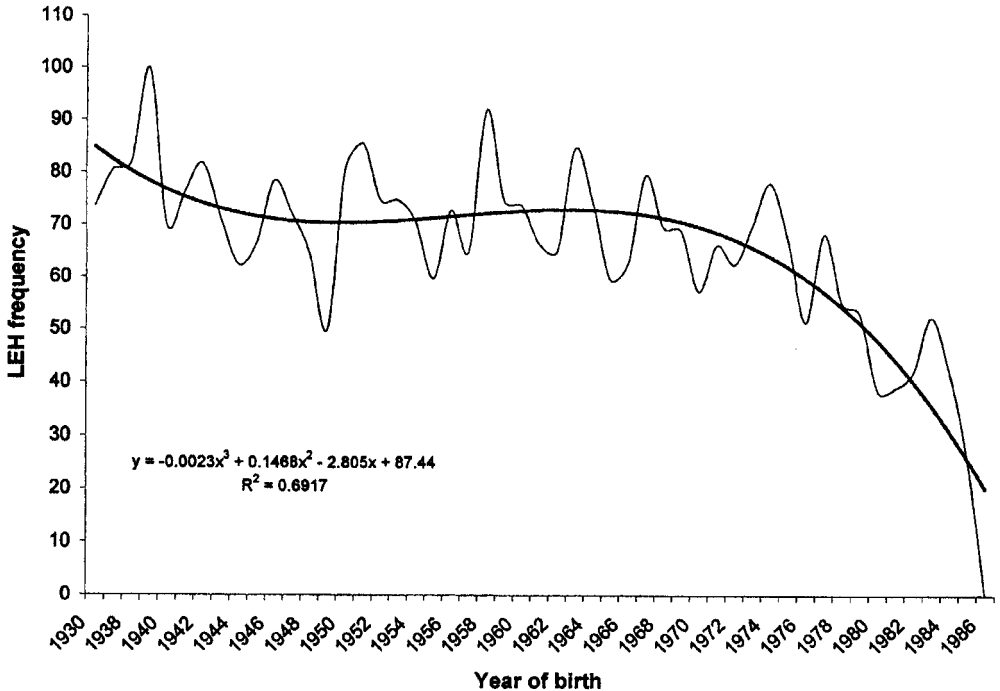


Fig. 2. LEH frequency by year of birth in the Maize Region, Yucatán, Mexico. Those born before 1930 are grouped together.

the central upper incisors, lower central incisors and mandibular canines in individuals born before 1971 were compared to the distributions of those born in 1971 and after using a Kolmogorov–Smirnov test (Table 5). Only the distributions for the upper central incisors were significantly different between cohorts. The distribution of the older cohort was more platokurtic than the distribution of the younger one. Both cohorts had higher LEH frequencies between the ages of 30 and 35 months (Fig. 4). The younger cohort had higher frequencies in the later stages of enamel formation, i.e., younger hypoplasias close to the cemento-enamel junction, than the older cohort, and the latter had a relatively lower number at peak age and more hypoplasias than the younger generation near the tip of the crown (older hypoplasias). The upper central incisors were also more sensitive to enamel disruption than both lower incisors and canines.

The first part of Table 6 shows the results of the Kaplan–Meier test on reported ages at menarche in the present sample divided

into five-year cohorts. There were no significant differences between cohorts, but the mean of 12.47 years in the 1981–1986 cohort was lower than the others (range 12.56 to 12.92 years). To obtain a more reliable estimate of age at menarche at the time of the survey a logit model was used (Table 6). All girls between the ages of 10 and 19 years old were included in the analysis. The sample thus includes almost all women in the 1976–1980 birth cohort, which had a recalled mean age of 12.67 years. Mean age at menarche at the time of survey was 12.84 years, with 95% confidence intervals of 12.33 and 13.31 years. This did not significantly differ from estimates obtained with the Kaplan–Meier survival test.

DISCUSSION

The purpose of this investigation was to evaluate the association between increased state participation and the availability of salaried labor, and positive changes in well-being. The indicators suggest that living conditions changed in two stages since the

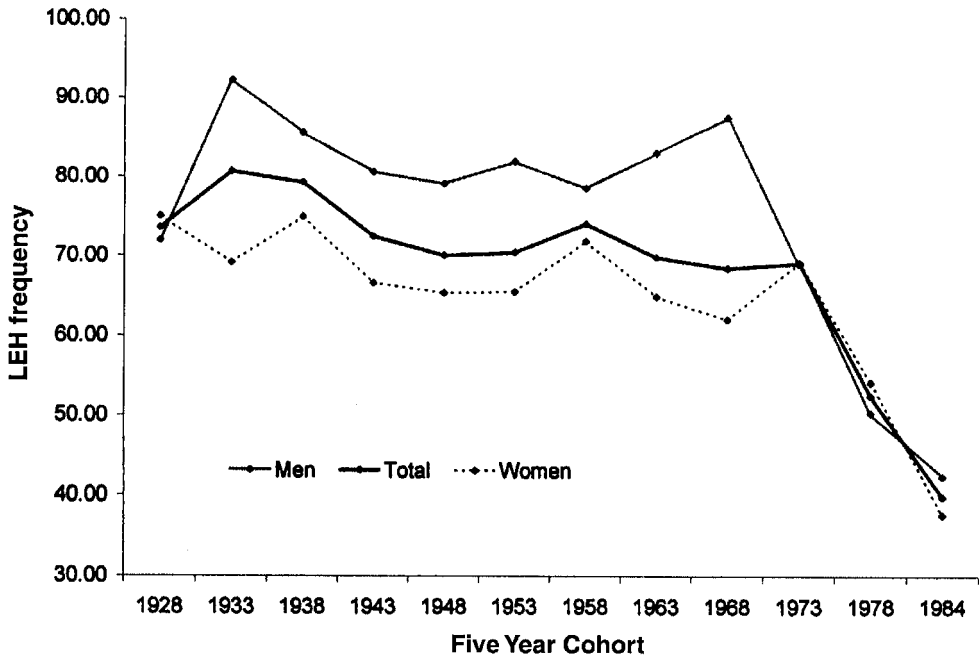


Fig. 3. LEH frequency by birth cohort and sex in the Maize Region, Yucatán, Mexico.

TABLE 4. LEH frequencies by cohort for individuals born in the maize region before 1987, odds ratios between men and women and χ^2 adjusted standardized residuals^a

Birth cohort	Sample size			LEH frequency			Odds ratio men/women	χ^2 adjusted standardized residuals
	Men	Women	Total	Men	Women	Total		
Before 1971	225	445	670	81.78	66.97	71.94	0.45*	
1971 and after	246	344	590	52.62	50.53	51.53	1.11	
1930 and before	25	28	53	72.00	75.00	73.58	1.17	1.72
1931-1935	13	13	26	92.31	69.23	80.77	0.19	1.96
1936-1940	14	20	34	85.71	75.00	79.41	0.50	2.08
1941-1945	26	36	62	80.77	66.67	72.58	0.48	1.70
1946-1950	29	55	84	79.31	65.45	70.24	0.49	1.54
1951-1955	28	64	92	82.14	65.63	70.65	0.42	1.70
1956-1960	33	68	101	78.79	72.06	74.26	0.69	2.57
1961-1965	24	63	87	83.33	65.08	70.11	0.37	1.54
1966-1970	33	98	131	87.88	62.24	68.70	0.23*	1.58
1971-1975	39	95	134	69.23	69.47	69.40	1.01	1.78
1976-1980	101	127	228	50.50	54.33	52.63	1.17	-3.36
1981-1986	106	122	228	42.45	37.70	39.91	0.82	-7.74
Total	471	789	1260	34.82	65.18	62.38	0.83	

* α significant at 0.05 odds ratio.

^a $\chi^2 = 55.72$, 1 df, $\alpha < 0.00001$ for born before vs. born during and after 1971. $\chi^2 = 90.04$, 11 df, $\alpha < 0.00001$ for five-year cohort comparisons.

early 1970s. The first may have been the result of the introduction of sanitary and vaccination campaigns, and the second as a result of a steady improvement in living conditions.

Declines in IMR in the maize region of

Yucatan until the 1970s were consistent with those observed in Latin America and other third-world countries. They were also consistent with rates obtained by the 1987 National Fecundity and Health Survey for southern Mexico (Bobadilla and Langer,

TABLE 5. Kolmogorov-Smirnov two-sample test comparing LEH age of onset distribution between individuals born before 1971 and those born during 1971 and after

Tooth	No. of hypoplasias	K-S Z	2-tail prob.
LI ¹	975	1.925	0.001
RI ¹	1006	1.685	0.007
LI ₁	327	0.610	0.851
RI ₁	330	0.688	0.732
LC _c	395	0.876	0.426
RC _c	413	0.428	0.993

1990), placing the epidemiological transition in the late 1960s early 1970s. Locally these changes coincided with the introduction of vaccination campaigns, and the eventual eradication of malaria through the widespread use of DDT (INI, 1976). The IMRs in Yucatan after 1980 were much lower than those of other Latin American countries at the same stage of the epidemiological transition (Behm, 1988), which suggested a second improvement in living conditions in the early 1980s.

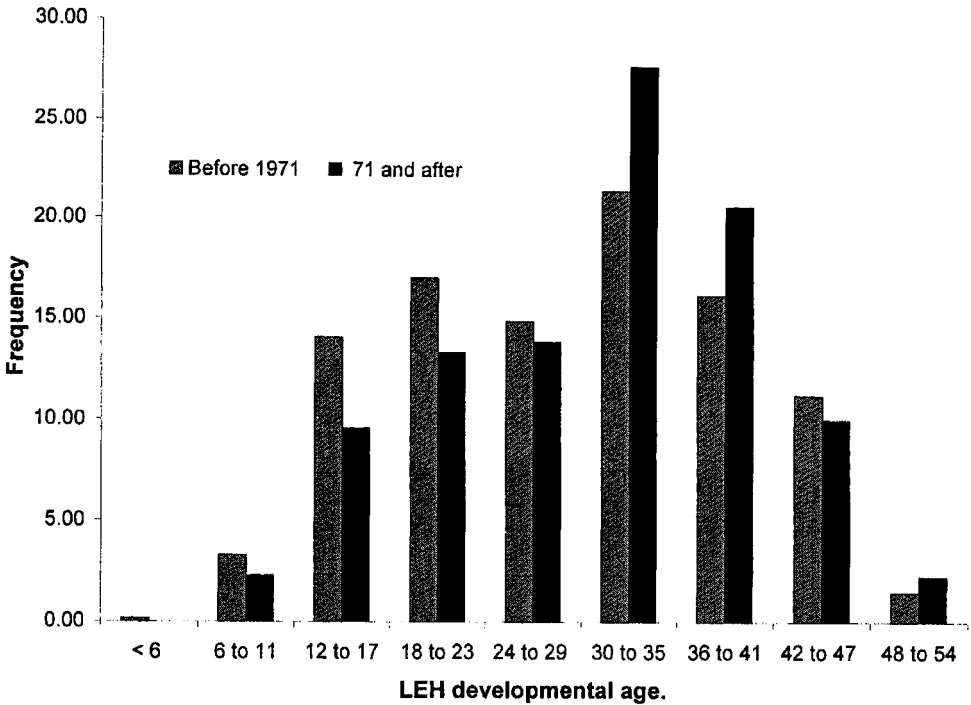
A reduction in frequencies of LEH and a disappearance of sexual dimorphism in LEH was observed in individuals born after 1971, which coincided with the reductions in infant mortality. Differences in eosensitivity leading to sexual dimorphism have been observed in several physical characteristics (Gerber et al., 1995; Schall, 1995; Stinson, 1985; Wolanski, 1970, 1977, 1978), and enamel development may not be an exception (see Guatelli-Steinberg and Lukacs, 1999, for a thorough review of the literature on sexual dimorphism in LEH). Even though in most cases males exhibit a higher prevalence of LEH, the results are significant only in large samples. The results of Zhou and Corruccini (1998) and Santos and Coimbra (1999) suggest that female buffering may be difficult to infer because sexual dimorphism is not necessarily greater in highly stressed than in less stressed populations.

Individuals in the Maize Region could be divided into those whose enamel developed in periods of high, medium and low environmental stress. The first transition responded to the introduction of the vaccination campaigns in the late 1960s early 1970s and resulted in a decrease in infant mortality of over 20 per 1,000 live births and a slight reduction in LEH frequencies. It was not until the 1980s, however, that reduced stress in children under 6 years of age was enough to influence LEH differences consid-

erably. This corresponded to the period when a circular migration strategy, which allowed the Maya to make optimal use of urban income and agricultural production was adopted (Sohn et al., 1999).

The youngest cohort, with individuals born between 1981 and 1986, exhibited an LEH prevalence of 39.9%. This prevalence was comparable to those exhibited in Guatemalan children whose diets were supplemented (38.5% in males and 58.3% in females; May et al., 1993), and in children from Tezonteapan, Mexico, who had received special medical and nutritional attention since birth (40%; Goodman et al., 1991). In contrast, 73.2% of individuals from Tezonteapan, who did not receive supplementation, had at least one hypoplasia in the mouth. Similar and even higher percentages were reported for highly stressed populations, for example, the recently integrated Tupí-Mondé Amazonian peoples of Brazil with frequencies of almost 100% (Santos and Coimbra, 1999), enslaved African Americans with frequencies ranging from 66.7% to 100% (Blakey et al., 1994), middle Mississippian agriculturists 80% (Goodman et al., 1980), and nineteenth century Americans from a poor house cemetery (71.4% in the upper central incisors; Lanphear, 1990).

In the five-year cohort comparisons, there were high negative adjusted standardized residuals only in the 1976-1980 and 1981-1986 cohorts, which suggested that the χ^2 value was affected by these two cohorts. The frequency of LEH in the 1976-1980 cohort was 52.6%, which was similar to 58.3% obtained for females receiving a nutritional supplement in Guatemala (May et al., 1993) and 59% and 57% in a stressed sample (Zhou and Corruccini, 1998). In the present sample sexual dimorphism disappeared in the 1971-1975 cohort when the overall LEH frequency was 69.4%. This overall frequency was obtained due to a decline in LEH frequency only in males. Prior to the introduction of vaccination campaigns, the prevalence of LEH in males was 81.8% and in females 67.0%. It may be, therefore, that sexual dimorphism in LEH will become apparent only after overall frequencies reach a threshold level. The "stressed" sample of Zhou and Corruccini (1998) like the 1971-1975 and 1976-1980 cohorts, may be only "medium stressed" where sexual dimorphism is not yet noticeable.



N= 1006,
K-S Z=1.685
 $\alpha=0.007$

Fig. 4. Onset age distribution of linear enamel hypoplasias (LEH) in the right upper incisor in the Maize Region, Yucatán, Mexico.

TABLE 6. Kaplan-Meier test for five-year cohort comparisons and logit status quo estimation of mean age at menarche in the Maize Region, Yucatan, Mexico

Birth cohort	Mean 95% confidence intervals			n	Censored
1950 and before	12.70	12.33	13.07	46	0
1951-1955	12.92	12.37	13.48	26	0
1956-1960	12.56	12.16	12.95	27	0
1961-1965	12.92	12.32	13.52	24	0
1966-1970	12.58	12.15	13.00	26	0
1971-1975	12.71	12.31	13.11	38	0
1976-1980	12.67	12.32	13.03	72	2
1981-1986	12.47	12.14	12.80	66	44
Status quo 1995	12.84	12.33	13.31	135	

Logit(Pi) = $-50.31 + 45.38(\log_{10}(\text{age}))$ $\chi^2 = 10.467, \text{df } 8, \alpha = 0.234$

Developmental alterations in both sexes will respond differently depending on the type and degree of stress to which the body must adjust. Wolanski (1978), for example, documents different responses and suggests that female buffering consists of females be-

ing more conservative. Female protection against environmental insult may take the form of slower response to change in either direction. Under conditions of excessive environmental deterioration, such as that faced by the Tupí-Mondé in the Amazon

(Santos and Coimbra, 1999), female buffering mechanisms may no longer protect them. Change will take place in response to extreme environmental stimuli, and sexual dimorphism can be expected to disappear.

The five-year cohort comparisons do not show significant odds ratios except for the 1966–1970 cohort. Because several comparisons are made, this significant result could have been obtained by chance. Nevertheless, the fact that, as a whole, LEH differences were significant before 1971 and that LEH frequencies in both men and women decreased together as living conditions improved after 1976 support the previous argument and suggest that thresholds exist beyond which LEHs will not show sexual dimorphism whether the population is stressed or not.

These thresholds will not be uniform and will depend on cultural characteristics as well as environmental conditions. Under relatively low stress conditions (nutritionally supplemented children and 40% overall LEH frequencies), for example, May et al. (1993) found that males who received a better treatment than females had lower LEH frequencies. On the other hand, Zhou and Corruccini (1998) and Lukacs and Guatelli-Steinberg (1994), in what may be more stressed populations, found greater frequencies in males in spite of male preference.

Among the Maya, boys and girls receive practically the same attention, and only after 4 years of age are differences observed. At this age girls begin to help in the kitchen, but they are not responsible for any duties. Helping is akin to playing. Only after age nine are there differences that could have an impact on growth (Gurri, 1997). If this way of treating boys and girls was the same as in the past, it is probable that sexual dimorphism prior to 1971 may reflect female buffering, and the disappearance of sexual dimorphism may be further evidence of positive environmental changes.

More than one methodology has been used to infer the intensity of stress that a lesion represents (Hutchinson and Larsen, 1988; Ensor and Irish, 1995). These attempts to classify lesion intensity have been criticized because the geometry of the tooth and the nature of prism enamel formation make the tip and cervical areas of the crown more resistant to LEH formation (Hillson,

1990). Based on this, it was hypothesized that the impact or reduced stress leading to reductions in LEH frequencies would be reflected in a relative reduction of LEHs in the most resistant areas of the crown that would show as a relative increase in the most susceptible areas.

However, only the distribution of LEH changes of the upper central incisors in the cohort born before 1973 and the cohort born after 1973 were significant. The changes at first sight appear to be expected. LEH distributions in the younger generation were more leptokurtic than in the older one, suggesting a relative increase of hypoplasias in the middle of the tooth (i.e., the most sensitive area). This could be due to a change in the severity of diseases leading to LEH formation. Any conclusions, however, are not warranted since older individuals show greater relative LEH frequencies near the tip of the crown.

Greater attrition in the older cohort could also be responsible for this difference in distributions. Early LEHs are encountered close to the tip of the crown and are likely to disappear in heavily worn teeth. Nevertheless, as attrition advances, the more sensitive areas of the crown gradually become those closest to the tip of the crown making developmentally younger hypoplasias appear as older. Considering that upper incisors are the oldest of all the teeth measured (Schour and Massler, 1941), the latter explanation may be correct. The relationship between attrition and LEH frequency distribution should be taken into consideration when making behavioral generalizations and comparing populations with different age profiles.

Positive secular trends in age at menarche (Burrell et al., 1961; Eveleth, 1986b, 1979; Eveleth and Tanner, 1990) have been used as indicators of environmental improvements affecting population health and nutritional status. Maya women in the cities of Mérida and the port of Progreso had significantly lower ages at menarche than their mothers, reflecting recent improvements in environmental conditions (Wolanski, 1993, 1995). It was, therefore, reasonable to expect similar reductions in the maize region.

Mean ages at menarche of mothers reported by Wolanski (1995), 12.51 to 12.85 years, decreased within the range presented by women before 1981, 12.67 to 12.92 years.

Age at menarche in the youngest cohort was intermediate (12.47 years, range for Maya daughters in Merida and Progreso 12.11–12.41). When estimated by the “status quo” method, age at menarche was in the “mothers” category in Wolanski’s (1995) samples and the median of 12.84 years was very similar to values obtained by Steggerda in 1941 (12.91 years), Beyene in 1989 (13.3 years), and more recently by Kelley (estimate corrected by Wolanski, 1995; 13.22 years), and Daltabuit (1992; 13.10 years).

In this population as well as other central and southern Mesoamerican populations studied in the 1970s there is no evidence of secular reductions in adult height and age at menarche since the last century (Himes and Malina, 1975; Malina et al., 1983; Wolanski, 1995). In most cases, the results have been interpreted as evidence of a lack of improvement in living conditions in Mesoamerican populations. However, in the maize region, lack of observable secular trends may be the result of the timing at which environmental improvements affecting menarche may have taken place, and the limitations of the probit and logit models which force the generalizations into a 10-year period.

Early improvements in nutritional status may have immediate results in preschool children and may be reflected in adolescent height and other indicators (Allen, 1995), but, particularly in women, it will not immediately lead to an acceleration in maturation. For example, Pickett and colleagues (1995) found that advances in skeletal maturation in girls who had received nutritional supplementation happened only in the larger villages in their sample. In the same population, Khan and colleagues (1995) found no significant differences in age at menarche between women who had been supplemented and those who had not. In order to see secular trends in sexual maturity particularly in women, environmental conditions may have to improve throughout the growth process and not be limited to nutritional improvements during early childhood which may result from improved disease environments that brake the undernutrition–disease cycle (Martorell, 1980; Shell-Duncan, 1997).

The secular trends observed in this investigation were the consequence of two historical moments where only the second affected sexual maturation in women. The

first moment derived from the beginning of the area’s integration into the state in the early 1970s. Cheap and effective immunization campaigns were responsible for drastic and immediate reductions in infant mortality that placed the area in Omran’s (1971) “pandemic stage.” These changes broke the undernutrition–disease cycle to improve health and nutrition enough to reduce LEH frequencies and neutralize the effects of female buffering in LEH expression. Improvement in overall living conditions reflected in a “modern stage” infant mortality rate and an almost disappearance of LEHs, may be the result of cumulative change that did not become apparent until the 1980s. The fact that the status quo method in this case combines women who happened to be born in both stages may obscure real changes suggested by the Kaplan–Meier test. If overall living conditions continue to improve or stay as they are today, accelerations in maturity should become noticeable.

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