Age at Menarche and Nutritional Supplementation[1,2]

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ABSTRACT Retrospective data on age at menarche were collected for 832 Guatemalans 15–30 y in age to test whether exposure to a high energy and high protein supplement (Atole: 163 kcals/682 kJ and 11.5 g protein per cup or 180 mL) during childhood led to earlier menarche than did exposure to a low energy, no protein supplement (Fresco: 59 kcals/247 kJ in 180 mL). Mean age at menarche was similar in Atole (13.75 ± 1.22 y; mean ± SD) and Fresco (13.74 ± 1.36 y) groups. The corresponding value for immigrants (n = 144), subjects not exposed to the supplements, was 13.55 ± 1.20 y. Year of birth as well as socioeconomic status (SES) were associated with age at menarche. Age at menarche declined by 0.69 y over the 15-y period and menarche occurred earlier in higher SES households. Significant positive interactions between supplement type and SES and between supplement type and year of birth were found, but plausible explanations for them could not be advanced. J. Nutr. 125: 1090S–1096S, 1995.

INDEXING KEY WORDS:

- *menarche* • *nutritional supplementation*
- *secular change* • *Guatemala*

Age at menarche occurs earlier than it once did in many parts of the world, especially in Europe and North America (Eveleth 1986, Laslett 1985, Tanner 1973, Wyshak and Frisch 1982). In these regions, age at menarche declined at the rate of ~0.3 y per decade till it stabilized at ~13 y (Eveleth 1986, Poppleton and Brown 1966, Sandler et al. 1984, Tanner 1981). This decline, also seen in some developing countries, has been attributed to improvements in nutrition and health (Bielicki et al. 1986, Eveleth 1986, Hulanicka and Waliszko 1991, Laslett 1985, Low et al. 1982, Malina et al. 1977, Rona 1975, Singh and Malhotra 1988). Similarly, the fact that menarche occurs later in the poorer social classes compared with the well-to-do in developing countries has been ascribed to disparities in nutrition and health (Charzewska et al. 1976, Chowdhury et al. 1977, Eveleth and Tanner 1990, Foster et al. 1986, Gandotra and Das 1982, Rana et al. 1986, Tan-Boom et al. 1983, Uche and Okorafor 1979).

Improvements in the quality of life during early childhood can result in earlier menarche. Indian and Bangladeshi girls adopted between 1 mo and 11 y of age (mean age 3.7 y) by Swedish families experienced earlier pubertal growth and menarche compared with Swedish and affluent Indian girls (Adolfsson and Westphal 1981, Proos et al. 1991a, Proos et al. 1991b). The timing of adoption had a significant but unexpected influence on menarche; girls who were adopted after 3 y of age reached menarche ~9 mo earlier than those adopted between birth and 3 y of age. Catch-up growth occurred in all age cohorts shortly upon arrival but in older girls it may have triggered endocrinological responses and early puberty, whereas in younger girls it did not. However, age at menarche still occurred earlier in girls adopted before 3 y of age than it did in subjects reared in India. The corresponding values were 11.9 and 11.1 y for girls adopted before and after 3 y of age, respectively, compared with 13.7 y for urban and 14.4 y for rural Indian-reared girls.

These findings suggest that broad improvements in nutrition and in living standards are determinants of

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age at menarche. However, no study has examined the impact of community-based nutrition interventions during childhood on age at menarche. The aim of this study is to test the hypothesis that women who were exposed to a high energy and high protein supplement during childhood reached menarche earlier than those exposed to a low energy, no protein supplement.

MATERIALS AND METHODS

Data source and study sample. Data for this study are derived from a longitudinal nutritional intervention study carried out between 1969 and 1977 in Guatemala and from resurveys of the study subjects starting in 1991 (Martorell et al. 1995). The community-based nutrition intervention study was conducted by the Institute of Nutrition of Central America and Panama (INCAP) and was designed to test whether improved nutrition in early childhood results in better growth and development. Four villages stratified by size (two large and two small) were selected randomly to receive either a high energy, high protein supplement called Atole or a low energy, no protein one called Fresco. Atole contained 163 kcal (682 kJ) and 11.5 g protein per cup or 180 mL, whereas the Fresco had 59 kcal (247 kJ) per 180 mL and no protein. Both supplements contained equal amounts of thiamin (1.1 mg), riboflavin (1.5 mg), niacin (18.5 mg), iron (5.0 mg) and vitamin A (1.2 mg). In addition, the Fresco contained a flavoring agent and Atole contained a small amount of fat (0.7 g), calcium (0.4 g) and phosphorus (0.3 g). More details about the intervention study are given elsewhere (Martorell et al. 1995).

Reproductive histories were collected in 976 women between 15 and 30 y of age in two survey rounds in 1991 and 1992. The target sample for these surveys was all women residents born between January 1962 and August 1977 (i.e., the range in birth dates of the subjects who participated in the longitudinal study). Women who were former participants (n = 832) of the longitudinal study are emphasized in this analysis. They represent 72% of the original sample with available supplementation records. Immigrants and subjects who were born after August 1977 (n = 144) are excluded from the main analyses but are used as a comparison group in some analyses. Immigrants were those who moved to the study villages because of marriage or the establishment of a new family after 1977 when the intervention ended.

Exposure to nutritional supplementation. Participation in the intervention study was voluntary and open to all members of the community. Intakes of supplement were measured daily for children until 7 y of age, pregnant women and women in the first 24 mo postpartum (Martorell et al. 1995). A limitation of the study is that supplement consumption was not recorded for other subjects. In addition, exposure to supplementation had variable entry ages and durations. For example, if a participant was 5 y old in 1969 when the intervention began, supplement intakes from 5 to 7 y were measured. She then could have received supplement for 7 more years until 1977 when the study ended, but these intakes were not measured.

Age at menarche. Menarche data were gathered during two rounds in 1991 and 1992. During each round, subjects were asked whether they had reached menarche. Those who answered affirmatively were then asked to recall the year and month of occurrence. All interviews were conducted at home.

Most of the subjects reported having reached menarche (i.e., 826/839). A total of 13 subjects had reached menarche but could not remember the date of the event in either round. This left 813 cases who had reached menarche and who reported some data in at least one of the rounds. Comparison of the reported age at menarche for subjects giving both year and month in both rounds (n = 420) revealed much inconsistency in response, with the dates matching in only 176 subjects. When differences were between 1 and 24 mo, values were averaged and included in the analyses (n = 237); cases with differences of >24 months were excluded (n = 7). If age at menarche was missing or the month was not recalled in one of the two rounds, the nonmissing value was selected or a value was assigned as described below (n = 393). When a month was not reported in either round but the reported year was the same, menarche was assumed to have occurred in midyear and an additional 6 mo of age was added to the reported year (n = 21). For cases where years differed by 1 or 2 but months were not given, the 1991 record for year was selected and an additional 6 mo was added to the reported year to estimate age at menarche (n = 90). The final sample consisted of 806 subjects who had reached menarche and 13 who had not.

Statistical analysis. Statistical analyses included Student's two-tailed t test of unequal sample size for comparison of mean ages at menarche in Atole and Fresco groups. Linear regression was used to evaluate the effects of possible covariates on age at menarche. The 13 cases that had not reached menarche, said to be "right censored," were left out of the above analyses (n = 806). Survival analysis techniques, primarily the SAS procedure PROC LIFEREG (SAS Institute, 1987), were used to include these cases (n = 819).

SES, village size and year of birth were included as predictors of age at menarche in the regression model. The SES score was derived from a principal components analysis and is based on household characteristics and an inventory of possessions in 1975; as such, the score measures accumulated wealth within the household (Rivera et al. 1995). The SES score was

TABLE 1

Exposure to supplementation (1969–1977) by year of birth for cases that had reached menarche by 1992[1]

Birth year	Age at exposure	Potential years of exposure	Age at interview	Sample size Atole	Sample size Fresco
	y		y		
1962	7–16	9	29–30	17	23
1963	6–15	9	28–29	17	25
1964	5–14	9	27–28	13	21
1965	4–13	9	26–27	21	18
1966	3–12	9	25–26	26	26
1967	2–11	9	24–25	20	21
1968	1–10	9	23–24	19	21
1969	0–9	9	22–23	30	24
1970	0–8	8	21–22	27	22
1971	0–7	7	20–21	26	34
1972	0–6	6	19–20	33	27
1973	0–5	5	18–19	32	32
1974	0–4	4	17–18	35	34
1975	0–3	3	16–17	28	38
1976	0–2	2	15–16	33	22
1977	0–1	1	14–15	19	22
Total				396	410

[1] Thirteen cases had not reached menarche by 1992; n = 806.

normalized within village with a mean of 0 and an SD of 1.

Differences in mean age at menarche were considered statistically significant at $P < 0.05$. Main effects and interactions were considered significant at $P < 0.05$ and $P < 0.10$, respectively. All analyses were done using SAS-PC version 6.04.

RESULTS

Supplementation and age at menarche. Ages at exposure, potential years of exposure to supplements, age at interview and sample sizes of those who had reached menarche by 1992 are presented in **Table 1.** The mean age at menarche for the entire sample is 13.71 ± 1.29 y (mean ± SD, and does not differ by supplement type; the values are 13.75 ± 1.22 y for Atole and 13.74 ± 1.36 y for Fresco villages (**Table 2**). Age at menarche does, however, vary by year of birth (**Fig. 1**). There is a decline in mean age at menarche over time for both groups; the overall rate of decline is ~0.69 y over the 15-y period as calculated by a regression of age at menarche on year of birth.

Determinants of age at menarche. **Table 3** shows the results of two separate regression models: with age at menarche as the dependent variable and supplement type, year of birth, a second degree polynomial of year of birth, SES score and village size as covariates in both models. Model 2 includes these variables and interactive terms. In Model 1, supplement type is not a significant predictor of menarche but all other covariates are. Older subjects reached menarche later and higher SES was associated with earlier menarche. Village size (large = 1, small = 0) was associated positively with age at menarche.

TABLE 2

Mean age at menarche by supplement type[1]

Birth year	Supplement type: Atole	Supplement type: Fresco	Difference[2]
	y		
1962	13.74 ± 1.22	13.55 ± 1.31	+0.19
1963	13.88 ± 1.32	14.01 ± 1.44	−0.13
1964	13.68 ± 1.62	13.77 ± 1.40	−0.09
1965	13.84 ± 1.21	14.50 ± 1.32	−0.66
1966	13.98 ± 1.01	14.37 ± 1.39	−0.39
1967	14.01 ± 1.43	13.93 ± 1.14	+0.08
1968	14.03 ± 1.09	14.11 ± 2.03	−0.08
1969	14.02 ± 1.24	13.75 ± 1.24	+0.27
1970	13.91 ± 1.31	14.29 ± 1.40	−0.38
1971	13.61 ± 1.42	14.01 ± 1.17	−0.40
1972	13.73 ± 1.51	13.89 ± 1.37	−0.16
1973	13.93 ± 1.40	13.35 ± 1.22	+0.58
1974	13.51 ± 1.44	13.57 ± 1.16	−0.06
1975	13.53 ± 0.73	13.29 ± 1.12	+0.24
1976	13.49 ± 1.04	13.18 ± 1.02	+0.31
1977	13.16 ± 0.93	12.80 ± 0.95	+0.36
Mean	13.75 ± 1.22	13.74 ± 1.36	+0.01
Overall	13.71 ± 1.29		

[1] Thirteen cases had not reached menarche and are not included; n = 799.

[2] Difference = Atole − Fresco. T tests comparing differences at each birth year were all nonsignificant at $P < 0.05$.

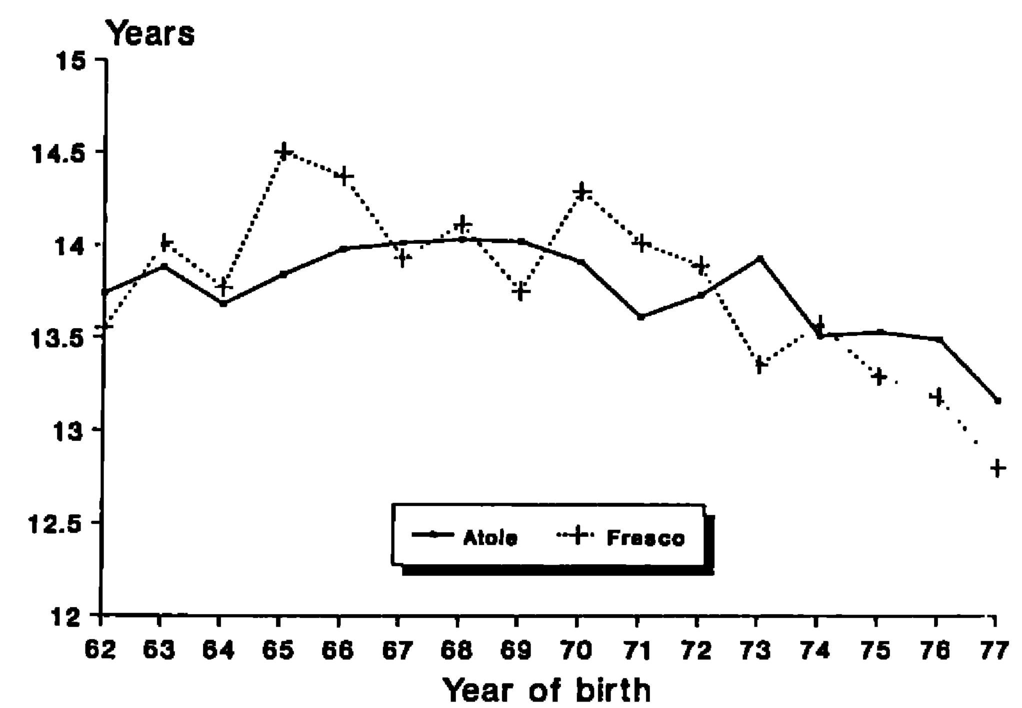

FIGURE 1 Mean age at menarche by supplement type and year of birth (n = 799).

TABLE 3

Determinants of age at menarche: multiple linear regression analyses

Independent variable	Model 1 b	Model 1 P	Model 2 b	Model 2 P
Supplement type[1]	0.069 ± 0.094	0.464	−0.337 ± 0.215	0.117
Year of birth[2]	0.130 ± 0.047	0.006	0.125 ± 0.047	0.009
Square of YRBIRTH[3]	−0.011 ± 0.003	0.001	−0.012 ± 0.003	0.001
SES[4]	−0.145 ± 0.050	0.004	−0.279 ± 0.073	0.001
Village size[5]	0.256 ± 0.097	0.008	0.317 ± 0.099	0.001
YRBIRTH*SUPPL[6]			0.046 ± 0.021	0.032
SES*SUPPL[7]			0.255 ± 0.102	0.012
CONSTANT	13.499 ± 0.193	0.000	13.549 ± 0.211	0.000
	R^2 = 0.07		R^2 = 0.09	
	df = 688[8]		*df* = 688	

[1] 1 for Atole and 0 for Fresco supplements, and abbreviated as SUPPL.
[2] Coded as 1962 = 1, 1963 = 2, etc., and abbreviated as YRBIRTH.
[3] Second degree polynomial term for year of birth.
[4] Composite score based on characteristics of home and household possessions in 1975. Scores are a standardized variable with a mean of zero. SES = socioeconomic status.
[5] 1 for large and 0 for small villages.
[6] Interaction of year of birth and supplement type.
[7] Interaction of SES and supplement type.
[8] The degrees of freedom are fewer than the original number of subjects because of missing data for some of the independent variables.

In Model 2, significant two-way interactions between year of birth and supplement type and between SES score and supplement type are included. Other two-way interactions between year of birth and SES score and between village size and supplement type also were tested but were not found to be statistically significant. The interaction between year of birth and supplement type in Model 2 reflects the fact that for cases who were exposed to the supplements at older ages, menarche occurred earlier in Atole villages compared with Fresco villages. In cases exposed at younger ages, menarche was later in Atole compared with Fresco villages (see Fig. 1 and Table 2).

The positive interaction between SES score and supplement type suggests that, at high levels of SES, exposure to Atole was associated with later menarche; at lower levels of SES, on the other hand, exposure to Atole was associated with earlier menarche.

Results using survival analysis to incorporate cases who had not reached menarche (n = 13) were nearly identical to those in Table 3 and therefore are not presented.

DISCUSSION

The mean age at menarche in subjects exposed to Atole, a high energy and high protein supplement was 13.74 y, nearly identical to the value of 13.75 y found in subjects exposed to Fresco, a low energy, no protein supplement. The mean age at menarche for immigrants (n = 144), subjects not exposed to either supplement, was 13.55 ± 1.20 y. Most of these immigrants married village men and are likely to be of similar SES and education as the sample of women exposed to the supplements. The fact that immigrants, in effect a control group, reached menarche at about the same age as Atole and Fresco women provides additional evidence that supplementation did not influence age at menarche.

Some reports of age at menarche in Guatemala are available, Sabharwal et al. (1966) reported a mean age at menarche of 12.8 y for 230 upper socioeconomic urban girls and 14.5 y for 218 lower socioeconomic rural Mayan Indian girls. Notably, a later recalculation using probit analysis estimated those values to be 13.3 and 15.1 y, respectively (Eveleth and Tanner, 1976). Delgado et al. (1984) reported that the median age of menarche of girls living under poor conditions on 12 coffee plantations located in Suchitepequez, Quezaltenango and Alta Verapaz was 14.81 y. The average values in the present study are only slightly later than found in the well-to-do urban sample (i.e., 13.71 vs. 13.3 y). In our study, women with higher SES (1.0 SD above the mean) reached menarche ~0.30 y earlier than those of lower SES (1.0 SD below the mean). Thus, women of higher SES in our sample had nearly identical mean age at menarche as the urban sample, if the recomputed value of 13.3 y is used.

Age at menarche showed a tendency to decline over time in Atole and Fresco groups as well as in immigrants. The observed rate of decline is slightly greater (0.50 y per decade) than reported in other studies. It may be that this value is an overestimation because 13 cases had not reached menarche by the end of data collection, artificially depressing the mean age at menarche. To test this theory, we assumed conservatively that all 13 subjects were "late" maturers and assigned them a value of 17.58 y, the overall mean plus 3 SD. Inclusion of these 13 subjects using assigned values did not alter the basic observation that menarche declined over time; however, the rate of decline was reduced to 0.39 y per decade.

Comparable data on changes in age at menarche over time in other Latin American populations are limited. A study from Chile (Rona 1975) found that the rate of decline was, on average, 0.29 y per decade between 1940 and 1970. Using recall data of women age 20–59 y, Malina et al. (1983) found no decline in age at menarche for girls in Oaxaca, Mexico.

A differential rate of decline in age at menarche according to SES has been reported (Low et al. 1982, Padro 1984, Rona 1975, Singh and Malhotra 1988). In Chile, Rona (1975) found that the rate of decline from 1940 to 1970 was greater in the middle classes than in the upper classes. In Madrid and a nearby suburb, Padro (1984) reported that menarche declined from 1935 and 1965 by 0.34 y per decade in the upper classes compared with 0.43 y in the lower classes. Similarly, among Malaysian Chinese, Indian and Malay females, ages at menarche fell on average 0.27 y per decade for women born between 1926 and 1961, with a greater decline observed in those raised in poorer households; about one half of the decline was accounted for by improved SES over the period studied (Tan-Boom et al. 1983). In summary, the secular trend in age at menarche is often greater in lower compared with higher SES groups.

In the present study, an interaction between year of birth and SES was not statistically significant in either Model 1 or 2, suggesting that the rate of decline in age at menarche was not influenced by SES. It may be that the variance in SES in our study is too small to pick up an interaction; in other studies (e.g., Padro 1984, Rona 1975), the socioeconomic differences were more extreme.

In the present study, statistically significant interactive effects of supplementation with SES and year of birth on menarche were found. At high SES (1.0 SD above the mean), subjects exposed to Atole reached menarche 0.90 mo later than those exposed to Fresco. At low SES, (1.0 SD below the mean) subjects exposed to Atole reached menarche 0.72 mo earlier than those exposed to Fresco. The strength of the interaction with year of birth can be ascertained from Figure 1. Reasonable and plausible explanations for these interactions have not been found despite considerable effort. In view of the moderate to small magnitude of the interactive effects and, more importantly, due to the lack of plausible explanations, these results are disregarded in drawing up the main conclusion of the analyses.

Intake of Atole was associated positively with childhood maturity as measured by the number of ossification centers present in subjects < 3 y of age (Martorell et al. 1979). Limiting the analysis of menarche to subjects exposed to supplement from birth to 3 y of age, the mean age at menarche (years) is exactly the same for both groups: 13.78 ± 1.26 for Atole (n = 178) and 13.78 ± 1.27 for Fresco (n = 167), respectively. This suggests that the previously demonstrated impact of supplementation on maturity during early childhood did not continue into early adulthood.

The relationship between supplementation and skeletal age in adolescence in our study population has been investigated by Pickett et al. (1995) using the Radius-Ulna-Short bones (RUS) option of the Tanner-Whitehouse-2 (TW2) method (Tanner et al. 1983). This method yields skeletal ages and relative maturation can be assessed by comparisons to chronological ages, with British data used as the reference population. Skeletal maturation was significantly delayed ($P < 0.05$) in the combined sample only in boys 11–14 y of age (by 1.2 y); in girls 11–14 years, values were slightly accelerated (+0.23 y) with respect to the reference. Many girls 14–18 y had reached maturity and a reliable estimate of maturational delay could not be made; in boys 14–18 y, there was a delay of 0.16 y, but this was not statistically significant. There were no significant differences ($P < 0.05$) in skeletal ages between Atole and Fresco subjects except in females 11–14 y of age, with those exposed to Atole being 0.4 y more advanced; however, these differences ceased to be statistically significant after controlling for SES. These findings corroborate those on menarche; there is no evidence of marked delays in maturation in the population and exposure to Atole has little or no impact.

There is the possibility that supplement intake in children older than 7 y of age may have attenuated Atole and Fresco differences in maturity. Very little Fresco was consumed in the first 3 y of life; however, by 5–7 y, consumption of Fresco was greater than that of Atole in terms of volume, such that high levels of energy and micronutrients were consumed at these ages in both Atole and Fresco villages. It is possible that these high levels of consumption persisted later into adolescence. This is unlikely, however, because former field workers recall that it was mostly women and the target children under 7 y of age who frequented the supplement centers. Nonetheless, the possibility should be entertained. Assuming that intakes of both Fresco and Atole remained high after 7 y of age and that these influenced age at menarche, one would have expected lower ages at menarche in the study sample compared with immigrants, but such was not the case.

The association between energy intakes and age at menarche has been examined previously, mostly in industrialized countries (Kissinger and Sánchez 1987, Maclure et al. 1991, Meyer et al. 1990, Moisan et al. 1990). In these studies, dietary intakes in the 1–3 y before menarche were examined; none looked at intakes during childhood as we have done. Results from these studies suggest that energy intakes in the years immediately before menarche have little or no relation to age at menarche, consistent with our own findings.

A limitation with this study is that the data on age at menarche were collected retrospectively. There is no reason to believe, however, that responses were biased either toward younger or older ages or that subjects of one supplement type responded differently from the other. Limiting the analyses to subjects who recalled their age at menarche within ±3 mo in the two surveys, the values were 13.78 ± 1.32 y (n = 111) and 13.56 ± 1.25 (n = 105) y for Atole and Fresco villages, respectively.

To our knowledge, no previous investigation of the effects of nutritional supplementation on menarche has been reported. Our study found that mean age at menarche was similar for subjects who received either a high energy and high protein supplement (Atole) or a low energy, no protein supplement (Fresco). No differences between supplement type were found when analyses were limited to those who accurately recalled their age at menarche or to those subjects who were exposed to supplements in the first 3 y of age. In addition, immigrants of similar SES background who were not exposed to any supplement had a similar mean age at menarche. Therefore, we conclude that nutritional supplementation did not have an affect on age at menarche in the present study. Nonetheless, the fact that both SES and year of birth were found to be associated with age at menarche indicates that menarche is subject to general environmental, and possibly nutritional, influences.

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