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Weight Gain in the First Two Years of Life Is an Important Predictor of Schooling Outcomes in Pooled Analyses from Five Birth Cohorts from Low- and Middle-Income Countries[1,2]

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Abstract

Schooling predicts better reproductive outcomes, better long-term health, and increased lifetime earnings. We used data from 5 cohorts (Brazil, Guatemala, India, the Philippines, and South Africa) to explore the relative importance of birthweight and postnatal weight gain for schooling in pooled analyses (n = 7945) that used appropriate statistical methods [conditional weight (CW) gain measures that are uncorrelated with prior weights] and controlled for confounding. One SD increase in birthweight, ~0.5 kg, was associated with 0.21 y more schooling and 8% decreased risk of grade failure. One SD increase in CW gain between 0 and 2 y, ~0.7 kg, was associated with higher estimates, 0.43 y more schooling, and 12% decreased risk of failure. One SD increase of CW gain between 2 and 4 y, ~0.9 kg, was associated with only 0.07 y more schooling but not with failure. Also, in children born in the lowest tertile of birthweight, 1 SD increase of CW between 0 and 2 y was associated with 0.52 y more schooling compared with 0.30 y in those in the upper tertile. Relationships with age at school entry were inconsistent. In conclusion, weight gain during the first 2 y of life had the strongest associations with schooling followed by birthweight; weight gain between 2 and 4 y had little relationship to schooling. Catch-up growth in smaller babies benefited schooling. Nutrition interventions aimed at women and children under 2 y are among the key strategies for achieving the millennium development goal of universal primary education by 2015. J. Nutr. 140: 348–354, 2010.

Introduction

Low birthweight and stunting in early childhood are associated with diminished adult human capital, including poorer cognitive development, behavioral problems, and lower schooling attainment, even after controlling for confounding factors such as parental schooling and socioeconomic status

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(SES)[12] (1–5). Years of schooling predict earnings (6). The average rate of return to income of another year of schooling is 10%. Returns are highest for Latin America and the Caribbean (12.0%) and sub-Saharan Africa (11.7%); the value for Asia is 9.9%. Maternal schooling is also important for child health and nutrition (7,8) and schooling brings long-term health benefits to individuals (9,10). For these reasons, achieving universal primary education by 2015, one of the millennium development goals, is important (11).

Few studies have investigated the relative importance of prenatal compared with postnatal growth for psycho-educational outcomes and even fewer have done so using appropriate statistical methods. Studies have focused on cognitive development or achievement tests (12–16) and few have dealt with schooling outcomes (17). Studies are particularly needed from low- and middle-income countries (LMIC), where the importance of establishing these relationships for policies and programs is greater due to high rates of growth failure and low schooling.

We used data from 5 well-described birth cohort studies in LMIC (1) to study the relative importance of birthweight and weight gain during 0–24 mo and 24–48 mo for highest grade attained, ever failed a grade, and age at school entry. Growth failure in LMIC is substantial during intrauterine life and the first 2 y of life; conversely, rates of growth after 2 y of age are generally similar to those found in the WHO reference population (18). Thus, we expected birthweight and weight gain from 0 to 24 mo to be more strongly associated with schooling outcomes than growth from 24 to 48 mo. We used statistical methods that account for interrelationships in growth during various periods of life to properly assess relative importance. We also controlled for maternal schooling and SES at birth.

Participants and Methods

Study populations. We used data from 5 cohorts participating in the Consortium on Health Orientated Research in Transitional Societies (COHORTS) (1): the 1982 Pelotas (Brazil) Birth Cohort (19); the Institute of Nutrition of Central America and Panama Nutrition Trial Cohort (INTC; Guatemala) (20); the New Delhi (India) Study (21,22); the Cebu Longitudinal Health and Nutrition Survey (CLHNS; Cebu, Philippines) (23), and the Birth to Twenty (Bt20; South Africa) cohort (24) (**Table 1**). For convenience, we refer to these studies below as Pelotas, Guatemala, New Delhi, Cebu, and Bt20. All studies were reviewed and approved by an appropriate ethics committee or institutional review board.

Outcome variables. The outcomes were highest grade attained (y), ever failed a grade (yes/no), and age at formal school entry (y). Pelotas, Guatemala, and Cebu contributed data for all schooling outcomes. Most Bt20 participants were still in school and for this reason we did not conduct an analysis for highest grade attained for this site. Only highest grade attained was available for New Delhi. Ever failed was defined as failing (or being retained for) 1 or more grades and was coded as ever failed = 1, never failed = 0.

Growth variables. Weight measures were available for all sites; birth length was not available for Pelotas and Bt20. For this reason, weight was used as the key exposure. Birthweight (kg) was measured by the research teams in Pelotas, New Delhi, and Guatemala. In Cebu, birthweight was measured by birth attendants who had been provided with mechanical scales for home births (60%) or obtained from hospital records for the remainder. For Bt20, weight was obtained from birth records assessed for reliability (25). Weight and length (all but Bt20) or height (Bt20) were obtained at 24 mo. Mid-childhood weight was measured at 48 mo in Pelotas, New Delhi, and Guatemala, at 60 mo for Bt20, and at 102 mo in Cebu. All measurements were converted into Z-scores (weight-for-age, height-for-age) using the WHO Growth Standards (26). To make mid-childhood weight comparable across sites, we imputed 48-mo Z-scores for Bt20 and Cebu participants, assuming a linear change in Z-score from 24 to 60 or 102 mo, respectively, and back-transformed the resulting Z-scores into weight (in kg). Stunting was defined as height-for-age Z-score <2.

Conditional weights. To eliminate statistical problems associated with modeling highly correlated weight measures, we used conditional weight (CW) variables to represent weight at a given age, independent of weight at earlier ages (27,28). CW is the residual derived by regressing weight in kg at each age on weight at birth and on any weight at prior ages and thus represents a child's deviation from his or her expected weight in the context of typical growth in the population. For example, the residual for CW at 48 mo was obtained by regressing weight at 48 mo on birthweight and weight at 24 mo. CW variables at 24 and 48 mo can be interpreted as weight gain in the period 0–24 and 24–48 mo, respectively, that is unexplained by prior weight measures. Models were site- and sex-specific, included age at measurement, and accounted for nonlinear relationships by including squared prior weight.

Covariates. Analyses included age at last follow-up, sex, whether the participant was still in school, SES near birth (5 categories), and years of maternal schooling (or paternal schooling in India). SES was represented by family income (Pelotas), father's occupation (New Delhi), or ownership of various household assets (elsewhere). A SES score was created for each site and study participants were allocated to 1 of 5 categories. The lowest group (SES 1) was designated as the reference category in regression analyses and 4 dummy variables were created to represent SES 2–5, respectively. More participants in India had schooling information for fathers than for mothers; the 2 variables were correlated ($r = 0.6$; $P < 0.0001$) and among participants with information for both, results were similar when using one or the other. For this reason, father's schooling was used in India as a proxy of maternal schooling. Site-specific variables considered as potential confounders included: race/ethnicity for Pelotas and Bt20, urban-rural residence for Cebu, and village of birth for Guatemala (to control for village size and nutrition intervention study design). However, key relationships were not affected by site-specific variables and, consequently, these variables were omitted.

Missing covariates (0.2% for SES, 1.0% for maternal schooling) were handled by adding a dummy variable to the model, coded 1 if missing and 0 otherwise, and recoding the missing values to the site-specific means for SES and maternal schooling. We tested for systematic bias due to the inclusion of individuals with 1 or more missing values by running all models on a data set that included only complete records and found that the differences between full and restricted models were trivial.

Analyses. The analyses included 7945 participants with information on birthweight, weight at 24 and 48 mo, any of 3 schooling outcomes, and length or height at 24 mo. Sample sizes were 7025, 6287, and 4668 for highest grade attained, ever failed a grade, and age at school entry, respectively.

The key objective was to assess the relative importance of birthweight and weight gain from 0 to 24 mo and 24 to 48 mo for schooling outcomes. We also explored the relationship between stunting at 24 mo, a widely used summary measure of growth failure, and schooling. For the former analyses, we used standardized measures (in Z-score units) of birthweight (ZBWT) and CW at 24 (ZCW0–24) and 48 mo (ZCW24–48) as the growth variables; these variables, by design, are uncorrelated

[12] Abbreviations used: Bt20, Birth to Twenty; CLHNS, Cebu Longitudinal Health and Nutrition Survey; COHORTS, Consortium on Health Oriented Research in Transitional Societies; CW, conditional weight; INTC, Institute of Nutrition of Central America and Panama Nutrition Trial Cohort; LMIC, low- and middle-income countries; SES, socioeconomic status; ZBWT, Z-score units of birthweight; ZCW0–24, Z-score units of conditional weight from 0 to 24 mo; ZCW24–48, Z-score units of conditional weight from 24 to 48 mo.

TABLE 1 Characteristics of the COHORTS Studies

Study	Design	Cohort recruitment	Age at recruitment	Initial sample	Age at last visit, *y*	Examined in the last visit, *n*	Comments
Pelotas Birth Cohort, Brazil	Prospective cohort	1982	Birth	5914	21–23	4297	Enrolled all children born in the city's maternity hospitals (>99% of all births) during 1982.
INTCS, Guatemala	Community trial	1969–1977	Birth–7 y	2392	26–41	1571	Intervention trial of a high-energy and protein supplement. All children < 7 y in 1969 and all born 1969–1977 were enrolled and followed until age 7 or until the study ended in 1977.
New Delhi Birth Cohort Study, India	Prospective cohort	1969–1972	Before pregnancy	8181	26–32	1583	Pregnancies were identified in a population of married women living in a defined area of New Delhi, and the newborns were enrolled and followed. Primarily a middle-class sample.
CLHNS, Cebu Philippines	Prospective cohort	1983–1984	Gestation	3080	21.4	2032	Pregnant women living in 33 randomly selected neighborhoods; 75% urban. First data collection at 30 wk gestation. All social classes included.
Bt20 cohort, Soweto-Johannesburg, South Africa	Prospective cohort	1990	Gestation	3273	15	2100	Pregnant women with a gestational age of 26–32 wk living in a delimited urban geographical area. Predominantly poor, black sample.

with each other. We estimated linear (highest grade attained and age at school entry) or logistic (ever failed) regression models. Because our growth variables were expressed in Z-score units, coefficients and CI for them could be compared to assess relative importance. We developed 2 models. The first model is similar to that used in previous studies and used stunting at 24 mo as the key exposure. In model 2, we included ZBWT, ZCW0–24, and ZCW24–48; because the coefficients for ZBWT were unaffected by CW variables, they could be compared with those in the literature concerning birthweight alone. In a basic specification of models 1 and 2, we adjusted for sex and site. In fully adjusted models, we incorporated SES and maternal schooling. We tested for interactions in model 2 to explore if relationships between ZCW0–24 and ZCW24–48 and schooling outcomes differed by birthweight. Tertiles of ZBWT were based on the distribution: low (<33.3%), medium 33.3–66.7%, and high (≥66.7%).

We tested for heterogeneity by sex and site. We found no evidence of heterogeneity for highest grade attained and ever failed and thus undertook pooled analyses. There was significant heterogeneity by site but not sex for age at school entry and thus these analyses were pooled by sex and stratified by site.

We used PROC REG and PROC LOGISTIC in SAS version 9.1 (29) to conduct the analyses. We present coefficients with 95% CI and *P*-values. Significance was declared when $P < 0.05$.

Results

Participants were youngest in Bt20, 15.6 y old, followed by Pelotas and Cebu (~21–22 y) and then New Delhi and Guatemala (~29–31 y) (**Table 2**). There were important differences in child size across sites. Mean birthweights ranged from 2.8 kg in New Delhi to 3.2 kg in Pelotas. At 4 y, participants from Guatemala, Cebu, and New Delhi were the lightest and shortest and those from Bt20 the largest. At follow-up, Bt20 participants were 2.8 kg heavier than those from Cebu and 7.3 cm taller than those from Guatemala. The extent of stunting at 2 y varied widely, from 86% in Guatemala to 12% in Pelotas.

Schooling varied markedly across sites. Maternal schooling was lowest in Guatemala and highest in Bt20 and New Delhi. Most participants in Bt20 were in school and had ~9 y of schooling at last contact. Whereas 43% were still in school in Pelotas, most in the remaining sites had completed formal schooling at follow-up. Levels of schooling were highest for New Delhi (13.5 y) and lowest for Guatemala (5.0 y). Grade failure was 69% in Pelotas, 47% in Guatemala and Cebu, and 30% in Bt20. Age at school entry was around 6.7 y in Pelotas, Guatemala, and Bt20 and 7.2 y in Cebu.

Stunting was associated with a reduction in schooling of 1.8 and 0.9 y before and after controlling for confounding, respectively (**Table 3**). In model 2, where ZBWT and the 2 conditional variables were included, we found a significant relationship with all 3 variables, but this was strongest for ZCW0–24 and weakest for ZWC24–48. Controlling for SES and maternal schooling reduced the coefficients by about one-half, but results remained significant. In fully adjusted models, 1 Z-score of birthweight, ZCW0–24, and ZCW24–48 were associated with 0.21, 0.43, and 0.07 y more schooling, respectively. Relationships with maternal schooling and SES were robust and in the expected direction (not shown).We found a significant interaction between ZBWT and ZCW0–24 (P = 0.002) but not between ZBWT and ZCW24–48 (P = 0.90) in analyses of highest grade attained. In fully adjusted models, the relationship between ZCW0–24 and highest grade attained varied across tertiles of birthweight, with coefficients as follows: 0.50 (CI 0.38, 0.62), 0.47 (CI 0.35, 0.58), and 0.33 (CI 0.22, 0.43), respectively, for tertiles 1, 2, and 3.

Stunting at 24 mo was a significant predictor of grade failure (**Table 4**). Stunting increased the odds by 50 and 16% before and after controlling for confounding, respectively. In fully adjusted models, 1 Z-score decreased the odds of failure by 8% for ZBWT and by 12% for ZCW0–24; the relationship with ZCW24–48 was not significant. Interactions between ZBWT and either of the 2 conditional variables were not significant. Adjustment for

TABLE 2 Selected characteristics of participants included in the analyses by study site[1]

Variables	Pelotas, Brazil	INTC, Guatemala	New Delhi, India	CLHNS, Cebu, Philippines	Bt20 South Africa
Male, %	52.6 (3793)	54.9 (268)	58.9 (1271)	52.9 (2065)	50.9 (548)
Female, %	47.4 (3793)	45.1 (268)	41.1 (1271)	47.1 (2065)	49.1 (548)
Age at follow-up, *y*	22.7 ± 0.4 (3602)	31.4 ± 1.3 (268)	29.2 ± 1.4 (1271)	21.2 ± 0.9 (1864)	15.6 ± 0.3 (531)
Small for gestational age, %	14.5 (3046)	31.1 (251)	39.9 (1158)	23.8 (2055)	13.9 (540)
Stunted 24 mo, %	11.7 (3793)	85.8 (268)	46.8 (1271)	67.5 (2065)	27.4 (548)
Weight, *kg*					
Birth	3.2 ± 0.5 (3793)	3.0 ± 0.5 (268)	2.8 ± 0.4 (1271)	3.0 ± 0.4 (2065)	3.1 ± 0.5 (548)
24 mo	11.1 ± 1.6 (3793)	9.7 ± 1.1 (268)	10.1 ± 1.3 (1271)	9.8 ± 1.2 (2065)	11.4 ± 1.7 (548)
48 mo	15.6 ± 2.3 (3793)	13.6 ± 1.5 (268)	13.7 ± 1.6 (1271)	13.1 ± 1.7 (2065)	15.9 ± 1.8 (548)
Length/height, *cm*					
Birth	N/A[2]	49.2 ± 2.4 (197)	48.6 ± 2.1 (1247)	49.1 ± 2.0 (2064)	N/A
24 mo	80.8 ± 4.9 (3793)	76.5 ± 3.7 (268)	80.5 ± 3.7 (1271)	79.3 ± 3.5 (2065)	83.0 ± 3.9 (548)
48 mo	97.5 ± 5.1 (3790)	93.0 ± 4.1 (268)	94.8 ± 4.3 (1269)	93.1 ± 3.9 (2065)	100.3 ± 3.7 (548)
In school, %	43.0 (3602)	0.0 (268)	0.0 (1271)	0.0 (2065)	100.0 (548)
Highest grade attained, *y*	9.5 ± 3.1 (3602)	5.0 ± 3.5 (268)	13.5 ± 3.3 (1271)	10.8 ± 3.2 (1884)	9.0 ± 0.9 (547)
Age at school entry, *y*	6.6 ± 0.7 (1807)	6.7 ± 1.0 (253)	N/A	7.2 ± 0.6 (2060)	6.7 ± 0.8 (548)
Ever failed, %	69.3 (3594)	46.6 (253)	N/A	46.7 (1886)	29.9 (548)
Maternal schooling, *y*	6.6 ± 4.2 (3788)	1.3 ± 1.5 (266)	10.8 ± 4.9 (1192)	7.4 ± 3.7 (2065)	9.9 ± 2.3 (548)
SES categories, %	100 (3779)	100 (266)	100 (1271)	100 (2065)	100 (548)
1 (poorest)	19.1	24.8	1.7	22.2	21.2
2	49.4	25.2	9.9	17.4	20.1
3	19.8	17.7	21.9	19.9	29.2
4	6.2	18.8	50.0	20.6	20.6
5 (richest)	5.5	13.5	16.5	19.9	8.9

[1] Values are means ± SD (*n*) or percent (*n*).
[2] N/A, Not available.

maternal schooling and SES attenuated relationships between growth and grade failure appreciably (model 2).

There were significant interactions between child growth and site in analyses for age at school entry; hence, stratified analyses were conducted (**Table 5**). There was considerable heterogeneity in the results, although all significant relationships indicated an association between faster weight gain and younger age at enrollment. In the adjusted analyses, there were no significant associations with any variable in Guatemala. Stunting was associated with an older age at enrollment in Pelotas, Cebu, and Bt20, with the largest coefficient, 0.32 y, for Pelotas. One Z-score for ZBWT was associated with a decrease in age at enrollment of about 0.08 y in Pelotas and Cebu. ZCW0–24 was associated with younger enrollment ages in Pelotas and Cebu and relationships with ZCW24–48 were in the same direction and significant for Cebu and Bt20.

Discussion

In this article, we assess the relative importance of birthweight and weight gain between 0 and 24 and 24 and 48 mo for schooling outcomes. Other than an analysis of attained schooling in Pelotas (17), we are not aware of other work addressing the topic. We found that weight gain from 0 to 24 mo had the strongest relationships with schooling outcomes followed by birthweight; weight gain from 24 to 48 mo had a weak or no relationship to schooling outcomes. The magnitudes of the relationships are of economic and public health importance. In fully adjusted models, stunting at 2 y, a widely used cumulative indicator of undernutrition during fetal and postnatal life, was associated with a reduction in schooling of 0.9 y, with a 16% increased risk of failing at least 1 grade in school and with older ages at enrollment in 3 of the sites. Given the estimate of 0.9 y of

TABLE 3 Coefficients from linear regression models of highest grade attained (y) according to stunting at 24 mo, standardized birthweight, and standardized CW gain from birth to 24 and from 24 to 48 mo (*n* = 7025)

	Basic[1]			Adjusted[2]		
	Coefficient	*P*-value	95% CI	Coefficient	*P*-value	95% CI
Model 1						
Stunted at 24 mo (1 = yes, 0 = no)	−1.84	<0.0001	−2.02, −1.66	−0.92	<0.0001	−1.08, −0.76
Model 2						
ZBWT	0.36	<0.0001	0.29, 0.44	0.22	<0.0001	0.15, 0.28
ZCW0–24	0.86	<0.0001	0.79, 0.93	0.43	<0.0001	0.37, 0.50
ZCW24–48	0.18	<0.0001	0.11, 0.26	0.07	0.04	0.00, 0.13

[1] Adjusted for site and sex.
[2] Adjusted for site, sex, SES, maternal schooling, and whether participant is still attending school.

TABLE 4 Odds ratio for ever failed (1 = yes, 0 = no) according to stunting at 24 mo, standardized birthweight, and standardized, CW gain from birth to 24 mo and from 24 to 48 mo (n = 6281)

	Basic[1]			Adjusted[2]		
	Odds ratio	*P*-value	95% CI	Odds ratio	*P*-value	95% CI
Model 1						
Stunted at 24 mo	1.55	<0.0001	1.34, 1.78	1.2	0.02	1.04, 1.39
Model 2						
ZBWT	0.88	<0.0001	0.83, 0.93	0.92	0.004	0.86, 0.97
ZCW0–24	0.78	<0.0001	0.74, 0.83	0.87	<0.0001	0.82, 0.92
ZCW24–48	0.95	0.06	0.90, 1.00	0.98	0.56	0.93, 1.04

[1] Adjusted for site and sex.
[2] Adjusted for site, sex, SES, and maternal schooling.

schooling lost, we would expect stunting to decrease lifetime income by ~10% in the countries included in our analyses (6).

One SD increase in birthweight, equivalent to ~0.5 kg, is associated with 0.21 y of additional schooling and 8% decreased risk of ever failing a grade. One SD increase in CW gain between birth and 24 mo, equivalent to ~0.7 kg, was associated with higher estimates of 0.43 y more schooling and 12% decreased risk of failing. One SD increase of CW gain from 24 to 48 mo, equivalent to ~0.9 kg, was associated with only 0.07 y more schooling and was not associated with school failure.

In addition, CW gain from 0 to 24 mo was more important for schooling in children born small. In children born in the lowest tertile of birthweight, 1 SD increase of weight gain from 0 to 24 mo was associated with 0.50 y of schooling compared with 0.33 y in those in the upper tertile. This suggests a beneficial effect on schooling of catch-up growth in smaller babies.

Our study has numerous strengths. It used prospective data from 5 well-described cohort studies. Schooling outcomes included 3 important variables: highest grade attained, ever failed a grade, and age at school entry. Pooled analyses were possible for all but age at school entry, thus increasing sample sizes and power and providing assurance that most of the relationships we explored were consistent across countries. An additional strength was the use of weight information at birth and 24 and 48 mo to assess the relative importance of growth during specific preschool periods. Further, we used standardized, CW gain variables to appropriately assess relative importance. Our growth measures were, by design, uncorrelated with each other, and the use of SD scores permitted direct comparison of estimates across weight variables. For example, had we used initial birthweight and postnatal weight gain, or initial Z-score at any age and subsequent change in Z-score, as has been done in studies of mental health (16) and cognitive development (12), respectively, we would not have removed the phenomenon of regression to the mean or controlled-for common error terms (e.g. measurement error will generate a negative correlation between initial and change values, because larger-than-true measurements at baseline will lead to smaller change values and smaller-than-true initial values will lead to larger change values). Finally, our analyses also controlled for confounding associated with children's early environment.

Our study also has weaknesses. Our schooling information was limited; only highest grade attained was available for New Delhi and most Bt20 participants were enrolled in school, so that analyses of highest grade attained could not be carried out for this site. We lacked birth length for Pelotas and Bt20 and therefore relied on analyses using weight. However, we conducted analyses that used growth in height from 0 to 24 and 24 to 48 mo that was conditioned on birthweight, available for all 5 sites, and these analyses gave similar results to those presented here.

We controlled for maternal schooling and SES. Our analyses showed that these variables attenuated coefficients substantially but that relationships with birthweight and weight gain from 0 to 24 mo remained significant. In studies with extensive control for confounding, the relationship between stunting or weight faltering with schooling or cognitive development also remained significant (30,15). Economists have been concerned with confounding in relating child size to schooling, particularly regarding unobserved characteristics (31). Use of econometric techniques that rely upon instrumental variables to control for confounding show that relationships between birthweight or

TABLE 5 Coefficients for site-specific regression models of age at school entry (y) according to stunting at 24 mo and standardized birthweight and standardized, CW gain from birth to 24 mo and from 24 to 48 mo (n = 4668)[1]

	Pelotas, Brazil, n = 1807			INTC, Guatemala, n = 253			CLHNS, Cebu, Philippines, n = 2060			Bt20, Soweto-Johannesburg, South Africa n = 548		
	β	95% CI	P	β	95% CI	P	β	95% CI	P	β	95% CI	P
Model 1												
Stunted at 24 mo	0.29	0.19, 0.39	<0.0001	−0.06	−0.42, 0.30	0.74	0.09	0.03, 0.14	0.001	0.18	0.03, 0.32	0.02
Model 2												
ZBWT	−0.06	−0.10, −0.03	0.0005	−0.01	−0.14, 0.12	0.87	−0.04	−0.07, −0.02	0.001	0.0	−0.07, 0.06	0.89
ZCW0–24m	−0.1	−0.13, −0.07	<0.0001	0.11	−0.01, 0.24	0.08	−0.06	−0.09, −0.04	<0.0001	−0.03	−0.09, 0.04	0.38
ZCW24–48m	−0.01	−0.04, 0.02	0.40	−0.06	−0.18, 0.07	0.38	−0.04	−0.06, −0.01	0.002	−0.13	−0.19, −0.06	0.002

[1] All regressions adjust for sex, SES, and maternal schooling.

child height for age and educational outcomes remain significant and can actually increase in magnitude after controlling for unobserved characteristics (32,33,5). Although economists often attribute causality in analyses of nonexperimental data with instrumental variables, they recognize that experimental data offer the best possibility for doing so. The nutrition intervention to which the Guatemalan cohort was exposed (Table 1) improved diets and reduced stunting at 3 y of age (34) and also had long-term effects on schooling (women), cognitive development (men and women), and wages (men) (35–37), thus providing support for a causal effect. In addition, the specificity of our finding of a much larger role for growth in the first 2 y of life than for later growth is in agreement with the physiology of brain growth, also supporting a causal association.

Few would argue that it is child size or growth per se that causes impaired cognitive development and low educational achievement. Rather, growth failure in early childhood should be viewed as a marker of lack of nutrients at the cellular level that has systemic effects on growth and development in general, including the brain and neurological development.

From a public health perspective, it is important to place these findings in the context of what is known about the timing of weight gain and chronic disease outcomes. Other analyses from the 5 cohorts showed that rapid weight gain in every age range from birth to mid-childhood is associated with increased blood pressure (38), but studies of body composition suggest that weight gains after 2 y of age are more closely associated with adult fat mass than earlier weight gains (39–42). Further analyses are needed for other chronic disease outcomes, but, to date, there is a good case for promoting weight gain in early life in low- and middle-income populations in light of its positive association with human capital outcomes such as schooling.

We showed important associations of prenatal and postnatal growth to 2 y with schooling outcomes. There are many other influences, such as school quality, that also determine schooling outcomes and achieving the millennium development goal of universal primary education by 2015 will require action along a broad front. Our results suggest that designing effective nutrition interventions and targeting them to mothers and children <2 y of age should be among these actions.

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