LIFECOURSE EPIDEMIOLOGY

Maternal and childhood nutrition and later blood pressure levels in young Guatemalan adults

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Background Low birth weight and subsequent rapid child growth are associated with later blood pressure levels. The role of maternal and child nutrition in this association remains unclear.

Methods We studied 450 men and women (ages 21–29 years) born during a randomized trial of protein-energy supplementation (Atole) vs low energy/no protein supplementation (Fresco) in pregnancy and early childhood in four rural Guatemalan villages from 1969 to 1977.

Results Protein-energy supplementation was not associated with differences in blood pressure in adulthood (diastolic blood pressure (DBP): \( \beta = 0.69 \text{ mm Hg}, 95\% \text{ confidence interval (CI)} (-0.82\text{–}2.19); P = 0.37\); systolic blood pressure (SBP): \( \beta = 0.17 \text{ mm Hg}, 95\% \text{ CI} (-1.68\text{–}2.02); P = 0.86\)). Within the Atole group, maternal height was associated with later SBP (0.22 mm Hg/cm, 95\% CI (-0.002\text{–}0.45); \( P = 0.05\)). No other associations between maternal nutritional status, birth size, child growth, or supplement intake were observed for adult blood pressure.

Conclusions Our data do not support the role of maternal nutrition during pregnancy, birth weight, or early child growth in programming adult blood pressure. Likewise, we found no effect of protein-energy supplementation in pregnancy or in early childhood on blood pressure in young adults.

Keywords Blood pressure, birth weight, Guatemala, dietary supplement, maternal nutrition

It has been hypothesized that growth-related fetal events ‘program’ an individual’s blood pressure.1-2 Extensive epidemiological evaluation of this hypothesis has yielded conflicting results. While numerous studies have demonstrated an inverse relationship between birth weight and later blood pressure,2-5 others have found no significant relationship.6-9 Recently, Morley et al.10 have stressed the importance of looking beyond birth weight to more modifiable gestational exposures, such as maternal nutrition. Animal studies suggest a role for maternal nutrition in blood pressure programming.11-13 However, results from the Leningrad siege14 and the Dutch famine15 suggest that exposure to malnutrition in utero is not related to later blood pressure. In a more recent study, Huxley et al.16 found no association between biochemical measures of maternal nutritional status and offspring blood pressure in adulthood. However, increasing evidence suggests that composition of the maternal diet, and not absolute intakes, may be the critical factor in blood pressure programming. Adair et al.17 report an inverse association between blood pressure and the percentage of calories from fat and protein, while studies from Aberdeen18 and the Dutch famine19 suggest that the balance of protein and carbohydrates in the maternal diet during late gestation is associated with later blood pressure, independent of absolute intakes.

Post-natal nutritional deprivation and consequent growth failure in childhood may also contribute to programming of blood pressure. It is hypothesized that growth-related fetal events ‘program’ an individual’s blood pressure. However, results from various studies have yielded conflicting results. While numerous studies have demonstrated an inverse relationship between birth weight and later blood pressure, others have found no significant relationship. Recently, Morley et al. have stressed the importance of looking beyond birth weight to more modifiable gestational exposures, such as maternal nutrition. Animal studies suggest a role for maternal nutrition in blood pressure programming. However, results from the Leningrad siege and the Dutch famine suggest that exposure to malnutrition in utero is not related to later blood pressure. In a more recent study, Huxley et al. found no association between biochemical measures of maternal nutritional status and offspring blood pressure in adulthood. However, increasing evidence suggests that composition of the maternal diet, and not absolute intakes, may be the critical factor in blood pressure programming. Adair et al. report an inverse association between blood pressure and the percentage of calories from fat and protein, while studies from Aberdeen and the Dutch famine suggest that the balance of protein and carbohydrates in the maternal diet during late gestation is associated with later blood pressure, independent of absolute intakes.

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Post-natal nutritional deprivation and consequent growth failure in childhood may also contribute to programming of
blood pressure. Increased duration of breastfeeding and consumption of human milk compared with formula have been associated with reduced blood pressure in later childhood. However, the direct effect of specific macronutrients, such as energy and protein, consumed during early childhood on later blood pressure remains unclear. Stunting in early childhood was associated with later increased systolic blood pressure (SBP) in Jamaican children, and improved growth from birth to 2 years was associated with decreased odds for high blood pressure among Filipino boys who had been growth restricted at birth. However, a recent systematic review of 16 studies reported an overall positive association between increased skeletal and non-skeletal growth in childhood and increased later blood pressure.

Follow-up of a longitudinal intervention study of the effects of maternal and early childhood nutritional supplementation conducted in Guatemala affords a unique opportunity to investigate how maternal nutritional status, prenatal protein-energy supplementation of the mother, birth size, post-natal protein-energy supplementation of the child, and child growth influence later blood pressure levels in early adulthood. We hypothesized that protein-energy supplementation would reduce blood pressure in adulthood. We further hypothesized that poor maternal nutritional status and lower supplement intake during pregnancy would be associated with higher offspring adult blood pressure; that birth size would be inversely associated with adult blood pressure; and that greater growth and supplement intake in early childhood would be associated with lowered adult blood pressure.

Subjects and methods
Study population, field surveys and data collection
1969–77 study
The Instituto de Nutrición de Centro América y Panamá (INCAP) conducted a longitudinal study on growth and development between 1969 and 1977 in four villages of mixed Spanish—Mayan descent, located 40–110 km east of Guatemala City, Guatemala. Village residents were provided with either Atole, a dietary supplement containing protein (6.4 g/100 ml) and 3.80 MJ (900 kcal)/litre, or Fresco, which contained no protein and 1.35 MJ (330 kcal)/litre. Both supplements contained micronutrients in equal concentrations by volume. Villages were randomized within pairs. Supplement was available and consumed twice daily in a centrally located feeding hall in each village. Supplement intake to the nearest 10 ml was recorded for all pregnant and lactating women and their offspring up to the age of 7 years. INCAP also maintained medical services for each village. Detailed descriptions of the original study and subsequent follow-up surveys appear elsewhere.

1997–98 follow-up
Participants eligible for this follow-up were born between 1969 and 1977 and resided in one of the four original study villages or in Guatemala City at the time of follow-up (Figure 1). Of the 585 cohort members who could be traced to a known address and had birth weight measures (n = 585), 450 (77%; 225 men, 225 women) were examined. Reasons for non-examination included not being home on multiple visits (n = 36), serious handicap or chronic illness (n = 4), pregnancy or nursing of infants (n = 25), and refusal to participate (n = 70). Eligible participants differed from eligible non-participants and from ineligible members of the birth cohort with respect to birth weight and supplement group but not with respect to maternal weight, maternal post-partum body mass index (BMI), or socioeconomic status (SES) (Table 1). In the Fresco group only, significant differences in maternal height were observed between participants (148.8 ± 5.0 cm) and non-participants (ineligible members = 149.5 ± 5.2 cm; eligible non-participants = 149.0 ± 5.4 cm; P = 0.0009). Participants did not differ from non-participants with respect to supplement intake in early childhood regardless of supplement group (data not shown). However, within the Atole group, the mothers of eligible participants consumed more supplement during pregnancy (505.4 ± 405.0 kJ/day) than did the mothers of ineligible members (499.5 ± 441.8 kJ/day) or eligible non-participants (436.5 ± 333.2 kJ/day; P = 0.01). No such differences in maternal intake existed in those born in the Fresco villages. Institutional review boards at INCAP and Emory University approved the study protocol, and all participants provided written consent.

Three blood pressure measurements were taken at 3–5 min intervals with an oscillometric digital sphygmomanometer (Model UA-767; A&D Medical, Milpitas, CA). These instruments are unbiased and highly concordant with manual
Our data consist of individuals clustered within families. Failure to control for the resulting correlation could lead to incorrect inferences.\textsuperscript{32,33} Therefore, we used a generalized estimating equations (GEE) approach (implemented in SAS procedure GENMOD), with an exchangeable working matrix, to control for the correlation in our data while evaluating the relationship between blood pressure and the exposure variables. Main effects were considered significant at $P < 0.05$.

### Results

Obesity (BMI $\geq$ 30 kg/m$^2$) was uncommon (\(<1\%\)) among the mothers of cohort members, while 7% were overweight (25 kg/m$^2$ $\leq$ BMI $< 30$ kg/m$^2$) (Table 2). As children, 6% of the study subjects had birth weights of $\leq$2500 g, and 67% were stunted (HAZ-24 $\leq$ -2.0) at 24 months of age. At follow-up

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**Table 1** Comparison of participants and non-participants in a cardiovascular disease risk follow-up study from 1997 to 1998 on selected maternal and early childhood characteristics

<table>
<thead>
<tr>
<th></th>
<th>Ineligible ($n = 391$)</th>
<th>Eligible but not studied ($n = 467$)</th>
<th>Studied ($n = 450$)</th>
<th>$P$-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal height</td>
<td>149.0 ± 5.1 (347)</td>
<td>148.6 ± 5.4 (426)</td>
<td>149.5 ±5.1 (446)</td>
<td>0.07</td>
</tr>
<tr>
<td>Maternal weight</td>
<td>46.9 ± 4.9 (76)</td>
<td>45.9 ± 6.8 (81)</td>
<td>47.0 ±6.3 (131)</td>
<td>0.40</td>
</tr>
<tr>
<td>Maternal BMI</td>
<td>20.9 ± 2.1 (76)</td>
<td>20.9 ± 2.2 (81)</td>
<td>20.9 ± 2.6 (131)</td>
<td>0.99</td>
</tr>
<tr>
<td>Supplement group</td>
<td>57.0 (391)</td>
<td>47.8 (467)</td>
<td>50.7 (450)</td>
<td>0.02</td>
</tr>
<tr>
<td>Birth weight</td>
<td>3.0 ± 0.5 (271)</td>
<td>3.0 ± 0.5 (246)</td>
<td>3.1 ± 0.5 (450)</td>
<td>0.0003</td>
</tr>
<tr>
<td>SES in 1975</td>
<td>$-0.23 ± 1.5$ (326)</td>
<td>$-0.2 ± 1.6$ (439)</td>
<td>$-0.3 ± 1.5$ (447)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Participants and non-participants were born between 1969 and 1977 in one of four villages in eastern Guatemala and participated in the INCAP Longitudinal Study.\textsuperscript{2}

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sphygmomanometers.\textsuperscript{26} The first measurement was taken after 5 min of seated rest. The mean of the last two measurements was used for analysis. In nine cases in which the second and third measures did not coincide within 10 mm Hg, a fourth measurement was taken and the mean of the two closest values was used for analysis. Standardized anthropometry was used to measure height, weight, and waist and hip circumferences. BMI and waist-to-hip ratio (WHR) were then calculated. Diet,\textsuperscript{27} customary physical activity level during the past 12 months,\textsuperscript{28} and other relevant covariates were ascertained by standardized interview. Current place of residence was characterized as rural or urban. The data collection methods are described more fully elsewhere.\textsuperscript{9,29,30}

### Variable definitions

Supplement group was either Atole or Fresco and we report supplement intake in energy units (kJ/day). Maternal supplement intake is defined as the mean daily energy intake of supplement by the mother from the time pregnancy was identified to birth. Post-natal supplement intake is defined as the average daily energy intake from supplement by the infant/child from birth to 24 months of age.

Indicators of maternal nutritional status included maternal height, pregnancy weight gain, and non-pregnant BMI. Pregnancy weight gain was calculated as the mean weight gain per month, over the period from month four to birth. Non-pregnant BMI was calculated using maternal weight $\geq 5.5$ months post-partum.

Infant and childhood nutritional status indicators included birth size (weight, length, and ponderal index) and length at 24 months. Ponderal index was calculated as weight (kg)/length (m$^3$). Height-for-age z-scores (HAZ) at birth and 24 months (HAZ-24) were derived from the 2000 National Center for Health Statistics (Bethesda, MD) reference data. In this cohort, HAZ scores stabilized around 12 months of age.\textsuperscript{25} If length was not measured at 24 months, we used linear interpolation to compute HAZ-24 using the two nearest measurements. If surrounding measurements within 1 year were not available then HAZ-24 was set to missing. Early childhood growth was calculated as the change in HAZ scores from birth to 24 months.

### Exclusions and missing data

Blood pressure measurements were available for all participants. We imputed missing values for continuous covariate variables using a multiple imputation approach.\textsuperscript{31} We repeated this procedure 15 times for each missing variable resulting in 15 unique datasets. The resulting estimates and standard errors were pooled using SAS PROC MIANALYZE. No categorical variables used in this analysis required imputation.

### Statistical methods

Statistical analyses were conducted using SAS (version 8, Cary, NC). We separately tested the following main effect associations on blood pressure: supplement group (Atole vs Fresco), maternal nutritional status (non-pregnant BMI, height, and pregnancy weight gain), intake of prenatal supplement, birth size (weight, length, and ponderal index), intake of post-natal supplement from birth to 24 months, and child growth from birth to 24 months. All analyses, other than the test of Atole vs Fresco, were stratified by supplement group. All models were adjusted for sex, adult anthropometry (BMI, WHR), SES at birth, current residence (urban vs rural), attained education, current physical activity level, age at follow-up, smoking status (yes/no), and alcohol consumption (yes/no). Exclusion of adult BMI and WHR did not alter our inferences. Both prenatal energy intake by the mother and post-natal energy intake by the child were included in models to separate the potential associations derived from these different sources of supplementation. Models were additionally adjusted for adult height, which might be in the causal pathway between child size and adult blood pressure. Parameter estimates and standard errors did not differ between models containing height and those without, therefore the results for the more parsimonious model are presented.

Our data consist of individuals clustered within families. Failure to control for the resulting correlation could lead to incorrect inferences.\textsuperscript{32,33} Therefore, we used a generalized estimating equations (GEE) approach (implemented in SAS procedure GENMOD), with an exchangeable working matrix, to control for the correlation in our data while evaluating the relationship between blood pressure and the exposure variables. Main effects were considered significant at $P < 0.05$. 

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(age, 20–29 years) none of the study participants had SBP > 140 mm Hg and/or diastolic blood pressure (DBP) > 90 mm Hg. Obesity was present in < 2% of men and 9% of women, with an additional 8% of men and 20% of women already overweight. Central obesity (WHR > 0.90 for men and WHR > 0.85 for women) was present in 20% of men and 17% of women. HAZ-24 were strongly associated with adult height (men $r = 0.66$; women $r = 0.60$; both $P < 0.0001$). Cohort members in the Atole group were significantly taller than their Fresco counterparts at the time of the 1997–98 follow-up (159.2 cm vs 157.0 cm; $P = 0.007$) and had taller mothers (150.0 cm vs 148.9 cm; $P = 0.007$) who had consumed more energy from prenatal supplement (483.3 kJ/day vs 371.7 kJ/day; $P = 0.001$). Additionally, participants born in the Atole villages had greater birth weight (3.17 kg vs 3.03 kg; $P = 0.002$), ponderal indices (25.3 vs 24.3; $P = 0.005$), and HAZ-24 ($-2.08$ vs $-2.51$; $P < 0.001$), and had consumed more energy from supplement than their Fresco counterparts (449.5 kJ/day vs 40.9 kJ/day; $P < 0.001$). Study participants did not differ by supplement group with respect to maternal BMI, weight gain in pregnancy, birth length, adult BMI, or WHR ($P > 0.05$ for all comparisons).

### Supplement group

There was no independent effect of supplement by supplement group (Atole vs Fresco) on either DBP or SBP (DBP: $\beta = 0.69$ mm Hg, 95% confidence interval (CI) ($-0.82$–$2.19$); $P = 0.37$; SBP: $\beta = 0.17$ mm Hg, 95% CI ($-1.68$–$2.02$); $P = 0.86$).

### Maternal nutritional status and prenatal supplementation

Weak inverse associations were observed for pregnancy weight gain and later blood pressure in both the Atole and the Fresco groups, though none reached statistical significance (Table 3). In the Atole group only, maternal height was positively associated with adult SBP ($0.22$ mm Hg/cm, 95% CI ($0.002$–$0.45$); $P = 0.05$). No other associations between maternal nutritional status or intake of prenatal supplement and later blood pressure were observed.

### Birth measures

No statistically significant estimates of association were observed between birth weight and blood pressure in either supplement group. There were no statistically significant

### Table 2 Selected characteristics of mothers and their children from four villages in eastern Guatemala who participated in the INCAP Longitudinal Study from 1969 to 1977 and were followed-up in 1997–1998

<table>
<thead>
<tr>
<th></th>
<th>Women Born in Atole villages</th>
<th>Women Born in Fresco villages</th>
<th>Men Born in Atole villages</th>
<th>Men Born in Fresco villages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>Mean ± SD or %</td>
<td>$n$</td>
<td>Mean ± SD or %</td>
</tr>
<tr>
<td>Maternal and early childhood characteristics measured during the 1969–77 INCAP study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal height (cm)</td>
<td>106</td>
<td>$150.7 ± 5.4$</td>
<td>110</td>
<td>$148.5 ± 4.6$</td>
</tr>
<tr>
<td>Average pregnancy weight gain (kg/month)</td>
<td>67</td>
<td>$1.5 ± 0.7$</td>
<td>61</td>
<td>$1.5 ± 0.7$</td>
</tr>
<tr>
<td>Post-partum BMI (kg/m$^2$)</td>
<td>77</td>
<td>$21.8 ± 2.8$</td>
<td>83</td>
<td>$21.2 ± 2.7$</td>
</tr>
<tr>
<td>Energy intake from supplement during pregnancy (kJ/day)</td>
<td>109</td>
<td>$500.3 ± 385.1$</td>
<td>116</td>
<td>$332.3 ± 258.3$</td>
</tr>
<tr>
<td>Birth weight (kg)</td>
<td>109</td>
<td>$3.1 ± 0.4$</td>
<td>116</td>
<td>$3.0 ± 0.4$</td>
</tr>
<tr>
<td>Birth length (cm)</td>
<td>100</td>
<td>$148.5 ± 4.6$</td>
<td>92</td>
<td>$149.2 ± 5.4$</td>
</tr>
<tr>
<td>Ponderal Index (kg/m$^3$)</td>
<td>100</td>
<td>$25.3 ± 2.9$</td>
<td>92</td>
<td>$24.9 ± 3.0$</td>
</tr>
<tr>
<td>HAZ-24</td>
<td>95</td>
<td>$-2.1 ± 0.8$</td>
<td>97</td>
<td>$-2.5 ± 1.1$</td>
</tr>
<tr>
<td>Energy intake from supplement during 0–2 years (kJ/day)</td>
<td>86</td>
<td>$399.5 ± 290.3$</td>
<td>84</td>
<td>$415.2 ± 42.0$</td>
</tr>
<tr>
<td>Socioeconomic score at birth</td>
<td>101</td>
<td>$-0.06 ± 0.8$</td>
<td>107</td>
<td>$-0.02 ± 0.9$</td>
</tr>
<tr>
<td>Adult characteristics measured during the 1997–98 CVD study</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>109</td>
<td>$103.2 ± 9.2$</td>
<td>116</td>
<td>$103.7 ± 11.4$</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>109</td>
<td>$65.6 ± 7.7$</td>
<td>116</td>
<td>$64.6 ± 8.0$</td>
</tr>
<tr>
<td>Age (years)</td>
<td>106</td>
<td>$24.4 ± 2.2$</td>
<td>116</td>
<td>$24.2 ± 2.3$</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>105</td>
<td>$23.4 ± 3.7$</td>
<td>115</td>
<td>$23.9 ± 4.7$</td>
</tr>
<tr>
<td>WHR</td>
<td>103</td>
<td>$0.8 ± 0.1$</td>
<td>113</td>
<td>$0.8 ± 0.1$</td>
</tr>
<tr>
<td>Adult height (cm)</td>
<td>116</td>
<td>$165 ± 6.8$</td>
<td>105</td>
<td>$153.0 ± 5.4$</td>
</tr>
<tr>
<td>Physical activity level (METS/day)</td>
<td>119</td>
<td>$1.65 ± 0.3$</td>
<td>109</td>
<td>$1.5 ± 0.1$</td>
</tr>
<tr>
<td>Residence (% urban)</td>
<td>117</td>
<td>$22.0$</td>
<td>116</td>
<td>$15.5$</td>
</tr>
<tr>
<td>Smoker (% currently smoke)</td>
<td>109</td>
<td>$0.0$</td>
<td>116</td>
<td>$0.9$</td>
</tr>
<tr>
<td>Alcohol (% that drink)</td>
<td>106</td>
<td>$3.8$</td>
<td>113</td>
<td>$0.0$</td>
</tr>
</tbody>
</table>
associations observed between ponderal index or birth length and later blood pressure (Table 4).

**Child nutrition and growth**

Supplement intake from birth to 24 months was not significantly associated with SBP or DBP in either the Atole or Fresco groups (Table 4). Similarly, there were no significant associations of early child growth with adult blood pressure in either the Atole or Fresco supplement group.

**Discussion**

This study, carried out in the context of a randomized controlled supplementation trial, is one of the few studies with sufficient exposure data available to evaluate the impact of maternal and early childhood nutritional supplementation and specific nutritional components on later adult blood pressure. The study design did not permit full differentiation of the effect of protein and energy. We found no significant associations between balanced protein-energy supplementation in pregnancy and early childhood...
and later blood pressure. In contrast to many studies, we found no overall inverse associations between birth size and later blood pressure supporting earlier work in this population.9 These findings are consistent with results observed among survivors of the Leningrad Siege14 and more recently from a study of adults in the United Kingdom.16 We observed a positive, borderline significant association between maternal height and offspring SBP in the Atole group. A similar relationship was not observed among those born in the Fresno villages. We are unable to explain this relationship and given the large number of models tested in this study (40) we would expect two to be significant by chance alone.

A positive association between growth in early childhood and later blood pressure has been reported4 but whether the effect of post-natal growth is independent of birth weight remains unclear. Birth weight was neither an effect modifier nor a confounder of the relationship between stature at 24 months and blood pressure in this population (data not shown). We did not evaluate the effect of growth after the age of 2 years as it is not considered a period of growth failure and average growth rates after 24 months were within international norms in this population and the original cohort.34 Furthermore, in this chronically undernourished population, few children reached the normal referent for HAZ scores at the age of 2 years; therefore, our results may not be applicable to those who are born small, grow rapidly and reach or exceed the normal HAZ referent. Rather, we are observing a population that is undernourished and, with protein-energy supplementation, experiences less severe growth faltering over time.

Balanced protein-energy supplementation improves birth weight35,36 and birth weight is inversely associated with later blood pressure in several studies.2,4,5,37–40 A potential role for maternal protein deficiency in the fetal programming of blood pressure has been identified in animal studies. The offspring of rat dams fed low protein diets (6–9%) exhibit hypertension41–43 and altered renal and endocrine physiology.13,43,44 Likewise, in humans, increased protein:carbohydrate dietary ratios in pregnancy are associated with reduced blood pressure.18,19 Our data do not offer support for an independent effect of balanced protein-energy supplementation during pregnancy or for larger birth size in the programming of later blood pressure in communities where the nutrition transition is occurring. A recent US study failed to observe an association between first and second trimester protein intake and infant blood pressure.42 though protein intake did not fall below the WHO recommendation of 51 g/kg-day for pregnant women. It is possible that a protein effect may be observed only at the lowest ends of the intake.

Our study was conducted in the context of a community-randomized supplementation trial. The unit of randomization was at the village level, limiting power to infer causal associations and analysis within supplement group must be considered observational. With sample sizes of ≥200 in each supplement group, we had 85% power to detect a two-tailed effect size of ≥0.30 at P < 0.05 equivalent to 3 and 2 mm Hg for SBP and DBP, respectively.46 The subset of individuals included in this analysis differs from the complete cohort on several measures. For example, the mothers of the current subset differ in height by supplement group (Table 1), while no such difference exists in the original cohort (Atole = 149.1 ± 5.3 cm; Fresco = 149.0 ± 5.2 cm; P = 0.91). To the extent that these differences are correlated with measured variables they are controlled for in our models. Significant differences in birth weight, supplement group, and maternal supplement intake in the Atole villages were observed between participants and non-participants. As such, potential bias could explain the null effects.

This cohort consists of relatively young, healthy adults whose blood pressure levels were all within the normal range. Nevertheless, given the typical increase in blood pressure with age, detection of individuals at the upper end of the distribution and identification of predictors of prevalence of higher levels of blood pressure, even within normal ranges, are valuable. In conclusion, our study fails to support a role for birth size, early child growth, or protein-energy supplementation in the programming of blood pressure in young, healthy adults.

Acknowledgements
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KEY MESSAGES

- Birth weight has been inversely associated with later blood pressure in numerous studies and protein-energy supplementation in pregnancy is associated with small increases in birth weight.
- In a population of young Guatemalan adults, balanced protein-energy supplementation in pregnancy and early childhood was not associated with later blood pressure.
- Neither birth weight nor growth in early childhood was associated with later blood pressure in young Guatemalan adults.

References


