# Nutritional Supplementation during the Preschool Years Influences Body Size and Composition of Guatemalan Adolescents[1,2]

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**ABSTRACT** Effects of supplementary feeding during early childhood on body size and composition at adolescence are examined in a population with marked growth failure in the first 3 y of life. The data came from a supplementation trial conducted in rural Guatemala from 1969 to 1977 and a 1988–89 follow-up study of the same subjects at adolescence. Two pairs of villages participated in the trial. One village from each pair received a high protein-energy supplement (Atole), which significantly improved dietary intakes, whereas the other village of the pair received a low-energy, no-protein supplement (Fresco), which did not impact appreciably on dietary intakes. Children from Atole villages grew better during the preschool period than children from Fresco villages. At adolescence, subjects from Atole villages were taller, weighed more and had greater fat-free masses than subjects from Fresco villages. Differences in height at adolescence were slightly reduced in magnitude relative to differences at 3 y of age. However, differences in weight were increased in adolescence relative to 3 y of age. J. Nutr. 125: 1068S–1077S, 1995.

INDEXING KEY WORDS:

- *supplementation* • *growth* • *height*
- *adolescence* • *rural Guatemala*

In a review of controlled supplementation trials, clear effects of supplementary feeding on growth were found in populations with evidence of growth retardation when the dietary intakes of young children were truly improved (Habicht and Butz 1979, Rivera 1988). On the other hand, the long-term effects of community-based supplementation programs during early childhood on the growth and body composition at adolescence or adulthood have not been studied.

This article examines effects of supplementary feeding during early childhood on body size and composition at adolescence in a population where effects of supplementation on growth rates were observed during the first 3 y of life but not from 3 to 7 y of age (Martorell et al. 1982, Schroeder et al. 1995). It remains to be shown whether these improvements in growth persist into adolescence.

Tanner (1986) has described human growth as a target-seeking function. In his view, children have their own natural growth trajectories; when deviations occur, restoring forces develop to return children to their original growth curves. Growth after 3 y of age in rural Guatemala is not significantly constrained (Martorell et al. 1995b) and thus, it may be possible for the differences in size in favor of supplemented children observed at 3 y of age to be reduced through faster growth subsequently in nonsupplemented children. In addition, nonsupplemented children may have a greater potential for growth than supplemented children because of delayed maturation. Martorell et al. (1979) found that nonsupplemented children were less mature at 3 y of age than supplemented children in this population. Less mature children, in turn, may have

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a more prolonged subsequent growth period that could compensate for some of the growth failure incurred in early childhood.

The hypothesis tested in the present study is that effects of supplementation on growth at 3 y of age persist into adolescence and that differences in attained growth at adolescence between supplemented and nonsupplemented groups are of similar magnitude as observed at 3 y of age. The data used in the analysis were collected during a supplementation trial of rural Guatemalan children conducted from 1969 to 1977 and from a follow-up study of the same subjects at adolescence. Results are presented for length and weight at 3 y of age and for height, weight and fat-free mass (FFM) at adolescence and young adulthood.

## MATERIALS AND METHODS

### Design and sample

***Design of the supplementation trial (1969–1977).*** A controlled supplementation trial was conducted in rural Guatemala between 1969 and 1977 by the Institute of Nutrition of Central America and Panama (INCAP). Detailed descriptions of the sample, methods, and quality control have been published elsewhere (Martorell et al. 1995a). A brief summary of the intervention follows.

Four rural Ladino (i.e., Spanish speaking, mixed Spanish-Indian ancestry) villages located in eastern Guatemala were selected for the study. The villages were selected to be as similar as possible in nutrition, health and demographic characteristics. Two villages were randomly allocated to receive a high-protein (11.5 g per 180 mL or 1 cup serving), high-energy (682 kJ/163 kcal per 180 mL) drink called Atole. The remaining two villages were assigned to receive a low-energy (247 kJ/59 kcal per 180 mL), nonprotein supplement called Fresco. The two drinks contained similar concentrations of vitamins and minerals. A preventive and curative health program was offered in all four villages. The supplements were distributed centrally in supplementary feeding centers and were available daily, on a voluntary basis, to all members of the community. Subjects were free to consume as much as desired and the amounts ingested by children 0–7 y were measured and recorded at each session to the nearest 10 mL.

***Design of the follow-up study (1988–89).*** A follow-up study of the children who participated in the supplementation trial was conducted between 1988 and 1989. At this time, the subjects were between 11 and 27 y of age, of which 2169 were known or believed to be alive. Of these, 1574 (73%) were studied at follow-up (Martorell et al. 1995a).

***Sample.*** The sample for the current analyses consists of 460 children (245 males and 215 females) who were exposed to supplementary feeding in the study villages from birth to 3 y of age (born between March 1969 and February 1974), had anthropometric measurements at 3 y of age (±7 d) and had anthropometric measurements at follow-up, when they were between 14 and 20 y of age (for convenience, this range in age is referred to hereafter as adolescence).

### Data utilized

***Data from the supplementation trial.*** Anthropometric measurements at 36 mo, home diet, duration of breastfeeding, diarrhea, maternal height, maternal education and socioeconomic status were used in the present analyses.

*Anthropometric measurements at 36 mo.* Weight, measured to the nearest 0.01 kg, using a beam balance scale, and recumbent length, measured to the nearest millimeter on a standard measuring table were used in the analyses.

*Home diet.* Energy intake from the home diet (excluding breastfeeding) was estimated by the 24-h recall method using surveys every 3 mo between 15 and 36 mo of age. The average daily energy intake (kilocalories/day) from the diet between 15 and 36 mo was obtained using all the recalls available during that period. The average was used in the analyses.

*Diarrhea.* Information about the occurrence and duration of diarrhea, as defined by the mother, was collected every two weeks during home visits. The percentage of time with diarrhea between 0 and 36 mo of age was used in the analyses. This variable was derived by dividing the number of days with diarrhea by the number of days for which information about morbidity was available, multiplied by 100.

*Maternal height.* Maternal height was measured every 3 mo during pregnancy and lactation starting in 1971. The median value of the repeated measures was used in the analyses.

*Socioeconomic status.* A socioeconomic score (SES) was generated from factor analysis using information about living conditions of the family in 1975. After initial testing, the model was restricted to one factor. Only variables with factor loadings ≥0.5 were retained. These were house characteristics (type of floor, an overall assessment of the quality of the house construction, type of excreta disposal, the location of the kitchen and facilities for cooking) and possession of household items (radio, TV, record player, bicycle, motorcycle, car, sewing machine and refrigerator). The variance explained by this model was 46%. Standardized factor scores were used in the analyses.

***Data from the follow-up study.*** Anthropometric measurements and maturation were used in the analyses.

*Anthropometric measurements.* A battery of anthropometric measurements were obtained on the sample (Martorell et al. 1995a). Only height, weight and estimated FFM were used as outcomes in the present analyses. Sex-specific prediction equations for FFM were developed in an urban group specifically selected to match the subjects of the follow-up study on age, anthropometric measurements and ethnic origin. The prediction equation for males included weight, bicristal diameter and arm-fat area as independent variables; the equation for females included weight, height, and waist circumference (Conlisk et al. 1992).

*Maturation.* The methods of assessing maturation in this study are given by Pickett et al. (1995). Left-hand-wrist X-rays of adolescents up to the age of 18 y, excluding pregnant women, were obtained by field workers who were trained by a radiologist. X-rays in older subjects were not obtained because the probability of finding anyone who had not reached skeletal maturity was very small. All X-rays were read and graded by a single person using the TW-2 (RUS) method (Tanner et al. 1983) in which skeletal maturity is assigned the value of 18.0 y in males and 16.0 y in females. The variable "maturation", which was used in the analyses, was given the hand-wrist X-ray rating value (bone age) if chronological age was <17.9 in males. All males ≥18 y were given a value of 18.0 for maturation. In females, bone age was used if chronological age was <15.9 y. Between chronological ages 16.0 and 17.9, bone age was used if skeletal maturity had not occurred, while 16.0 was assigned when skeletal maturity had occurred. All females ≥18 y were given a value of 16.0 for maturation. Haas et al. (1995) also use this variable as a covariate but refer to it as skeletal age (SA). A nonlinear association between maturation and growth at adolescence was found in males; therefore, a quadratic term was used in the models for males.

### Conceptual Model

The variables included in the regression models were based on a conceptual model of the determinants of growth. From evidence in the literature and from previous analyses of the data, the direct determinants of growth during the first 3 y of age are dietary intake (Habicht and Butz 1979) and morbidity, particularly diarrhea (Rivera and Martorell 1988). Two variables representing dietary intake initially were considered: breastfeeding duration and home energy intake. However, breastfeeding duration was dropped from the analyses because of the large number of missing values. Previous analyses in this population showed that maternal height was an important determinant of children's growth. It is probably an indicator of both the genetic potential for growth and of the socioeconomic condition of the family. Maturation was included in all models for adolescents. Socioeconomic status of the family and maternal education were selected for analysis but the latter was dropped because of high rates of missing values. Socioeconomic status operates through dietary intake and morbidity. Because dietary intake and diarrhea, which are direct determinants of growth, were included in the model, incorporation of socioeconomic status may be redundant and should therefore be justified. One important reason for including the three variables in the model is that measures of dietary intake are imprecise (the reliability of the 24-h dietary recall method is low and breast-milk intake was not measured). Also, diarrhea was the only indicator of morbidity used. Therefore, socioeconomic status may capture some of the variability in growth that would be lost because of imperfect measurement of dietary intake and morbidity.

### Analysis methodology

Full rather than reduced models (i.e., models in which only those variables found to be statistically significant are retained) were used to decrease biases in the regression coefficients as a result of omitting relevant variables (Johnston 1984). The precision of estimation of the full models was very similar to that observed in the reduced models.

Unadjusted differences in attained growth between supplement groups (Atole and Fresco) were analyzed by t-test. Analysis of variance (ANOVA) and ordinary least squares (OLS) regression analysis were used to control for potential confounding variables and to compute adjusted means. The conceptual model described above guided the choice of variables. The outcome variables analyzed were: length (centimeters) and weight (kilograms) at 3 y of age and height (centimeters), weight (kilograms) and FFM (kilograms) at adolescence. The independent variables included: supplement type (Atole = 1; Fresco = 0), maternal height (centimeters), percent of time with diarrhea between 0 and 3 y of age, SES and home diet (kilocalories). The variable "home diet" was dichotomized using the sex-specific median: diet was considered low (0) if the energy intake from the diet was lower than the median and high (1) if the energy intake was greater than or at the median. The reasons for dichotomizing were that the relationship between energy intake and attained growth is not linear and because of imprecision in the measurement of home diet (Habicht et al. 1995). Maturation was included in all adolescent models. Also included in some adolescent models were anthropometric measurements at 3 y of age and height at adolescence. The former was used to test if differences in attained growth at adolescence were totally explained by differences at 3 y; the latter was used to test if effects on FFM and weight at adolescence were independent of effects on height.

The analytical approach consisted of: testing the effect of supplementation on length, weight and weight adjusting for length, at 3 y of age; testing the long-term effect of supplementation on height, weight and FFM at adolescence and on weight and FFM adjusting for height; and testing the effect of supplementation on weight and height at adolescence, controlling for anthropometric measurements at 3 y of age. These last models tested whether the effect of supplementation on adolescents' outcomes still remained when anthropometric measurements at 3 y of age were included in the model.

Data for males and females were analyzed separately, mainly because of differences in patterns of maturation. In females maturation was related linearly to height at adolescence whereas in males the relationship was quadratic.

Atole versus Fresco differences were considered statistically significant at an alpha level <0.05, using two-tailed tests in descriptive analyses. Statistical power was inadequate to analyze these data according to the intervention design, which would require the unit of analysis to be the village and not the individual (see Habicht et al. 1995 for the application of this approach to size at 3 y of age). However, the important inferences about the long-term effects of supplementation depend more on major changes in the absolute differences in size between Atole and Fresco subjects than on shifts in statistical significance.

All analyses were done using the SAS version 6.04 for microcomputers.

## RESULTS

Descriptive statistics for outcome variables (**Table 1**) and independent variables (**Table 2**) are presented by sex and supplement type. Length and weight at 3 y of age were significantly greater in Atole compared with Fresco villages for both genders ($P < 0.05$). Differences in favor of Atole villages were 1.6 and 2.7 cm in length and 0.7 and 1.2 kg in weight for males and females, respectively. Weight, height and FFM at adolescence were also significantly greater in Atole villages in females ($P < 0.05$) but comparisons were not significantly different between Atole and Fresco villages in males. Chronological age as well as maturation were significantly greater in Fresco males (e.g., 16.1 and 16.6 y for Atole and Fresco males, respectively, for chronological age; Table 2); later analyses of size at adolescence adjust for these differences. Table 2 also shows that energy intake from the supplement was significantly greater in Atole villages ($P < 0.05$) for both genders, and that energy intake from home diets, although slightly greater in Fresco villages, was not significantly greater. Maternal height, socioeconomic status and percent time with diarrhea did not differ between supplement types for either gender.

**Tables 3–5** present adjusted mean values of the various outcome variables for Atole and Fresco villages, by gender. The regression models (numbered consecutively from 1 to 18) used to compute these adjusted means are presented in **Appendices 1–3**.

At 3 y of age, adjusted lengths and weights for both males and females were significantly greater in Atole compared with Fresco villages (Tables 3 and 4). In length, differences in adjusted means between Atole and Fresco were 2.0 cm in males and 2.9 cm in females, while in weight they were 0.7 kg and 1.3 kg for males and females, respectively. These differences were slightly greater in length compared with those obtained using unadjusted means (unadjusted differences were 1.6 and 2.7 cm, respectively in males and females; from data in Table 1) but nearly similar in the case of weight (unadjusted differences were 0.7 and 1.2 kg, respectively, in males and females; Table 1).

Adolescents from Atole villages were taller (Table 3) and heavier (Table 4) than those of Fresco villages, although the differences were not statistically significant in males. The adjustments, particularly the correction for differences in maturation at adolescence between Atole and Fresco samples, reversed the sign of the anthropometric differences in males to favor Atole (i.e., Fresco males were taller and heavier at adolescence before adjustment but shorter and lighter

**TABLE 1**

***Descriptive statistics for outcome variables by sex and type of supplement***

| | Males | | Females | |
|---|---|---|---|---|
| Variable | Atole ($n$ = 118) | Fresco ($n$ = 127) | Atole ($n$ = 116) | Fresco ($n$ = 99) |
| Length at 3 y, *cm* | 86.9 ± 3.8 | 85.3 ± 4.0* | 86.3 ± 3.5 | 83.6 ± 3.6* |
| Weight at 3 y, *kg* | 12.5 ± 1.2 | 11.8 ± 1.3* | 12.1 ± 1.3 | 10.9 ± 1.1* |
| Height at adolescence, *cm* | 157.5 ± 9.2 | 158.3 ± 7.6 | 150.5 ± 5.3 | 148.8 ± 4.7* |
| Weight at adolescence, *kg* | 48.3 ± 8.1 | 49.6 ± 7.9 | 48.3 ± 6.7 | 46.0 ± 5.7* |
| Fat-free mass at adolescence, *kg* | 41.9 ± 6.7 | 43.1 ± 6.4 | 37.3 ± 5.3 | 35.2 ± 4.6* |

Values are means ± SD.

* $P < 0.05$, $t$-test comparing Atole and Fresco. Length at 3 y of age did not differ between Atole and Fresco in 1968, at baseline (Habicht et al. 1995, Ruel et al. 1992). Also note that maternal height (Table 2) did not differ by village type.

**TABLE 2**

***Descriptive statistics for independent variables by sex and village type***

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| | Atole | | Fresco | | Atole | | Fresco | |
| Variable | n[1] | | n | | n | | n | |
| Supplement energy, *kJ/day* | 118 | 536 ± 377 | 127 | 88 ± 75* | 116 | 481 ± 322 | 99 | 71 ± 54* |
| Home diet energy, *kJ/day*[2] | 118 | 2996 ± 912 | 126 | 3209 ± 971 | 113 | 2795 ± 787 | 97 | 2908 ± 1013 |
| Supplement energy, *kcal/day* | 118 | 128 ± 90 | 127 | 21 ± 18* | 116 | 115 ± 77 | 99 | 17 ± 13* |
| Home diet energy, *kcal/day*[2] | 115 | 716 ± 218 | 126 | 767 ± 232 | 113 | 668 ± 188 | 97 | 695 ± 242 |
| Maternal height, *cm* | 116 | 148.8 ± 5.1 | 123 | 148.8 ± 5.1 | 114 | 149.0 ± 5.2 | 97 | 149.3 ± 5.6 |
| SES[3] | 116 | −0.1 ± 0.9 | 122 | −0.1 ± 0.8 | 114 | −0.1 ± 0.9 | 97 | 0.0 ± 1.0 |
| Time w/diarrhea, % | 117 | 8.8 ± 8.2 | 126 | 7.7 ± 6.7 | 115 | 6.4 ± 6.2 | 97 | 7.9 ± 7.8 |
| Maturation, *years* | 116 | 16.1 ± 2.0 | 123 | 16.8 ± 1.9* | 107 | 16.7 ± 1.8 | 97 | 16.7 ± 2.0 |
| Age, *years* | 118 | 16.1 ± 1.4 | 127 | 16.6 ± 1.5* | 116 | 16.5 ± 1.4 | 99 | 16.4 ± 1.6 |
| Duration of breastfeeding, *months* | 113 | 19.1 ± 6.9 | 121 | 19.3 ± 4.5 | 110 | 18.0 ± 5.6 | 94 | 19.7 ± 5.2* |

Values are means ± SD.

* $P < 0.05$, *t*-test comparing Atole and Fresco.

[1] Differences in sample sizes among variables are due to missing values.

[2] The percent with dietary energy intakes equal to the median or greater was 45.2%; ($n$ = 115) and 54% ($n$ = 126) in males and females respectively in Atole villages. The corresponding values for Fresco were 50.4% ($n$ = 113) and 49.5% ($n$ = 97). Differences between Atole and Fresco were not significant for males or females.

[3] Standarized scores from factor analysis are unitless.

after adjustment). Relative to adjusted differences at 3 y of age, adjusted differences at adolescence were smaller for height (1.2 versus 2.0 cm in males and 2.1 versus 2.9 cm in females; Table 3) but larger for weight (1.2 versus 0.7 kg in males and 2.2 versus 1.3 kg in females; Table 4).

Differences between Atole and Fresco villages at adolescence ceased to be significant after adjustment for length or weight at 3 y, indicating that differences observed at adolescence were due to differences already established at 3 y of age (Tables 3 and 4).

When weight at adolescence was adjusted for height at adolescence (Table 4), differences in weight between Atole and Fresco villages were about half the size of the unadjusted values—but still substantial in females—and not statistically significant for either sex.

FFM at adolescence was greater in Atole villages in both males (0.8 kg) and females (2.1 kg). When FFM was adjusted for height, the Atole versus Fresco difference in males was reduced to 0.2 kg and became nonsignificant whereas that in females was reduced to 1.2 kg but remained significant (Table 5).

## DISCUSSION

Our results confirm the hypothesis that the positive effects of supplementation on growth at 3 y of age

**TABLE 3**

***Adjusted length/height (cm) of Atole and Fresco subjects***

| Gender, variable | Atole[1] | Fresco[1] | Difference[2] | P |
|---|---|---|---|---|
| Males | | | | |
| Length at 3 y, *cm* | 87.3 ± 0.3 | 85.3 ± 0.3 | 2.0 | 0.000 |
| Height at adolescence, *cm* | 158.6 ± 0.5 | 157.4 ± 0.5 | 1.2 | 0.111 |
| Height at adolescence adjusted for length at 3 y, *cm* | 157.5 ± 0.4 | 158.4 ± 0.4 | −0.9 | 0.111 |
| Females | | | | |
| Length at 3 y, *cm* | 86.5 ± 0.3 | 83.6 ± 0.3 | 2.9 | 0.000 |
| Height at adolescence, *cm* | 150.7 ± 0.4 | 148.6 ± 0.5 | 2.1 | 0.001 |
| Height at adolescence adjusted for length at 3 y, *cm* | 149.6 ± 0.4 | 149.8 ± 0.4 | −0.2 | 0.631 |

[1] Means ± SE. Means were adjusted for dietary intake, percent of time with diarrhea, socioeconomic status, maternal height and maturation (adolescence only).

[2] Atole minus Fresco.

**TABLE 4**

***Adjusted weight (kg) of Atole and Fresco subjects***

| Gender, variable | Atole[1] | Fresco[1] | Difference[2] | P |
|---|---|---|---|---|
| Males | | | | |
| Weight at 3 y, *kg* | 12.5 ± 0.1 | 11.8 ± 0.1 | 0.7 | 0.000 |
| Weight at adolescence, *kg* | 49.4 ± 0.5 | 48.2 ± 0.5 | 1.2 | 0.084 |
| Weight at adolescence adjusted for weight at 3 y, *kg* | 48.5 ± 0.4 | 49.1 ± 0.4 | −0.6 | 0.273 |
| Weight at adolescence adjusted for height at adolescence, *kg* | 49.1 ± 0.4 | 48.6 ± 0.4 | 0.5 | 0.347 |
| Females | | | | |
| Weight at 3 y, *kg* | 12.2 ± 0.1 | 10.9 ± 0.1 | 1.3 | 0.000 |
| Weight at adolescence, *kg* | 48.2 ± 0.6 | 46.0 ± 0.6 | 2.2 | 0.009 |
| Weight at adolescence adjusted for weight at 3 y, *kg* | 46.7 ± 0.5 | 47.7 ± 0.5 | −1.0 | 0.174 |
| Weight at adolescence adjusted for height at adolescence, *kg* | 47.8 ± 0.5 | 46.5 ± 0.6 | 1.3 | 0.109 |

[1] Means ± SE. Means were adjusted for dietary intake, percent time with diarrhea, socioeconomic status, maternal height and maturation (in the case of adolescence only).
[2] Atole minus Fresco.

persist at adolescence, although slightly attenuated. Children supplemented with Atole (high-protein/high-energy drink) in their first 3 y of life were taller, heavier and had higher FFMs at adolescence than those supplemented with Fresco (low-energy/no-protein drink). The study also showed that differences between the Atole and Fresco groups at adolescence were largely explained by the effect of supplementation on body size at 3 y of age. This was demonstrated by statistical analyses that showed that Atole and Fresco differences at adolescence disappeared when body size at 3 y of age was included in the models.

Differences between Atole and Fresco were larger in females than in males for all outcomes and at both 3 y of age and adolescence. Differences in favor of females were striking, particularly in FFM, with differences being almost three times larger in females than in males. An intriguing finding was that Atole versus Fresco differences in FFM in females were not totally explained by height at adolescence, suggesting a long-term effect of early supplementation on FFM, independent of the effect on height.

Differences at adolescence relative to those observed at 3 y of age were larger for weight than for height for both genders. Differences in weight were explained mainly by differences in height (i.e., differences in weight disappeared after controlling for height) and for this reason, the remainder of the discussion focuses on height.

The differential response to supplementation between males and females, both at 3 y of age and at adolescence is difficult to explain. It appears that this gender difference at adolescence was mainly due to differences already existing at 3 y of age. Differences between Atole and Fresco in females at 3 y of age were greater by 0.9 cm compared with those found in males. Between 3 y of age and adolescence, both males and females in Fresco villages grew ~0.8 cm more than children in Atole villages (see below). This increased rate of growth among Fresco children resulted in attenuated differences between Atole and Fresco at adolescence in both genders. In males, however, the smaller magnitude of the difference at 3 y of age, combined with larger standard errors at adolescence, resulted in differences between Atole and Fresco at adolescence that were no longer statistically significant. Larger standard errors in adolescent males are thought to be due to variations in maturity. Although a large

**TABLE 5**

***Adjusted fat-free mass (FFM) in Atole and Fresco subjects***

| Gender, variable | Atole[1] | Fresco[1] | Difference[2] | P |
|---|---|---|---|---|
| Males | | | | |
| FFM, not adjusted for height, *kg* | 42.8 ± 0.4 | 42.0 ± 0.4 | 0.8 | 0.162 |
| FFM, adjusted for height, *kg* | 42.5 ± 0.3 | 42.3 ± 0.3 | 0.2 | 0.641 |
| Females | | | | |
| FFM, not adjusted for height, *kg* | 37.3 ± 0.4 | 35.2 ± 0.5 | 2.1 | 0.002 |
| FFM, adjusted for height, *kg* | 36.9 ± 0.4 | 35.7 ± 0.4 | 1.2 | 0.052 |

[1] Means ± SE. Means were adjusted for dietary intake, percent time with diarrhea, socioeconomic status, maternal height and for maturation (in the case of adolescence only).
[2] Atole minus Fresco.

proportion of females had reached maturity at the time of the study, this was not the case for males. Although skeletal age was used in the analyses to control for maturation, extreme variations in height associated with differences in maturity could not be completely controlled for.

We have explored possible reasons for the smaller magnitude of difference between Atole and Fresco villages observed in males at 3 y of age. Examination of results within village pairs indicates that differences in favor of Atole in the pair of large villages were statistically significant in males (**Table 6**) and similar to differences seen in females. Also, differences between Atole and Fresco in males in the large villages remained statistically significant at adolescence. In contrast, differences were less and not statistically significant in males in the small villages either at 3 y ($P = 0.28$) or at adolescence ($P = 0.32$). We have no adequate explanation for the lack of a supplement effect in males in the small pair of villages.

Differences in attained height at adolescence in favor of Atole villages disappeared after controlling for length at 3 y of age. This was expected because most of the growth deficit observed in adolescents and adults in this population occurs during the first 3 y of life. Growth after 3 y in this population is generally adequate and may even be greater than that observed in Mexican-Americans (Martorell et al. 1995b). In our study, children in the Fresco villages grew slightly more from 3 y of age to follow-up than children in Atole villages. (72.1 versus 71.3 cm in Fresco and Atole males respectively and 65.0 cm and 64.2 cm, respectively, in females; from data in Table 3). This small difference in growth may be the result of accelerating effects of the Atole on bone maturation in the preschool period (Martorell et al. 1979), which would provide children in the Fresco villages with a greater growth potential after 3 y of age. Another possible explanation for the above is better environmental conditions during school age and adolescence in Fresco villages. Our data suggest that environmental factors may have had an effect on growth from 3 y of age to adolescence (see Appendices 1–3). In females, socioeconomic status was a statistically significant determinant of height at adolescence and the effect continued to be significant after controlling for length at 3 y of age. This suggests a positive effect of socioeconomic factors on growth in height after 3 y of age in females.

A number of variables besides supplementation were statistically significant in the models (see Appendices 1–3). In addition to maturation, maternal height was an important determinant of height and weight at 3 y of age and at adolescence in both sexes. Moreover, maternal height was also a statistically significant predictor of growth at adolescence once size at 3 y of age was controlled for, indicating an effect on growth after 3 y of age. As mentioned earlier, maternal height is thought to be a proxy for both genetic potential and environmental factors. Dietary intake and diarrhea during the first 3 y of life were statistically significant predictors of size at adolescence in some models but were not significant when size at 3 y of age was controlled for. These results suggest that, although the effects of diarrhea and dietary intake on growth take place during the first 3 y of age, the effects persist into adolescence.

In summary, the results show long-lasting effects of supplementation during the first 3 y of life on body size and composition at adolescence. Although differences in height at adolescence were reduced in magnitude relative to those found at 3 y of age, the degree of reduction was similar in both males and females, and the results at adolescence did not change substantially relative to results at 3 y of age. In weight, differences were increased at adolescence relative to 3 y of age.

In this population, the first 3 y of life is the period of maximum growth retardation, whereas growth thereafter may be adequate (Martorell et al. 1995). Our results show that investments in nutrition during early childhood have effects on growth that persist into adulthood. Greater height and FFM in turn may have effects on reproductive performance in females, notably on fetal growth, and consequently on the health and survival of the next generation. Effects on body

**TABLE 6**

***Adjusted length/height (cm) of Atole and Fresco males by village size***

| Variable | Small villages | | | Large villages | | |
|---|---|---|---|---|---|---|
| | Atole[1] | Fresco[1] | Difference[2] | Atole[1] | Fresco[1] | Difference[2] |
| Adjusted length at 3 y[1] | 86.9 ± 0.48 | 86.1 ± 0.51 | 0.8 | 87.6 ± 0.44 | 84.7 ± 0.43 | 2.9* |
| Adjusted height at adolescence[1] | 157.8 ± 0.76 | 158.9 ± 0.81 | −1.1 | 159.0 ± 0.68 | 156.2 ± 0.68 | 2.8* |

* $P < 0.05$ (two-tailed).

[1] All means were adjusted for dietary intake, percent time with diarrhea, socioeconomic status, maternal height and maturation (in the case of adolescence only). Values are means ± SE.

[2] Atole minus Fresco.

size in adolescent males, through its association with greater work capacity (Haas et al. 1995), may in turn be associated with increased future earning power.

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## APPENDIX 1

***Multiple Regression models for length at 3 y and height at adolescence***

| | Males | | | | | | Females | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length at 3 y (cm) | | Height at adolescence (cm) | | Height at adolescence controlling for length at 3 y | | Length at 3 y (cm) | | Height at adolescence (cm) | | Height at adolescence controlling for length at 3 y | |
| Model number | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| | β | P | β | P | β | P | β | P | β | P | β | P |
| Independent variables | | | | | | | | | | | | |
| Intercept | 48.77 | 0.000 | −76.48 | 0.000 | −109.40 | 0.000 | 53.15 | 0.000 | 71.17 | 0.000 | 30.53 | 0.001 |
| Supplement[1] | 1.97 | 0.000 | 1.15 | 0.111 | −0.94 | 0.111 | 2.83 | 0.000 | 2.03 | 0.001 | −0.27 | 0.631 |
| Maternal height | 0.24 | 0.000 | 0.53 | 0.000 | 0.29 | 0.000 | 0.20 | 0.000 | 0.47 | 0.000 | 0.31 | 0.000 |
| SES | 0.60 | 0.025 | 0.54 | 0.202 | 0.01 | 0.965 | 0.24 | 0.320 | 0.74 | 0.030 | 0.55 | 0.050 |
| Time w/diarrhea, % | −0.07 | 0.015 | −0.04 | 0.416 | 0.03 | 0.454 | −0.06 | 0.063 | −0.05 | 0.280 | −0.01 | 0.893 |
| Home Diet[2] | 1.66 | 0.000 | 1.76 | 0.016 | 0.24 | 0.677 | 0.00 | 0.029 | 0.51 | 0.425 | −0.27 | 0.611 |
| Maturation, y | — | — | 16.66 | 0.000 | 15.16 | 0.000 | — | — | 0.44 | 0.011 | 0.41 | 0.004 |
| Maturation sq. | — | — | −0.44 | 0.000 | 0.40 | 0.000 | — | — | — | — | — | — |
| Length 3 y, cm | — | — | — | — | 0.98 | 0.000 | — | — | — | — | 0.77 | 0.000 |
| Adjusted R sq. | 0.25 | | 0.61 | | 0.76 | | 0.27 | | 0.31 | | 0.53 | |

[1] Supplement type: Atole = 1, Fresco = 0.
[2] Dietary intake: at or above gender specific median = 1, below gender specific median = 0.

**APPENDIX 2**

***Multiple regression models for weight at 3 y of age and at adolescence***

| | Males | | | | | | | | Females | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight at 3 y (kg) | | Weight at adolescence (kg) | | Weight at adolescence (kg) controlling for weight at 3 y | | Weight at adolescence (kg) controlling for height at adolescence | | Weight at 3 y (kg) | | Weight at adolescence (kg) | | Weight at adolescence (kg) controlling for weight at 3 y | | Weight at adolescence (kg) controlling for height at adolescence | |
| Model number | 7 | | 8 | | 9 | | 10 | | 11 | | 12 | | 13 | | 14 | |
| | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* |
| Independent variables | | | | | | | | | | | | | | | | |
| Intercept | 1.37 | 0.560 | −82.46 | 0.000 | −84.93 | 0.000 | −38.11 | 0.015 | 1.86 | 0.429 | −20.75 | 0.106 | −27.22 | 0.014 | −51.78 | 0.000 |
| Supplement[1] | 0.79 | 0.000 | 1.17 | 0.084 | −0.66 | 0.273 | 0.50 | 0.347 | 1.24 | 0.000 | 2.16 | 0.009 | −1.08 | 0.174 | 1.27 | 0.109 |
| Maternal height | 0.07 | 0.000 | 0.28 | 0.000 | 0.13 | 0.031 | 0.02 | 0.705 | 0.06 | 0.000 | 0.32 | 0.000 | 0.17 | 0.016 | 0.11 | 0.186 |
| SES | 0.16 | 0.084 | 0.19 | 0.629 | 0.52 | 0.122 | 0.50 | 0.106 | 0.00 | 0.986 | −0.21 | 0.630 | −0.24 | 0.528 | −0.54 | 0.208 |
| Time w/diarrhea, % | −0.02 | 0.029 | −0.02 | 0.702 | 0.03 | 0.375 | 0.01 | 0.875 | −0.03 | 0.031 | −0.04 | 0.508 | 0.02 | 0.648 | −0.02 | 0.751 |
| Home Diet[2] | 0.43 | 0.007 | 1.64 | 0.016 | 0.65 | 0.265 | 0.61 | 0.253 | 0.25 | 0.125 | 0.39 | 0.640 | −0.15 | 0.839 | 0.17 | 0.832 |
| Maturation, *y* | — | — | 7.71 | 0.000 | 7.71 | 0.000 | −1.95 | 0.283 | — | — | 1.15 | 0.000 | 1.19 | 0.000 | 0.96 | 0.000 |
| Maturation sq. | — | — | −0.14 | 0.027 | 0.14 | 0.008 | 0.11 | 0.047 | — | — | — | — | — | — | — | — |
| Weight 3 y, *kg* | — | — | — | — | 2.24 | 0.000 | — | — | — | — | — | — | 2.56 | 0.000 | — | — |
| Height at adolescence, *cm* | — | — | — | — | — | — | 0.59 | 0.000 | — | — | — | — | — | — | 0.44 | 0.000 |
| Adjusted R sq. | 0.21 | | 0.63 | | 0.71 | | 0.77 | | 0.29 | | 0.18 | | 0.40 | | 0.27 | |

[1] Supplement type: Atole = 1, Fresco = 0.
[2] Dietary intake: at or above gender specific median = 1, below gender specific median = 0.

**APPENDIX 3**

***Multiple regression models for fat-free mass (FFM) at adolescence***

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| | FFM (kg) at adolescence | | FFM (kg) at adolescence controlling for height at adolescence | | FFM (kg) at adolescence | | FFM (kg) at adolescence controlling for height at adolescence | |
| Model number | 15 | | 16 | | 17 | | 18 | |
| | *β* | *P* | *β* | *P* | *β* | *P* | *β* | *P* |
| Independent variables | | | | | | | | |
| Intercept | −68.32 | 0.000 | −31.06 | 0.010 | −21.67 | 0.034 | −51.38 | 0.000 |
| Supplement[1] | 0.75 | 0.162 | 0.19 | 0.641 | 2.04 | 0.002 | 1.19 | 0.052 |
| Maternal height | 0.23 | 0.000 | −0.02 | 0.587 | 0.28 | 0.000 | 0.09 | 0.192 |
| SES | −0.21 | 0.509 | −0.47 | 0.050 | 0.06 | 0.870 | −0.25 | 0.446 |
| Time w/diarrhea, % | −0.02 | 0.524 | −0.00 | 0.891 | −0.03 | 0.599 | −0.00 | 0.920 |
| Home diet[2] | 1.33 | 0.014 | 0.48 | 0.250 | −0.24 | 0.716 | 0.03 | 0.963 |
| Maturation, *y* | 6.73 | 0.000 | −1.38 | 0.323 | 0.88 | 0.000 | 0.70 | 0.000 |
| Maturation sq. | −0.13 | 0.012 | 0.08 | 0.053 | — | — | — | — |
| Height at adolescence, *cm* | — | — | 0.49 | 0.000 | — | — | 0.42 | 0.000 |
| Adjusted R sq. | 0.65 | | 0.80 | | 0.19 | | 0.32 | |

[1] Supplement type: Atole = 1, Fresco = 0.
[2] Dietary intake: at or above gender specific median = 1, below gender specific median = 0.