Social and Intergenerational Determinants of Children's Physical and Cognitive Development

Citation	Krishna, Aditi. 2015. Social and Intergenerational Determinants of Children's Physical and Cognitive Development. Doctoral dissertation, Harvard T.H. Chan School of Public Health.
Citable link	http://nrs.harvard.edu/urn-3:HUL.InstRepos:23205171
Terms of Use	This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA

Social and Intergenerational Determinants of Children's Physical and Cognitive Development

Aditi Krishna

A Dissertation Submitted to the Faculty of

The Harvard T.H. Chan School of Public Health

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Science

in the Department of Social and Behavioral Sciences

Harvard University

Boston, Massachusetts.

November 2015

Dissertation Advisor: Dr. S.V. Subramanian Aditi Krishna

Social and Intergenerational Determinants of Children's Physical and Cognitive Development

Abstract

Identifying the key determinants of poor developmental outcomes is critical in improving the lives of millions of children who suffer from poor physical growth and cognitive deficits. Much research suggests that early life conditions, particularly those experienced within the household, critically influence children's development across the life course. In this dissertation exercise, I explore how three dimensions of early experiences – prenatal conditions, parental education, and household socioeconomic conditions – influence children's physical and cognitive development. Chapter 1 found that the influences of low birth weight, which is a key determinant of later health, on physical development wane over time with increasing importance of postnatal factors. Chapter 2 also countered accepted evidence that maternal education matters more for children's physical development by finding that both parents' education matters equally in both infancy and childhood with no mechanisms distinguishing maternal and paternal education. Chapter 3 supported the evidence that household socioeconomic status matters for children's cognitive development and found that household assets are the critical determinant of cognitive status. Findings from each of these chapters will not only contribute new scientific evidence but will also help inform policies and programs to improve children's health and well-being.

TABLE OF CONTENTS

II. LIST OF FIGURES

III. LIST OF TABLES

IV. ACKNOWLEDGEMENTS

None of this work would have been possible without the support of family and friends as well as the resources available at the Center for Population and Development Studies and the Harvard T.H. Chan School of Public Health. I would particularly like to thank my parents, Vidya and Anirudh, for their unconditional love and unshakeable faith, as well as my brother, Abhay, who has always been able to ground me to reality. Many thanks also to peers, postdoctoral fellows, faculty, and staff who have guided me through this process. Final but no less heartfelt words of gratitude to Subu, who has been a tremendous, albeit demanding advisor, and to Lisa and Günther who have both been wonderful mentors.

V. INTRODUCTORY REMARKS

Identifying the key determinants of poor developmental outcomes is critical in improving the lives of the 161 million children who suffer from stunting (1) – low height for age used as one metric of poor physical development – and the nearly 200 million children who suffer from a loss of developmental potential (2). Children experiencing physical and cognitive impairments have poorer schooling and learning outcomes as well as poorer employment and economic prospects (2). In addition, stunted children suffer from a higher burden of disease and ill-health (3). Aggregated across the 20% and 25% of children under age five who suffer from poor physical and cognitive development respectively, the consequences of stunting and cognitive impairment pose a significant burden for low- and middle-income countries, which have both the highest burden of stunting (1) and cognitive impairment (2) as well as a large proportion of young people. Much research suggests that early life conditions, particularly those experienced within the household, critically influence children's development across the life course (2,4-6). In this dissertation exercise, I explore how three dimensions of early experiences – prenatal conditions, parental education, and household socioeconomic conditions – influence children's physical and cognitive development.

Birth weight and children's physical development

Birth weight, the measure of prenatal conditions used in this dissertation, influences children's physical development with low birth weight children experiencing growth impairments across the life-course (7,8). In developing countries, the main cause of low birth weight is intrauterine growth restriction, which is a result of multiple factors both biological and social in nature (9). Poor socioeconomic conditions, young maternal age, and poor maternal health are among a multitude of factors causing low birth weight (9). While much research has shown that birth weight matters for children's height, one measure of physical development, many of these studies use data from only one country or present associations between birth weight and height at one point using cross-sectional data. The first chapter of the dissertation series extends this research by investigating associations between birth weight and height in infancy as well as later in life to examine whether the contributions of prenatal factors are trumped by postnatal factors such as household wealth. Shorter-run relationships may suggest biological mechanisms through which prenatal experiences fade as children age. Conversely, lasting associations between birth weight and height into late childhood would further underscore the importance of the first 1,000 days beyond age four years as established in prior research (10). Lastly, the modifying influences of household wealth on the relationship between birth weight and height has significant implications for programs and policies seeking to improve child development; that is the influences of birth weight on physical development across the life course may be remediable by improvements in living standards. While raising living standards for millions of children in poverty is no easy endeavor, the potential for improving growth outcomes postnatally is promising for children born at low birth weights, who may otherwise be resigned to poor developmental and health outcomes.

Parental education and children's physical development

The second chapter examines associations between parental education and physical development, comparing the relative contributions of maternal and paternal education to children's height. Studies have largely focused on maternal education, undoubtedly because of the larger child care role played by mothers (11), however, downplaying the importance of paternal education is not only methodological flawed but also conceptually limited as fathers play important roles in decision-making as well as in income generation. Methodologically, modeling only maternal education while ignoring paternal education raises the issue that associations between maternal education and children's physical development may be confounded by household socioeconomic conditions (12-16) and by the correlations between maternal and paternal education (17,18). Our study attempts to control for confounding by accounting for paternal education and other household characteristics. Additionally, it attempts to understand whether there are distinct pathways by which maternal and paternal education may influence children's physical development. Findings from this study will help uncover how parental characteristics affect children's development.

Household socioeconomic status and children's physical and cognitive development

The last chapter in the dissertation series further investigates the role of parental education, also looking at another dimension of socioeconomic status – household wealth – to understand how varying socioeconomic conditions may influence children's development. Significant evidence indicates that household poverty and relatedly low levels of parental education are key risk factors for poor cognitive outcomes (2,5,6). Children growing up in poorer households and with less educated parents also tend to experience physical impairments (3), suggesting that physical development may be a potential mediating condition between socioeconomic conditions and cognitive development. Additionally, children in households with low socioeconomic status are more likely to grow up in unstimulating environments with fewer resources invested in their development (2,5,6). Thus, inadequate investments in child development are another way by which household socioeconomic conditions influence children's cognitive development. By considering both physical and cognitive development as well as multiple measures of household conditions, and by examining mediating experiences by which socioeconomic conditions influence children's development, this paper provides a comprehensive assessment of how some of the earliest experiences – those within the household – affect children's development.

The Young Lives Study

Together these three papers investigate how early experiences affect children's development in resource-constrained settings. These research questions are answerable due to the richness of the data collected by the Young Lives study, a project examining health and well-being among children growing up in poverty. The Young Lives study was designed to follow two cohorts of children over 15 years, surveying them and their families multiple times through quantitative surveys and more in-depth qualitative investigations. The younger cohort was ages 6-18 months at enrollment and has been followed till age 7-8 years. The older cohort was enrolled at 7-8 years and has also been surveyed over the same time period to age 14-15 years. The three dissertation papers only use data from the younger cohort, as the particular relationships of interest are most salient in early life. The nearly 8,000 children enrolled in the younger cohort were surveyed three times – at baseline (age 6-18 months) and then at 4-5 and 7-8 years of age. Repeated measures collected from the same children are critical in investigations into the short- and long-term relationships between early life experiences and later outcomes. Additionally, the breadth and depth of the quantitative surveys allow for a profound investigation into how early experiences, particularly household dynamics, influence children's development.

Research Implications

Findings from this dissertation exercise will answer important questions about the key determinants of children's development, identifying the critical levers for improving physical and cognitive outcomes. Most critically, relying on the richness of the Young Lives data, these papers will shed light on the mechanisms by which early adversity influences children's development. Evidence collected by each of these studies will help support the initiatives of global movements such as the Millennium Development Goals, the Scaling Up Nutrition movement, and the Zero Hunger Challenge among others in averting poor developmental outcomes for millions of children globally.

VI. CHAPTER 1: SHORT- AND LONG-RUN ASSOCIATIONS BETWEEN BIRTH WEIGHT AND CHILDREN'S HEIGHT

Abstract:

Objective: Much evidence suggests that the 1,000 days spanning from conception to children's second birthdays are critical for children's physical growth. Whether influence of the exposures occurring during this window lasts later in life is unclear. Our study investigates changes in the association between birth weight and height, one measure of physical growth, over different life-stages and whether greater household wealth promotes better growth for children born at low birth weight (LBW).

Methods: Using longitudinal data from the Young Lives project (2002-2009), we analyzed associations between birth weight and physical growth and examined differences across ages and by household wealth for 3,999 children from Ethiopia, India, Peru, and Vietnam.

Results: At age 6-18 months, LBW children had 0.53-SD (95% confidence interval [CI]: (0.38-0.68) lower HAZ. Over time, the gap between normal and LBW children narrowed significantly to 0.21-SD (CI: 0.11-0.30) and 0.24-SD (CI: 0.14-0.34) at ages 4-5 years and 7-8 years, respectively. Household wealth did not moderate the relationship between LBW and height at age 6-18 months. LBW did not predict growth after age 2. Household wealth also did not moderate the relationship between birth weight and growth, in terms of changes in HAZ across ages.

Conclusions: The results presented suggest that the relationship between birth weight and height becomes substantially weaker over time. However, although prenatal experiences may be most salient in the first years of life, they are likely to have persistent effects as LBW do not fully catch-up in height to non-LBW children after age two.

Introduction

Over 161 million children suffer from stunting or low height for age that reflects sustained experiences of undernutrition (19). Stunting begins early during a critical window spanning the first 1,000 days of life (10) with significant consequences across the life course (3,19). Children born at low birth weight, a measure of poor fetal conditions (9), are more likely to be stunted or more generally experience worse physical growth (7,8,20). Cross-sectional (21-30) and longitudinal studies (8,31,32) demonstrate that children who were born at low birth weight are either more likely to be stunted or experience deficits in height at various ages; however these studies, examining associations at only one point in time, are unable to investigate how postnatal factors may affect the relationship between birth weight and postnatal growth. Few studies explore the lasting effects of birth weight on children's growth over time with some finding that low birth weight children are able to catch-up in growth (33,34) while others conclude that height deficits are unlikely to be remediated (35,36). The paucity of research on the long-term effects of birth weight and the mixed evidence from small, country-level studies suggests that further research needs to investigate whether the relationship between birth weight and physical growth exists only early in life or whether it persists over the life course.

Using a uniquely rich longitudinal data set from four low-and middle-income countries, our study investigates whether birth weight, a measure of prenatal experiences, influences postnatal growth and compares the relative contributions of prenatal factors to postnatal factors to height. In contrast to early work that largely shows associations between birth weight and height at one time, our analysis considers whether the relationship persists over time. In addition, we compare associations across four countries with different social, economic, and political contexts. We also explore how household socioeconomic status influences the relationship between birth weight, height and catch-up growth.

Methods

Study Population

This study used data from Young Lives, a longitudinal study of child health and well-being in Ethiopia, India, Peru, and Vietnam (37-41). Young Lives was designed to follow two cohorts: born in 2000-01 and born in 1994-95. We used only the younger cohort, ages 6-18 months when enrolled in 2002 and surveyed again at ages 4-5 and 7-8 years, because birth weight was reported in the first survey, close to the child's birth.

The sampling design for Young Lives was similar across the four countries; although only one state was sampled in India. In each country, 20 sentinel sites were chosen, enumerating all households with children born between 2000-2001 in each site, and then randomly selected 100 households for the study. Households that refused – less than 2% – were replaced with others (37). One child per household was chosen, resulting in approximately 2000 children surveyed for the younger cohort in each country (37).

Excluding attrition due to mortality, the attrition rate of 4.7% was notably low compared to other longitudinal studies in similar contexts (42). Rates were similar across countries with slightly higher attrition in Peru at 6.7% and lowest attrition rates in Vietnam at 2.4% (**Supplementary Table 1.1**). The most common reasons for attrition were households moving away from survey areas, refusing to participate, and infant mortality. Across all four countries, 243 children or 3.0% of children enrolled in round 1 were lost due to households moving or refusal to participate and 139 or 1.7% due to death. For our analyses, only individuals present in all rounds were used with 382 children excluded due to attrition (**Supplementary Figure 1.1**).

Explanatory measures and covariates

The key explanatory variable was birth weight (g) reported by the biological mother or primary caregiver and corroborated with documentation if available. For the main analyses, we used the clinical cutoff for LBW, defined as a birth weight of less than 2,500g. Additional analyses using birth weight transformed into standard deviation (SD) units and very low birth weight (VLBW), classified as less than 1,500g, are shown in Supplemental Material. We excluded all children with missing birth weight data – a large portion, particularly in Ethiopia and India – as well as those with missing data on the following covariates (Supplementary Figure 1). An alternate measure – mother's perception of child's size at birth – was used in sensitivity analyses. To ascertain reporting bias, sensitivity analyses examined the subset of individuals who had documented birth weights.

Covariates included child's age, child's sex, and primary caregiver's educational attainment (none, primary, and secondary). Nearly all primary caregivers were mothers. We also included mother's height (also in SD) to address intergenerational aspects of child stunting. Other key covariates included wealth index at baseline (age 6-18 months), measured through the asset-based wealth index developed by Filmer and Pritchett (43). Young Lives used a continuous measure ranging from the least well-off households with scores of 0 to the most at 1. Models also included some household characteristics such as number of household members and place of residence (rural and urban).

Outcome measures

The outcome was height for age z-scores (HAZ), standardized measures of height created by the World Health Organization (WHO) Multicentre Growth Study (44). Trained enumerators obtained weight, height, and length (in round 1), taking repeated measurements until consensus was achieved. Children with extreme values of HAZ, either less than or greater than six SD from the median HAZ, were excluded (see Supplementary Figure 1.1). In our main analyses, we used HAZ as the key outcome, with height in Supplemental Material. We use height or HAZ to refer to HAZ while growth refers to changes in height or HAZ.

Statistical Analysis

In addition to descriptive statistics, differences in mean birth weight by key covariates were also calculated to understand differences in size at birth by key socio-demographic factors. Regression models examined associations between birth weight and HAZ and changes in associations at different ages. Models tested for differential effects of birth weight by wealth index at ages 6-18 months, a critical period for growth faltering (10). Other analyses examined the longer-run effects of birth weight, examining whether there is greater catch-up growth among LBW children born into wealthier families. Ordinary least squares models were used for analyses pooling data across all countries with country-specific analyses in the Supplemental Material. Models were specified iteratively first without socio-demographic covariates, then with interaction terms between birth weight and covariates of interest (e.g. survey round, wealth index), and lastly with covariates. All models included survey fixed effects, and sentinel site fixed effects. Models also included clustered standard errors, clustered at the sentinel site level, to account for sampling.

Sensitivity analyses

To investigate biased estimates due to misreported birth weight, we conducted the analyses on the subset of individuals who had birth weight corroborated with hospital, clinic, or maternity home records. In addition, we assessed differences in the baseline characteristics of households who reported birth weight compared to those who do not in order to address concerns about selection bias i.e. that household reporting birth weight were systematically different from those that do not.

Ethical Review

This study was reviewed by the Institutional Review Board at Harvard T.H. Chan School of Public Health and deemed exempt from review because the data are anonymized and publicly available.

Results

Key characteristics of the sample are presented in **Table 1.1**. Although all countries enrolled approximately 2000 children in the study, analytical sample sizes varied substantially due to differential availability of birth weight data. Across all countries, mean birth weight was 3082.71g (Standard error [SE]: 25.30) with the highest mean birth weight in Peru at 3207.04g (SE: 29.64) and the lowest mean birth weight in India at 2772.72g (SE: 39.42). The prevalence of LBW also varied across countries with a pooled sample average of 8.00% (SE: 0.80). Across all four countries, mean height increased from 72.08cms (SE: 0.18) to 120.99cms (SE: 0.32) from ages 6-18 months to ages 7-8 years. Average HAZ decreased from -1.13 (SE: 0.06) in round 1 to -1.35 (SE: 0.06) to round 2 and then increased to -1.06 (SE: 0.06) in round 3 with similar patterns for stunting. Other key descriptive statistics, including country statistics, are presented in Table 1.1 with changes in physical growth presented in **Supplementary Table 1.2**. Among all countries, males have higher birth weight than females ($p<0.01$) (**Table 1.2**). Wealthier households, those in urban areas, and with more educated caregivers also had children born at higher weights ($p<0.01$).

Table 1.1 Descriptive statistics[a]

	All countries (n=3,999)	Ethiopia (n=267)	India (n=761)	Peru (n=1,543)	Vietnam (n=1,428)
Birth weight (g)	3082.71 (25.30)	3154.68 (143.69)	2772.72 (39.42)	3207.04 (29.64)	3100.13 (21.15)
Low birth weight (<2500g)	8.00 (0.80)	14.23 (4.56)	16.56 (2.36)	5.51 (0.60)	5.04 (0.51)
Very low birth weight (<1500g)	0.27 (0.08)	0.37 (0.39)	0.78 (0.29)	0.19 (0.11)	0.07 (0.07)
Height (cms)					
Ages 6-18 months (Round 1)	72.08 (0.18)	71.82 (0.61)	72.17 (0.27)	71.61 (0.32)	72.59 (0.23)
Ages 4-5 years (Round 2)	105.12 (0.37)	104.81 (0.69)	105.04 (0.27)	104.80 (0.87)	105.57 (0.45)
Ages 7-8 years (Round 3)	120.99 (0.32)	122.12 (0.86)	120.09 (0.44)	120.52 (0.62)	121.77 (0.50)
Height for age z-score					
Ages 6-18 months (Round 1)	-1.13 (0.06)	-1.33 (0.23)	-1.11 (0.09)	-1.20 (0.13)	-1.01 (0.09)
Ages 4-5 years (Round 2)	-1.35 (0.06)	-1.27 (0.13)	-1.43 (0.05)	-1.43 (0.13)	-1.23 (0.10)
Ages 7-8 years (Round 3)	-1.06 (0.06)	- 0.99 (0.13)	-1.19 (0.08)	-1.06 (0.11)	-0.99 (0.09)
Stunting Prevalence (%)					
Ages 6-18 months (Round 1)	22.56 (1.83)	35.21 (6.14)	24.05 (2.11)	24.95 (3.94)	16.81 (1.88)
Ages 4-5 years (Round 2)	25.73 (2.15)	24.34 (3.34)	26.81 (2.11)	29.49 (4.77)	21.36 (2.73)
Ages 7-8 years (Round 3)	17.70 (1.51)	14.98 (2.92)	20.24 (2.20)	17.95 (3.16)	16.60 (2.27)
Female (%)	47.59 (0.71)	39.33 (3.77)	45.86 (1.73)	49.25 (0.99)	48.25 (1.07)
Age (months)					
(Round 1)	12.23 (0.07)	12.35 (0.17)	12.25 (0.17)	12.02 (0.09)	12.43 (0.15)
(Round 2)	64.03 (0.29)	62.43 (0.39)	64.58 (0.35)	64.19 (0.67)	63.87 (0.31)
(Round 3)	96.33 (0.18)	97.82 (0.32)	96.01 (0.34)	95.37 (0.09)	97.26 (0.32)
Baseline wealth index (Round 1)	0.46 (0.02)	0.33 (0.07)	0.50 (0.04)	0.45 (0.04)	0.48 (0.03)
Wealth index					
Ages 4-5 years (Round 2)	0.51 (0.02)	0.38 (0.06)	0.54 (0.04)	0.49 (0.04)	0.52 (0.02)
Ages 7-8 years (Round 3)	0.59 (0.02)	0.41 (0.06)	0.59 (0.03)	0.57 (0.03)	0.64 (0.03)
Rural residence	50.26 (6.11)	31.96 (16.73)	56.59 (12.93)	26.33 (7.87)	76.17 (10.14)
Caregiver's educational attainment					
None	14.72	37.58	41.31	7.34	4.38
Primary	40.16	35.71	22.95	40.27	50.05

Table 1.1 (Continued)

Household size	5.14 (0.07)	5.79 (0.19)	5.24 (0.11)	5.45 (0.09)	4.63 (0.07)

[a]All values are means or proportions with standard errors in parentheses corrected for clustered sampling.

Table 1.2 Mean birth weight by covariates, for all countries and for each country[a]

	All countries (n=3,999)	Ethiopia (n=267)	India (n=761)	Peru (n=1,543)	Vietnam (n=1,428)
Sex					
Male	3122.65 (28.87)	3307.41 (153.02)	2795.35 (42.85)	3244.43 (33.18)	3135.59 (27.47)
Female	3038.73 (25.32)	2919.05 (126.49)	2746.00 (41.84)	3168.51 (33.25)	3062.09 (20.38)
(p-value)[b]	(<0.01)	(<0.01)	(0.12)	(0.02)	(0.01)
Baseline wealth index					
Low	3019.46 (33.13)	2772.37 (211.26)	2727.60 (55.09)	3124.68 (46.85)	3050.71 (25.70)
Middle	3105.23 (29.31)	3400.94 (151.35)	2698.33 (51.87)	3244.71 (31.96)	3103.78 (36.78)
High	3132.49 (37.52)	3272.65 (123.57)	2844.76 (33.04)	3275.89 (30.27)	3176.86 (18.45)
(p-value)[b]	(0.02)	(0.03)	(0.03)	(0.05)	(0.01)
Place of residence					
Urban	3171.53 (31.46)	3286.95 (105.57)	2866.11 (40.66)	3245.79 (24.90)	3165.23 (27.47)
Rural	2993.84 (31.51)	2877.34 (266.09)	2701.08 (46.96)	3098.62 (46.01)	3079.76 (23.78)
(p-value) [b]	(<0.01)	(0.18)	(0.01)	(0.01)	(0.03)
Caregiver's educational attainment					
None	2831.79 (49.42)	2934.05 (232.31)	2705.03 (49.28)	3012.24 (45.64)	2976.34 (70.28)
Primary	3080.74 (21.81)	3255.25 (94.82)	2785.44 (58.94)	3157.22 (37.25)	3063.15 (23.23)
Secondary or more	3166.34 (24.03)	3330.61 (145.17)	2842.09 (34.90)	3272.64f (24.06)	3152.48 (23.08)
(p-value)[b]	(<0.01)	(0.42)	(0.044)	(<0.01)	(0.02)

[a]All values are means or proportions with standard errors in parentheses, corrected for cluster sampling.
[b]p-values are from Wald tests for differences in means.

In pooled, unadjusted models, LBW children had 0.38-SD lower HAZ (95% confidenc interval [CI]: 0.28-0.49) (**Table 1.3**, *1*). Associations between LBW and HAZ were halvec round 1 to round 2 and from round 1 to round 3 in both unadjusted and adjusted models (T 1.3, *2-3;* **Supplementary Figure 1.2**). Models examining differences in associations betw LBW and HAZ by wealth index at age 6-18 months suggest that although household weal matter for height (**Table 1.4**, *1*), there were no differential associations between LBW and by wealth index (Table 1.4, *2-3*, **Supplementary Figure 1.3**). The inclusion of HAZ at 6- months, which substantially attenuated the association between LBW and HAZ, was stron associated with HAZ at 4-5 years and 7-8 years (**Table 1.5**, *1-2*). Compared to HAZ at 6-1 months, HAZ at 4-5 years had a larger association with HAZ at 7-8 years (Table 1.5, *3*), a inclusion of HAZ at 4-5 years attenuated the association between HAZ at 6-18 months anc at 7-8 years (Table 1.5, *2* & *3*). Lastly, insignificant interaction terms between HAZ in the previous round, wealth index, and LBW suggested similar patterns of growth among LBW children with different levels of household wealth at ages 4-5 and 7-8 years (Table 1.5, *5;* **Supplementary Figure 1.4**). Results from country-specific models presented in **Supplem Tables 1.3-1.6** show similar results with some variability in associations.

Models using alternate exposures and outcomes found similar results. Associations between birth weight and HAZ (**Supplementary Tables 1.7-1.9**) and VLBW and HAZ (**Supplementary Tables 1.10-1.12**) mirrored those in the main analyses. There was no attenuation in associations between LBW and height (cm) over ages; however other result consistent with main results (**Supplementary Tables 1.13-1.15**).

Table 1.3 Associations between low birth weight[a] and height for age z-scores from pooled analyses (n=3,999)[b]

	(1)	*(2)*	*(3)*
Low birth weight	-0.38***	-0.59***	-0.53***
	(-0.49 - -0.28)	(-0.75 - -0.42)	(-0.68 - -0.38)
Ages 4-5 years	-0.22***	-0.25***	0.85***
	(-0.29 - -0.16)	(-0.31 - -0.19)	(0.43 - 1.26)
Ages 7-8 years	0.070**	0.047	1.82***
	(0.00063 - 0.14)	(-0.022 - 0.11)	(1.16 - 2.49)
Low birth weight*ages 4-5 years		0.32***	0.32***
		(0.17 - 0.47)	(0.17 - 0.47)
Low birth weight*ages 7-8 years		0.29***	0.29***
		(0.13 - 0.45)	(0.13 - 0.45)
Constant	-0.78***	-0.76***	-0.90***
	(-0.82 - -0.73)	(-0.81 - -0.72)	(-1.12 - -0.68)
Covariates[c]	No	No	Yes

[a]Low birth weight is defined as being born at a weight less than 2,500g.
[b]Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[c]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Table 1.4 Associations between low birth weight[a] and height for age z-scores at age 6-18 months, by baseline wealth index from pooled analyses (n=3,999)[b]

	(1)	*(2)*	*(3)*
Low birth weight	-0.59***	-0.35**	-0.33**
	(-0.76 - -0.42)	(-0.69 - -0.016)	(-0.62 - -0.031)
Baseline wealth index	1.06***	1.11***	0.74***
	(0.77 - 1.36)	(0.80 - 1.41)	(0.45 - 1.03)
Low birth weight*baseline wealth index		-0.54*	-0.45
		(-1.16 - 0.079)	(-1.02 - 0.11)
Constant	-0.79***	-0.81***	0.19
	(-0.92 - -0.65)	(-0.95 - -0.66)	(-0.20 - 0.58)
Covariates[c]	No	No	Yes

[a]Low birth weight is classified as being born at a weight less than 2,500g.
[b]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects.
[c]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Table 1.5 Associations between low birth weight (LBW)[a], baseline wealth index (BWI)[b], and growth in height in age z-scores (HAZ), across all countries (n=3,999).[c]

HAZ at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-0.20*** (-0.29 - -0.12)	0.018 (-0.060 - 0.097)			-0.019 (-0.48 - 0.44)
BWI	0.73*** (0.52 - 0.94)	0.45*** (0.29 - 0.62)			0.62*** (0.36 - 0.87)
HAZ at 6-18 months		0.42*** (0.39 - 0.46)			0.36*** (0.29 - 0.43)
LBW*BWI					-0.0059 (-0.75 - 0.74)
LBW*HAZ at 6-18 months					-0.018 (-0.21 - 0.17)
HAZ at 6-18 months*BWI					0.16** (0.0029 - 0.32)
LBW*HAZ at 6-18 months*BWI					-0.021 (-0.36 - 0.34)
Constant	-1.34*** (-1.98 - -0.70)	-3.64*** (-4.26 - -3.03)			-3.70*** (-4.32 - -3.08)
HAZ at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-0.24*** (-0.34 - -0.15)	-0.039 (-0.12 - 0.044)	-0.092** (-0.17 - -0.015)	-0.050 (-0.13 - 0.026)	-0.22 (-0.59 - 0.15)
BWI	0.77*** (0.55 - 0.99)	0.52*** (0.30 - 0.73)	0.21*** (0.056 - 0.37)	0.20** (0.038 - 0.36)	0.23** (0.050 - 0.41)
HAZ at 6-18 months		0.39*** (0.36 - 0.43)		0.11*** (0.081 - 0.14)	0.067*** (0.019 - 0.12)
HAZ at 4-5 years			0.74*** (0.71 - 0.78)	0.67*** (0.62 - 0.71)	0.69*** (0.61 - 0.77)
LBW*BWI					0.42 (-0.33 - 1.18)

Table 1.5 (Continued)

LBW*HAZ at 6-18 months					0.028 (-0.10 - 0.22)
LBW*HAZ at 4-5 years					-0.069 (-0.38 - 0.10)
HAZ at 6-18 months*BWI					0.08 (0.0030 - 0.21)
HAZ at 4-5 years*BWI					-0.037 (-0.21 - 0.095)
LBW*HAZ at 6-18 months*BWI					-0.16 (-0.49 - 0.096)
LBW*HAZ at 4-5 years*BWI					0.40* (-0.048 - 0.87)
Constant	-0.14 (-0.98 - 0.70)	-3.52*** (-4.31 - -2.72)	0.71** (0.11 - 1.30)	-0.34 (-1.06 - 0.37)	-0.35 (-1.08 - 0.37)

[a]Low birth weight is classified as being born at a weight less than 2,500g.
[b]Baseline wealth index is measured in the first survey round.
[c]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Using mothers' perception of a child's size at birth as an alternative anthropometric measure showed similar relationships to the main findings (**Supplementary Tables 1.16-1.19**). Analyses for the subset of individuals with documented birth weight showed larger but not statistically significantly different associations between birth weight and height (**Supplementary Tables 1.20-1.22**), supporting the main findings and questioning possible reporting bias. Comparison of key socio-demographic characteristics between children with and without birth weight data showed that although those who lacked birth weight data were poorer, more likely to live in rural areas, live in larger households, have caregivers with lower educational attainment, and shorter mothers, limiting the generalizability of our findings to the entire Young Lives sample (**Supplementary Table 1.23**).

Discussion

Our study had several important findings. Height deficits among LBW children, greatest during the first year, were halved after infancy in all countries. However, the absolute gap in HAZ at age 4-5 years remained unchanged later on with similar growth rates among children born at low and normal birth weights. Furthermore, associations between birth weight and height at age 4-5 and 7-8 years were attenuated to the null after accounting for past height, suggesting that the lagged influences of height mattered more than birth weight at later ages. Lastly, social and economic conditions, as reflected in household wealth, did not lead to increases in height for LBW children in the first year or help them catch-up to normal birth weight children. The rest of this discussion section will contextualize our findings within the literature, suggesting possible explanations for our findings.

Although there is significant evidence supporting associations between birth weight and height (8), our novel contribution is in using four cohorts from early infancy to late childhood to demonstrate that the association is most salient in the first year. A recent meta-analysis reviewed studies examining associations between birth weight and height at different ages, concluding that birth weight had lasting associations with height (8). This study overstates the significance of birth weight because it does not control for height in the first two years when modeling associations between birth weight and later height. Only a few studies have used repeated measures to understand how associations between birth weight and height change over time, with some finding parallel growth trajectories (35,36) while others conclude that LBW children had higher growth rates (33,34,45). Our study resolves the ambiguity about the long-term associations between birth weight and height, demonstrating that although LBW children recover some height deficits by age 4-5 years, they grow at similar rates to normal birth weight children and thus never fully catch-up. Our finding suggests that prenatal explanations are the most relevant in infancy because they create initial height deficits; however, in contrast to other studies linking birth weight with later height, we found that prenatal factors, as measured by birth weight, do little to explain later height or growth.

Previous work suggests that prenatal conditions influence health in childhood and later in life, establishing the importance of pregnancy as a critical period for later outcomes (46,47). Much of this work is based on David J. Barker's seminal work in the 1980s and 1990s, particularly the fetal origins hypothesis, which posits that conditions in utero have lasting effects on adult health (47,48). The fetal origins hypothesis is founded on the critical periods model, which describes how exposures experienced during a particular time e.g. pregnancy have later health effects because their effects become biologically programmed (46). In contrast to Barker's studies and other subsequent work (49-54), our study finds support for an alternate theory of how early life conditions affect later health.

Attenuated associations between birth weight and height after age two, and the absence of an independent influence of birth weight on height after controlling for height in the first two years of life suggest that the pathways model may be more appropriate in describing how prenatal exposures effect height. Unlike the critical periods model, which posits that a *single event or exposure* has lasting influences on later health, the pathways model suggests that a *chain of events* initiated by an early exposure such as nutritional deprivation in utero leads to adverse health outcomes later in life (46). In our study, birth weight leads to poorer stature between 6-18 months, which then affects height at 4-5 and 7-8 years, suggesting that the pathway through which birth weight operates is in influencing earlier height rather than independently affecting later height.

These findings also raise the question of whether pre- or postnatal factors are more salient in predicting height and height attainment after the first two years of life. Although children from wealthier households were less likely to be LBW and were taller at each age, our finding that greater household wealth does not help LBW children catch up in the first two years of life (if anything, LBW children from high income households fare worse), and the mostly parallel growth trajectories for low and normal birth weight children, as well as poorer and richer households after age two suggest that the degree to which early life deficits can be remediated by household resources is very limited. LBW, a measure of poor fetal conditions, influences height within the first 6-18 months of life, setting height statuses that are unlikely to be modified in later childhood or adolescence. This finding is consistent with the evidence that most but not all growth faltering occurs within the first 1000 days (55-57), creating an imperative for interventions to improve maternal and fetal health (10).

The analysis presented has some limitations. Despite the longitudinal nature of the data and the temporal precedence of birth weight, it is difficult to infer causality from the associations between birth weight and child growth. The influence of unobserved covariates, affecting both birth weight and child growth, may lead to residual confounding in spite of attempts to eliminate bias through the inclusion of key socio-demographic covariates and survey and sentinel site fixed effects and individual-level random effects. Second, there was missing birth weight data with significant differences in the characteristics of households with and without birth weight data. Although we model these characteristics in our analyses to address possible confounding, it is likely that there are other unobserved characteristics that confound the true relationship between birth weight and height. However, our sensitivity analyses using an alternate measure of size at birth that had less missing data found similar associations between child's size at birth and height, suggesting that estimated associations are unbiased. Third, and relatedly, there is the potential for "healthy survivor bias" or error created by only estimating associations for children who survived. While it is likely that the unhealthiest children may have died before enrollment or been lost to follow-up, Young Lives children were enrolled fairly close to birth and only 139 of 8,062 died during follow-up, casting doubt on the possibility for biased estimates.

Lastly, Young Lives only provided data on children until age 7-8 years, allowing for an examination of only the intermediate effects of birth weight. Future waves of Young Lives should permit an investigation into longer-term associations between birth weight and height. This research will be important in exploring whether birth weight predicts growth faltering in later childhood and adolescence, found in the older cohort of Young Lives (55).

Conclusion

Our study suggests that birth weight is an important predictor of early height, with the strongest associations in the first 6-18 months and weakening associations over time, possibly due to the waning influence of biological pathways connecting birth weight and height. Similar effects of birth weight and similar recovery in growth over time among both normal and LBW infants from households with varying living standards further underscores that biological factors, established in utero and reflected in birth weight, rather than postnatal factors affect children's height. This paper adds to existing evidence about pregnancy and infancy as critical junctures, supporting interventions to interrupt seemingly unbreakable cycles of poverty and deprivation that begin with conception.

VII. CHAPTER 2: PARENTAL EDUCATION AND CHILDREN'S HEIGHT: DOES ONE PARENT MATTER MORE?

Abstract:

Objectives: Much research suggests that parental education, particularly maternal education, affects children's health. Which parent's education is more important is unclear. This study considers how mothers' and fathers' education affects physical growth, using height as one measure, extending the limited body of work to compare the influences of both parents' education.

Methods: Using longitudinal data from the younger cohort of the Young Lives project (2002-2009), we explored the lasting influences of parental education through late infancy and childhood, conducting a cross-national comparison of the relationship between parental education and height for 6,564 children from Ethiopia, India, Peru, and Vietnam.

Findings: In pooled models, a one-year increase in mother's education was associated with a 0.037-standard deviation (SD) (Standard error [SE]: 0.0039) increase in height for age z-score (HAZ) while a one-year increase in father's education was associated with 0.031-SD (SE: 0034) greater HAZ. There were no significant differences in estimates for mother's and father's education or evidence of multiplicative effects of parental education. Parental education mattered across all survey rounds. Inclusion of typical risk factors only suggested partial mediation, indicating that parents' education may operate through similar pathways. Variation between countries in the associations between parental education and height suggests that the relationship between parents' education and children's height may be context-specific.

Conclusions: Both parents' education is equally important for physical growth in infancy and childhood and may operate through similar pathways such as greater household wealth. Raising parental education and living standards are key strategies to better children's physical growth.

Introduction

Much work has investigated the relationship between mother's education and child health, downplaying father's education (58-67). While the focus on maternal education has been validated by the greater child care role played by mothers (11), other work finds that the effect of maternal education is largely confounded by household socioeconomic conditions (12-16) and by the correlation between mother's and father's education (18,68,69). Some studies comparing the contributions of each parent's education show that mother's education is more important for child health and nutrition (69-71) while others find that both parents' education is equally important in predicting child mortality.(18,72) The ambiguous nature of the evidence, much of which comes from country studies, suggests that the effects of parental education on child health may be context-dependent. Our work fills the gap in the literature, using a cross-national approach to compare the relative contributions of both parents' education to children's physical growth over time.

Building on the limited work considering the effects of maternal and paternal education on child health, this study examines and compares associations between mothers' and fathers' education and height, one measure of physical growth. Relatedly, we also explore particular pathways by which mother's or father's educational attainment may independently influence height. Using eight years of longitudinal data, this study explores associations through late infancy and childhood. Lastly, we examine how the relationship between parental education and height varies among children in four low-and middle-income countries.

Methods

Study Population

This study used data on 6,564 children from Young Lives, a longitudinal study of health and well-being in Ethiopia, India, Peru, and Vietnam (37). The Young Lives study was designed to follow two cohorts: a younger cohort born in 2000-01 and an older one born in 1994-95. This study used only the younger cohort, ages 6-18 months at baseline, and ages 4-5 and 7-8 years at follow-ups, to understand how parental education mattered in early life, particularly in the first two years – a period of significant growth faltering (10).

The sampling design was similar across countries, although only one state was surveyed in India. In each country, staff chose 20 sentinel sites, enumerating households with children born between 2000-2001, and then randomly selecting 100 households within each site. Households that refused – less than 2% – were replaced with others (37). One child per household was chosen, resulting in approximately 2000 children surveyed for the younger cohort in each country. Further details are available in Barnett (37).

Excluding attrition due to mortality, the attrition rate of 4.7% was notably low compared to longitudinal studies in similar contexts (42) (**Supplementary Table 2.1**). The most common reasons for attrition were households moving away from survey areas, refusing to participate, and infant mortality. Across all four countries, 243 children or 3.0% of children enrolled in round 1 were lost due to households moving or refusal to participate and 139 or 1.7% due to death. Attrition was non-random but was shown to cause minimal bias (42). Due to the large sample size, only individuals present in all rounds – 96% of the sample – were included. Children with missing parental education information (15.1%) and those missing data on key covariates were excluded. Overall, 1496 children (18.6% of the sample) were excluded (**Supplementary Figure 2.1**).

Explanatory measures and covariates

The key explanatory variable was parental education reported by the primary caregiver, nearly all of who are mothers. A preponderance or 99% of mothers and 96% of fathers reside within the home. Primary caregivers, with assistance from other family members, enumerated household members and provided socio-demographic information such as household members' age, sex, and educational attainment. The first twelve years of schooling were documented numerically with a value of 13 and 14 for post-secondary and graduate schooling respectively (Supplementary Table 2.1). Analyses included child's age (in months) as there is some variation in the age of participants, sex, mother's height as well as household characteristics such as wealth index, using an asset-based indicator (43), number of household members, and place of residence (rural and urban).

Outcome measures

Height for age z-scores (HAZ) were used as measures of height. Trained enumerators obtained weight, height, and length (in round 1), taking repeated measurements until consensus was achieved. Anthropometric data were transformed into HAZ using growth standards from the WHO Multi-center Growth Reference Study. HAZ calculated by Young Lives were directly used in our analyses.

Statistics

Regression models were used to assess associations between parental education and height across all countries and survey rounds. In these models, all adjusted for age and sex, we introduced covariates in a stepwise fashion, considering the conceptual relationships between variables of interest as well as potential confounders and mediators. The first set of models adjusted only for maternal height, a reflection of a mother's genetic potential for physical growth and health status (73). We also iteratively adjusted for place of residence, wealth index, and household size in subsequent model specifications to understand whether associations could be explained by mediators such as wealth, a consequence of greater educational attainment, or covariates such as household size and place of residence.

Models stratified by round were also used to identify associations at particular life stages. We also used country-specific models, pooled across all rounds, to understand differences in the associations between parental education and HAZ in varying contexts. Lastly, we included models with interactions between mother's and father's education to ascertain multiplicative effects. All models adjusted for child age and sex and included survey and sentinel site fixed effects. Models also included clustered standard errors, clustered at the sentinel site level, to account for cluster-based sampling. Models over survey rounds included individual random effects appropriate when modeling longitudinal data. In all models, we compared the influences of mother's education to father's education using Wald tests for differences in associations.

Sensitivity analyses explored whether total years of parental education have similar associations with HAZ. Additionally, Young Lives also collected data on paternal height in Peru, allowing us to model associations between both parents' height and child's height. As a further investigation, we conducted a sub-analysis for children with birth weight data, reported by caregivers. Low levels of parental particularly maternal education are strongly associated with low birth weight (9,74) and it is important to consider whether the relationship between parental education and HAZ is mediated by birth weight or through an independent path operating through postnatal factors. We also analyzed the associations between parental education and HAZ at 4-5 years and 7-8 years, controlling for HAZ at 6-18 months, to understand whether the associations between parental education and later height are mediated through early height.

Pathways of parental influence on physical growth

We modeled some of the pathways through which parental education affects height (3,64). The possible pathways that we proposed were current breastfeeding status (only at age 6-18 months), immunization status, child's illness history, access to clean drinking water, access to a toilet, as well as food diversity, expenditures, and food shortage. We compared models with and without these proximal factors to assess whether parental education operates through these determinants.

Ethical Review

This study was reviewed by the Institutional Review Board at Harvard T.H. Chan School of Public Health and deemed exempt from review because the data are anonymized and publicly available.

Results

Descriptive statistics

Key characteristics are presented in **Table 2.1**. Across all countries, fathers had higher educational attainment. The lowest levels of maternal and paternal education were in Ethiopia and Vietnam. Mean HAZ scores were lowest for Ethiopia and India at ages 6-18 months. In contrast to other countries that experienced declines, Ethiopia experienced improvements in HAZ from ages 6-18 months to 4-5 years. However, by ages 7-8 years, average HAZ scores were once again lowest for Ethiopia and India. Stunting prevalence followed similar patterns. All families were relatively poor at the first survey round and experienced improvements in living standards over survey rounds. More than half of families lived in rural areas with average families sizes of 5.43 members (SE: 0.08). Across all countries, average mother's height was 152.85 cm (SE: 0.38). More details on the distribution of key variables and variation between countries are provided in Table 2.1.

Table 2.1 Descriptive statistics[1]

	All countries (n=6,564)	Ethiopia (n=1,458)	India (n=1,831)	Peru (n=1,481)	Vietnam (n=1,794)
Mother's education					
None	37.80	60.80	60.26	9.12	19.84
Primary	27.73	30.36	19.65	43.82	20.57
Secondary or more	34.47	8.84	20.09	47.06	59.59
Father's education					
None	28.43	46.61	46.89	1.42	17.11
Primary	26.77	36.74	18.50	41.59	14.88
Secondary or more	44.79	16.66	34.61	56.99	68.00
Mother's education (years)	5.70 ± 0.41	3.03 ± 0.50	3.35 ± 0.52	7.70 ± 0.66	8.61 ± 0.62
Father's education (years)	7.15 ± 0.35	5.24 ± 0.51	4.97 ± 0.48	8.92 ± 0.49	9.48 ± 0.58
Height for age z-score					
6-18 months	-1.12 ± 0.07	-1.54 ± 0.14	-1.34 ± 0.12	-1.29 ± 0.13	-1.11 ± 0.11
4-5 years	-1.49 ± 0.05	-1.49 ± 0.09	-1.64 ± 0.07	-1.53 ± 0.13	-1.32 ± 0.12
7-8 years	-1.22 ± 0.05	- 1.23 ± 0.07	-1.41 ± 0.08	-1.14 ± 0.11	-1.08 ± 0.11
Female	47.41 ± 0.54	45.92 ± 1.33	46.23 ± 1.02	49.02 ± 1.06	48.50 ± 0.84
Age (months)					
Round 1	12.21 ± 0.06	12.09 ± 0.13	12.28 ± 0.10	12.06 ± 0.08	12.35 ± 0.15
Round 2	63.69 ± 0.22	62.25 ± 0.26	64.64 ± 0.27	63.90 ± 0.68	63.72 ± 0.30
Round 3	96.42 ± 0.15	97.26 ± 0.22	95.87 ± 0.29	95.43 ± 0.08	97.11 ± 0.32
Wealth index					
6-18 months	0.37 ± 0.02	0.20 ± 0.03	0.41 ± 0.03	0.43 ± 0.04	0.44 ± 0.04
4-5 years	0.43 ± 0.02	0.27 ± 0.03	0.46 ± 0.03	0.47 ± 0.04	0.50 ± 0.03
7-8 years	0.51 ± 0.02	0.32 ± 0.03	0.51 ± 0.02	0.55 ± 0.03	0.61 ± 0.03
Rural residence	64.21 ± 4.97	67.16 ± 9.93	74.62 ± 9.47	30.02 ± 8.15	79.39 ± 8.98
Mother's height (cm)	152.96 ± 0.38	158.74 ± 0.34	151.48 ± 0.27	149.96 ± 0.39	152.26 ± 0.36
Household size	5.43 ± 0.08	6.14 ± 0.11	5.46 ± 0.13	5.52 ± 0.11	4.72 ± 0.09

[1]All values are means or proportions ± standard errors corrected for clustered sampling

Across all countries, we find that nearly 29% of children have parents who both ha secondary schooling and beyond, about 13% have both parents with only primary schoolir 23% have uneducated parents (**Supplementary Table 2.2**). There are more children with educated fathers – more than a quarter of participants. In contrast, less than 10% of childre more educated mothers. There are country differences in parental education are with lowe educational attainment in Ethiopia and India. HAZ scores are highest for children whose p both have secondary schooling and lowest for those with two uneducated parents (**Supplementary Table 2.3**). Education gradients in HAZ over survey rounds for each cou and parent are further explored in **Figure 2.1** with tabular data **in Supplementary Table 2** Overall, the largest differences were observed between children whose parents were unedu and those who had secondary schooling with similar gradients for both parents.

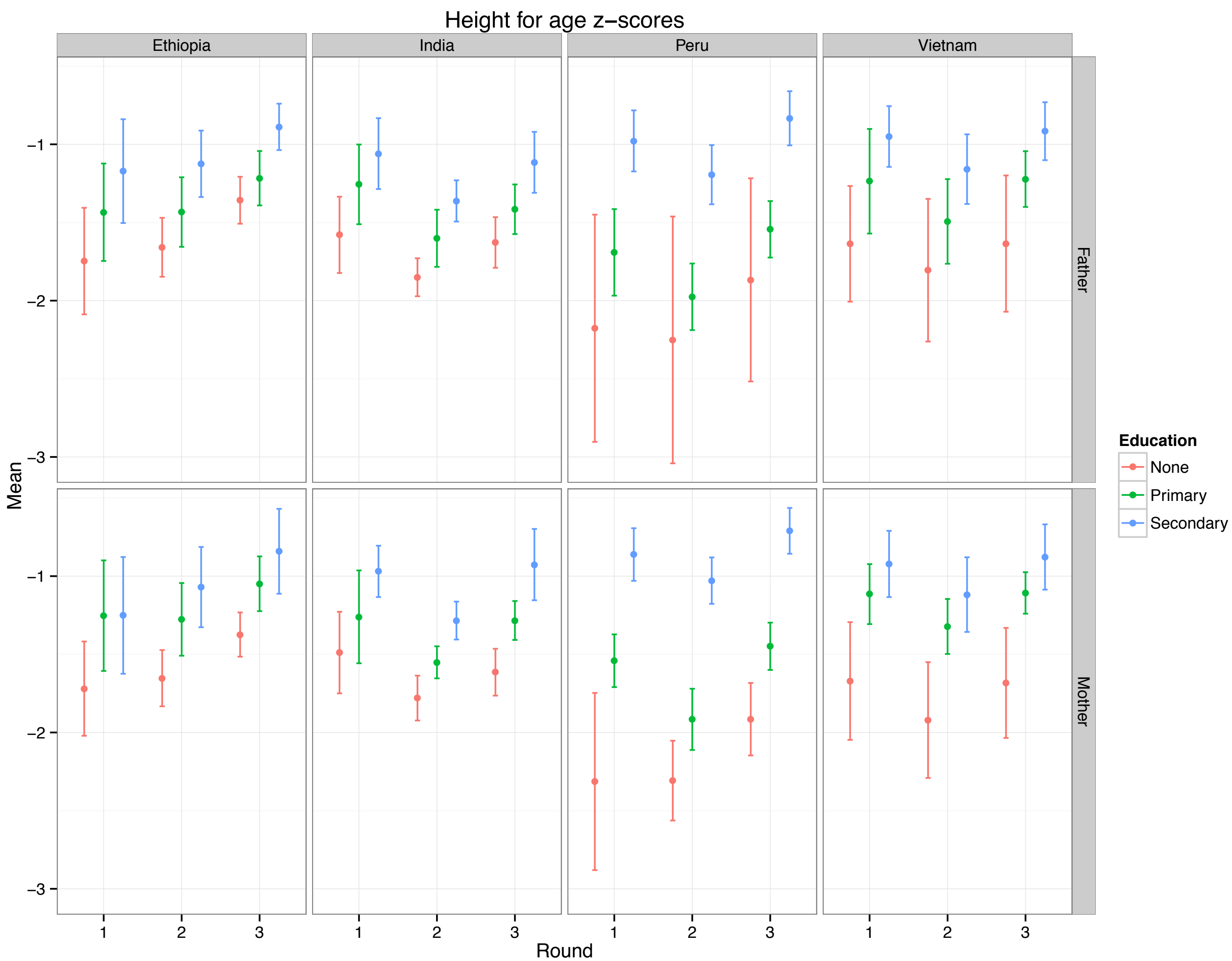


Figure 2.1 Mean height for age z-scores by levels of parental education[1]

Parental education and physical growth

Table 2.2 presents associations between HAZ and parental education across all countries and survey rounds. In age- and sex-adjusted models (Table 2.2, *1*), a one-year increase in mother's education was associated with 0.037-SD (SE: 0.0039) greater HAZ. Accounting for maternal height, the association was lower at 0.031 (SE: 0.0035) (Table 2.2, *2*), suggesting that maternal height may indeed confound the relationship between maternal education and children's height. Attenuation after accounting for wealth index indicated that maternal education may operate through increases in household wealth (Table 2.2, *4*). Similar associations and patterns of attenuation with the stepwise inclusion of covariates were observed for father's education (Table 2, *6-10*). In models comparing maternal and paternal education (Table 2.2, *11-15*), estimates for maternal education were larger in all models; however, these differences are not statistically significant.

Table 2.3 presents associations at each survey round across all countries. These models once again showed that parental education was positively associated with HAZ. In separate models for mother's education (Table 2.3, *1-2*) and father's education (Table 2.3, *3-4*), there were similar estimates across all rounds. Differences in the influences of parents' education were once again statistically insignificant (Table 3, *5-6*). Over all rounds and in models stratified by survey round, there were no multiplicative effects of parental education, suggesting that neither parent's educational attainment modifies the effect of the other parent's education (**Table 2.4**). Once again differences in associations by parent were insignificant.

Table 2.5 contains results from country-specific models examining associations between parental education and HAZ across all survey rounds. There was significant variation in associations between parents' education and HAZ in each country, suggesting that mother's and father’s education may have different influences on children’s physical growth in different social, cultural, economic, and political contexts.

Table 2.2 Associations between height for age z-scores and parental education from pooled models across all four countries and all survey rounds (n=6,564)[1]

	Mother	Father	Controlling for mother's height?	Controlling for place of residence?	Controlling for wealth index?	Controlling for household size?	p-value[2]
(1)	0.037*** (0.0039)		No	No	No	No	
(2)	0.031*** (0.0035)		Yes	No	No	No	
(3)	0.031*** (0.0034)		Yes	Yes	No	No	
(4)	0.024*** (0.0033)		Yes	No	Yes	No	
(5)	0.024*** (0.0033)		Yes	Yes	Yes	Yes	
(6)		0.031*** (0.0034)	No	No	No	No	
(7)		0.026*** (0.0031)	Yes	No	No	No	
(8)		0.026*** (0.0031)	Yes	Yes	No	No	
(9)		0.019*** (0.0030)	Yes	No	Yes	No	
(10)		0.019*** (0.0030)	Yes	Yes	Yes	Yes	
(11)	0.028*** (0.0038)	0.021*** (0.0032)	No	No	No	No	0.14
(12)	0.024*** (0.0034)	0.018*** (0.0030)	Yes	No	No	No	0.21
(13)	0.024*** (0.0034)	0.017*** (0.0030)	Yes	Yes	No	No	0.22
(14)	0.019*** (0.0033)	0.013*** (0.0029)	Yes	No	Yes	No	0.25
(15)	0.019*** (0.0033)	0.013*** (0.0029)	Yes	Yes	Yes	Yes	0.26

[1]Results are from linear mixed effects models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, include survey and sentinel site fixed effects and random effects for individuals.
[2]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Table 2.3 Associations between height for age z-scores and parental education from pooled models across all four countries, by survey rounds (n=6,564).[1]

	Mother	Father	Covariates[2]	p-value[3]
Round 1: Ages 6-18 months				
(1)	0.040*** (0.0052)		No	
(2)	0.024*** (0.0048)		Yes	
(3)		0.034*** (0.0044)	No	
(4)		0.020*** (0.0043)	Yes	
(5)	0.030*** (0.0052)	0.023*** (0.0044)	No	0.39
(6)	0.019*** (0.0052)	0.015*** (0.0043)	Yes	0.64
Round 2: 4-5 years				
(1)	0.034*** (0.0039)		No	
(2)	0.017*** (0.0031)		Yes	
(3)		0.029*** (0.0036)	No	
(4)		0.014*** (0.0030)	Yes	
(5)	0.026*** (0.0037)	0.019*** (0.0033)	No	0.23
(6)	0.014*** (0.0032)	0.0099*** (0.0030)	Yes	0.41
Round 3: 7-8 years				
(1)	0.038*** (0.0044)		No	
(2)	0.017*** (0.0035)		Yes	
(3)		0.030*** (0.0040)	No	
(4)		0.012*** (0.0032)	Yes	
(5)	0.029*** (0.0042)	0.019*** (0.0036)	No	0.09
(6)	0.015*** (0.0036)	0.0079*** (0.0032)	Yes	0.21

Table 2.3 (Continued).

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, include survey and sentinel site fixed effects.

[2]Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)

[3]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Table 2.4 Associations between height for age z-scores and parental education from pooled models across all four countries, by survey rounds (n=6,564): results from interaction models[1]

	Mother	Father	Mother*Father	Covariates[3]	p-value[4]
All rounds	0.024***	0.018***	0.00054	No	0.32
	(0.0058)	(0.0042)	(0.00054)		
	0.019***	0.014***	-0.000091	Yes	0.24
	(0.0050)	(0.0038)	(0.00047)		
Round 1: Ages 6-18 months	0.028***	0.022***	0.00020	No	0.35
	(0.0083)	(0.0065)	(0.00082)		
	0.023***	0.018***	-0.00042	Yes	0.40
	(0.0075)	(0.0063)	(0.00080)		
Round 2: Ages 4-5 years	0.018***	0.015***	0.00089*	No	0.63
	(0.0057)	(0.0041)	(0.00053)		
	0.012**	0.0088**	0.00025	Yes	0.55
	(0.0048)	(0.0036)	(0.00044)		
Round 3: Ages 7-8 years	0.023***	0.016***	0.00066	No	0.24
	(0.0065)	(0.0044)	(0.00055)		
	0.014**	0.0077**	0.000042	Yes	0.27
	(0.0058)	(0.0038)	(0.00048)		

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, include survey and sentinel site fixed effects. Models pooled across all rounds also include random effects for individuals.
[2]The reference group for both parents' education is having no education.
[3]Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)
[4]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Table 2.5 Associations between height for age z-scores and differences in parental education from pooled models by four countries across all survey rounds[1]

	Mother	Father	Covariates[2]	p-value[3]	Mother	Father	Covariates[2]	p-value[3]
	Ethiopia (n=1,458)				**India (n=1,831)**			
(1)	0.042*** (0.0074)		No		0.035*** (0.0057)		No	
(2)	0.034*** (0.0064)		Yes		0.019*** (0.0051)		Yes	
(3)		0.026*** (0.0086)	No			0.034*** (0.0056)	No	
(4)		0.019*** (0.0074)	Yes			0.020*** (0.0056)	Yes	
(5)	0.035*** (0.0070)	0.016** (0.0083)	No	0.12	0.019*** (0.0061)	0.026*** (0.0059)	No	0.50
(6)	0.029*** (0.0063)	0.012 (0.0075)	Yes	0.13	0.0090* (0.0051)	0.015*** (0.0057)	Yes	0.48
	Peru (n=1,481)				**Vietnam (n=1,794)**			
(1)	0.069*** (0.0067)		No		0.023*** (0.0070)		No	
(2)	0.037*** (0.0067)		Yes		0.016*** (0.0058)		Yes	
(3)		0.066*** (0.0068)	No			0.018*** (0.0041)	No	
(4)		0.038*** (0.0059)	Yes			0.0095*** (0.0033)	Yes	
(5)	0.051*** (0.0073)	0.037*** (0.0065)	No	0.22	0.019*** (0.0068)	0.012*** (0.0037)	No	0.37
(6)	0.023*** (0.0072)	0.023*** (0.0058)	Yes	0.99	0.012* (0.0062)	0.0053 (0.0036)	Yes	0.37

[1]Results are from linear mixed effects models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, include survey and sentinel site fixed effects and random effects for all individuals.

Table 2.5 (Continued).
[2]Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)
[3]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Sensitivity analyses

Supplementary Table 2.5 shows positive associations between total years of education and HAZ with lower estimates than presented in the main analyses in Table 4.In Peru, inclusion of maternal height led to far greater attenuation in the association between parental education and HAZ compared to inclusion of paternal height (**Supplementary Table 2.6**). Additionally, there was no attenuation of associations in models that adjust for low birth weight (**Supplementary Table 2.7**) and later associations were also not fully mediated by HAZ at age 6-18 months (**Supplementary Table 2.8**).

Pathways of parental influence on physical growth

Analyses considering the effect of these proximal determinants on the main effects of parental education, conducted separately at each survey round, showed insignificant attenuations on the estimated associations (**Supplementary Tables 2.9-2.11**). Although several of these covariates had positive associations with child development, inclusion of these risk factors did not suggest that parental education operated through these covariates to affect height.

Discussion

Our study had four key findings. First, building on the substantial evidence that maternal education is important, we found *both* parents' education mattered in late infancy as well as in early and late childhood. Second, there was no evidence of differing associations between mother's and father's education, in late infancy or in childhood. Similar associations and the absence of mediation through some of the typical determinants suggest that both parents' education may operate through similar mechanisms, one of which is household wealth. Third, we also did not find that there is a multiplicative effect of parents' education. Lastly, variation between countries in the associations between parental education and height suggests that the relationship between parents' education and children's development may be context-specific. The remainder of the discussion section will focus on placing these findings within the larger body of work on parental education and child development.

Although there is much literature linking parental education with height, including associational evidence from observational studies (13,16,60,62,71,75-78) as well as causal inferences from quasi-experimental designs (18,69), few studies utilize longitudinal data to understand differences in the influences of parental education at various life stages. The Young Lives data, following a cohort from the first year of life to age 7-8 years, permits an investigation into the associations between parental education and height at multiple time periods. To our knowledge, no other study has used a cohort study or panel data to investigate this question, using cross-sectional data instead. Our study builds on evidence that parental education does matter for children's height at different ages; however, it extends this work by noting that parental status continues to matter for the same individuals at ages 6-18 months, 4-5 years, and 7-8 years.

Our finding that there are no differences in associations between mother's and father's education and height contrasts with recent work finding that maternal education was more important (71). It is consistent however with work critiquing the methods used to compare maternal vs. paternal influences (18,68). Our finding suggests that both parents' educational statuses affect children's height. That the influences are similar at various ages also questions whether mother's and father's education operate through distinct pathways at different developmental stages. Given the greater caregiving responsibilities faced by mothers when children are younger, one would expect maternal education to have greater influence at age 6-18 months compared to paternal education. However, these hypotheses do not appear to have any support. Our finding that various risk factors did not entirely explain how parental education affected physical growth not only suggests that the pathways through which parental education affects physical growth need to be further explored but also that there may not be distinct ways in which father's education affects physical growth in comparison to a mother's education. Instead, our analyses find that both parents' education operates through household wealth to influence height suggesting that greater household assets are key determinants in contrast to the conventional proximal risk factors.

The absence of a multiplicative effect of parental education on height is somewhat surprising given that higher levels of education for one parent may moderate the influence of the other parent's education on height. For example, it is plausible that in households in which a father is highly educated and thus perhaps earns a higher income, that the effect of the mother's education on height may be higher because increased household resources allow her to provide better care for the child. However, we find no evidence that this occurs in the data.

Country-specific variability in the effects of parental education on children's height is well-known (71). Several reasons exist, ranging from variations in parenting styles that influence how parental education may affect children in different ways to school-related characteristics such as the quality of education provided. As parental education is only measured as years of schooling in Young Lives, it is likely that there is some variability in what primary schooling confers in terms of cognitive development, learning, and knowledge in each of the four countries.

Our study had some limitations. First, we used observational data to estimate associations between parental education and children's height, rendering our findings vulnerable to confounding. The influence of unobserved covariates, affecting both parental education and height, may lead to biased estimates in spite of attempts to eliminate bias through the inclusion of key socio-demographic covariates and survey and sentinel site fixed effects and individual-level random effects. A key concern is assortative mating or the correlated nature of parents' education. Unfortunately we are unable to completely eliminate the problem of assortative mating, noting it as a potential weakness. These problems of confounding render it difficult to infer causal claims from our study, despite the longitudinal nature of the data and the temporal precedence of parental education. Lastly, we do not have information on all possible pathways through which parental education may operate. While we have explored the ones on which data were collected, a more comprehensive review would consider others such as nutritional or health knowledge. We also were only able to conduct simple mediation analyses comparing models with these proximal risk factors to models without these determinants to examine any attenuation in the estimated associations between parental education and physical growth. While absence of any change in the estimates may indicate that parental education does not operate through these pathways, it is equally likely that either these pathways were not adequately measured or that the relationship between parental education and the mechanisms may be confounded. More research is needed using an experimental or quasi-experimental design to flesh out these pathways.

Our study adds the evidence that that parental education is critically important for children's height. We provide new evidence that both parents' education matters equally and at different life stages without any parent-specific mechanism explaining how mother's or father's education may distinctly affect children's physical growth. Our contributions support further investments in education, agriculture, and social welfare programs, which are nutrition-sensitive interventions (79), to improve children's physical growth, complementing the efforts of nutrition-specific programs. Further investments in education would improve the social, economic, and political conditions shaping the dynamics of poor physical growth and undernutrition in low- and middle-income countries and curtailing the intergenerational transmission of ill health and poverty.

VIII. CHAPTER 3: HOUSEHOLD SOCIOECONOMIC CONDITIONS AND CHILDREN'S COGNITIVE DEVELOPMENT

Abstract:

Objectives: Over 200 million children suffer from cognitive deficits, which are rooted in adversity experienced early in life. Two key dimensions of early adversity that negatively influence children's cognitive development are household poverty and low levels of parental education. While much research has explored the influences on household wealth and parental education on children's cognitive development, little work examines this relationship in low- and middle-income countries with even fewer studies looking at associations at different life stages. Our study comprehensively assesses short- and long-run associations between household wealth and parental education and children's cognitive development, examining the mediating influence of early investments in child development, school enrollment, and physical growth.

Methods: Using longitudinal data from the Young Lives project (2002-2009), we analyzed associations between household wealth and parental education and cognitive status, using scores on the Peabody Picture Vocabulary Test (PPVT), for 6,005 children from Ethiopia, India, Peru, and Vietnam. Mediating influences of early investments in child development, school enrollment, and physical growth are also assessed with models including both concurrent as well as lagged measures of these mediating conditions.

Results: A one-year increase in mother's education was associated with a 0.048-SD (SE: 0.0049) increase in PPVT score at 4-5 years. Household wealth had the largest association with PPVT score and controlling for wealth attenuated the association between mother's education and cognitive status by 25%. Similar patterns of attenuating associations were found for father's education. A one-SD increase in HAZ at 4-5 years was associated with a 0.091-SD (SE: 0.015) and a 0.094-SD (SE: 0.013) increase in PPVT score at 4-5 and 7-8 years, which are nearly three

and four times greater than the association between mother's education and PPVT score at each age respectively. Preschool/crèche attendance at age 4-5 years (ECD) was associated with a 0.18-SD (SE: 0.046) increase in PPVT score, nearly 20 times greater than associations between parental education and children's cognitive status. Similarly, at age 7-8 years, being enrolled in school was associated with a 0.028-SD (SE: 0.0035) increase in PPVT score, controlling for mother's education. Similar patterns were observed for fathers and when jointly modeling associations between both parents' education and children's cognitive status.

Conclusion: Our study found that household socioeconomic conditions, particularly household wealth, were critical determinants of children's cognitive development with key relationships between physical growth and early investments in child development and cognition.

Introduction

Over 200 million children suffer from developmental deficits, for which poverty, ill-health, poor nutritional status, and improper care are key risk factors (2). Children experiencing adversity early on have poorer physical, cognitive, motor, and socioemotional development on average, all of which negatively affect educational attainment, employment opportunities, livelihoods, health as well as a multitude of other longer term outcomes (2,5). Thus, the consequences of these early life experiences persist across the life-course with lasting and often compounded effects of multiple deficits and deprivation on well-being (2). Furthermore, evidence suggests that the influences of early life conditions span generations; for example, children of stunted parents are often face cognitive deficits, even after controlling for parents' cognitive status (80). Early deprivation, in terms of household poverty, ill-health, poor nutrition, and unstimulating environments, has significant implications on child development and ultimately on the intergenerational transmission of poverty.

Household poverty and low levels of parental education are aspects of early deprivation that greatly influence children's development (2,6). Household poverty influences cognitive status indirectly through nutritional status, by affecting food availability, sanitation, and hygiene; it also operates through low educational attainment for parents that then influences cognitive development by affecting child care and stimulation (2). Many studies have explored the effects of parental, particularly maternal education, on children's cognitive development (81-84). Others have jointly considered the role of both parental education and household wealth as two dimensions of household socioeconomic conditions with many of the studies focusing on developed countries (85-89). In comparison, there is relatively little work that comprehensively compares the influences of both parental education and household socioeconomic status on children's cognition in low- and middle-income countries. One example is a recent study that examines the role of both parental education and household wealth, particularly examining how these associations between these determinants and cognition are mediated through physical growth and early investments in child development in Zambia (90). However, this study and others investigating the role of household socioeconomic status (91-95) only examine these associations using cross-sectional data. Meanwhile a few longitudinal studies examine associations between socioeconomic status and child development over time (96-98).

In this study we extend prior work by examining the relationships between parental education and household wealth and children's cognitive development in cohorts from four low- and middle-income countries during early infancy and later childhood. The main objective is to investigate associations between household SES, specifically parental education and household wealth, and children's cognitive status at age 4-5 years and again at age 7-8 years. Related aims include: (1) examining differences in associations between mother's and father's education and children's cognitive development; (2) comparing associations between parental education and cognition with associations between household wealth and cognition; (3) investigating and comparing the extent to which associations between parental education and children's cognition are mediated through physical growth and investments in childhood development (attendance in preschool/crèche or school enrollment and examining the multiplicative effects of physical growth and investments in early childhood development. To our knowledge, our study is the first to jointly consider these multiple dimensions of children's development for children from four low- and middle-income countries.

Methods

Study population

This study used data from the Young Lives study, a longitudinal study of child health and well-being in four countries – Ethiopia, India, Peru, and Vietnam (37-41). The Young Lives study was designed to follow two cohorts: a younger cohort born in 2000-01 and an older one born in 1994-95. Only the younger cohort was used for this analysis because we wanted to examine how conditions in infancy and early childhood affected cognitive development. Children in the younger cohort were ages 6-18 months at the first survey and 4-5 and 7-8 years at the two subsequent follow-up surveys.

The sampling design for Young Lives was similar across the four countries, although only one state, Andhra Pradesh, later split into Andhra Pradesh and Telangana, was surveyed in India. In each country, staff chose 20 sentinel sites, enumerating households with children born between 2000-2001, and then randomly selected 100 households within each site. Households that refused – less than 2% – were replaced with others (37). One child per household was chosen, resulting in approximately 2000 children surveyed for the younger cohort in each country. Further information on the sampling design for Young Lives is available in Outes-Leon and Sanchez (99), Kumra (100), Escobal and Flores (101), and Nguyen (102).

Excluding attrition due to mortality, the attrition rate of 4.7% was notably low compared to other longitudinal studies in similar contexts (42). Rates were similar across countries with slightly higher attrition in Peru at 6.7% and lowest attrition rates in Vietnam at 2.4% (**Supplementary Figure 3.1**). The most common reasons for attrition were households moving away from survey areas, refusing to participate, and infant mortality. Across all four countries, 243 children or 3.0% of children enrolled in round 1 were lost due to households moving or refusal to participate and 139 or 1.7% due to death. Attrition in Young Lives was non-random but was shown to cause minimal bias (42). Due to the large sample size, only individuals present in all rounds – 95.3% of the sample – were included. We further excluded children with missing information on parental education, cognitive tests, and other covariates. In total, 2,057 children (25.5% of the sample) were excluded due to loss to follow-up and missing data (Supplementary Figure 1). Approximately 5% of 8,062 children surveyed at baseline were excluded due to loss to follow-up. Of the 7,680 children followed across all three rounds, 22% were excluded due to missing data on parental education, cognitive tests, and other key covariates of interest. A total of 6,005 children were included in the analysis.

Explanatory measures and covariates

The key explanatory variable of interest was parental education reported by the primary caregiver. Most primary caregivers are biological parents of which nearly all are mothers. Nearly all (99%) of mothers and 96% of fathers co-reside with the child. As part of the household roster the primary caregiver, often with assistance from other family members present, was asked to enumerate household members and provide socio-demographic information such as household members' age and sex as well as the highest grade of education completed. In cases where the education level of a particular household member is not known by the primary caregiver, other family members were often requested to provide the missing information. For primary and secondary school, numbers 1-12 were used to document years of schooling. Post-secondary schooling was coded as 13 while any further education including university education or graduate studies was coded as 14. Years of schooling was used as an explanatory measure in the main analyses; however, to explore gradients in cognitive status in the sensitivity analyses, parental education was operationalized into three categories – no education, primary education (years 1-6), and secondary education (7 or more years of education). For more information on coding used for parental education, see **Supplementary Table 3.1** in the Appendix.

The other key explanatory measure was household wealth, measured at baseline when the child was ages 6-18 months. Household wealth was measured using an asset-based index developed by Filmer and Pritchett (43). The index was constructed from an enumeration of key indicators of living standards such as number of household members, ownership of material goods, housing quality, water and sanitation quality, and access to energy sources and was refined through principal components analysis (43,103,104). The wealth index is frequently used as an indicator of living standards in low resource settings (105). In the Young Lives study, a wealth index was constructed from three equally weighted components – a housing quality index, a services quality index, and a consumer durables index – and ranges from 0 to 1 (104). More information on construction of the wealth index is available in **Supplementary Table 3.2** in the Appendix. In the analyses, household wealth is centered at the grand mean, separately for each country. Tertiles of baseline wealth index are also used for descriptive analyses.

As mediating conditions, we considered the role of physical development measured through height for age z-scores (HAZ). Trained enumerators obtained weight, height, and length (in round 1), taking repeated measurements until consensus between measures was achieved. Final height and weight data in Young Lives data reflect reliable measurements taken by trained staff. Height and weight data were transformed into HAZ and stunting using growth standards from the WHO Multicentre Growth Reference Study. Young Lives staff used child's age in days to calculate HAZ. The analysis also included early investments in child development, operationalized as any attendance in preschools or crèches at age 4-5 years, and school enrollment at age 7-8 years.

Analyses also adjusted for child's age (in months) in our analyses as there is some variation in the age of participants at each survey and child's sex. We also controlled for mother's height to address intergenerational aspects of child stunting. Unfortunately father's height was not available, except in Peru. We also included household characteristics such as number of household members and place of residence (rural and urban) as key covariates.

Outcome measures

The key outcome of interest was score on the Peabody Picture Vocabulary Test (PPVT) at ages 4-5 and 7-8 years, a test that is widely used to assess children's receptive vocabulary (106,107). First developed in 1959, the test has been revised several times (108). For the Young Lives sample, the third version of the PPVT, which has 204 items was used in Ethiopia, India, and Vietnam (109,110), and was translated into each country's major languages. In Peru, the Spanish version of the revised form of the first version of the PPVT (PPVT-R) with 124 items was used (110,111). Prior to being implemented in the surveys, locally adapted PPVTs were field-tested and refined through consultation with an expert panel (110). More details on PPVT adaptation and pilot-testing are available in Cueto and Leon (110).

The PPVT is administered orally, on an individual basis, in an untimed fashion and in the local language with which the respondent is familiar (110). For children ages 4-5 years and 7-8 years, Young Lives staff delivered an oral stimulus i.e. spoke a word for which children were expected to select a pictorial card that best represented the stimulus (110). The test begins with easier cards and becomes progressively harder over time. At some point, the child cannot identify any more cards, which serve as a ceiling for his or her receptive vocabulary (110). Scores represent the number of items accurately identified (110). The same versions of the PPVT were delivered to children at age 4-5 and 7-8 years, allowing for comparison of scores over time (110). However, cross-national comparisons are complicated by slight differences in the test taking procedures, particularly in how each version establishes base and ceiling abilities; these are described in further detail in Cueto and Leon (110).

For our analysis, we use standardized measures of PPVT, normalized for each round in each country. These normed versions of PPVT provide a better understanding of children's receptive vocabulary relative to their peers in the same country. Additionally, as noted earlier, the PPVT measures receptive vocabulary, which is only one dimension of cognitive ability (112). For the sake of brevity, we will refer to standardized PPVT scores as children's cognitive status in the remaining sections of the article.

Statistical analyses

Table 3.1 contains descriptive statistics on key characteristics of the sample with more details on the distribution of parental education in **Supplementary Table 3.2** and differences in HAZ and PPVT scores by parental education and baseline household wealth index in **Supplementary Tables 3.3A-3.5B**. **Figures 3.1-3.5** also present gradients in cognitive status by parental education, household wealth, and by both concurrent and past stunting status.

Regression analyses using ordinary least squares models appropriate for continuous outcomes were used to assess associations between parental education and physical growth. Models were pooled across all countries. Standardization of PPVT scores by country and differences in the PPVT versions used in Young Lives countries suggest that country-specific models may be more appropriate in understanding cognitive status; however, pooled models provide a general idea of associations.

Separate models were used for cognitive status at age 4-5 years and 7-8 years. In these models, we introduced covariates in a stepwise fashion, first considering each parent's education separately and then together. We also examined whether baseline household wealth index was a key determinant of children's cognitive status, comparing associations between household wealth and cognition to parental education and cognition. Fully adjusted models accounted for maternal height, place of residence, and household size in addition to these key explanatory variables.

We also examined the mediating influences of physical growth and early investments in child development. In addition to models examining the role of concurrent height, height in the previous round was used to understand the associations between past physical development and cognitive status. Similarly, associations between preschool or crèche attendance at age 4-5 years and cognitive status at age 7-8 years were also examined. As with height, analyses also examined associations with both contemporaneous and lagged versions of early investments in child development. Interactions between physical growth and early investments in child development were also examined to understand whether children who experienced from better growth had differential gains from early childhood development experiences.

All models adjusted for child's age and sex and included survey and sentinel site fixed effects. Models also included clustered standard errors, clustered at the sentinel site level, to account for cluster-based sampling. In all models, we compared the influences of mother's education to father's education using Wald tests for differences in associations. Wald tests were also used to examine differences in associations between contemporaneous and past physical development and cognitive status and contemporaneous and past investments in child development and cognitive status. Sensitivity analyses, presented in the Appendix, used stunting as an alternate measure of physical development or more specifically of growth faltering.

Ethical review

This study was reviewed by the Institutional Review Board at Harvard T.H. Chan School of Public Health and deemed exempt from review because the data are anonymized and publicly available.

Results

Descriptive statistics

Table 3.1 presents results from descriptive analyses. On average, children have raw PPVT scores of 28.81 (Standard error [SE]: 1.30) at age 4-5 years with a minimum of 20.74 (SE: 1.23) in Ethiopia and maximum of 37.37 (SE: 2.30) in Vietnam. At age 7-8 years, the average PPVT score is 71.71 (SE: 2.49) with the lowest average score in India of 58.67 (SE: 2.97) and the highest in Vietnam at 94.34 (SE: 2.86). Scores are higher for older children because they are able to identify more items on the same version of the PPVT, which they took when they were ages 4-5 years. Globally, as well as in each country, mothers are less educated than fathers with pooled averages of 5.65 years (SE: 0.40) for mothers and 7.11 years (SE: 0.35) for fathers. Further information on parental education is provided in **Supplementary Table 3.3**. Baseline wealth index is 0.37, with the poorest country being Ethiopia, which has a mean baseline wealth index of 0.20 (SE: 0.03) while Vietnam is the least poor with an average wealth index of 0.44 (SE: 0.03). Across all four countries, nearly three-quarters of children attend preschool or crèches at age 4-5 years; at age 7-8 years, 94% of children attend school. Pooled across all countries, the mean HAZ was -1.32 (SE: 0.06) at age 6-18 months, -1.50 (SE: 0.05) at 4-5 years, and -1.22 (SE: 0.05) at 7-8 months. Relatedly, 30% of children (SE: 2.00) are stunted at age 6-18 months, 31% (SE: 2.00) at 4-5 years, and 23% (SE: 1.00) at 7-8 years. Slightly less than half or 47.0% (SE: 1:00) of the sample is female and 64% (SE: 5.00) resides in rural areas. Average mother's height is 153.03 (SE: 0.39) cm and mean household size is 5.44 (SE: 0.08) members.

Table 3.1 Descriptive statistics (n=6,005)[1]

	All countries (n=6,005)	Ethiopia (n=1,400)	India (n=1,728)	Peru (n=1,383)	Vietnam (n=1,494)
PPVT score[2]					
4-5 years	28.81 (1.30)	20.75 (1.23)	27.59 (2.56)	29.25 (2.61)	37.37 (2.30)
7-8 years	71.71 (2.49)	75.54 (6.22)	58.67 (2.97)	59.66 (2.10)	94.34 (2.86)
Mother's education (years)	5.65 (0.40)	3.07 (0.51)	3.38 (0.52)	7.74 (0.65)	8.77 (0.59)
Father's education (years)	7.11 (0.35)	5.29 (0.51)	4.97 (0.48)	8.97 (0.48)	9.58 (0.53)
Baseline wealth index (at 6-18 months)	0.37 (0.02)	0.20 (0.03)	0.41 (0.03)	0.43 (0.04)	0.44 (0.03)
Preschool/crèche attendance at age 4-5 years	0.73 (0.04)	0.22 (0.07)	0.88 (0.02)	0.86 (0.03)	0.93 (0.01)
School attendance at 7-8 years	0.94 (0.02)	0.75 (0.06)	0.99 (0.00)	1.00 (0.00)	1.00 (.)
Height for age z-score					
6-18 months	-1.32 (0.06)	-1.55 (0.14)	-1.35 (0.12)	-1.26 (0.13)	-1.13 (0.11)
4-5 years	-1.50 (0.05)	-1.49 (0.09)	-1.64 (0.07)	-1.51 (0.13)	-1.33 (0.12)
7-8 years	-1.22 (0.05)	-1.23 (0.07)	-1.41 (0.08)	-1.13 (0.11)	-1.08 (0.10)
Stunting					
6-18 months	0.30 (0.02)	0.42 (0.03)	0.31 (0.03)	0.27 (0.04)	0.21 (0.03)
4-5 years	0.31 (0.02)	0.32 (0.03)	0.36 (0.03)	0.32 (0.05)	0.25 (0.03)
7-8 years	0.23 (0.01)	0.22 (0.03)	0.29 (0.03)	0.20 (0.03)	0.20 (0.03)
Female	0.47 (0.01)	0.46 (0.01)	0.46 (0.01)	0.49 (0.01)	0.48 (0.01)
Age (months)					
Round 1	12.24 (0.06)	12.08 (0.13)	12.33 (0.11)	12.08 (0.09)	12. 41 (0.16)
Round 2	63.73 (0.22)	62.23 (0.27)	64.71 (0.27)	63.95 (0.67)	63.82 (0.29)
Round 3	96.44 (0.15)	97.26 (0.21)	95.93 (0.29)	95.45 (0.08)	97.22 (0.32)
Rural residence	0.64 (0.05)	0.67 (0.10)	0.75 (0.09)	0.30 (0.08)	0.82 (0.08)
Mother's height (cm)	153.03 (0.39)	158.76 (0.34)	151.53 (0.27)	149.99 (0.38)	152.22 (0.31)
Household size	5.44 (0.08)	6.13 (0.10)	5.46 (0.14)	5.53 (0.11)	4.69 (0.09)

Parental education, household wealth, and cognitive status

Figure 3.1 presents the gradient in cognitive status by parental education at age 4-: and 7-8 years, showing that at both ages, children with parents who are educated at the sec schooling or greater level have better cognitive status compared to those with uneducated parents. These patterns are evident in both the pooled data and for each country with some variability in the magnitude of differences in cognitive status for varying levels of parenta education. **Figure 3.2** presents similar patterning in cognitive status by household wealth v children from households in the top tertile having the best cognitive status. Differences in cognitive status by household wealth exist at both ages and in all countries. Tabular data fo cognitive status by parental education and household wealth are available in **Supplementa Tables 3.4A-B and 3.5A-B**.

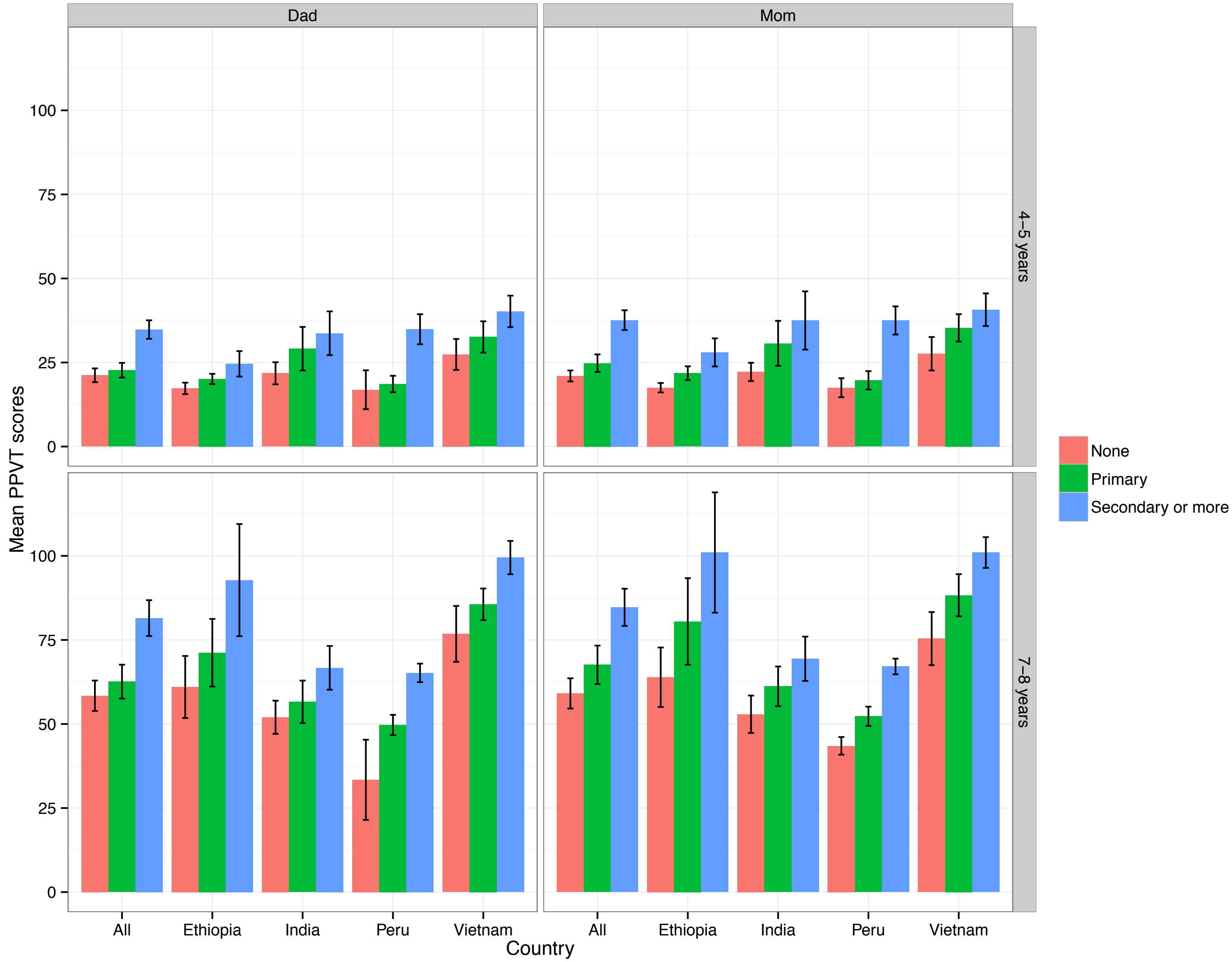


Figure 3.1 Mean scores on Peabody Picture Vocabulary Tests (PPVT) at age 4-5 and 7-8 years, by parental education and country

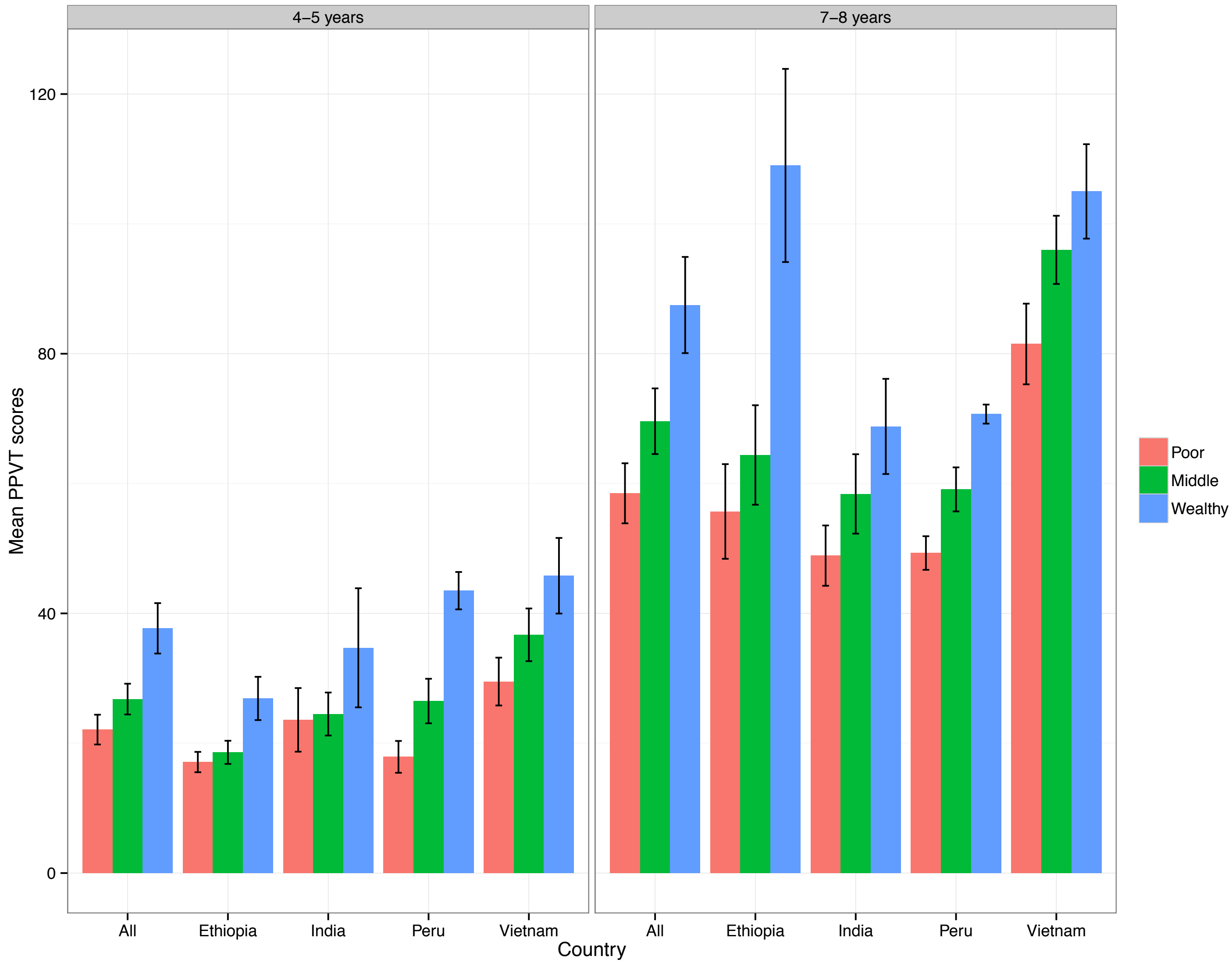


Figure 3.2 Mean scores on Peabody Picture Vocabulary Tests (PPVT) at age 4-5 and 7-8 years, by baseline wealth index (at age 6-18 months) and country

Building on these descriptive summaries, results from analytic models in **Table 3.** compare associations between each parental education and children's cognitive status as w with associations between household wealth and cognitive status. At age 4-5 years, a one- increase in mother's education was associated with a 0.048-SD (SE: 0.0049) increase in P score (Table 3.2, *1*). Controlling for wealth index attenuated the association between moth education and cognitive status by 25% (Table 3.2, *2*) while further adjustment for other sociodemographic covariates weakened the association by a smaller magnitude (Table 3.2 Similar patterns of attenuating associations were found for father's education and children cognitive status (Table 3.2, *4-6*). Estimates from fully adjusted models comparing mother' father's education indicated that the associations between mother's education and children cognitive status were significantly larger than associations between father's education and children's cognitive status (p-value: 0.02) with a one-year increase in mother's education associated with 0.028-SD (SE: 0.0038) increase in PPVT score as compared to a 0.019-SI 0.0030) increase in PPVT score associated with a one-year increase in father's education (3.2, *9*). Similar associations were estimated at age 7-8 years; however, there were no signi differences between mother's and father's education and children's cognitive status at age years (Table 3.2, *16-18*). At both ages and for both parents' education, associations betwe wealth index and children's cognitive status were of a greater magnitude compared to the associations between mother's or father's education and children's cognitive status (Table

Table 3.2 Associations between parental education, household wealth, and children's cognitive status, by age (n=6,005)[1]

Age 4-5 years	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mother's education	0.048***	0.036***	0.035***				0.037***	0.029***	0.028***
	(0.0049)	(0.0042)	(0.0041)				(0.0041)	(0.0038)	(0.0038)
Father's education				0.038***	0.027***	0.026***	0.025***	0.019***	0.019***
				(0.0042)	(0.0034)	(0.0034)	(0.0033)	(0.0030)	(0.0030)
Wealth index		0.98***	0.94***		1.06***	1.01***		0.84***	0.80***
		(0.11)	(0.11)		(0.12)	(0.11)		(0.11)	(0.11)
Constant	-2.87***	-2.94***	-3.23***	-2.85***	-2.93***	-3.23***	-2.99***	-3.03***	-3.28***
	(0.21)	(0.21)	(0.32)	(0.21)	(0.21)	(0.33)	(0.21)	(0.21)	(0.32)
Covariates[2]	No	No	Yes	No	No	Yes	No	No	Yes
R-squared	0.375	0.390	0.393	0.367	0.385	0.389	0.385	0.396	0.399
p-value[3]							*0.01*	*0.02*	*0.04*
Age 7-8 years	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Mother's education	0.044***	0.031***	0.028***				0.033***	0.024***	0.022***
	(0.0041)	(0.0036)	(0.0035)				(0.0039)	(0.0037)	(0.0035)
Father's education				0.036***	0.025***	0.023***	0.025***	0.018***	0.017***
				(0.0035)	(0.0028)	(0.0028)	(0.0030)	(0.0027)	(0.0027)
Wealth index		1.10***	1.03***		1.15***	1.07***		0.97***	0.91***
		(0.12)	(0.11)		(0.12)	(0.11)		(0.12)	(0.11)
Constant	-3.46***	-3.52***	-3.24***	-3.45***	-3.51***	-3.24***	-3.57***	-3.60***	-3.28***
	(0.33)	(0.33)	(0.49)	(0.34)	(0.34)	(0.49)	(0.33)	(0.33)	(0.49)
Covariates[2]	No	No	Yes	No	No	Yes	No	No	Yes
R-squared	0.335	0.354	0.363	0.330	0.352	0.361	0.345	0.359	0.368
p-value[3]							*0.10*	*0.18*	*0.27*

[1]Parental education is measured in years of schooling. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Results are from

Table 3.2 (Continued).
[2]Covariates include place of residence (urban/rural), household size, and mother's height.
[3]p-values are from significance tests for differences in associations between mother's and father's education and children's cognitive status.

Mediating influences of physical growth

Poorer physical development was more prevalent in households with lower socioeconomic status (**Supplementary Tables 3.6A-C and 3.7** and **Supplementary Figu 3.2A-C and 3.3**), and there were different distributions of PPVT scores among children w were contemporaneously stunted at both 4-5 and 7-8 years (**Figure 3.3**). **Figures 3.4 and** which compared PPVT score distributions between children who experienced concurrent past stunting at age 4-5 years and 7-8 years respectively, showed overlapping PPVT distri between children who experienced past stunting and contemporaneous stunting. This findi suggests that both previous and current growth faltering are equally important for cognitiv status.

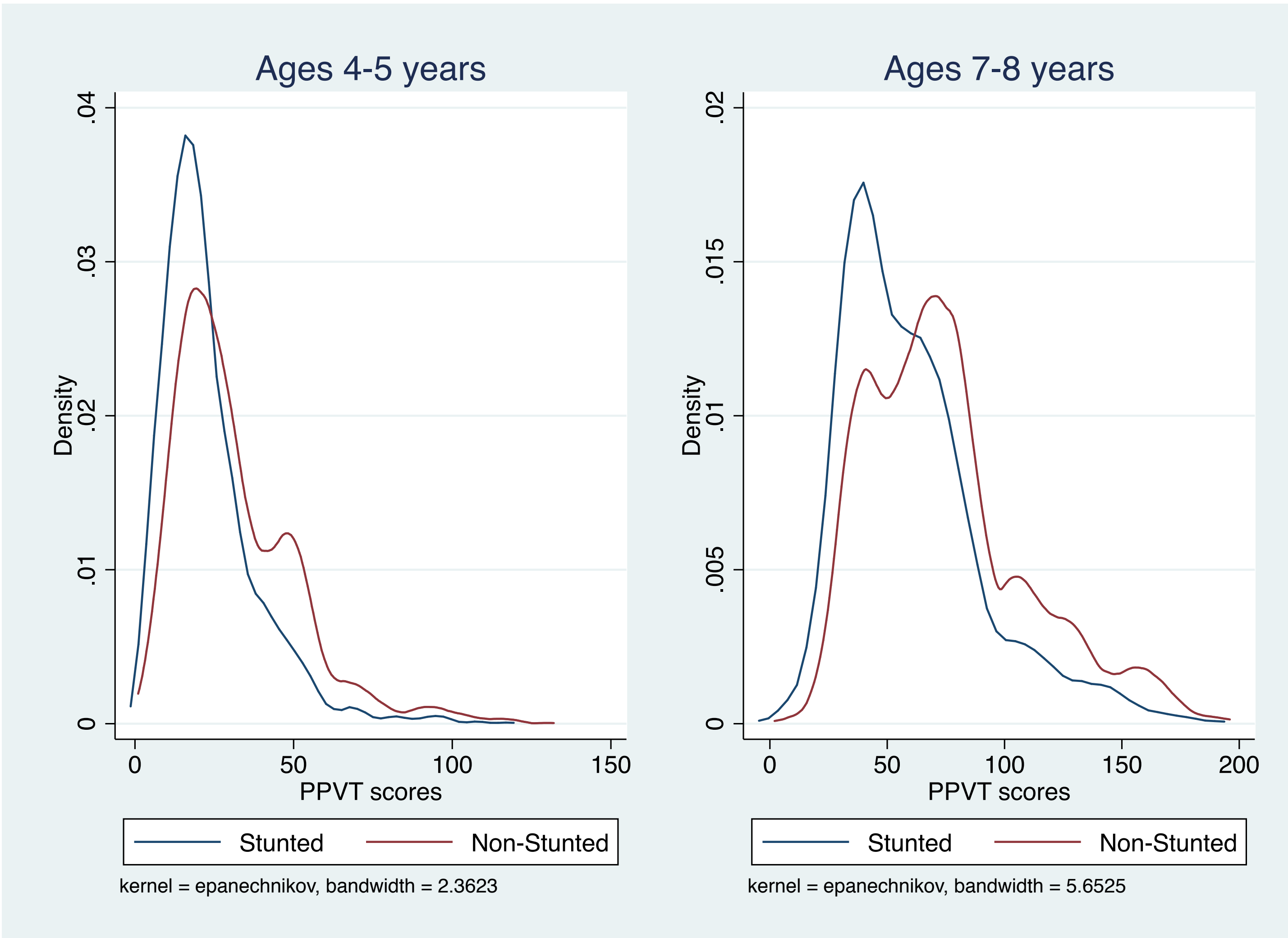


Figure 3.3 Distributions of Peabody Picture Vocabulary Tests (PPVT) by age and concurrent stunting status (pooled sample)

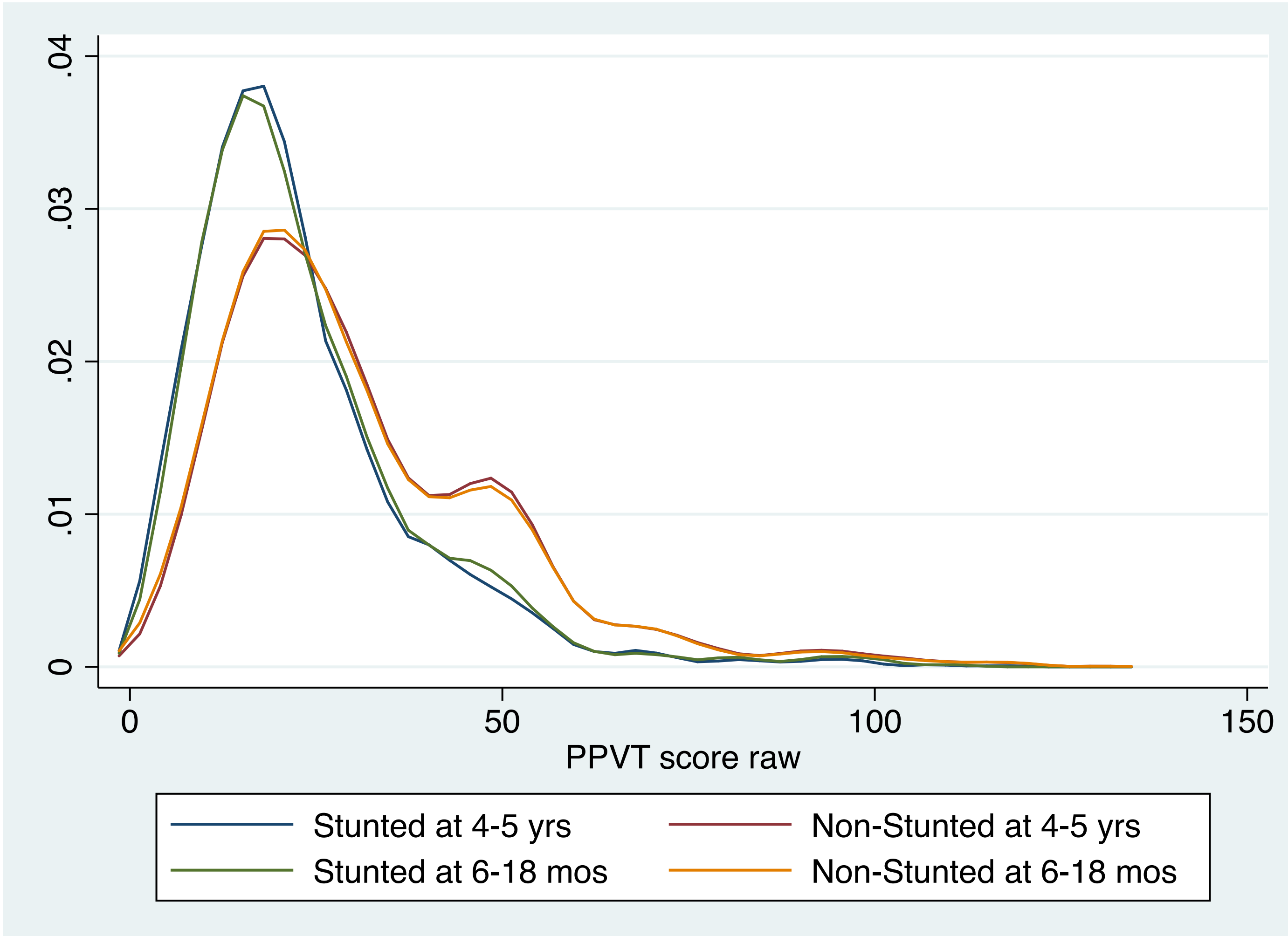


Figure 3.4 Distributions of Peabody Picture Vocabulary Tests (PPVT) at age 4-5 years and concurrent stunting status and stunting status at age 6-18 months (pooled sample)

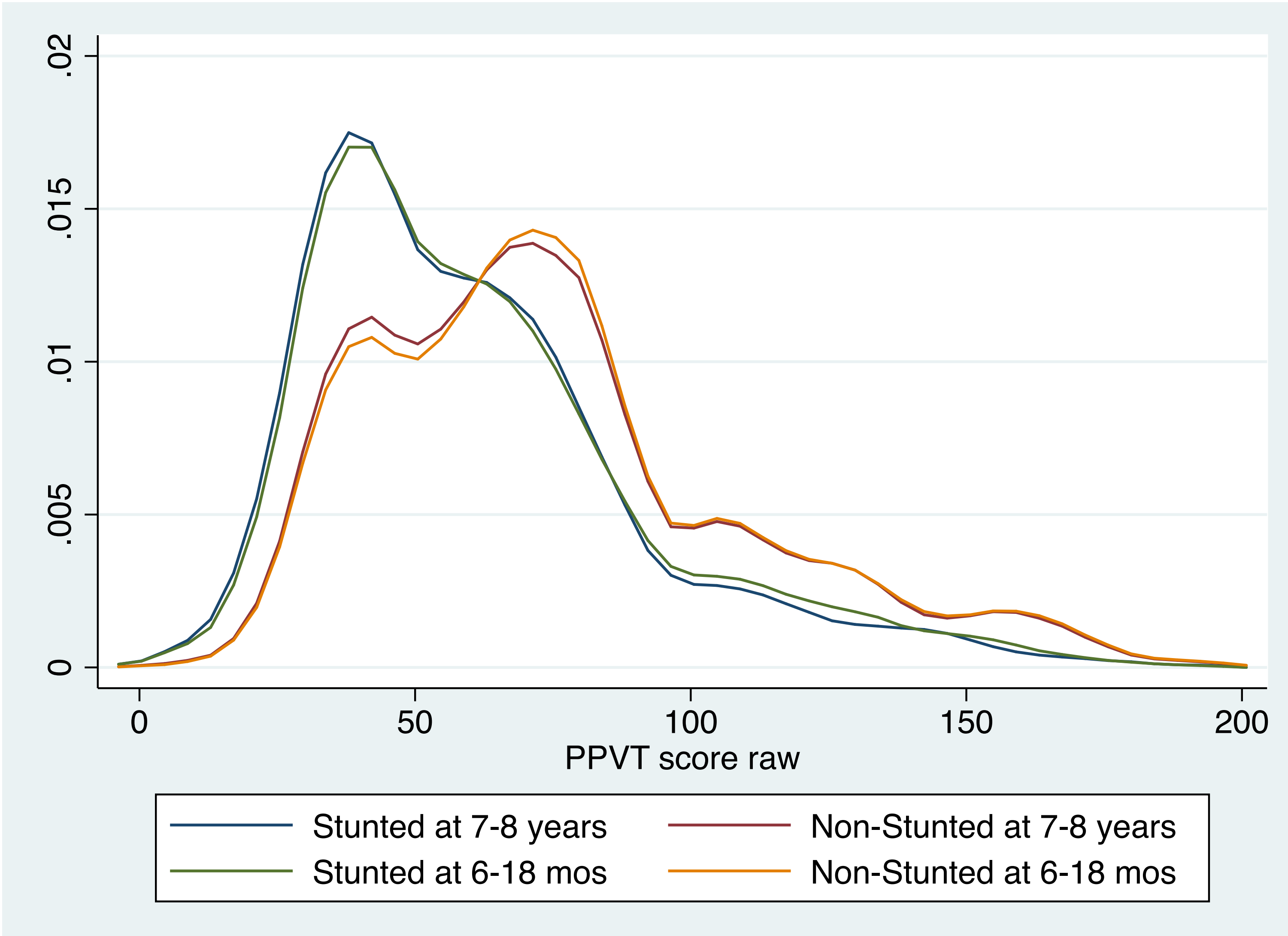


Figure 3.5 Distributions of Peabody Picture Vocabulary Tests (PPVT) at age 7-8 years and concurrent stunting status and stunting status at age 6-18 months (pooled sample)

Tables 3.3-3.4 present results from statistical models supporting these descriptive analyses. Controlling for concurrent HAZ attenuated the association between mother's edu and children's cognitive status by approximately 5% at age 4-5 years (Table 3.3, *1-2*) and age 7-8 years. Additionally, a one-SD increase in HAZ at 4-5 years was associated with a SD (SE: 0.015) increase in PPVT score at age 4-5 years (Table 3.3, *2*), and a 0.094-SD (SE 0.013) increase in PPVT score (Table 3.3, *11*) at 7-8 years, which are nearly three and fou greater than the association between mother's education and PPVT score at each age respectively. Accounting for past HAZ in addition to concurrent HAZ led to a very small, attenuation in the association between mother's education and children's cognitive status a ages (Table 3.3, *3* and *12-13*). Tests of significance showed no differences in the associati between past and concurrent HAZ and cognitive status at age 4-5 years (p-value: 0.75), as suggested in Figure 3.4. At age 7-8 years, there were significant differences only between at 7-8 years and HAZ at 6-18 months and HAZ at 7-8 months and HAZ at 4-5 years; howe the estimate for HAZ at 4-5 years was not statistically significant. Similar estimates were observed for fathers and when jointly modeling associations between both parents' educat children's cognitive status (Table 3.3, *4-9* and *14-21*).

Table 3.3 Associations between parental education, household wealth, and children's cognitive status by age, controlling for concurrent height for age z-scores (HAZ) and past HAZ (n=6,005)[1]

Age 4-5 years	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mother's education	0.035***	0.033***	0.032***				0.028***	0.027***	0.027***
	(0.0041)	(0.0040)	(0.0040)				(0.0038)	(0.0037)	(0.0037)
Father's education				0.026***	0.025***	0.025***	0.019***	0.018***	0.017***
				(0.0034)	(0.0033)	(0.0033)	(0.0030)	(0.0030)	(0.0030)
Wealth index	0.94***	0.85***	0.84***	1.01***	0.92***	0.91***	0.80***	0.73***	0.72***
	(0.11)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)
HAZ(2)[2]		0.091***	0.057***		0.093***	0.059***		0.088***	0.055***
		(0.015)	(0.017)		(0.015)	(0.017)		(0.015)	(0.016)
HAZ(1)[2]			0.050***			0.050***			0.048***
			(0.0095)			(0.0095)			(0.0094)
Constant	-3.23***	-2.41***	-2.65***	-3.23***	-2.39***	-2.63***	-3.28***	-2.49***	-2.72***
	(0.32)	(0.33)	(0.33)	(0.33)	(0.34)	(0.34)	(0.32)	(0.33)	(0.33)
R-squared	0.393	0.401	0.405	0.389	0.397	0.400	0.399	0.406	0.409
p-values[2]									
Mother's vs. Father's							*0.04*	*0.04*	*0.05*
HAZ(2) vs. HAZ(1)			*0.75*			*0.71*			*0.76*

Age 7-8 years	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Mother's education	0.028***	0.026***	0.026***	0.026***					0.022***	0.021***	0.021***	0.021***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0034)	(0.0034)	(0.0034)
Father's education					0.023***	0.022***	0.022***	0.021***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.94***	0.93***	0.92***	1.07***	0.98***	0.96***	0.96***	0.91***	0.83***	0.82***	0.82***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
HAZ(3)[2]		0.094***	0.073***	0.066***		0.096***	0.074***	0.067***		0.092***	0.071***	0.065***
		(0.013)	(0.015)	(0.015)		(0.013)	(0.015)	(0.015)		(0.013)	(0.015)	(0.014)
HAZ(2)[2]			0.035**	0.023			0.035**	0.023			0.033**	0.022
			(0.015)	(0.015)			(0.015)	(0.016)			(0.015)	(0.015)
HAZ(1)[2]				0.025***				0.025***				0.024***
				(0.0081)				(0.0080)				(0.0081)

Table 3.3 (Continued).

Constant	-3.24***	-2.47***	-2.34***	-2.57***	-3.24***	-2.47***	-2.33***	-2.56***	-3.28***	-2.54***	-2.41***	-2.63***
	(0.49)	(0.50)	(0.49)	(0.51)	(0.49)	(0.51)	(0.50)	(0.51)	(0.49)	(0.51)	(0.50)	(0.51)
R-squared	0.363	0.372	0.373	0.373	0.361	0.370	0.371	0.372	0.368	0.376	0.377	0.377
p-values[3]												
Mother's vs. Father's									*0.27*	*0.31*	*0.31*	*0.30*
HAZ(3) vs. HAZ(2)			*0.17*	*0.10*			*0.16*	*0.10*			*0.16*	*0.10*
HAZ(3) vs. HAZ(1)				*0.01*				*0.01*				*0.01*
HAZ(2) vs. HAZ(1)				*0.91*				*0.91*				*0.92*
HAZ(3) vs. HAZ(2) vs. HAZ(1)				*0.04*				*0.03*				*0.04*

[1]Parental education is measured in years of schooling. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]HAZ(1)=HAZ at age 6-18 months; HAZ(2)=HAZ at age 4-5 years; HAZ(3)=HAZ at age 7-8 years.

[3]p-values are from significance tests for differences in associations

.

Table 3.4 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for investments in early child development (ECD) (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)
Mother's education	0.035***	0.033***			0.028***	0.027***
	(0.0041)	(0.0042)			(0.0038)	(0.0038)
Father's education			0.026***	0.026***	0.019***	0.018***
			(0.0034)	(0.0034)	(0.0030)	(0.0030)
Wealth index	0.94***	0.90***	1.01***	0.96***	0.80***	0.77***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
ECD		0.18***		0.19***		0.17***
		(0.046)		(0.046)		(0.046)
Constant	-3.23***	-3.28***	-3.23***	-3.28***	-3.28***	-3.33***
	(0.32)	(0.32)	(0.33)	(0.34)	(0.32)	(0.32)
R-squared	0.393	0.396	0.389	0.392	0.399	0.401
p-values[2]					*0.04*	*0.06*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]p-values are from significance tests for differences in associations between mother's and father's education and children's cognitive status.

Mediating influences of early investments in child development

Mean PPVT scores were significantly higher among children who did attend presc or crèches in pooled analyses as well as in each country except India (**Figure 3.6**). As nea children attended school (Table 1), differences in PPVT scores by school enrollment were difficult to estimate. Multivariate model results presented in **Tables** 3.4-**3.5** confirm that preschool/crèche attendance mattered for cognitive status. Preschool/crèche attendance at 5 years (ECD) was associated with a 0.18-SD (SE: 0.046) increase in PPVT score, control for mother's education (Table 3.4, *2*). Although there was a socioeconomic gradient in preschool/crèche attendance (**Supplementary Tables 3.8-3.9** and **Supplementary Figure 3.5**), accounting for ECD attenuated the coefficient on maternal education by approximate (Table 3.4, *1-2*). Even less attenuation was observed for father's education and when joint modeling associations between both parents' education and children's cognitive status (Ta 3.4, *3-6*). However, associations between investments in ECD and children's cognitive sta nearly 20 times greater than associations between parental education and children's cognit status. These findings suggest that although preschool or crèche attendance may not medi relationship between parental education or household wealth and children's cognitive stat early investments in child development mattered for cognitive status. Similarly, at age 7-8 being enrolled in school was associated with a 0.028-SD (SE: 0.0035) increase in PPVT s controlling for mother's education (Table 3.5, *2*). Accounting for school enrollment did n attenuate the estimate on mother's education by a large magnitude. Similar patterns were observed for fathers and when jointly modeling associations between both parents' educat children's cognitive status (Table 3.5, *3-6*).

Figure 3.6 Mean Scores on Peabody Picture Vocabulary Tests (PPVT) at age 4-5 years by preschool/crèche attendance.

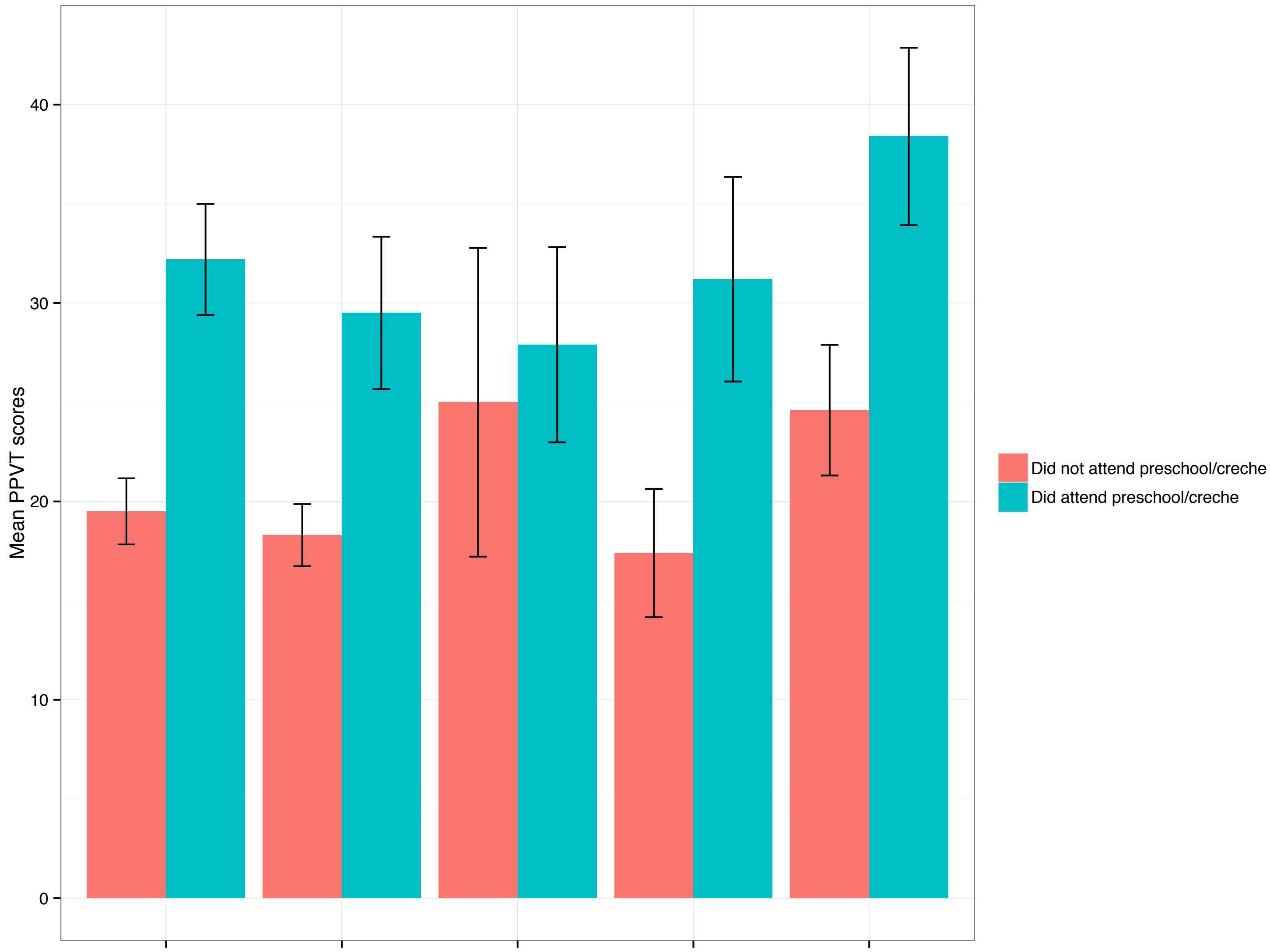


Table 3.5 Associations between parental education, household wealth, and children's cogı status at age 7-8 years, controlling for school enrollment (SCH) (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)
Mother's education	0.028***	0.028***			0.022***	0.022***
	(0.0035)	(0.0035)			(0.0035)	(0.0035)
Father's education			0.023***	0.023***	0.017***	0.017***
			(0.0028)	(0.0028)	(0.0027)	(0.0027)
Wealth index	1.03***	1.02***	1.07***	1.06***	0.91***	0.90***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
SCH		0.19***		0.19***		0.18***
		(0.054)		(0.055)		(0.055)
Constant	-3.24***	-3.36***	-3.24***	-3.37***	-3.28***	-3.41***
	(0.49)	(0.50)	(0.49)	(0.50)	(0.49)	(0.50)
R-squared	0.363	0.364	0.361	0.362	0.368	0.369
p-values[2]					*0.27*	*0.26*

[1] Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabod Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as binar variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered samp presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include surv sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, mother's height.

[3]p-values are from significance tests for differences in association between mother's and father's education

Multiplicative effects of physical growth and early investments in child development

Tables 3.6-3.8 present results from models comparing the mediating influences of physical growth, and preschool/crèche attendance at age 4-5 years, as well as interactions between these covariates. In models for maternal education, a one-SD increase in HAZ at age 4-5 years was associated with a 0.089-SD (SE: 0.015) increase in PPVT score (Table 3.6, *3*). In comparison, attending preschool/crèches was associated with a 0.16-SD (SE: 0.0.046) increase in PPVT score (Table 3.6, *3*); however, these differences were not statistically significant (p-value: 0.17). Models with interactions for HAZ and ECD also showed significant differential associations between ECD and cognition by HAZ. Similar results were found in models for paternal education and those jointly considering both parents' education. Analyses presented in Table 7, which used past HAZ instead of concurrent HAZ as an exposure, and Table 8, which included both past and concurrent HAZ, also found non-significant differences in estimated associations for HAZ and ECD, except for in models for father's education with HAZ as the exposure (Table 3.7, *7*) and between HAZ at 6-18 months and ECD in models controlling for both past and concurrent HAZ (Table 3.8, *4, 8, 12*). These analyses also found that the association between concurrent HAZ and cognitive status attenuated by more than 30% after accounting for past HAZ at 6-18 months; however, there were no significant differences in associations between concurrent and past HAZ and cognitive status (Table 3.8, *2-3*).

Table 3.6 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 4-5 years and concurrent height for age z-scores (HAZ) at 4-5 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.033***	0.032***	0.032***					0.028***	0.027***	0.026***	0.026***
	(0.0041)	(0.0040)	(0.0041)	(0.0040)					(0.0038)	(0.0037)	(0.0038)	(0.0037)
Father's education					0.026***	0.025***	0.024***	0.024***	0.019***	0.018***	0.017***	0.017***
					(0.0034)	(0.0033)	(0.0033)	(0.0032)	(0.0030)	(0.0030)	(0.0030)	(0.0030)
Wealth index	0.94***	0.85***	0.82***	0.81***	1.01***	0.92***	0.88***	0.87***	0.80***	0.73***	0.70***	0.69***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)
HAZ(2)[2]		0.091***	0.089***	0.048***		0.093***	0.091***	0.047***		0.088***	0.087***	0.045**
		(0.015)	(0.015)	(0.018)		(0.015)	(0.015)	(0.017)		(0.015)	(0.015)	(0.017)
ECD			0.16***	0.27***			0.18***	0.29***			0.15***	0.26***
			(0.046)	(0.059)			(0.046)	(0.057)			(0.046)	(0.057)
ECD*HAZ(2)[2]				0.063***				0.067***				0.063***
				(0.021)				(0.021)				(0.021)
Constant	-3.23***	-2.41***	-2.47***	-2.48***	-3.23***	-2.39***	-2.46***	-2.47***	-3.28***	-2.49***	-2.55***	-2.56***
	(0.32)	(0.33)	(0.34)	(0.33)	(0.33)	(0.34)	(0.34)	(0.34)	(0.32)	(0.33)	(0.34)	(0.33)
R-squared	0.393	0.401	0.403	0.404	0.389	0.397	0.399	0.401	0.399	0.406	0.408	0.409
p-values[3]												
HAZ(2) vs. ECD			*0.17*				*0.11*				*0.21*	
Mother's vs. Father's									*0.04*	*0.04*	*0.06*	*0.07*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]HAZ(2)=HAZ at age 4-5 years.

[3]p-values are from significance tests for differences in associations**.**

Table 3.7 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 4-5 years and past height for age z-scores (HAZ) at 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.033***	0.032***	0.032***					0.028***	0.027***	0.026***	0.026***
	(0.0041)	(0.0040)	(0.0041)	(0.0040)					(0.0038)	(0.0037)	(0.0037)	(0.0037)
Father's education					0.026***	0.025***	0.024***	0.024***	0.019***	0.018***	0.017***	0.017***
					(0.0034)	(0.0033)	(0.0033)	(0.0033)	(0.0030)	(0.0030)	(0.0030)	(0.0030)
Wealth index	0.94***	0.87***	0.84***	0.83***	1.01***	0.94***	0.90***	0.89***	0.80***	0.75***	0.72***	0.72***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)
HAZ(1)[2]		0.069***	0.068***	0.043***		0.070***	0.068***	0.043***		0.067***	0.066***	0.041***
		(0.0087)	(0.0088)	(0.011)		(0.0086)	(0.0087)	(0.010)		(0.0086)	(0.0087)	(0.010)
ECD			0.16***	0.22***			0.17***	0.24***			0.15***	0.21***
			(0.045)	(0.053)			(0.045)	(0.053)			(0.045)	(0.053)
ECD* HAZ(1)[2]				0.042***				0.042***				0.041***
				(0.015)				(0.014)				(0.014)
Constant	-3.23***	-3.14***	-3.19***	-3.19***	-3.23***	-3.13***	-3.19***	-3.19***	-3.28***	-3.19***	-3.23***	-3.24***
	(0.32)	(0.31)	(0.32)	(0.31)	(0.33)	(0.33)	(0.33)	(0.33)	(0.32)	(0.31)	(0.32)	(0.32)
R-squared	0.393	0.402	0.404	0.405	0.389	0.398	0.400	0.401	0.399	0.407	0.409	0.410
p-value[3]												
HAZ(1) vs. ECD			*0.06*				*0.03*				*0.08*	
Mother's vs. Father's									*0.04*	*0.04*	*0.06*	*0.06*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]HAZ(1)=HAZ at age 6-18 months.

[3]p-values are from significance tests for differences in associations between mother's and father's education and children's cognitive status.

Table 3.8 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 4-5 years and height for age z-scores (HAZ) at 4-5 years and 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.033***	0.032***	0.031***					0.028***	0.027***	0.027***	0.026***
	(0.0041)	(0.0040)	(0.0040)	(0.0040)					(0.0038)	(0.0037)	(0.0037)	(0.0037)
Father's education					0.026***	0.025***	0.025***	0.024***	0.019***	0.018***	0.017***	0.017***
					(0.0034)	(0.0033)	(0.0033)	(0.0032)	(0.0030)	(0.0030)	(0.0030)	(0.0030)
Wealth index	0.94***	0.85***	0.84***	0.81***	1.01***	0.92***	0.91***	0.87***	0.80***	0.73***	0.72***	0.69***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)	(0.10)
HAZ(2)[2]		0.091***	0.057***	0.056***		0.093***	0.059***	0.058***		0.088***	0.055***	0.054***
		(0.015)	(0.017)	(0.016)		(0.015)	(0.017)	(0.016)		(0.015)	(0.016)	(0.016)
HAZ(1)[2]			0.050***	0.048***			0.050***	0.049***			0.048***	0.047***
			(0.0095)	(0.0093)			(0.0095)	(0.0093)			(0.0094)	(0.0092)
ECD				0.16***				0.17***				0.15***
				(0.045)				(0.046)				(0.045)
Constant	-3.23***	-2.41***	-2.65***	-2.71***	-3.23***	-2.39***	-2.63***	-2.70***	-3.28***	-2.49***	-2.72***	-2.77***
	(0.32)	(0.33)	(0.33)	(0.34)	(0.33)	(0.34)	(0.34)	(0.35)	(0.32)	(0.33)	(0.33)	(0.34)
R-squared	0.393	0.401	0.405	0.407	0.389	0.397	0.400	0.403	0.399	0.406	0.409	0.411
p-values[3]												
HAZ(2) vs. HAZ(1)			*0.75*	*0.72*			*0.71*	*0.68*			*0.76*	*0.74*
HAZ(2) vs. ECD				*0.07*				*0.04*				*0.09*
HAZ(1) vs. ECD				*0.02*				*0.01*				*0.03*
Mother's vs. Father's									*0.04*	*0.04*	*0.05*	*0.06*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]HAZ(1)=HAZ at age 6-18 months.
[3]p-values are from significance tests for differences in association.

Modeling cognitive status at age 7-8 years, **Tables 3.9-3.12** showed similar results Tables 3.6-3.8, indicating that HAZ, both past and concurrent, as well school enrollment mattered for children's cognitive status. Tests indicated that associations between school enrollment and cognitive status were significantly larger than associations between physic growth and cognitive status only when considering past HAZ at 6-18 months as the exposı (Table 3.11, *3, 7, 9*). Although interaction terms in Tables 3.9-3.11 suggested that childrer are taller either concurrently or early on may experience additional cognitive benefits fron in school, insignificant main effects of HAZ indicate that these additional benefits may no accrue to children at the median HAZ values. Models in Table 3.12 iteratively accounted f concurrent and past HAZ, preschool/crèche attendance, school enrollment, and past cogni status. Comparisons of past and current physical growth and investments in child develop showed that associations between contemporaneous HAZ and cognitive status were signif greater than associations between HAZ at 6-18 months and cognitive status at 7-8 years. A increase in PPVT score at age 4-5 years was associated with a 0.23-SD (SE: 0.021) increm PPVT score at 7-8 years (Table 3.12, *7*). Although there was some attenuation in the estim for parent's education, household wealth index, physical growth, and early investments in development, associations between these covariates and cognitive status were still signific suggesting that past cognitive status does not fully explain current cognitive status.

Stunting results

Results from additional analyses using stunting instead of HAZ were similar to the findings presented here. Full results can be found in **Supplementary Tables 3.10-3.17** in Appendix.

Table 3.9 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and height for age z-scores (HAZ) at 7-8 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.026***	0.026***	0.026***					0.022***	0.021***	0.021***	0.021***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0034)	(0.0034)	(0.0035)
Father's education					0.023***	0.022***	0.022***	0.022***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.94***	0.94***	0.93***	1.07***	0.98***	0.97***	0.97***	0.91***	0.83***	0.83***	0.82***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
HAZ(3)[2]		0.094***	0.092***	-0.013		0.096***	0.094***	-0.012		0.092***	0.090***	-0.013
		(0.013)	(0.013)	(0.032)		(0.013)	(0.013)	(0.031)		(0.013)	(0.013)	(0.031)
SCH			0.15**	0.34***			0.15**	0.34***			0.15**	0.33***
			(0.058)	(0.083)			(0.059)	(0.083)			(0.059)	(0.083)
SCH*HAZ(3)[2]				0.11***				0.12***				0.11***
				(0.034)				(0.033)				(0.033)
Constant	-3.24***	-2.47***	-2.59***	-2.76***	-3.24***	-2.47***	-2.58***	-2.75***	-3.28***	-2.54***	-2.65***	-2.82***
	(0.49)	(0.50)	(0.51)	(0.51)	(0.49)	(0.51)	(0.52)	(0.52)	(0.49)	(0.51)	(0.52)	(0.52)
R-squared	0.363	0.372	0.373	0.374	0.361	0.370	0.371	0.372	0.368	0.376	0.377	0.378
p-values[3]												
HAZ(3) vs. SCH			*0.33*				*0.36*				*0.36*	
Mother's vs. Father's									*0.27*	*0.31*	*0.31*	*0.31*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]HAZ(3)=HAZ at age 7-8 years.
[3]p-values are from significance tests for differences in association between mother's and father's education.

Table 3.10 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and height for age z-scores (HAZ) at 4-5 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.027***	0.027***	0.027***					0.022***	0.021***	0.021***	0.021***
	(0.0035)	(0.0034)	(0.0034)	(0.0035)					(0.0035)	(0.0035)	(0.0035)	(0.0035)
Father's education					0.023***	0.022***	0.022***	0.022***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.95***	0.95***	0.95***	1.07***	0.99***	0.99***	0.98***	0.91***	0.84***	0.84***	0.84***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
HAZ(2)[2]		0.083***	0.080***	-0.0077		0.084***	0.081***	-0.015		0.080***	0.078***	-0.013
		(0.013)	(0.013)	(0.025)		(0.013)	(0.013)	(0.024)		(0.013)	(0.013)	(0.025)
SCH			0.15***	0.34***			0.15**	0.35***			0.15**	0.34***
			(0.058)	(0.078)			(0.059)	(0.081)			(0.058)	(0.080)
SCH*HAZ(2)[2]				0.094***				0.10***				0.097***
				(0.027)				(0.026)				(0.026)
Constant	-3.24***	-2.51***	-2.63***	-2.80***	-3.24***	-2.50***	-2.63***	-2.81***	-3.28***	-2.58***	-2.70***	-2.87***
	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)
R-squared	0.363	0.369	0.370	0.371	0.361	0.368	0.368	0.369	0.368	0.374	0.374	0.375
p-values[3]												
HAZ(2) vs. SCH			*0.23*				*0.25*				*0.25*	
Mother's vs. Father's									*0.27*	*0.29*	*0.28*	*0.30*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Household wealth index is mean-centered. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]HAZ(2)=HAZ at age 4-5 years.
[3]p-values are from significance tests for differences in association between mother's and father's education.

Table 3.11 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and height for age z-scores (HAZ) at 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.027***	0.027***	0.027***					0.022***	0.021***	0.021***	0.021***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0035)	(0.0035)	(0.0035)
Father's education					0.023***	0.022***	0.022***	0.022***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.98***	0.97***	0.97***	1.07***	1.02***	1.01***	1.01***	0.91***	0.87***	0.86***	0.86***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
HAZ(1)		0.053***	0.052***	-0.0030		0.054***	0.052***	-0.0035		0.051***	0.050***	-0.0047
		(0.0079)	(0.0079)	(0.010)		(0.0079)	(0.0079)	(0.011)		(0.0079)	(0.0079)	(0.011)
SCH			0.17***	0.29***			0.17***	0.29***			0.16***	0.28***
			(0.055)	(0.065)			(0.056)	(0.067)			(0.055)	(0.067)
SCH* HAZ(1)				0.061***				0.062***				0.061***
				(0.013)				(0.013)				(0.013)
Constant	-3.24***	-3.37***	-3.49***	-3.60***	-3.24***	-3.38***	-3.49***	-3.61***	-3.28***	-3.41***	-3.52***	-3.64***
	(0.49)	(0.49)	(0.50)	(0.49)	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)
R-squared	0.363	0.368	0.369	0.370	0.361	0.367	0.368	0.368	0.368	0.372	0.373	0.374
p-values												
HAZ(1) vs. SCH			*0.04*				*0.04*				*0.05*	
Mother's vs. Father's									*0.27*	*0.27*	*0.27*	*0.27*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]HAZ(1)=HAZ at age 6-18 months
[3]p-values are from significance tests for differences in association between mother's and father's education.

Table 3.12 Associations between parental education, household wealth, and children's cognitive status at ages 7-8 years, controlling for school enrollment (SCH) at 7-8 years, early investments in child development (ECD) at 4-5 years, and height for age z-scores (HAZ) at 7-8 years, at 4-5 years and 6-18 months and past cognitive status (n=6,005)[1]

Mother's education	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mother's education	0.028***	0.026***	0.026***	0.026***	0.026***	0.025***	0.018***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0029)
Wealth index	1.03***	0.94***	0.93***	0.92***	0.92***	0.89***	0.71***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)
HAZ(3)[2]		0.094***	0.073***	0.066***	0.065***	0.064***	0.054***
		(0.013)	(0.015)	(0.015)	(0.014)	(0.014)	(0.014)
HAZ(2)[2]			0.035**	0.023	0.021	0.021	0.013
			(0.015)	(0.015)	(0.015)	(0.015)	(0.013)
HAZ(1)[2]				0.025***	0.025***	0.024***	0.014*
				(0.0081)	(0.0081)	(0.0081)	(0.0077)
SCH					0.14**	0.14**	0.12*
					(0.058)	(0.059)	(0.061)
ECD						0.15***	0.12**
						(0.052)	(0.050)
Past PPVT score[3]							0.23***
							(0.021)
Constant	-3.24***	-2.47***	-2.34***	-2.57***	-2.69***	-2.69***	-1.73***
	(0.49)	(0.50)	(0.49)	(0.51)	(0.52)	(0.51)	(0.49)
R-squared	0.363	0.372	0.373	0.373	0.374	0.376	0.408
p-values[4]							
HAZ(3) vs. HAZ(2)			*0.17*	*0.10*	*0.09*	*0.09*	*0.09*
HAZ(3) vs. HAZ(1)				*0.01*	*0.01*	*0.01*	*0.01*
HAZ(2) vs. HAZ(1)				*0.91*	*0.84*	*0.89*	*0.96*
HAZ(3) vs. HAZ(2) vs. HAZ(1)				*0.04*	*0.04*	*0.04*	*0.05*
SCH vs. ECD						*0.86*	*0.94*
Father's education	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**
Father's education	0.023***	0.022***	0.022***	0.021***	0.021***	0.021***	0.015***

	(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0028)	(0.0027)	(0.0026)
Wealth index	1.07***	0.98***	0.96***	0.96***	0.96***	0.92***	0.72***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)
HAZ(3)^2		0.096***	0.074***	0.067***	0.066***	0.065***	0.055***
		(0.013)	(0.015)	(0.015)	(0.015)	(0.014)	(0.014)
HAZ(2)^2			0.035**	0.023	0.021	0.021	0.013
			(0.015)	(0.016)	(0.016)	(0.015)	(0.013)
HAZ(1)^2				0.025***	0.025***	0.023***	0.014*
				(0.0080)	(0.0080)	(0.0080)	(0.0076)
SCH					0.14**	0.13**	0.12*
					(0.059)	(0.059)	(0.062)
ECD						0.16***	0.12**

Table 3.12 (Continued).

						(0.052)	(0.049)
Past PPVT score[3]							0.23***
							(0.022)
Constant	-3.24***	-2.47***	-2.33***	-2.56***	-2.68***	-2.69***	-1.72***
	(0.49)	(0.51)	(0.50)	(0.51)	(0.52)	(0.51)	(0.49)
R-squared	0.361	0.370	0.371	0.372	0.373	0.375	0.407
p-values[4]							
HAZ(3) vs. HAZ(2)			*0.16*	*0.10*	*0.09*	*0.09*	*0.09*
HAZ(3) vs. HAZ(1)				*0.01*	*0.01*	*0.01*	*0.01*
HAZ(2) vs. HAZ(1)				*0.91*	*0.85*	*0.90*	*0.96*
HAZ(3) vs. HAZ(2) vs. HAZ(1)				*0.03*	*0.03*	*0.03*	*0.04*
SCH vs. ECD						*0.73*	*0.97*
Both parents' education	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Mother's education	0.022***	0.021***	0.021***	0.021***	0.021***	0.020***	0.014***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0031)
Father's education	0.017***	0.016***	0.016***	0.016***	0.016***	0.015***	0.012***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	0.91***	0.83***	0.82***	0.82***	0.81***	0.79***	0.63***

	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)
HAZ(3)[2]		0.092***	0.071***	0.065***	0.064***	0.063***	0.053***
		(0.013)	(0.015)	(0.014)	(0.014)	(0.014)	(0.014)
HAZ(2)[2]			0.033**	0.022	0.020	0.020	0.013
			(0.015)	(0.015)	(0.015)	(0.015)	(0.013)
HAZ(1)[2]				0.024***	0.024***	0.022***	0.014*
				(0.0081)	(0.0081)	(0.0081)	(0.0077)
SCH					0.14**	0.13**	0.12*
					(0.058)	(0.059)	(0.062)
ECD						0.14***	0.11**
						(0.051)	(0.049)
Past PPVT score[3]							0.22***
							(0.021)
Constant	-3.28***	-2.54***	-2.41***	-2.63***	-2.74***	-2.75***	-1.80***
	(0.49)	(0.51)	(0.50)	(0.51)	(0.52)	(0.52)	(0.50)
R-squared	0.368	0.376	0.377	0.377	0.378	0.380	0.410
p-values[4]							
Mother's vs. Father's	*0.27*	*0.31*	*0.31*	*0.30*	*0.30*	*0.36*	*0.61*
HAZ(3) vs. HAZ(2)			*0.16*	*0.10*	*0.09*	*0.09*	*0.09*
HAZ(3) vs. HAZ(1)				*0.01*	*0.01*	*0.01*	*0.01*
HAZ(2) vs. HAZ(1)				*0.92*	*0.85*	*0.89*	*0.96*
HAZ(3) vs. HAZ(2) vs. HAZ(1)				*0.04*	*0.04*	*0.05*	*0.04*
SCH vs. ECD						*0.88*	*0.93*

Table 3.12 (Continued).
[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. School attendance is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]HAZ(1)=HAZ at age 6-18 months; HAZ(2)=HAZ at age 4-5 years; HAZ(3)=HAZ at 7-8 years.
[3]Past PPVT score is the standardized PPVT score at age 4-5 years.
[4]p-values are from significance tests for differences in association between mother's and father's education.

Discussion

Our study demonstrated that early socioeconomic conditions do matter and that both physical growth and early investments in child development were critical determinants of children's cognitive development. However, there are some facets of early household conditions that matter more than others. Household wealth had the largest association with children's cognitive status as compared to parental education. While household wealth mediates the relationship between parental education and children's cognition, the association between parental education and children's cognition remains robust and substantial after accounting for household wealth. Mother's education mattered more for children's cognitive development at age 4-5 years; however, by age 7-8 years, there were no significant differences in associations between mother's and father's education and children's cognition. Both physical growth and early investments in child development were critical determinants of cognition with no discernable differences in associations between previous and current experiences. Neither physical development nor early investments in child development appear to entirely mediate the pathway between parental education or household wealth and children's cognitive status. Explanations and implications of these findings will be further explored in the remainder of this section.

Genetic explanations

The relationship between parental characteristics and children's cognitive status may be confounded by the heritability of abilities (113,114). Indeed, twin and sibling studies as well as other experimental and quasi-experimental studies have demonstrated that associations between parental education and children's cognition may be overstated (115,116). Our study finds little attenuation in estimates for both maternal and paternal education after accounting for HAZ, which suggests that the influence of parental education may not be mediated through child care or health knowledge resulting in better physical development. Additionally, similar estimates between maternal and paternal education, particularly at later ages, further suggests that child care, which is primarily done by mothers in these settings, is not the key mechanism by which education influences cognitive development. Instead of these care- and knowledge-related mechanisms, parental education may influence children's cognitive status through genetics.

Importance of socioeconomic factors

Non-genetic mechanisms have also been proposed to help explain socioeconomic gradients in children's cognition have been widely observed in both developed countries (85,89,117) as well as developing countries (2,5,6). There are distinct changes in brain structure and function facilitated by conditions of early deprivation (118-120), suggesting that the relationship between parental or household characteristics and children's development cannot be attributed entirely to heritability of cognitive abilities. Three broad non-genetic mechanisms have been posited to explain how household socioeconomic status influences children's development: (1) greater family and environmental stress in poorer families impairs children's cognitive development; (2) poorer families have fewer resources and ability to invest in children's development; and, (3) the culture related to children's development varies between families of different socioeconomic backgrounds (116).

Importance of household wealth

Support for these mechanisms was found in the large associations between household wealth and children's cognitive development. Associations between household wealth and cognition, which eclipsed associations between parental education and cognition, suggest that increased resources within the household may help promote children's cognitive development.

Estimating the causal effect of household wealth on children's cognition is complicated by several factors. First, household wealth and parental education are highly correlated with greater household wealth accruing from higher educational attainment (115). Furthermore, the relationship between household wealth and cognition as well as parental education and children's cognition may be confounded by genetics or parental endowments, as noted earlier (113,115,116). However, evidence from quasi-experimental studies suggests that exogenous income shocks or cash transfers that are uncorrelated with parental cognitive abilities have positive effects on children's cognition (121,122). Other quasi-experimental studies using data from twins or siblings to adjust for unobserved family characteristics also find relationships between household wealth and cognitive or educational outcomes (85). Similar to these studies, we found large and robust associations between household wealth and cognition.

Contributions of parental education

Our finding that parental education mattered for children's cognitive status is also unsurprising given the evidence (113). However, the relatively small associations between years of schooling for parents and children's cognition, especially in comparison to household wealth and even in models that do not account for household wealth, suggested that parents' education matters less than household wealth. The high correlations between parental education and household wealth (116), the influence of education on household wealth, and the context of dire poverty experienced by Young Lives families (37) may all mask the importance of parental education. We did however find that associations between parental education and children's cognition were not fully attenuated in models accounting for household wealth, indicating that household wealth and parental education may have somewhat independent associations with cognitive status. While the pathways from household wealth to children's cognitive development rely on a resources story, there are distinct mechanisms by which parental education affect children's cognition, which involve knowledge and attitudes towards child care and development as well as parental decisions around how to invest in their children (115). While household resources undoubtedly affect these mechanisms, greater health literacy and child rearing skills acquired through higher educational attainment may independently influence children's development.

The mediating influences of health literacy as well as knowledge and attitudes towards child care are critical especially for mothers, who are the primary caregivers in Young Lives families (37). In early childhood, at age 4-5 years, we found that mother's education mattered more than father's education for children's cognitive development. Other studies in similar contexts have also found the greater importance of maternal education (92). However, a key limitation in comparing the relative importance of maternal vs. paternal characteristics in observational studies is assortative mating or correlated traits that result in individuals choosing each other in the marriage market (113). A relevant example is that more educated women would choose to marry men who were more educated thereby confounding comparisons of maternal and paternal education. Evidence from quasi-experimental studies that adjust for assortative mating find larger effects of maternal education compared to paternal (123). Other studies using similar methods are also able to identify causal effects of parental education on children's cognition (124) and educational attainment (82,125).

Role of physical growth and greater importance of early investments

In concordance with global evidence of higher stunting rates among poorer children (3), we found that children in the lowest wealth tertile were more likely to be stunted than children in the top tertile. One mechanism by which household poverty affects children is through food insecurity (126), poorer quality and less diversity of food (122,127,128), as well as a greater burden of infectious diseases and ill-health leading to poor physical development (3,129). Physical growth, measured as height, is often used an indicator of nutritional status with low height for age or stunting used as a measure of chronic nutritional deprivation and poor health in general (3,130).

Stunting, affecting 165 million children globally (19) is a key risk factor for cognitive impairments (2,5,6). Stunted children often start school at a later age (131). They often have poorer learning outcomes, slower grade progression, and higher drop-out rates (2,132,133). In addition to affecting schooling outcomes, slower growth has been shown to directly impair cognitive development (134). Thus, it is not surprising that we find that physical growth is correlated with cognition with lower cognitive status among stunted children at both 4-5 and 7-8 years.

In addition to being vulnerable to stunting, poor children often grow up in unstimulating environments in which few resources are invested into their development; as a result, they fare poorly in terms of cognitive development (2,5,6). Our finding that there was better cognitive status among children who attend preschool or crèches at an early age is in line with the evidence suggesting that early childhood development centers promote cognitive development, particularly for poor children with low stimulation at home (135,136).

Furthermore, our study found that investments in early childhood development had differential effects for children with varying physical growth. Children with higher HAZ reaped greater cognitive benefits from attending preschools/crèches and schools compared to children with lower HAZ. Similar results were found in sensitivity analyses using stunting as the exposure. Indeed, the apathy and detachment characterizing stunted children may inhibit their cognitive development (2), either through neurological changes associated with nutritional deprivation (137-139) or through the functiona isolation hypothesis, which posits that stunted and thus socially disengaged children may be further isolated by caregivers and other members of their households because they fail to demonstrate any liveliness or cognitive or social potential (140). Both the biological and psychosocial mechanisms suggest that physical growth and early investments may act in tandem to influence children's cognitive development.

Our comparisons of the relative contributions of physical growth and early investments in child development found that early investments in child development, particularly preschool/crèche attendance, had greater associations with cognition than physical development at age 6-18 months. This finding is significant for two reasons. First, much work has emphasized the relationship between poor physical growth and cognitive impairment (141) with increasing attention on the multiple deprivations, not only in terms of nutrition and physical health, but also in terms of stimulation, care, and psychosocial factors that affect overall children's development (2,5,6). Other work, notably a nutritional supplementation and stimulation trial in Jamaica (142-146), found that the impacts of psychosocial stimulation lasted far longer than nutritional supplementation, which promoted better physical growth and cognitive development but had waning influences over time (147). Our work builds on this seminal research, finding that among Young Lives children, preschool/crèche attendance had larger associations with cognitive status compared to physical development.

Furthermore, the second reason why this finding is important is because it questions the notion of the critical window of cognitive development that has been the source of much debate (139). As previously noted, child development studies, particularly those occurring in low- and middle-income countries and those linking poor physical health with cognitive impairments, underscore the importance of the first two years (2,5,6,148). However, there are periods of brain development that occur outside of this window (138) during which exposures such as a stimulating environment in a preschool can be quite critical in shaping cognitive skills (149). Relatedly, we also found that for cognitive status at age 7-8 years, current physical status at age 7-8 years was more important than past status at 6-18 months. Other research has also found that concurrent stunting or physical status may be more important than past status (150) and that children who recover from early stunting are also able to catch-up in cognitive abilities (55,151). Significantly larger associations between concurrent height and cognitive status compared to previous height, further questions the notion of the critical window for child development, from which we can infer that experiences in early childhood that occur after the second birthday may still be very important for cognitive development.

Limitations

Our study was limited by a few factors. First, Young Lives data only included one measure of cognition that was measured at different time points for the younger cohort. The PPVT, which has been validated and used in many countries, only measures receptive vocabulary rather than other cognitive abilities or functions. It does however have a high degree of correlation with other cognitive tests such as the Wechsler and McCarthy scales that measure intelligence quotient (IQ), considered a more general form of cognition (112). Ideally, we would have been able to take multiple measures to more fully assess cognitive capacity (152). Furthermore, it would have been helpful to take these measurements at greater increments rather than only twice between the ages of 6 months and 8 years. Greater frequency of measurement would help us to better understand cognitive trajectories, particularly the timing of exposures and their effects on cognitive outcomes.

Second, Young Lives gathered self-reported data on preschool/crèche attendance and school enrollment without corroborating subjective reports with objective records. Caregivers could have been subject to response bias, reporting that their children went to preschool or schools because they believed that attendance was normative. Biased estimates would result from misreporting if the error in reports were systematically correlated with parental education, which is plausible given that parents who are highly educated may perceive greater social pressure to send their children to school and would thus report that their children attended even when they did not. However, in Young Lives, we find that nearly two-thirds of children attend preschool/crèches and nearly all children attend schools, casting doubt on the likelihood of mispreporting, particularly systematic errors in responses. Third, and relatedly, preschool/crèche attendance and school enrollment questions, to which participants repond yes or no, do not provide any insights into either the frequency of attendance or the quality or types of stimulation which the children experience in those institutions. Without this qualitative information, it is difficult to fully determine how preschool or school attendance may influence cognitive development. Furthermore, we only have information on these two variables rather than a more comprehensive picture of the early childhood environment experienced by Young Lives children. More data on the school environment as well as the household environment would be helpful.

Third, although our study uses longitudinal data from Young Lives, there are several issues with making causal inferences about the effects of household socioeconomic status on children's development using observational data (113,115,116). The relationships analyzed in our study – between household wealth and cognitive status or parental education and cognition – are interrelated and situated within an overall context of resource deprivation and poverty that affects not only Young Lives children but has also had impacts on their parents. Disentangling causal mechanisms is difficult; however, our study does find that two facets of household socioeconomic status – parental education and household wealth – are related to children's cognitive development. Other research using the same data and quasi-experimental designs (153-156) show robust effects of poor socioeconomic conditions on cognition. This work in addition to other studies in similar contexts supports our findings that parental and household characteristics are critical for children's development.

Conclusion

In summary, our study using four cohorts of children followed from infancy to late childhood found that household socioeconomic conditions, particularly household wealth, were critical determinants of children's cognitive development with key relationships between physical growth and early investments in child development and cognition.

IX. CONCLUDING REMARKS

This dissertation examines how social conditions experienced early in life influence children's development in infancy but also later in childhood. The first chapter revealed how children born at low birth weight (LBW), a measure of adverse fetal conditions caused by poor socioeconomic conditions and other social and biological realities (9), experience poorer physical development compared to normal birth weight children. While height differentials between low and normal birth weight children halve after the first two years, the gap persisted, even among wealthier children. These findings suggest prenatal conditions, as reflected in birth weight, are critical for children's development in the first year of life; however the importance of prenatal factors wanes over time. The fading influence of birth weight and the absence of a moderating influence of household wealth suggest that the relationship between birth weight and early physical growth may have biological mechanisms that diminish over age. Investments in prenatal health will thus have the greatest payoffs in the first year of life while later physical development must be supported through investments in later childhood.

The second chapter looks further upstream at maternal and paternal education, finding that both were equally important for children's physical development. Explorations into distinct pathways by which mother's and father's education may influence children's height revealed that there may indeed be no parent-specific mechanisms linking education and height. Indeed both parents' education may operate through increasing resources as greater household wealth had the strongest positive associations with children's height. These findings support investments in both parents' education as well as further research into other unexplored pathways, which may distinguish maternal contributions from paternal ones.

The third and last chapter resulted in a similar finding that household wealth had the largest associations with children's cognitive development. Although parental education, physical development, and preschool/crèche and school attendance were also positively associated with cognition, the influences of household wealth outweighed the relative contributions of these other determinants. This chapter underscored how the poverty experienced by the children surveyed in Young Lives and others around the world greatly determines their development.

In summary, the three chapters of this dissertation nuances the considerable evidence suggesting that health and well-being of children is determined by the conditions in which they develop. Chapter 1 finds that the influences of low birth weight, often touted as a key determinant of later health, wane over time with increasing importance of postnatal factors. Chapter 2 also counters accepted evidence that maternal education matters more for children's physical development by finding that both parents' education matters equally in both infancy and childhood with no mechanisms distinguishing maternal and paternal education. Chapter 3 supports the evidence that household socioeconomic status matters for children's cognitive development and finds that household assets are the critical determinant of cognitive status. Findings from each of these chapters will not only contribute new scientific evidence but will also help inform policies and programs to improve children's health and well-being.

X. REFERENCES

1. UNICEF. State of the world's children 2015. New York, NY: UNICEF; 2015.

2. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B. Developmental potential in the first 5 years for children in developing countries. Lancet. 2007;369(9555):60–70.

3. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet; 2013;382(9890):427–51.

4. Black RE, Alderman H, Bhutta ZA, Gillespie S, Haddad L, Horton S, et al. Maternal and child nutrition: building momentum for impact. Lancet. 2013;382(9890):372–5.

5. Walker SP, Wachs TD, Gardner JM, Lozoff B, Wasserman GA, Pollitt E, et al. Child development: risk factors for adverse outcomes in developing countries. Lancet. 2007;369(9556):145–57.

6. Walker SP, Wachs TD, Grantham-McGregor S, Black MM, Nelson CA, Huffman SL, et al. Inequality in early childhood: risk and protective factors for early child development. Lancet. 2011;378(9799):1325–38.

7. Christian P. Fetal growth restriction and preterm as determinants of child growth in the first two years and potential interventions. Nestle Nutr Inst Workshop Ser. 2014;78:81–91.

8. Christian P, Lee SE, Donahue Angel M, Adair LS, Arifeen SE, Ashorn P, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. Int J Epidemiol. 2013;42(5):1340–55.

9. Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. Bull World Health Organ. 1987;65(5):663.

10. Victora CG, de Onis M, Hallal PC, Blossner M, Shrimpton R. Worldwide timing of growth faltering: Revisiting implications for interventions. Pediatrics. 2010;125(3):e473–80.

11. Grossman M. Education and nonmarket outcomes. Handbook of the economics of education. New York: Elsevier; 2006. pp. 577–633.

12. Desai S, Alva S. Maternal education and child health: Is there a strong causal relationship? Demography. 1998;35(1):71–81.

13. Behrman JR, Wolfe BL. How does mother's schooling affect family health, nutrition, medical care usage, and household sanitation? J Econometrics. 1987;36(1-2):185–204.

14. Handa S. Maternal education and child height. Econ Dev Cult Change. 1999;47(2):421–39.

15. Strauss J. Households, Communities, and preschool children's nutrition outcomes: Evidence from rural Côte d'Ivoire. Econ Dev Cult Change. 1990;38(2):231–61.

16. Thomas D, Strauss J, Henriques M-H. How does mother's education affect child height? J Hum Resour. 1991;26(2):183–211.

17. Behrman JR, Rosenzweig MR. Does increasing women's schooling raise the schooling of the next generation? Am Econ Rev. 2002;92(1):323–34.

18. Breierova L, Duflo E. The impact of education on fertility and child mortality: Do fathers really matter less than mothers? Cambridge, MA: NBER Working Paper Series; 2004. Report No.: 10513.

19. UNICEF. The state of the world's children 2014 in numbers: Every child counts. UNICEF; 2014.

20. Christian P. Prenatal origins of undernutrition. Nestle Nutr Workshop Ser Pediatr Program. 2009;63:59–73.

21. Alasfoor D, Traissac P, Gartner A, Delpeuch F. Determinants of persistent underweight among children, aged 6-35 months, after huge economic development and improvements in health services in Oman. J Health Popul Nutr. 2007;25(3):359–69.

22. Adekanmbi VT, Kayode GA, Uthman OA. Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis. Matern Child Nutr. 2013;9(2):244–59.

23. Bove I, Miranda T, Campoy C, Uauy R, Napol M. Stunting, overweight and child development impairment go hand in hand as key problems of early infancy: Uruguayan case. Early Hum Dev. 2012;88(9):747–51.

24. Gewa CA, Yandell N. Undernutrition among Kenyan children: contribution of child, maternal and household factors. Public Health Nutr. 2012;15(6):1029–38.

25. Jesmin A, Yamamoto SS, Malik AA, Haque MA. Prevalence and determinants of chronic malnutrition among preschool children: a cross-sectional study in Dhaka City, Bangladesh. J Health Popul Nutr. 2011 Oct;29(5):494–9.

26. Madzingira N. Malnutrition in children under five in Zimbabwe: Effect of socioeconomic factors and disease. Soc Biol. 1995;42(3-4):239–46.

27. Marins VMR, Almeida RMVR. Undernutrition prevalence and social determinants in children aged 0-59 months, Niteroi, Brazil. Ann Hum Biol. 2002;29(6):609–18.

28. Massad SG, Nieto FJ, Palta M, Smith M, Clark R, Thabet A-A. Nutritional status of Palestinian preschoolers in the Gaza Strip: A cross-sectional study. BMC Public Health. 2012;12:27.

29. Varela-Silva MI, Azcorra H, Dickinson F, Bogin B, Frisancho AR. Influence of maternal stature, pregnancy age, and infant birth weight on growth during childhood in Yucatan, Mexico: a test of the intergenerational effects hypothesis. Am J Hum Biol. 2009;21(5):657–63.

30. Cornu A, Massamba JP, Traissac P, Simondon F, Villeneuve P, Delpeuch F. Nutritional change and economic crisis in an urban Congolese community. Int J Epidemiol. 1995;24(1):155–64.

31. Araujo CLP, Hallal PC, Nader GA, Menezes AMB, Victora CG. Size at birth and height in early adolescence: a prospective birth cohort study. Cad Saude Publica. 2008;24(4):871–8.

32. Tome FS, Cardoso VC, Barbieri MA, Silva AAMD, Simoes VMF, Garcia CA, et al. Are birth weight and maternal smoking during pregnancy associated with malnutrition and excess weight among school age children? Braz J Med Biol Res. 2007;40(9):1221–30.

33. Schmidt MK, Muslimatun S, West CE, Schultink W, Gross R, Hautvast JGAJ. Nutritional status and linear growth of Indonesian infants in West Java are determined more by prenatal environment than by postnatal factors. J Nutr. 2002;132(8):2202–7.

34. Das S, Bapat U, More NS, Alcock G, Fernandez A, Osrin D. Nutritional status of young children in Mumbai slums: A follow-up anthropometric study. Nutr J. 2012;11:100.

35. Arifeen SE, Black RE, Caulfield LE, Antelman G, Baqui AH, Nahar Q, et al. Infant growth patterns in the slums of Dhaka in relation to birth weight, intrauterine growth retardation, and prematurity. Am J Clin Nutr. 2000;72:1010–7.

36. Sania A, Spiegelman D, Rich-Edwards J, Hertzmark E, Mwiru RS, Kisenge R, et al. The contribution of preterm birth and intrauterine growth restriction to childhood undernutrition in Tanzania. Matern Child Nutr. 2014.

37. Barnett I, Ariana P, Petrou S, Penny ME, Duc LT, Galab S, et al. Cohort profile: The Young Lives study. Int J Epidemiol. 2013;42(3):701–8.

38. Boyden J. Young Lives: An international study of childhood poverty: Round 2, 2006 [Internet]. 2nd ed. Colchester, Essex: UK Data Archive; 2014. Available from: http://dx.doi.org/10.5255/UKDA-SN-6852-2

39. Boyden J. Young Lives: An international study of childhood poverty: Round 3, 2009 [Internet]. 2nd ed. Colchester, Essex: UK Data Archive; 2014. Available from:

http://dx.doi.org/10.5255/UKDA-SN-6853-1.

40. Boyden J. Young Lives: An international study of childhood poverty: Rounds 1-3 Constructed Files, 2002-2009 [Internet]. Colchester, Essex: UK Data Archive; 2014. Available from: http://dx.doi.org/10.5255/UKDA-SN-7483-1

41. Huttly S, Jones N. Young Lives: An international study of childhood poverty: Round 1, 2002 [Internet]. 5 ed. Colchester, Essex: UK Data Archive; 2014. Available from: http://dx.doi.org/10.5255/UKDA-SN-5307-1

42. Outes-Leon I, Dercon S. Survey attrition and attrition bias in Young Lives. Young Lives Technical Note. 2008;5.

43. Filmer D, Pritchett L. Estimating wealth effects without expenditure data--Or tears: An application to educational enrollments in states of India. Demography. 2001;38(1):115–32.

44. de Onis M, Garza C, Onyango AW, Martorell R, editors. WHO child growth standards. Acta Paediatr. 2006;95(Supplement 450).

45. Knops NB, Sneeuw KC, Brand R, Hille ET, Ouden den AL, Wit J-M, et al. Catch-up growth up to ten years of age in children born very preterm or with very low birth weight. BMC Pediatrics. 2005;5(1):26.

46. Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. J Epidemiol Community Health. 2003;57:778–83.

47. Barker DJP. Fetal and infant origins of adult disease. BMJ. 1990;301(6761):1111.

48. Barker DJP, Osmond C. Inequalities in health in Britain: specific explanations in three Lancashire towns. Br Med J (Clin Res Ed). 1987;294(6574):749–52.

49. Roseboom TJ. Coronary heart disease after prenatal exposure to the Dutch famine, 1944-45. Heart. 2000;84(6):595–8.

50. Ravelli GP, Stein ZA, Susser MW. Obesity in young men after famine exposure in utero and early infancy. N Engl J Med. 1976;295(7):349–53.

51. Painter RC, Roseboom TJ, Bleker OP. Prenatal exposure to the Dutch famine and disease in later life: An overview. Reprod Toxicol. 2005 Feb 17;20(3):345–52.

52. Misra A, Khurana L. Obesity and the Metabolic Syndrome in Developing Countries. J Clin Endocrinol Metab. 2008;93(Supplement 11):s9–s30.

53. Jain V, Singhal A. Catch up growth in low birth weight infants: striking a healthy balance. Rev Endocr Metab Disord. 2012 Jun;13(2):141–7.

54. Sachdev HS, Fall CH, Osmond C, Lakshmy R, Biswas SKD, Leary SD, et al.

Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort. Am J Clin Nutr. 2005;82:456–66.

55. Fink G, Rockers PC. Childhood growth, schooling, and cognitive development: further evidence from the Young Lives study. Am J Clin Nutr. 2014;100(1):182–8.

56. Lundeen EA, Behrman JR, Crookston BT, Dearden KA, Engle P, Georgiadis A, et al. Growth faltering and recovery in children aged 1–8 years in four low-and middle-income countries: Young Lives. Public Health Nutr. 2013:1–7.

57. Crookston BT, Schott W, Cueto S, Dearden KA, Engle P, Georgiadis A, et al. Postinfancy growth, schooling, and cognitive achievement: Young Lives. Am J Clin Nutr. 2013;98(6):1555–63.

58. Schultz TP. Studying the impact of household economic and community variables on child mortality. 1984.

59. Behrman JR. The action of human resources and poverty on one another: what we have yet to learn. Living standards measurement study working paper. World Bank; 1990;(74).

60. Behrman JR, Deolalikar AB. Health and nutrition. In: Chenery H, Srinivasan TN, editors. Handbook of development economics. Amsterdam: Elsevier; 1988. pp. 631–711.

61. Frost MB, Forste R, Haas DW. Maternal education and child nutritional status in Bolivia: finding the links. Soc Sci Med. 2005;60(2):395–407.

62. Aslam M, Kingdon GG. Parental education and child health—Understanding the pathways of impact in Pakistan. World Dev. 2012;40(10):2014–32.

63. Smith LC, Haddad LJ. Explaining child malnutrition in developing countries. Washington, DC: IFPRI; 2000.

64. Glewwe P. Why does mother's schooling raise child health in developing countries? Evidence from Morocco. J Hum Resourc. 1999;34(1):124.

65. Hobcraft J. Women's education, child welfare and child survival: a review of the evidence. Health Transit Rev. 1993;3(2):159–75.

66. Webb P, Block S. Nutrition information and formal schooling as inputs to child nutrition*. Econ Dev Cult Change. 2004 Jul;52(4):801–20.

67. Caldwell JC. Education as a factor in mortality decline an examination of Nigerian data. Population studies. 1979;33(3):395–413.

68. Lindeboom M, Llena-Nozal A, van der Klaauw B. Parental education and child

health: Evidence from a schooling reform. J Health Econ. 2009 Jan;28(1):109–31.

69. Chou S-Y, Liu J-T, Grossman M, Joyce TJ. Parental education and child health: Evidence from a natural experiment in Taiwan. American Economic Journal: Applied Economics. 2010. pp. 33–61.

70. Headey DD. Developmental Drivers of Nutritional Change: A Cross-Country Analysis. World Dev. 2013;42:76–88.

71. Alderman H, Headey DD. The nutritional returns to parental education. Washington, DC: IFPRI; 2014. Report No.: 01379.

72. Headey DD, Hoddinott J, Ali D, Tesfaye R, Dereje M. The other Asian enigma: Explaining the rapid reduction of undernutrition in Bangladesh. IFPRI Discussion Paper; 2014. Report No.: 01358.

73. Subramanian SV, Ackerson LK, Smith GD, John NA. Association of maternal height with child mortality, anthropometric failure, and anemia in India. JAMA. 2009;301(16):1691–701.

74. Kramer MS. Socioeconomic determinants of intrauterine growth retardation. Eur J Clin Nutr. 1998;52 Suppl 1:S29–32; discussionS32–3.

75. Moestue H, Huttly S. Adult education and child nutrition: the role of family and community. J Epidemiol Community Health. 2008;62(2):153–9.

76. Schultz TP. Studying the impact of household economic and community variables on child mortality. Popul Dev Rev. 1984;10:215.

77. Thomas D, Strauss J. Prices, infrastructure, household characteristics and child height. Journal of development economics. 1992;39(2):301–31.

78. Victora CG, Huttly SRA, Barros FC, Lombardi C, Vaughan JP. Maternal education in relation to early and late child health outcomes: Findings from a Brazilian cohort study. Soc Sci Med. 1992;34(8):899–905.

79. Ruel MT, Alderman H. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet; 2013;382(9891):536–51.

80. Walker SP, Chang SM, Wright A, Osmond C, Grantham-McGregor SM. Early childhood stunting is associated with lower developmental levels in the subsequent generation of children. J Nutr. 2015;145(4):823–8.

81. Harding JF, Morris PA, Hughes D. The Relationship Between Maternal Education and Children's Academic Outcomes: A Theoretical Framework. J Marriage Fam. 2015;77(1):60–76.

82. Black S, Devereux P, Salvanes K. Why the apple doesn't fall far: Understanding intergenerational transmission of human capital. Cambridge, MA: National Bureau of Economic Research; 2003.

83. Psacharopoulos G, Arriagada AM. The determinants of early age human capital formation: Evidence from Brazil. Econ Dev Cult Change. 1989;37(4):683–708.

84. Rosenzweig MR, Wolpin KI. Are there increasing returns to the intergenerational production of human capital? Maternal schooling and child intellectual achievement. J Hum Resourc. 1994;29(2):670.

85. Currie J. Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. NBER Working Paper Series. 2008.

86. Almond D, Currie J. Human capital development before age five. In: Handbook of Labor Economics. Elsevier; 2011. pp. 1315–486.

87. Case A, Lubotsky D, Paxson C. Economic status and health in childhood: The origins of the gradient. Cambridge, MA: National Bureau of Economic Research; 2001.

88. Brooks-Gunn J, Duncan GJ. The Effects of Poverty on Children. Future Child. 1997;7(2):55.

89. Bradley RH, Corwyn RF. Socioeconomic status and child development. Annu Rev Psychol. 2002;53(1):371–99.

90. McCoy DC, Zuilkowski SS, Fink G. Poverty, physical stature, and cognitive skills: Mechanisms underlying children's school enrollment in Zambia. Dev Psychol. 2015;51(5):600–14.

91. Rubio-Codina M, Attanasio O, Meghir C, Varela N, Grantham-McGregor S. The socioeconomic gradient of child development: Cross-sectional evidence from children 6–42 months in Bogota. J Hum Resourc. 2015;50(2):464–83.

92. Paxson C, Schady N. Cognitive development among young children in Ecuador: The roles of wealth, health, and parenting. J Hum Resourc. 2007;42(1):49–84.

93. Ghuman S, Behrman JR, Borja JB, Gultiano S, King EM. Family background, service providers, and early childhood development in the Philippines: Proxies and interactions. Econ Dev Cult Change. 2005;54(1):129–64.

94. Fernald LCH, Kariger P, Hidrobo M, Gertler PJ. Socioeconomic gradients in child development in very young children: Evidence from India, Indonesia, Peru, and Senegal. PNAS. 2012;109(Supplement 2):17273–80.

95. Fernald LCH, Weber A, Galasso E, Ratsifandrihamanana L. Socioeconomic gradients and child development in a very low income population: Evidence from

Madagascar. Dev Sci. 2011;14(4):832–47.

96. Hamadani JD, Tofail F, Huda SN, Alam DS, Ridout DA, Attanasio O, et al. Cognitive deficit and poverty in the first 5 years of childhood in Bangladesh. Pediatrics. 2014;134(4):e1001–8.

97. Schady N, Behrman J, Araujo MC, Azuero R, Bernal R, Bravo D, et al. Wealth gradients in early childhood cognitive development in five Latin American countries. J Hum Resourc. 2015;50(2):446–63.

98. Marques dos Santos L, Neves dos Santos D, Bastos ACS, Assis AMO, Prado MS, Barreto ML. Determinants of early cognitive development: hierarchical analysis of a longitudinal study. Cad Saude Publica. 2008;24(2):427–37.

99. Outes-Leon I, Sanchez A. An assessment of the Young Lives sampling approach in Ethiopia. Oxford: Young Lives Technical Note; 2008. Report No.: 1.

100. Kumra N. An assessment of the Young Lives sampling approach in Andhra Pradesh, India. Oxford: Young Lives Technical Note; 2008. Report No.: 2.

101. Escobal J, Flores E. An Assessment of the Young Lives Sampling Approach in Peru. Oxford: Young Lives Technical Note; 2008. Report No.: 3.

102. Nguyen N. An assessment of the Young Lives sampling approach in Vietnam. Oxford: Young Lives Technical Note; 2008. Report No.: 4.

103. Petrou S, Kupek E. Poverty and childhood undernutrition in developing countries: A multi-national cohort study. Soc Sci Med. 2010;71(7):1366–73.

104. Alemu T, Asgedom G, Liebenberg J, Mekonnen A, Seager A, Tefera B, et al. Young Lives Preliminary Country Report: Ethiopia. Oxford, UK: Young Lives; 2003.

105. ICF International. Demographic and Health Surveys (various) [Datasets]. 1997-2014. Calverton, MD: ICF International. Available from: https://dhsprogram.com/

106. Grantham-McGregor SM, Fernald LCH, Kagawa RMC, Walker S. Effects of integrated child development and nutrition interventions on child development and nutritional status. Ann N Y Acad Sci. 2014;1308:11–32.

107. Grantham-McGregor S, Baker-Henningham H. Review of the evidence linking protein and energy to mental development. Public Health Nutr. Cambridge University Press; 2005;8(7a):1191–201.

108. Dunn LM. Peabody Picture Vocabulary Test. Minneapolis, MN: American Guidance Service; 1959.

109. Dunn LM, Dunn LM. PPVT-III: Peabody picture vocabulary test. Circle Pines, MN: American Guidance Service; 1997.

110. Cueto S, Leon J. Psychometric characteristics of cognitive development and achievement instruments in round 3 of Young Lives. Young Lives Technical Note; 2012. Report No.: 25.

111. Dunn LM, Padilla ER, Lugo DE, Dunn LM. Examiner's manual for the Test de Vocabulario en Images Peabody (Peabody Picture Vocabulary Test) Adaptacion Hispanoamericana (Hispanic American adaptation). Circle Pines, MN: American Guidance Service; 1986.

112. Saklofske DH, Reynolds CR, Schwean VL, editors. The Oxford handbook of child psychological assessment. New York: Oxford University Press; 2013.

113. Holmlund H, Lindahl M, Plug E. The causal effect of parents' schooling on children's schooling: A comparison of estimation methods. J Econ Lit. 2011;49(3):615–51.

114. Bingley P, Christensen K, Jensen VM. Parental Schooling and Child Development: Learning from Twin Parents. The Danish national center for social research working paper. 2009; 7.

115. Duncan GJ, Magnuson K. Socioeconomic status and cognitive functioning: moving from correlation to causation. WIREs Cogn Sci. 2012;3(3):377–86.

116. Duncan GJ, Magnuson K, Votruba-Drzal E. Children and socioeconomic status. Handbook of child psychology and developmental science. Hoboken, NJ, USA: John Wiley & Sons, Inc; 2015. pp. 534–73.

117. Almond D, Currie J. Human capital development before age five. Handbook of labor economics. Elsevier; 2011. pp. 1315–486.

118. Brito NO, Noble KG. Socioeconomic status and structural brain development. Frontiers in Neuroscience. Frontiers Media SA; 2014;8.

119. Shonkoff JP, Phillips DA, editors. From Neurons to Neighborhoods: The Science of Early Childhood Development. eric.ed.gov. National Academy of Sciences Press; 2000.

120. Hackman DA, Farah MJ, Meaney MJ. Socioeconomic status and the brain: mechanistic insights from human and animal research. Nat Rev Neurosci. 2010 Sep;11(9):651–9.

121. Behrman J, Hoddinott J. An evaluation of the impact of PROGRESA on child height. Washington, DC: International Food Policy Research Insitute; 2001.

122. Hoddinott J, Skoufias E. The Impact of PROGRESA on Food Consumption. Econ Dev Cult Change. 2004;53(1):37–61.

123. Haegeland T, Kirkeboen LJ, Raaum O, Salvanes KG. Why children of college

graduates outperform their schoolmates: A study of cousins and adoptees. Statistics Norway, Research Department; 2010. Report No.: 628.

124. Gennetian LA, Magnuson K, Morris PA. From statistical associations to causation: What developmentalists can learn from instrumental variables techniques coupled with experimental data. Dev Psychol. 2008;44(2):381–94.

125. Chevalier A. Parental education and child's education: A natural experiment. Bonn, Germany: Institute for the study of labor; 2004. Report No.: 1153.

126. Humphries DL, Dearden KA, Crookston BT, Fernald LC, Stein AD, Woldehanna T, et al. Cross-sectional and longitudinal associations between household food security and child anthropometry at ages 5 and 8 years in Ethiopia, India, Peru, and Vietnam. J Nutr. 2015.

127. Maluccio JA, Hoddinott J, Behrman JR, Martorell R, Quisumbing AR, Stein AD. The impact of improving nutrition during early childhood on education among Guatemalan adults. Economic Journal. 2009;119(537):734–63.

128. Saha KK, Tofail F, Frongillo EA, Rasmussen KM, Arifeen SE, Persson LA, et al. Household food security is associated with early childhood language development: results from a longitudinal study in rural Bangladesh. Child Care Health Dev. 2010;36(3):309–16.

129. Black RE, Allen LH, Bhutta ZA, Caulfield LE, De Onis M, Ezzati M, et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet; 2008;371(9608):243–60.

130. UNICEF. Improving child nutrition: The achievable imperative for global progress. New York, NY: UNICEF; 2013.

131. Mendez MA, Adair LS. Severity and timing of stunting in the first two years of life affect performance on cognitive tests in late childhood. J Nutr. 1999;129(8):1555–62.

132. Adair LS, Fall CHD, Osmond C, Stein AD, Martorell R, Ramirez-Zea M, et al. Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: Findings from five birth cohort studies. Lancet. 2013;382(9891):525–34.

133. Dewey KG, Begum K. Long-term consequences of stunting in early life. Matern Child Nutr. 2011;7 Suppl 3:5–18.

134. Yang S, Tilling K, Martin R, Davies N, Ben-Shlomo Y, Kramer MS. Pre-natal and post-natal growth trajectories and childhood cognitive ability and mental health. Int J Epidemiol. 2011;40(5):1215–26.

135. Engle PL, Fernald LC, Alderman H, Behrman J, O'Gara C, Yousafzai A, et al.

Strategies for reducing inequalities and improving developmental outcomes for young children in low-income and middle-income countries. Lancet. 2011;378(9799):1339–53.

136. Engle PL, Black MM, Behrman JR, Cabral de Mello M, Gertler P, Kapiriri L, et al. Strategies to avoid the loss of developmental potential inmore than 200 million children in the developing world. Lancet. 2007;369:229–42.

137. Prado EL, Dewey KG. Nutrition and brain development in early life. Nutr Rev. 2014;72(4):267–84.

138. Isaacs E, Oates J, ILSI Europe a.i.s.b.l. Nutrition and cognition: assessing cognitive abilities in children and young people. Eur J Nutr. D. 2008;47(S3):4–24.

139. Thompson RA, Nelson CA. Developmental science and the media: Early brain development. American Psychologist. 2001;56(1):5–15.

140. Levitsky DA, Barnes RH. Nutritional and environmental interactions in the behavioral development of the rat: long-term effects. Science. 1972;176(4030):68–71.

141. Sudfeld CR, Charles McCoy D, Danaei G, Fink G, Ezzati M, Andrews KG, et al. Linear growth and child development in low- and middle-income countries: A meta-analysis. Pediatrics. 2015;135(5):e1266–75.

142. Grantham-McGregor SM, Cumper G. Jamaican studies in nutrition and child development, and their implications for national development. Proc Nutr Soc. 1992;51(1):71–9.

143. Walker SP, Chang SM, Powell CA, Grantham-McGregor SM. Effects of early childhood psychosocial stimulation and nutritional supplementation on cognition and education in growth-stunted Jamaican children: Prospective cohort study. Lancet. 2005;366(9499):1804–7.

144. Grantham-McGregor SM, Walker SP, Chang SM, Powell CA. Effects of early childhood supplementation with and without stimulation on later development in stunted Jamaican children. Am J Clin Nutr. 1997;66(2):247–53.

145. Chang SM, Walker SP, Grantham-McGregor S, Powell CA. Early childhood stunting and later behaviour and school achievement. J Child Psychol Psychiatry. 2002;43(6):775–83.

146. Chang SM, Walker SP, Grantham-McGregor S, Powell CA. Early childhood stunting and later fine motor abilities. Dev Med Child Neurol. 2010;52(9):831–6.

147. Walker SP, Grantham-McGregor SM, Powell CA, Chang SM. Effects of growth restriction in early childhood on growth, IQ, and cognition at age 11 to 12 years and the benefits of nutritional supplementation and psychosocial stimulation. J Pediatr.

2000;137(1):36–41.

148. Victora CG, Adair L, Fall C, Hallal PC, Martorell R, Richter L, et al. Maternal and child undernutrition: consequences for adult health and human capital. Lancet. 2008;371(9609):340–57.

149. Wachs TD, Georgieff M, Cusick S, McEwen BS. Issues in the timing of integrated early interventions: contributions from nutrition, neuroscience, and psychological research. Ann N Y Acad Sci. 2013;1308(1):89–106.

150. Crookston BT, Dearden KA, Alder SC, Porucznik CA, Stanford JB, Merrill RM, et al. Impact of early and concurrent stunting on cognition. Matern Child Nutr. 2011;7(4):397–409.

151. Crookston BT, Penny ME, Alder SC, Dickerson TT, Merrill RM, Stanford JB, et al. Children who recover from early stunting and children who are not stunted demonstrate similar levels of cognition. J Nutr. 2010;140(11):1996–2001.

152. Frongillo EA, Tofail F, Hamadani JD, Warren AM, Mehrin SF. Measures and indicators for assessing impact of interventions integrating nutrition, health, and early childhood development. Ann N Y Acad Sci. 2014;1308(1):68–88.

153. Sanchez A. The structural relationship between nutrition, cognitive and non-cognitive Skills. Young Lives working paper. 2013.

154. Outes-Leon I, Porter C, Sanchez A. Early nutrition and cognition in Peru: A within-sibling investigation. Inter-American Development Bank; 2011. Report No.: 241.

155. Mani S, Behrman JR, Galab S, Reddy P. Impact of the NREGS on schooling and intellectual human capital. GCC Working Paper Series; 2014. Report No.: GCC 14-01.

156. Berhane G, Abay MH, Woldehanna T. Childhood shocks, safety nets, and cognitive skills: Panel data evidence from Ethiopia. IFPRI; 2015.

XI. SUPPLEMENTAL MATERIAL

PAPER 1 SUPPLEMENTAL MATERIAL

Supplementary Table 1.1 Attrition rates by country

	Number of children by cause of attrition		Total attrition	
	Death	*Households moved or refused to participate*	*Number*	*% of children enrolled in round 1*
Ethiopia	72	44	116	5.80%
India	36	45	81	4.03%
Peru	20	117	137	6.68%
Vietnam	11	37	48	2.40%
Total	**139**	**243**	**382**	**4.73%**

Supplementary Table 1.2 Changes in physical growth over survey rounds[1]

	Ages 6-18 months to ages 4-5 years (Round 1 to round 2)	Ages 4-5 years to ages 7-8 years (Round 2 to round 3)
All countries		
Height gain (cm)	33.04 (0.07)	15.87 (0.06)
Change in height for age z-scores	-0.22 (0.02)	0.29 (0.01)
Stunting		
Stay stunted	62.97 (1.61)	56.46 (1.55)
Become not stunted	37.03 (1.61)	43.54 (1.55)
Stay non-stunted	85.11 (0.64)	95.72 (0.37)
Become stunted	14.89 (0.64)	4.28 (0.37)
Ethiopia		
Height gain (cm)	32.99 (0.32)	17.32 (0.30)
Change in height for age z-scores	0.057 (0.10)	0.29 (0.06)
Stunting		
Stay stunted	48.94 (5.18)	46.15 (6.23)
Become not stunted	51.06 (5.18)	53.85 (6.23)
Stay non-stunted	89.02 (2.38)	95.05 (1.53)
Become stunted	10.98 (2.38)	4.95 (1.53)
India		
Height gain (cm)	32.87 (0.16)	15.05 (0.14)
Change in height for age z-scores	-0.32 (0.04)	0.24 (0.03)
Stunting		
Stay stunted	55.74 (3.68)	60.78 (3.43)
Become not stunted	44.26 (3.68)	39.22 (3.42)
Stay non-stunted	82.35 (1.59)	94.61 (0.96)
Become stunted	17.65 (1.59)	5.39 (0.96)
Peru		
Height gain (cm)	33.19 (0.13)	15.73 (0.10)
Change in height for age z-scores	-0.23 (0.03)	0.37 (0.02)
Stunting		
Stay stunted	65.19 (2.43)	52.75 (2.34)
Become not stunted	34.81 (2.43)	47.25 (2.34)
Stay non-stunted	82.38 (1.12)	96.60 (0.55)
Become stunted	17.62 (1.11)	3.40 (0.55)
Vietnam		
Height gain (cm)	32.97 (0.09)	16.20 (0.09)
Change in height for age z-scores	-0.22 (0.02)	0.24 (0.02)
Stunting		
Stay stunted	70.41 (2.95)	61.31 (2.79)
Become not stunted	29.58 (2.95)	38.69 (2.79)
Stay non-stunted	88.55 (0.92)	95.55 (0.62)
Become stunted	11.45 (0.92)	4.45 (0.62)

[1]All values are means or proportions with standard errors in parentheses.

Supplementary Table 1.3 Associations between low birth weight[1] and height for age z-scores, by country[2]

	Ethiopia (n=267)			India (n=761)			Peru (n=1,543)			Vietnam (n=1,428)		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Low birth weight	-0.21	-0.54**	-0.57**	-0.32***	-0.54***	-0.53***	-0.48***	-0.71***	-0.63***	-0.42***	-0.57***	-0.45***
	(-0.47 - 0.054)	(-1.02 - - 0.052)	(-1.07 - - 0.070)	(-0.50 - - 0.15)	(-0.85 - - 0.23)	(-0.82 - - 0.25)	(-0.66 - - 0.30)	(-1.05 - - 0.38)	(-0.96 - - 0.30)	(-0.64 - - 0.21)	(-0.80 - - 0.33)	(-0.64 - - 0.26)
Ages 4-5 years	0.057	-0.010	4.28***	-0.32***	-0.37***	0.97**	-0.23***	-0.25***	0.073	-0.22***	-0.23***	1.35***
	(-0.41 - 0.52)	(-0.50 - 0.48)	(3.33 - 5.23)	(-0.47 - - 0.16)	(-0.54 - - 0.20)	(0.17 - 1.76)	(-0.33 - - 0.14)	(-0.34 - - 0.16)	(-0.55 - 0.70)	(-0.30 - - 0.14)	(-0.31 - - 0.15)	(0.62 - 2.08)
Ages 7-8 years	0.34	0.27	7.58***	-0.080	-0.14	2.01***	0.14***	0.12***	0.63	0.023	0.018	2.63***
	(-0.13 - 0.82)	(-0.25 - 0.79)	(5.65 - 9.50)	(-0.27 - 0.11)	(-0.34 - 0.062)	(0.78 - 3.23)	(0.051 - 0.23)	(0.034 - 0.20)	(-0.34 - 1.61)	(-0.069 - 0.12)	(-0.073 - 0.11)	(1.40 - 3.86)
Low birth weight* Ages 4-5 years		0.48 (-0.15 - 1.11)	0.46 (-0.21 - 1.14)		0.30*** (0.075 - 0.53)	0.32*** (0.092 - 0.54)		0.33** (0.012 - 0.65)	0.33** (0.0074 - 0.65)		0.31*** (0.13 - 0.50)	0.32*** (0.14 - 0.51)
Low birth weight* Ages 7-8 years		0.51 (-0.26 - 1.28)	0.50 (-0.30 - 1.29)		0.35*** (0.088 - 0.61)	0.36*** (0.093 - 0.62)		0.37** (0.087 - 0.66)	0.37** (0.081 - 0.65)		0.11 (-0.061 - 0.28)	0.12 (-0.051 - 0.29)
Constant	-0.99***	-0.95***	-1.78***	-0.85***	-0.82***	-1.26***	-0.91***	-0.90***	-1.61***	-1.25***	-1.25***	-0.74**
	(-1.32 - - 0.67)	(-1.29 - - 0.61)	(-2.95 - - 0.60)	(-0.96 - - 0.74)	(-0.94 - - 0.69)	(-1.91 - - 0.62)	(-0.97 - - 0.86)	(-0.96 - - 0.85)	(-1.92 - - 1.30)	(-1.31 - - 1.20)	(-1.30 - - 1.20)	(-1.40 - - 0.078)
Covariates[3]	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

[1]Low birth weight is defined as less than 2,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Supplementary Table 1.4 Associations between low birth weight[1] and height for age z-scores at age 6-18 months, by baseline wealth index and country[2]

	Ethiopia (n=267)			India (n=761)			Peru (n=1,543)			Vietnam (n=1,428)		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
Low birth weight	-0.51*	-0.042	-0.21	-0.55***	-0.24	-0.23	-0.68***	-0.35	-0.27	-0.56***	-0.71**	-0.53**
	(-1.09 - 0.073)	(-0.60 - 0.51)	(-0.96 - 0.53)	(-0.87 - -0.24)	(-1.20 - 0.72)	(-1.15 - 0.69)	(-1.05 - -0.31)	(-0.91 - 0.21)	(-0.73 - 0.20)	(-0.81 - -0.32)	(-1.23 - -0.19)	(-1.05 - -0.0055)
Baseline wealth index	2.02**	2.24***	2.38***	1.21***	1.31***	1.17***	1.06***	1.10***	0.76***	0.88**	0.86**	0.42
	(0.53 - 3.51)	(0.69 - 3.79)	(1.15 - 3.62)	(0.68 - 1.74)	(0.77 - 1.85)	(0.64 - 1.71)	(0.64 - 1.49)	(0.64 - 1.56)	(0.32 - 1.19)	(0.23 - 1.52)	(0.19 - 1.53)	(-0.091 - 0.94)
Birth weight*baseline wealth index		-2.05***	-1.62*		-0.63	-0.56		-0.79	-0.78		0.33	0.16
		(-3.27 - -0.84)	(-3.45 - 0.21)		(-2.15 - 0.88)	(-2.03 - 0.90)		(-1.95 - 0.38)	(-1.81 - 0.25)		(-0.62 - 1.28)	(-0.90 - 1.22)
Constant	-1.22***	-1.24***	0.30	-1.69***	-1.75***	0.85	-1.58***	-1.60***	-1.12***	-1.63***	-1.62***	0.064
	(-1.90 - -0.53)	(-1.92 - -0.56)	(-1.86 - 2.46)	(-2.06 - -1.33)	(-2.12 - -1.37)	(-0.47 - 2.17)	(-1.82 - -1.33)	(-1.86 - -1.34)	(-1.67 - -0.57)	(-1.95 - -1.30)	(-1.95 - -1.28)	(-0.71 - 0.84)
Covariates[3]	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

[1]Low birth weight is defined as less than 2,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).
[4]In the stunting models, 8 observations from three sentinel sites were dropped due to problems with perfect prediction.

Supplementary Table 1.5 Associations between low birth weight (LBW)[1], baseline wealth index (BWI)[2], and growth in height for age z-scores, for each country at ages 4-5 years[3]

	Ethiopia (n=261)			**India (n=761)**			**Peru (n=1,543)**			**Vietnam (n=1,428)**		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(11)*	*(12)*	*(13)*
LBW	-0.20**	-0.011	-0.51	-0.20***	-0.011	0.37	-0.29***	-0.048	-0.41	-0.13	0.12	1.03*
	(-0.39 - -0.0018)	(-0.22 - 0.20)	(-1.55 - 0.53)	(-0.32 - -0.078)	(-0.13 - 0.10)	(-0.30 - 1.05)	(-0.42 - -0.16)	(-0.22 - 0.13)	(-1.41 - 0.59)	(-0.36 - 0.11)	(-0.043 - 0.29)	(-0.090 - 2.15)
BWI	1.44*	0.81	0.70	0.84***	0.42**	0.55*	0.58***	0.36***	0.45**	0.76***	0.55***	0.82***
	(-0.030 - 2.90)	(-0.83 - 2.44)	(-1.02 - 2.42)	(0.50 - 1.17)	(0.045 - 0.79)	(-0.066 - 1.17)	(0.29 - 0.88)	(0.11 - 0.61)	(0.055 - 0.85)	(0.25 - 1.27)	(0.19 - 0.90)	(0.36 - 1.29)
HAZ at 6-18 months		0.28***	0.30***		0.38***	0.37***		0.41***	0.36***		0.54***	0.40***
		(0.16 - 0.40)	(0.11 - 0.50)		(0.30 - 0.46)	(0.15 - 0.58)		(0.34 - 0.47)	(0.24 - 0.48)		(0.49 - 0.58)	(0.27 - 0.54)
LBW*BWI			1.39			-0.67			0.55			-1.75**
			(-1.32 - 4.09)			(-1.93 - 0.58)			(-0.94 - 2.05)			(-3.46 - -0.038)
LBW*HAZ at 6-18 months			-0.19			0.039			-0.10			0.46**
			(-0.54 - 0.16)			(-0.33 - 0.40)			(-0.48 - 0.28)			(0.0076 - 0.91)
HAZ at 6-18 months*BWI			-0.030			0.015			0.12			0.29**
			(-0.41 - 0.35)			(-0.46 - 0.49)			(-0.15 - 0.38)			(0.048 - 0.53)
LBW*HAZ at 6-18 months*BWI			0.43			-0.0014			0.066			-0.90**
			(-0.41 - 1.26)			(-0.77 - 0.77)			(-0.64 - 0.77)			(-1.62 - -0.18)
Constant	0.85	-2.82**	-2.35	-1.65*	-3.00***	-3.03***	-1.56***	-3.20***	-3.20***	-1.90***	-4.42***	-4.52***
	(-1.36 - 3.06)	(-5.07 - -0.57)	(-5.25 - 0.55)	(-3.64 - 0.34)	(-4.77 - -1.22)	(-4.72 - -1.34)	(-2.69 - -0.43)	(-4.28 - -2.12)	(-4.28 - -2.12)	(-3.27 - -0.52)	(-5.91 - -2.93)	(-6.06 - -2.97)

[1]Low birth weight is defined as less than 2,500g.

[2]Baseline wealth index is measured in the first survey round.

[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.6 Associations between low birth weight (LBW)[1], baseline wealth index (BWI)[2], and growth in height for age z-scores, for each country at ages 7-8 years[3]

	Ethiopia (n=267)					India (n=761)				
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*
LBW	-0.013	0.15	0.11	0.17	0.62	-0.22***	-0.043	-0.064	-0.032	-0.90***
	(-0.47 - 0.45)	(-0.24 - 0.54)	(-0.33 - 0.56)	(-0.25 - 0.60)	(-0.20 - 1.43)	(-0.36 - - 0.079)	(-0.16 - 0.075)	(-0.18 - 0.054)	(-0.15 - 0.082)	(-1.54 - - 0.27)
BWI	1.02	0.39	0.012	-0.14	-0.15	0.89***	0.52**	0.25	0.21	0.045
	(-0.76 - 2.80)	(-1.30 - 2.08)	(-2.11 - 2.13)	(-2.07 - 1.79)	(-2.45 - 2.14)	(0.46 - 1.32)	(0.016 - 1.02)	(-0.15 - 0.66)	(-0.20 - 0.62)	(-0.36 - 0.45)
HAZ at 6-18 months		0.30***		0.14***	0.081		0.36***		0.092***	-0.12*
		(0.20 - 0.40)		(0.051 - 0.22)	(-0.018 - 0.18)		(0.28 - 0.43)		(0.042 - 0.14)	(-0.24 - 0.0016)
HAZ at 4-5 years			0.68***	0.59***	0.67***			0.76***	0.69***	0.90***
			(0.57 - 0.79)	(0.48 - 0.70)	(0.47 - 0.87)			(0.68 - 0.83)	(0.61 - 0.78)	(0.68 - 1.12)
LBW*BWI					-2.14					1.94***
					(-5.23 - 0.94)					(0.67 - 3.21)
LBW*HAZ at 6-18 months					0.010					0.49***
					(-0.16 - 0.18)					(0.21 - 0.76)
LBW* HAZ at 4-5 years					0.30					-0.78***
					(-0.16 - 0.75)					(-1.16 - - 0.40)
HAZ at 6-18 months*BWI					0.20					0.41***
					(-0.18 - 0.58)					(0.19 - 0.64)
HAZ at 4-5 years*BWI					-0.30					-0.38*
					(-0.92 - 0.32)					(-0.78 - 0.016)
LBW* HAZ at 6-18 months*BWI					0.15					-0.85***
					(-0.83 - 1.13)					(-1.37 - - 0.34)

LBW*HAZ at 4-5 years*BWI					-1.96					1.56***
					(-5.64 - 1.72)					(0.75 - 2.38)
Constant	2.85**	-2.13	0.91	-1.08	-1.17	-0.11	-2.36**	0.85	0.19	0.34
	(0.45 - 5.24)	(-6.11 - 1.86)	(-2.45 - 4.26)	(-5.24 - 3.08)	(-5.66 - 3.32)	(-2.00 - 1.78)	(-4.14 - -0.59)	(-0.41 - 2.12)	(-1.18 - 1.57)	(-1.21 - 1.88)
	Peru (n=1,543)					**Vietnam (n=1,428)**				
	(11)	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*	*(19)*	*(20)*
LBW	-0.28***	-0.035	-0.078	-0.0023	-0.080	-0.35***	-0.15	-0.25***	-0.25***	-0.36
	(-0.41 - -0.16)	(-0.17 - 0.100)	(-0.18 - 0.026)	(-0.088 - 0.083)	(-0.74 - 0.58)	(-0.59 - -0.12)	(-0.34 - 0.045)	(-0.41 - -0.086)	(-0.41 - -0.091)	(-1.09 - 0.37)
BWI	0.70***	0.46***	0.28**	0.25*	0.28**	0.74***	0.54**	0.078	0.077	0.15
	(0.35 - 1.04)	(0.13 - 0.80)	(0.048 - 0.52)	(-0.0037 - 0.50)	(0.022 - 0.55)	(0.26 - 1.22)	(0.12 - 0.97)	(-0.20 - 0.36)	(-0.20 - 0.35)	(-0.25 - 0.55)
HAZ at 6-18 months		0.41***		0.18***	0.12***		0.44***		-0.0048	0.046
		(0.35 - 0.47)		(0.13 - 0.22)	(0.037 - 0.20)		(0.38 - 0.50)		(-0.056 - 0.046)	(-0.058 - 0.15)
HAZ at 4-5 years			0.68***	0.57***	0.61***			0.83***	0.84***	0.77***
			(0.62 - 0.74)	(0.51 - 0.64)	(0.51 - 0.70)			(0.76 - 0.91)	(0.75 - 0.93)	(0.58 - 0.97)
LBW*BWI					0.19					0.025
					(-0.91 - 1.28)					(-1.86 - 1.91)
LBW*HAZ at 6-18 months					0.11					0.046
					(-0.059 - 0.27)					(-0.44 - 0.54)
LBW* HAZ at 4-5 years					-0.17					-0.16
					(-0.52 - 0.19)					(-0.47 - 0.15)
HAZ at 6-18 months*BWI					0.16*					-0.11
					(-0.016 - 0.33)					(-0.34 - 0.13)
HAZ at 4-5 years*BWI					-0.091					0.14
					(-0.29 -					(-0.19 -

					0.11)					0.46)
LBW* HAZ at 6-18 months*BWI					-0.49**					-0.19
					(-0.93 - -0.048)					(-1.06 - 0.69)
LBW*HAZ at 4-5 years*BWI					0.71					0.30
					(-0.19 - 1.60)					(-0.31 - 0.92)
Constant	-1.04	-3.66***	-0.14	-1.43***	-1.40**	-0.51	-3.96***	1.06***	1.11**	1.03**
	(-2.44 - 0.37)	(-4.90 - -2.43)	(-1.16 - 0.89)	(-2.45 - -0.42)	(-2.46 - -0.34)	(-1.97 - 0.94)	(-5.42 - -2.49)	(0.32 - 1.81)	(0.11 - 2.10)	(0.081 - 1.98)

[1]Low birth weight is defined as less than 2,500g.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.7 Associations between birth weight[1] and height for age z-scores pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Birth weight	0.20***	0.30***	0.25***
	(0.18 - 0.23)	(0.26 - 0.34)	(0.21 - 0.28)
Ages 4-5 years	-0.22***	-0.22***	0.84***
	(-0.29 - -0.16)	(-0.29 - -0.16)	(0.41 - 1.26)
Ages 7-8 years	0.070**	0.071**	1.79***
	(0.00063 - 0.14)	(0.0032 - 0.14)	(1.12 - 2.46)
Birth weight*ages 4-5 years		-0.13***	-0.13***
		(-0.17 - -0.093)	(-0.16 - -0.090)
Birth weight*ages 7-8 years		-0.15***	-0.15***
		(-0.19 - -0.12)	(-0.19 - -0.12)
Constant	-0.80***	-0.80***	-0.95***
	(-0.84 - -0.76)	(-0.84 - -0.76)	(-1.16 - -0.73)
Covariates[3]	No	No	Yes

[1]Birth weight is measured in standard deviations.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted f clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place residence (rural/urban).

Supplementary Table 1.8 Associations between birth weight[1] and height for age z-scores at age 6-18 months, by baseline wealth index from pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Birth weight	0.29***	0.26***	0.23***
	(0.25 - 0.33)	(0.17 - 0.34)	(0.14 - 0.31)
Baseline wealth index	0.96***	0.96***	0.66***
	(0.66 - 1.26)	(0.66 - 1.26)	(0.37 - 0.94)
Birth weight*baseline wealth index		0.065	0.041
		(-0.093 - 0.22)	(-0.11 - 0.19)
Constant	-0.78***	-0.78***	0.16
	(-0.91 - -0.65)	(-0.91 - -0.65)	(-0.21 - 0.53)
Covariates[3]	No	No	Yes

[1]Birth weight is measured in standard deviations.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.9 Associations between birth weight (BW)[1], baseline wealth index (BWI)[2], and growth in height in age z-scores (HAZ), across all countries (n=3,999).[3]

HAZ at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
BW	0.11***	0.0086			-0.039
	(0.086 - 0.14)	(-0.019 - 0.036)			(-0.14 - 0.064)
BWI	0.71***	0.45***			0.60***
	(0.50 - 0.93)	(0.28 - 0.62)			(0.35 - 0.85)
HAZ at 6-18 months		0.42***			0.35***
		(0.38 - 0.46)			(0.28 - 0.43)
BW*BWI					0.077
					(-0.100 - 0.25)
BW*HAZ at 6-18 months					-0.035
					(-0.089 - 0.018)
HAZ at 6-18 months*BWI					0.17**
					(0.0063 - 0.33)
BW*HAZ at 6-18 months*BWI					0.064
					(-0.032 - 0.16)
Constant	-1.38***	-3.64***			-3.68***
	(-2.02 - -0.75)	(-4.25 - -3.02)			(-4.30 - -3.06)
HAZ at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
BW	0.11***	0.0086	0.021*	0.0016	0.0010
	(0.073 - 0.14)	(-0.021 - 0.038)	(-0.0028 - 0.044)	(-0.022 - 0.025)	(-0.11 - 0.11)
BWI	0.75***	0.51***	0.21**	0.20**	0.28***
	(0.52 - 0.97)	(0.30 - 0.73)	(0.052 - 0.37)	(0.036 - 0.36)	(0.12 - 0.45)
HAZ at 6-18 months		0.39***		0.11***	0.070***
		(0.36 - 0.43)		(0.082 - 0.14)	(0.025 - 0.11)
HAZ at 4-5 years			0.74***	0.67***	0.67***
			(0.70 - 0.78)	(0.62 - 0.71)	(0.60 - 0.74)
BW*BWI					-0.063
					(-0.27 - 0.14)
BW*HAZ at 6-18 months					-0.028
					(-0.080 - 0.023)
BW*HAZ at 4-5 years					0.017
					(-0.051 - 0.084)
HAZ at 6-18 months*BWI					0.097**
					(0.00017 - 0.19)
HAZ at 4-5 years*BWI					-0.0059
					(-0.15 - 0.13)
BW*HAZ at 6-18 months*BWI					0.089

					(-0.021 - 0.20)
BW*HAZ at 4-5 years*BWI					-0.11 (-0.26 - 0.038)
Constant	-0.21 (-1.06 - 0.63)	-3.52*** (-4.31 - -2.72)	0.69** (0.090 - 1.29)	-0.35 (-1.07 - 0.36)	-0.41 (-1.15 - 0.32)

[1]Birth weight is measured in standard deviations.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.10 Associations between very low birth weight[1] and height for age z-scores from pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Very low birth weight	-0.68***	-0.95***	-0.92***
	(-1.07 - -0.30)	(-1.46 - -0.45)	(-1.45 - -0.39)
Ages 4-5 years	-0.22***	-0.23***	0.87***
	(-0.29 - -0.16)	(-0.29 - -0.16)	(0.46 - 1.29)
Ages 7-8 years	0.070**	0.069*	1.85***
	(0.00063 - 0.14)	(-0.00047 - 0.14)	(1.19 - 2.52)
Very low birth weight*ages 4-5 years		0.43	0.44
		(-0.17 - 1.02)	(-0.14 - 1.02)
Very low birth weight*ages 7-8 years		0.38*	0.40**
		(-0.024 - 0.78)	(0.018 - 0.79)
Constant	-0.84***	-0.84***	-0.97***
	(-0.89 - -0.80)	(-0.89 - -0.80)	(-1.18 - -0.75)
Covariates[3]	No	No	Yes

[1]Very low birth weight is defined as less than 1,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Supplementary Table 1.11 Associations between very low birth weight (VLBW)[1] and height for age z-scores at age 6-18 months, by baseline wealth index from pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Very low birth weight	-0.93***	0.41	0.38
	(-1.46 - -0.40)	(-0.44 - 1.25)	(-0.81 - 1.57)
Baseline wealth index	1.08***	1.08***	0.71***
	(0.78 - 1.38)	(0.78 - 1.38)	(0.42 - 0.99)
Very low birth weight*baseline wealth index		-2.96***	-2.31*
		(-5.14 - -0.78)	(-4.74 - 0.13)
Constant	-0.90***	-0.90***	0.13
	(-1.03 - -0.77)	(-1.03 - -0.77)	(-0.26 - 0.53)
Covariates[3]	No	No	Yes

[1]Very low birth weight is defined as less than 1,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.12 Associations between very low birth weight (VLBW)[1], baseline wealth index (BWI)[2], and growth in height for age z-scores, across all countries (n=3,999).[3]

HAZ at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
VLBW	-0.58**	-0.33			1.10
	(-1.12 - -0.038)	(-0.89 - 0.23)			(-2.07 - 4.26)
BWI	0.74***	0.46***			0.62***
	(0.53 - 0.95)	(0.29 - 0.63)			(0.37 - 0.87)
HAZ at 6-18 months		0.42***			0.36***
		(0.39 - 0.46)			(0.29 - 0.43)
VLBW*BWI					-3.49
					(-9.96 - 2.97)
VLBW*HAZ at 6-18 months					0.64
					(-0.81 - 2.10)
HAZ at 6-18 months*BWI					0.16**
					(0.011 - 0.30)
VLBW*HAZ at 6-18 months*BWI					-1.59
					(-4.35 - 1.17)
Constant	-1.37***	-3.65***			-3.71***
	(-2.01 - -0.73)	(-4.27 - -3.04)			(-4.33 - -3.09)
HAZ at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
VLBW	-0.55***	-0.32**	-0.14	-0.12	-1.08*
	(-0.84 - -0.26)	(-0.60 - -0.045)	(-0.40 - 0.12)	(-0.33 - 0.091)	(-2.29 - 0.12)
BWI	0.77***	0.52***	0.21***	0.20**	0.25***
	(0.55 - 1.00)	(0.30 - 0.73)	(0.055 - 0.37)	(0.037 - 0.37)	(0.080 - 0.42)
HAZ at 6-18 months		0.39***		0.11***	0.074***
		(0.36 - 0.43)		(0.083 - 0.14)	(0.030 - 0.12)
HAZ at 4-5 years			0.75***	0.67***	0.68***
			(0.71 - 0.79)	(0.62 - 0.71)	(0.61 - 0.75)
VLBW*BWI					0.53
					(-2.06 - 3.12)
VLBW*HAZ at 6-18 months					-0.90***
					(-1.27 - -0.53)
VLBW* HAZ at 4-5 years					0.62
					(-0.33 - 1.58)
HAZ at 6-18 months*BWI					0.091*
					(-0.0082 - 0.19)
HAZ at 4-5 years*BWI					-0.033
					(-0.18 - 0.11)
VLBW* HAZ at 6-18 months*BWI					1.88***
					(1.03 - 2.73)
VLBW*HAZ at 4-5 years*BWI					-2.06*

					(-4.20 - 0.080)
Constant	-0.17	-3.54***	0.70**	-0.36	-0.36
	(-1.00 - 0.67)	(-4.34 - -2.74)	(0.11 - 1.30)	(-1.08 - 0.35)	(-1.09 - 0.36)

[1]Very low birth weight is defined as less than 1,500g.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.13 Associations between low birth weight[1] and height (cm) from pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Low birth weight	-1.31***	-1.16***	-1.03***
	(-1.78 - -0.84)	(-1.69 - -0.62)	(-1.45 - -0.61)
Ages 4-5 years	33.0***	33.0***	3.54***
	(32.5 - 33.6)	(32.5 - 33.6)	(1.71 - 5.37)
Ages 7-8 years	48.9***	49.0***	1.07
	(48.5 - 49.4)	(48.5 - 49.4)	(-1.86 - 3.99)
Low birth weight*ages 4-5 years		0.0088	-0.012
		(-0.49 - 0.51)	(-0.45 - 0.43)
Low birth weight*ages 7-8 years		-0.47	-0.54*
		(-1.11 - 0.17)	(-1.15 - 0.070)
Constant	73.4***	73.4***	66.6***
	(73.1 - 73.8)	(73.1 - 73.8)	(65.7 - 67.6)
Covariates[3]	No	No	Yes

[1]Low birth weight is defined as less than 2,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Supplementary Table 1.14 Associations between low birth weight[1] and height (cm) at age 6-18 months, by baseline wealth index from pooled analyses (n=3,999)[2]

	(1)	*(2)*	*(3)*
Low birth weight	-1.21***	-0.88*	-0.68*
	(-1.67 - -0.75)	(-1.87 - 0.097)	(-1.44 - 0.072)
Baseline wealth index	3.07***	3.13***	1.89***
	(2.05 - 4.09)	(2.10 - 4.16)	(1.14 - 2.65)
Low birth weight*baseline wealth index		-0.75	-1.38*
		(-2.98 - 1.48)	(-2.81 - 0.037)
Constant	73.1***	73.0***	64.0***
	(72.6 - 73.5)	(72.6 - 73.5)	(63.0 - 65.1)
Covariates[3]	No	No	Yes

[1]Low birth weight is defined as less than 2,500g.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.15 Associations between low birth weight (LBW)[1], baseline wealth index (BWI)[2], and growth in height (cm), across all countries.[3]

Height at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-0.95***	0.054			-0.71
	(-1.33 - -0.57)	(-0.31 - 0.42)			(-13.4 - 12.0)
BWI	3.51***	2.18***			2.38
	(2.49 - 4.53)	(1.35 - 3.00)			(-8.30 - 13.1)
Height at 6-18 months		0.75***			0.75***
		(0.69 - 0.81)			(0.66 - 0.84)
LBW*BWI					7.24
					(-14.9 - 29.3)
LBW*Height at 6-18 months					0.013
					(-0.17 - 0.20)
Height at 6-18 months*BWI					-0.0026
					(-0.15 - 0.15)
LBW*Height at 6-18 months*BWI					-0.11
					(-0.42 - 0.21)
Constant	77.5***	61.6***			61.3***
	(74.5 - 80.5)	(58.4 - 64.7)			(55.7 - 66.9)

Height at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-1.41***	-0.28	-0.57**	-0.36	9.21
	(-1.95 - -0.87)	(-0.75 - 0.19)	(-1.01 - -0.14)	(-0.80 - 0.079)	(-6.34 - 24.8)
BWI	4.39***	2.81***	1.19***	1.08**	-2.76
	(3.11 - 5.66)	(1.59 - 4.04)	(0.29 - 2.08)	(0.16 - 2.00)	(-13.6 - 8.06)
Height at 6-18 months		0.85***		0.22***	0.17***
		(0.79 - 0.92)		(0.15 - 0.29)	(0.043 - 0.29)
Height at 4-5 years			0.89***	0.81***	0.83***
			(0.84 - 0.94)	(0.75 - 0.87)	(0.73 - 0.93)
LBW*BWI					-21.1
					(-62.1 - 20.0)
LBW*Height at 6-18 months					0.12
					(-0.23 - 0.47)
LBW*Height at 4-5 years					-0.18
					(-0.46 - 0.11)
Height at 6-18 months*BWI					0.13
					(-0.067 - 0.33)
Height at 4-5 years*BWI					-0.054
					(-0.23 - 0.12)
LBW*Height at 6-18 months*BWI					-0.50
					(-1.13 - 0.14)
LBW*Height at 4-5 years*BWI					0.54**
					(0.014 - 1.07)
Constant	85.6***	93.0***	27.9***	35.1***	36.8***

	(80.7 - 90.4)	(88.3 - 97.7)	(23.0 - 32.8)	(29.5 - 40.7)	(30.6 - 43.0)

[1] Low birth weight is defined as less than 2,500g.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.16 Descriptive statistics on child's size at birth[1]

	Global	**Ethiopia**	**India**	**Peru**	**Vietnam**
Very small	9.94	5.78	6.04	1.05	5.62
Small	17.78	25.20	14.91	13.84	18.00
Average	42.46	44.97	51.12	65.66	51.13
Large	22.45	20.17	16.70	16.31	18.81
Very large	7.37	3.87	11.23	3.15	6.43
Total	100	100	100	100	100
Obs.	6,565	1,479	1,730	1,737	1,619

[1]Size at birth is reported by the mother.

Supplementary Table 1.17 Associations between child's size at birth[1] and height for age z-scores from pooled analyses (n=6,565)[2]

	(1)	*(2)*	*(3)*
Size at birth	0.15***	0.22***	0.21***
	(0.12 - 0.18)	(0.18 - 0.27)	(0.16 - 0.25)
Ages 4-5 years	-0.20***	0.057	1.19***
	(-0.30 - -0.11)	(-0.071 - 0.18)	(0.78 - 1.60)
Ages 7-8 years	0.073	0.43***	2.28***
	(-0.024 - 0.17)	(0.31 - 0.55)	(1.64 - 2.93)
Size at birth* Ages 4-5 years		-0.087***	-0.087***
		(-0.13 - -0.040)	(-0.13 - -0.040)
Size at birth* Ages 7-8 years		-0.12***	-0.12***
		(-0.16 - -0.077)	(-0.16 - -0.077)
Constant	-1.29***	-1.49***	-1.74***
	(-1.38 - -1.20)	(-1.61 - -1.38)	(-1.97 - -1.50)
Covariates[3]	No	No	Yes

[1]Child's size at birth is reported by the mother.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Supplementary Table 1.18 Associations between child's size at birth[1] and height for age z-scores at age 6-18 months by baseline wealth index from pooled analyses (n=6,565)[2]

	(1)	*(2)*	*(3)*
Size at birth	0.21***	0.17***	0.20***
	(0.16 - 0.25)	(0.083 - 0.26)	(0.12 - 0.29)
Baseline wealth index	1.20***	0.93***	0.84***
	(0.91 - 1.48)	(0.37 - 1.49)	(0.33 - 1.36)
Size at birth*baseline wealth index		0.089	0.011
		(-0.083 - 0.26)	(-0.15 - 0.17)
Constant	-1.60***	-1.50***	-0.68***
	(-1.75 - -1.45)	(-1.77 - -1.23)	(-1.10 - -0.26)
Covariates[3]	No	No	Yes

[1]Child's size at birth is reported by the mother.
[2]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.19 Associations between child's size at birth[1], baseline wealth index (BWI)[2], and growth in height in age z-scores (HAZ), across all countries for children with documented birth weight (n=6,565).[3]

HAZ at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Size at birth	0.11***	0.037***			-0.025
	(0.086 - 0.14)	(0.014 - 0.060)			(-0.091 - 0.041)
BWI	0.81***	0.52***			0.55**
	(0.61 - 1.01)	(0.35 - 0.68)			(0.045 - 1.05)
HAZ at 6-18 months		0.36***			0.35***
		(0.32 - 0.39)			(0.25 - 0.45)
Size at birth*BWI					0.076
					(-0.060 - 0.21)
Size at birth*HAZ at 6-18 months					-0.022
					(-0.053 - 0.010)
HAZ at 6-18 months*BWI					0.24*
					(-0.039 - 0.51)
Size at birth*HAZ at 6-18 months*BWI					-0.0056
					(-0.098 - 0.086)
Constant	-1.86***	-3.54***			-3.48***
	(-2.36 - -1.35)	(-4.03 - -3.06)			(-4.02 - -2.95)

HAZ at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Size at birth	0.096***	0.026**	0.015	0.0014	-0.031
	(0.067 - 0.13)	(0.0015 - 0.050)	(-0.0043 - 0.034)	(-0.017 - 0.019)	(-0.11 - 0.047)
BWI	0.86***	0.59***	0.26***	0.24***	0.19
	(0.66 - 1.07)	(0.40 - 0.77)	(0.12 - 0.40)	(0.10 - 0.38)	(-0.24 - 0.62)
HAZ at 6-18 months		0.34***		0.11***	0.097*
		(0.31 - 0.37)		(0.082 - 0.13)	(-0.0056 - 0.20)
HAZ at 4-5 years			0.73***	0.66***	0.71***
			(0.70 - 0.77)	(0.61 - 0.70)	(0.56 - 0.86)
Size at birth*BWI					0.035
					(-0.10 - 0.17)
Size at birth*HAZ at 6-18 months					-0.0054
					(-0.036 - 0.025)
Size at birth*HAZ at 4-5 years					-0.016
					(-0.069 - 0.037)
HAZ at 6-18 months*BWI					0.0032

					(-0.25 - 0.26)
HAZ at 4-5 years*BWI					-0.040
					(-0.39 - 0.31)
Size at birth* HAZ at 6-18 months*BWI					0.026
					(-0.050 - 0.10)
Size at birth*HAZ at 4-5 years*BWI					0.0056
					(-0.10 - 0.12)
Constant	-0.91***	-3.64***	0.39	-0.60**	-0.57*
	(-1.56 - -0.26)	(-4.24 - -3.04)	(-0.13 - 0.90)	(-1.18 - -0.023)	(-1.20 - 0.064)

[1]Child's size at birth is reported by the mother.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.20 Associations between low birth weight[1] and height for age z-scores from pooled analyses for children with documented birth weight (n=1,685)[2]

	(1)	*(2)*	*(3)*
Low birth weight	-0.44***	-0.70***	-0.68***
	(-0.59 - -0.29)	(-0.93 - -0.47)	(-0.91 - -0.46)
Ages 4-5 years	-0.23***	-0.26***	0.43
	(-0.32 - -0.13)	(-0.35 - -0.16)	(-0.098 - 0.95)
Ages 7-8 years	0.086	0.057	1.15***
	(-0.017 - 0.19)	(-0.045 - 0.16)	(0.30 - 2.00)
Low birth weight* Ages 4-5 years		0.40***	0.40***
		(0.19 - 0.61)	(0.19 - 0.61)
Low birth weight* Ages 7-8 years		0.38***	0.38***
		(0.15 - 0.61)	(0.16 - 0.61)
Constant	-0.93***	-0.91***	-1.15***
	(-1.00 - -0.87)	(-0.98 - -0.85)	(-1.43 - -0.88)
Covariates[3]	No	No	Yes

[1]Low birth weight is defined as less than 2,500g.
[2]Results are from ordinary least squares and logit models used for height for age z-scores and stunting as outcomes, respectively. Coefficient estimates are presented for height for age z-score models and odds ratios for stunting. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), baseline wealth index, household size, and place of residence (rural/urban).

Supplementary Table 1.21 Associations between low birth weight[1] and height for age z-scores at age 6-18 months, by baseline wealth index from pooled analyses for children with documented birth weight (n=1,685).[2]

	(1)	*(2)*	*(3)*
Low birth weight	-0.72***	-0.57**	-0.40*
	(-0.97 - -0.47)	(-1.05 - -0.093)	(-0.85 - 0.049)
Baseline wealth index	1.09***	1.11***	0.81***
	(0.70 - 1.49)	(0.71 - 1.52)	(0.45 - 1.17)
Low birth weight*baseline wealth index		-0.30	-0.51
		(-1.22 - 0.62)	(-1.41 - 0.38)
Constant	-0.87***	-0.89***	0.037
	(-1.05 - -0.70)	(-1.07 - -0.70)	(-0.39 - 0.46)
Covariates[3]	No	No	Yes

[1]Birth weight is measured in standard deviations.
[2]Results are from ordinary least squares and logit models used for height for age z-scores and stunting as outcomes, respectively. Coefficient estimates are presented for height for age z-score models and odds ratios for stunting. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[3]Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.22 Associations between low birth weight (LBW)[1], baseline wealth index (BWI)[2], and growth in height in age z-scores (HAZ), across all countries for children with documented birth weight (n=1,685).[3]

HAZ at age 4-5 years (Round 2)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-0.28***	-0.0057			0.17
	(-0.41 - -0.14)	(-0.13 - 0.12)			(-0.55 - 0.90)
BWI	0.73***	0.42***			0.54***
	(0.47 - 0.99)	(0.17 - 0.66)			(0.21 - 0.87)
HAZ at 6-18 months		0.42***			0.36***
		(0.36 - 0.47)			(0.24 - 0.49)
LBW*BWI					-0.42
					(-1.55 - 0.70)
LBW*HAZ at 6-18 months					0.056
					(-0.24 - 0.35)
HAZ at 6-18 months*BWI					0.12
					(-0.12 - 0.35)
LBW*HAZ at 6-18 months*BWI					-0.17
					(-0.73 - 0.39)
Constant	-1.70***	-3.50***			-3.53***
	(-2.60 - -0.79)	(-4.31 - -2.69)			(-4.33 - -2.74)
HAZ at age 7-8 years (Round 3)	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
LBW	-0.30***	-0.030	-0.11**	-0.030	-0.38
	(-0.43 - -0.16)	(-0.16 - 0.098)	(-0.20 - -0.024)	(-0.12 - 0.063)	(-1.00 - 0.25)
BWI	0.66***	0.36**	0.15	0.10	0.16
	(0.34 - 0.98)	(0.054 - 0.66)	(-0.11 - 0.42)	(-0.16 - 0.37)	(-0.11 - 0.44)
HAZ at 6-18 months		0.41***		0.17***	0.079
		(0.36 - 0.46)		(0.12 - 0.22)	(-0.019 - 0.18)
HAZ at 4-5 years			0.68***	0.57***	0.61***
			(0.62 - 0.73)	(0.51 - 0.64)	(0.47 - 0.75)
LBW*BWI					0.67
					(-0.48 - 1.81)
LBW*HAZ at 6-18 months					-0.21*
					(-0.42 - 0.0073)
LBW* HAZ at 4-5 years					0.18
					(-0.15 - 0.51)
HAZ at 6-18 months*BWI					0.23***
					(0.073 - 0.38)
HAZ at 4-5 years*BWI					-0.10
					(-0.33 - 0.13)
LBW* HAZ at 6-18 months*BWI					0.073
					(-0.34 - 0.49)
LBW*HAZ at 4-5 years*BWI					-0.030

					(-0.62 - 0.56)
Constant	-0.20 (-1.68 - 1.27)	-3.30*** (-4.65 - -1.96)	0.69 (-0.43 - 1.80)	-0.75 (-1.96 - 0.46)	-0.81 (-2.05 - 0.43)

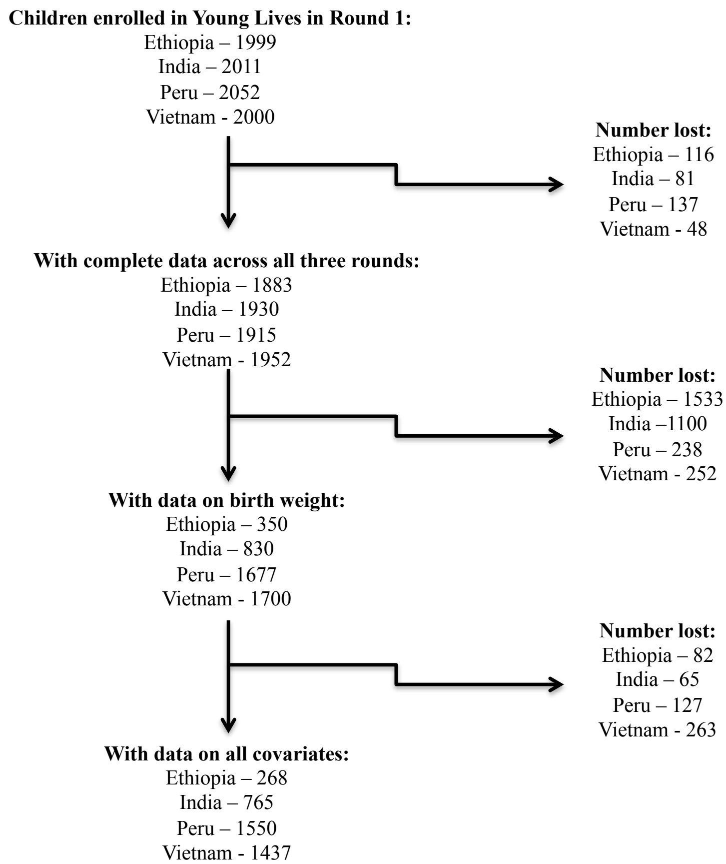
[1]Low birth weight is classified as born at a weight less than 2,500g.
[2]Baseline wealth index is measured in the first survey round.
[3]Results are from ordinary least squares models. Confidence intervals using robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals. Covariates include child's age (in months), child's sex, mother's height (in standard deviations), caregiver's educational attainment (none, primary, secondary or more), household size, and place of residence (rural/urban).

Supplementary Table 1.23 Characteristics of children with reported birth weight and those missing birth weight data

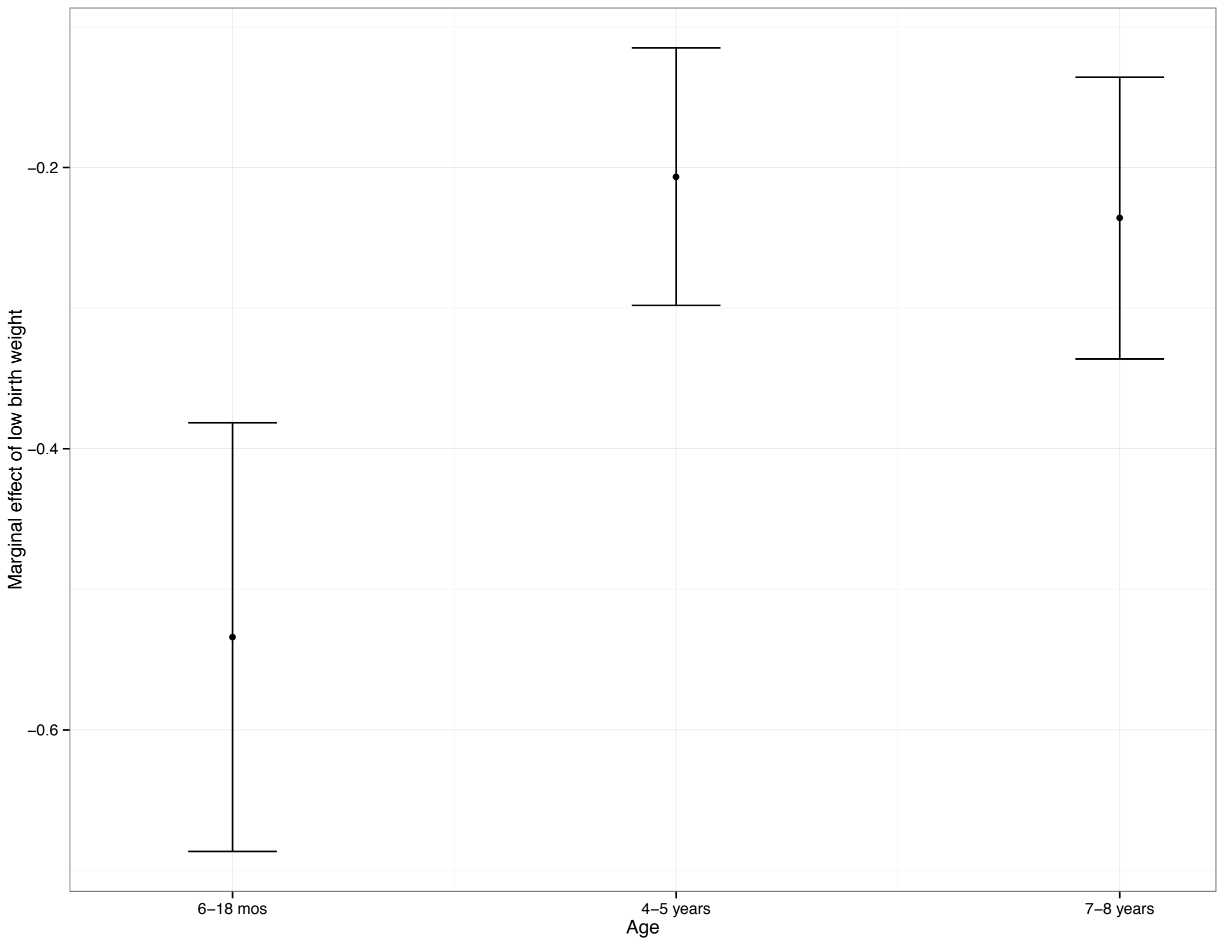
	Availability of birth weight data		
	No (n=2,635)	*Yes (n=3,999)*	*p-value*[1]
Age (months)	12.17 (0.08)	12.23 (0.07)	0.54
Female	0.48 (0.01)	0.48 (0.01)	0.50
Mother's height (in SD)	-0.07 (0.04)	0.03 (0.03)	0.03
Rural	0.80 (0.05)	0.51 (0.06)	<0.01
Caregiver's education			
None	62.91	14.65	
Primary	29.11	40.29	<0.01
Secondary or more	6.98	45.06	
Household size	5.69 (0.08)	5.26 (0.08)	<0.01
Wealth index	0.25 (0.02)	0.46 (0.02)	<0.01
Height for age z-score	-1.55 (0.92)	-1.13 (0.06)	<0.01

All statistics are means or proportions with robust standard errors, adjusted for clustered sampling, in parentheses.
[1]p-values are from *t*-tests for continuous variables and Chi-squared tests from categorical variables.

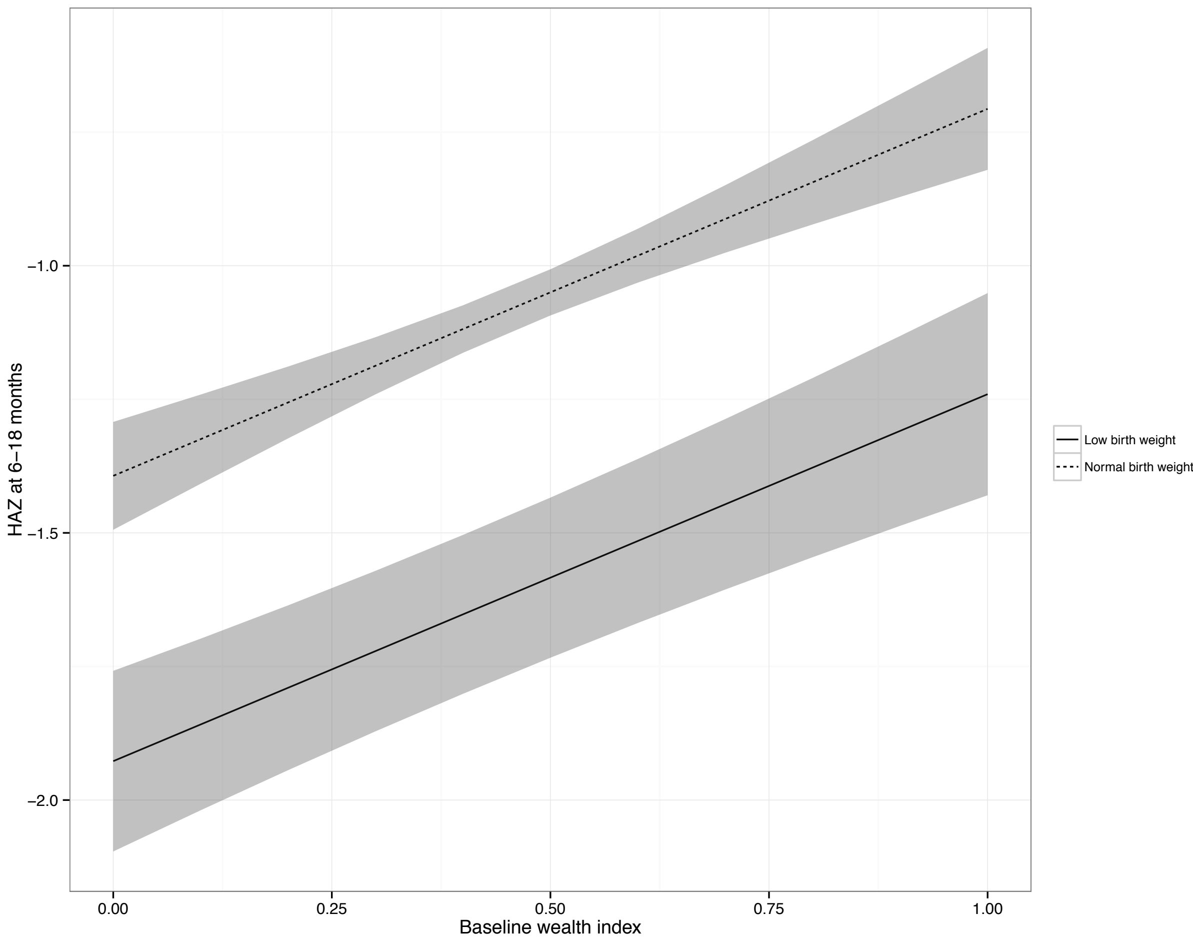
Supplementary Figure 1.1 Exclusion criteria and numbers excluded



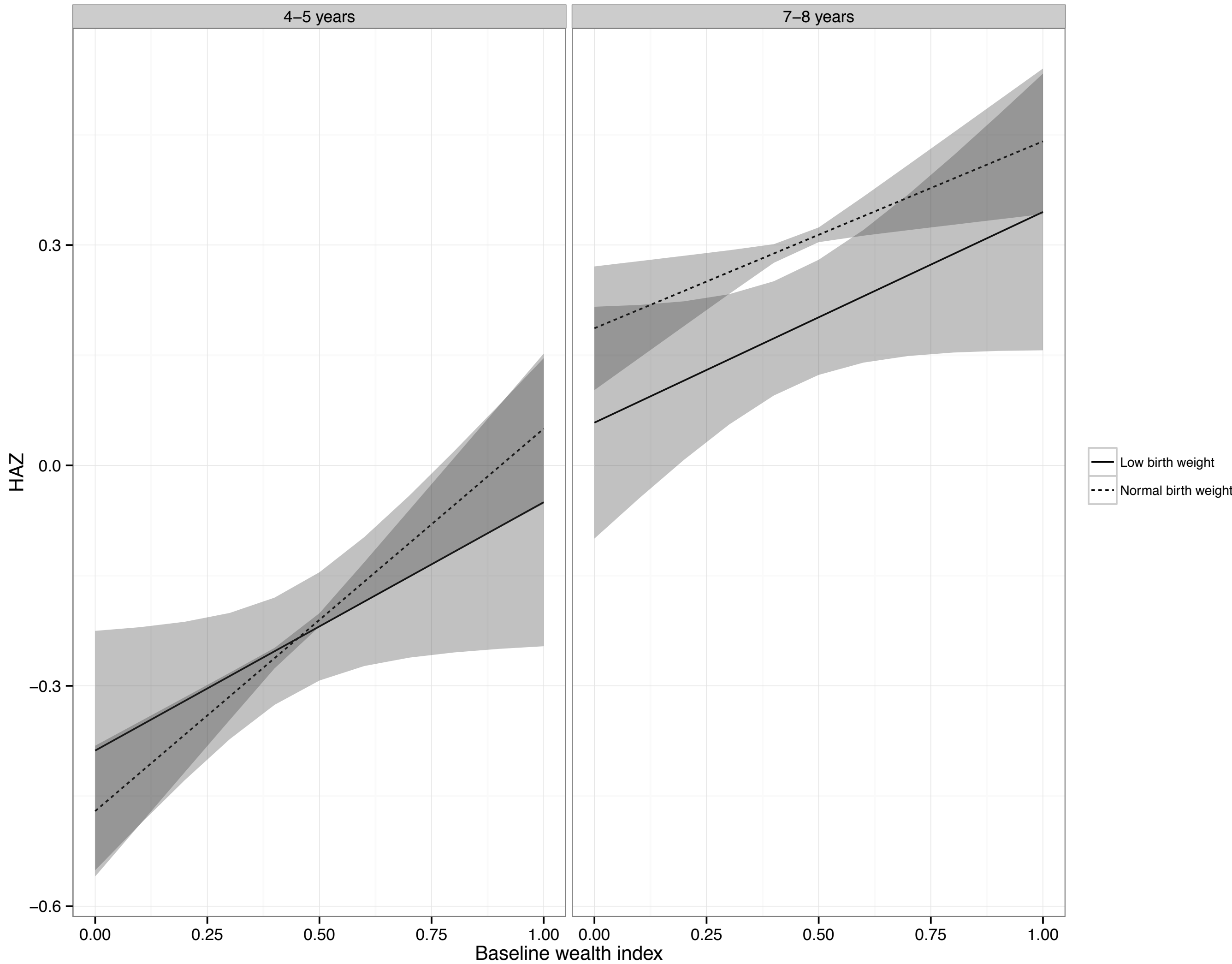
Supplementary Figure 1.2 Associations between low birth weight and height for age z-scores over ages



Supplementary Figure 1.3 Predicted height for age z-scores by wealth index and birth weight at age 6-18 months.



Supplementary Figure 1.4 Change in height for age z-scores by wealth index and birth weight.



PAPER 2 SUPPLEMENTAL MATERIAL

Supplementary Table 2.1 Classification of parental education

Values	Young Lives classification			Our classification of years of schooling
	Ethiopia/India	Peru	Vietnam	
0	No education	No education	No education	0
1-8	Years of primary and secondary schooling	Years of primary and secondary schooling	Years of primary and secondary schooling	1-8
9-12				9-12
13	Post-secondary	Incomplete technical college	Post-secondary	13
14	University	Complete technical college	University	14
15	Master's education	Incomplete university	.	
16	.	Complete university	.	
17	.	Adult literacy program	.	0
18	.	Other	.	0
28	Adult literacy	.	.	0
29	Religious education	.	.	0
42-46	.	.	Graduate studies	14

Supplementary Table 2.2 Parental education levels. *Proportion of parents in each level, by the other parent's educational attainment.*

All

		Father		
		No education	Primary	Secondary +
Mother	No education	23.01	9.53	5.28
	Primary	3.76	13.25	10.72
	Secondary +	1.66	3.99	28.78

Ethiopia

		Father		
		No education	Primary	Secondary +
Mother	No education	40.85	17.61	2.33
	Primary	5.55	17.07	7.75
	Secondary +	0.21	2.06	6.58

Vietnam

		Father		
		No education	Primary	Secondary +
Mother	No education	0.68	7.83	0.74
	Primary	0.61	27.08	16.14
	Secondary +	0.14	6.68	40.11

India

		Father		
		No education	Primary	Secondary +
Mother	No education	39.90	10.75	9.61
	Primary	5.19	5.29	9.17
	Secondary +	1.80	2.46	15.83

Peru

		Father		
		No education	Primary	Secondary +
Mother	No education	9.70	3.12	7.02
	Primary	3.46	6.86	10.26
	Secondary +	3.96	4.91	50.72

Supplementary Table 2.3 Mean height for age z-scores by parental education level[1]

All

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.71 (0.062)	-1.67 (0.070)	-1.42 (0.055)
	Primary	-1.51 (0.059)	-1.47 (0.066)	-1.22 (0.051)
	Secondary +	-1.21 (0.067)	-1.17 (0.057)	-0.91 (0.058)

Ethiopia

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.62 (0.089)	-1.52 (0.092)	-1.39 (0.080)
	Primary	-1.57 (0.079)	-1.37 (0.069)	-1.24 (0.076)
	Secondary +	-1.34 (0.068)	-1.14 (0.070)	-1.01 (0.070)

Vietnam

		Father		
		No education	Primary	Secondary +
Mother	No education	-2.39 (0.35)	-2.19 (0.16)	-1.87 (0.15)
	Primary	-1.95 (0.34)	-1.75 (0.075)	-1.43 (0.089)
	Secondary +	-1.34 (0.33)	-1.14 (0.057)	-0.81 (0.077)

India

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.72 (0.081)	-1.51 (0.084)	-1.39 (0.080)
	Primary	-1.57 (0.079)	-1.37 (0.069)	-1.24 (0.076)
	Secondary +	-1.34 (0.068)	-1.14 (0.070)	-1.01 (0.071)

Peru

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.93 (0.20)	-1.74 (0.18)	-1.53 (0.13)
	Primary	-1.44 (0.13)	-1.25 (0.12)	-1.04 (0.082)
	Secondary +	-1.33 (0.15)	-1.14 (0.12)	-0.93 (0.11)

[1]Standard errors are in parentheses.

Supplementary Table 2.4 Height for age z-scores by parental education level[1]

	All countries (n=6,564)			**Ethiopia (n=1,458)**			**India (n=1,831)**			**Peru (n=1,481)**			**Vietnam (n=1,794)**		
	Round 1	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**	**Round 1**	**Round 2**	**Round 3**
Mother's education															
None	-1.64***	-1.78***	-1.55***	-1.72***	-1.65***	-1.37***	-1.49***	-1.78***	-1.61***	-2.31***	-2.31***	-1.92***	-1.67***	-1.92***	-1.68***
	(0.089)	(0.058)	(0.055)	(0.15)	(0.092)	(0.072)	(0.13)	(0.073)	(0.076)	(0.29)	(0.13)	(0.12)	(0.19)	(0.19)	(0.18)
Primary	-1.33***	-1.57***	-1.25***	-1.25***	-1.28***	-1.05***	-1.26***	-1.55***	-1.28***	-1.54***	-1.92***	-1.45***	-1.11***	-1.32***	-1.11***
	(0.070)	(0.067)	(0.047)	(0.18)	(0.12)	(0.089)	(0.15)	(0.052)	(0.064)	(0.086)	(0.100)	(0.077)	(0.098)	(0.090)	(0.068)
Secondary or more	-0.93***	-1.11***	-0.83***	-1.25***	-1.07***	-0.84***	-0.97***	-1.28***	-0.93***	-0.86***	-1.03***	-0.71***	-0.92***	-1.12***	-0.88***
	(0.060)	(0.063)	(0.059)	(0.19)	(0.13)	(0.14)	(0.084)	(0.062)	(0.12)	(0.086)	(0.076)	(0.075)	(0.11)	(0.12)	(0.11)
Father's education															
None	-1.66***	-1.78***	-1.53***	-1.75***	-1.66***	-1.36***	-1.58***	-1.85***	-1.63***	-2.18***	-2.25***	-1.87***	-1.64***	-1.81***	-1.64***
	(0.089)	(0.061)	(0.064)	(0.17)	(0.096)	(0.077)	(0.12)	(0.062)	(0.083)	(0.37)	(0.40)	(0.33)	(0.19)	(0.23)	(0.22)
Primary	-1.46***	-1.66***	-1.37***	-1.43***	-1.43***	-1.22***	-1.26***	-1.60***	-1.42***	-1.69***	-1.98***	-1.54***	-1.24***	-1.49***	-1.22***
	(0.084)	(0.071)	(0.052)	(0.16)	(0.11)	(0.089)	(0.13)	(0.093)	(0.081)	(0.14)	(0.11)	(0.092)	(0.17)	(0.14)	(0.091)
Secondary or more	-1.00***	-1.21***	-0.93***	-1.17***	-1.12***	-0.89***	-1.06***	-1.36***	-1.12***	-0.98***	-1.19***	-0.83***	-0.95***	-1.16***	-0.92***
	(0.057)	(0.057)	(0.052)	(0.17)	(0.11)	(0.076)	(0.12)	(0.067)	(0.099)	(0.100)	(0.097)	(0.088)	(0.099)	(0.11)	(0.095)

[1]All values are means with standard errors corrected for clustered sampling in parentheses.

Supplementary Table 2.5 Associations between height for age z-scores and total parental educati from pooled models across all four countries and all survey rounds (n=6,564)[1]

	Total years of education for both parents	Controlling for mother's height?	Controlling for place of residence?	Controlling for wealth index?	Controlling for household size?
(1)	0.026*** (0.0023)	No	No	No	No
(2)	0.022*** (0.0021)	Yes	No	No	No
(3)	0.021*** (0.0020)	Yes	Yes	No	No
(4)	0.017*** (0.0020)	Yes	No	Yes	No
(5)	0.017*** (0.0020)	Yes	Yes	Yes	Yes

[1]Results are from linear mixed effects models. Robust standard errors adjusted for clustered sampl presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, includ survey and sentinel site fixed effects and random effects for individuals.

Supplementary Table 2.6 Associations between height for age z-scores and parental education from pooled models in Peru and all survey rounds (n=1,481)[1]

	Mother	Father	Controlling for mother's height?	Controlling for father's height?	Controlling for mother's height and father's height?	Controlling for wealth index, household size, and place of residence?	p-value[2]
(1)	0.071*** (0.0099)		No	No	No	No	
(2)	0.050*** (0.0092)		Yes	No	No	No	
(3)	0.051*** (0.0086)		No	Yes	No	Yes	
(4)	0.037*** (0.0086)		Yes	Yes	Yes	No	
(5)	0.032*** (0.0087)		Yes	Yes	Yes	Yes	
(6)		0.062*** (0.0090)	No	No	No	No	
(7)		0.049*** (0.0091)	Yes	No	No	No	
(8)		0.042*** (0.0099)	No	Yes	No	Yes	
(9)		0.035*** (0.0094)	Yes	Yes	Yes	No	
(10)		0.030*** (0.0090)	Yes	Yes	Yes	Yes	
(11)	0.056*** (0.013)	0.033*** (0.012)	No	No	No	No	0.32
(12)	0.036*** (0.012)	0.031*** (0.011)	Yes	No	No	No	0.82
(13)	0.042*** (0.012)	0.022* (0.013)	No	Yes	No	Yes	0.38
(14)	0.027** (0.011)	0.023** (0.01`)	Yes	Yes	Yes	No	0.84
(15)	0.025* (0.011)	0.020* (0.011)	Yes	Yes	Yes	Yes	0.80

[1]Results are from linear mixed effects models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted, include survey and sentinel site fixed effects and random effects for individuals.
[2]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Supplementary Table 2.7 Associations between height for age z-scores and parental education and low birth weight (<2,500g) from pooled models across all four countries and all survey rounds (n=3,918)[1]

	Low birth weight	Mother	Father	Covariates[2]	p-value[3]
(1)		0.032***		No	
		(0.0047)			
(2)		0.019***		Yes	
		(0.0038)			
(3)			0.031***	No	
			(0.0043)		
(4)			0.018***	Yes	
			(0.0035)		
(5)		0.024***	0.021***	No	0.63
		(0.0044)	(0.0039)		
(6)		0.014***	0.013***	Yes	0.87
		(0.0038)	(0.0035)		
(1)	-0.37***	0.032***		No	
	(0.057)	(0.0047)			
(2)	-0.33***	0.018***		Yes	
	(0.050)	(0.0038)			
(3)	-0.38***		0.031***	No	
	(0.057)		(0.0043)		
(4)	-0.34***		0.019***	Yes	
	(0.049)		(0.0035)		
(5)	-0.37***	0.024***	0.022***	No	0.76
	(0.057)	(0.0044)	(0.0039)		
(6)	-0.33***	0.014***	0.014***	Yes	1.00
	(0.050)	(0.0038)	(0.0035)		

[1]Results are from linear mixed effects models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects and random effects for individuals.
[2]Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)
[3]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Supplementary Table 2.8 Associations between height for age z-scores and parental education from pooled models across all four countries, by survey rounds, **controlling for height for age z-score at age 6-18 months** (n=6,564).[1]

	Mother	Father	HAZ at 6-18m	Covariates[2]	p-value[3]
	Round 1: Ages 6-18 months				
(1)	0.040*** (0.0052)			No	
(2)	0.024*** (0.0048)			Yes	
(3)		0.034*** (0.0044)		No	
(4)		0.020*** (0.0043)		Yes	
(5)	0.030*** (0.0052)	0.023*** (0.0044)		No	0.39
(6)	0.019*** (0.0048)	0.015*** (0.0044)		Yes	0.64
	Round 2: 4-5 years				
(1)	0.019*** (0.0030)		0.38*** (0.018)	No	
(2)	0.0088*** (0.0026)		0.35*** (0.017)	Yes	
(3)		0.016*** (0.0027)	0.38*** (0.018)	No	
(4)		0.0067*** (0.0024)	0.35*** (0.017)	Yes	
(5)	0.015*** (0.0029)	0.011*** (0.0026)	0.37*** (0.018)	No	0.36
(6)	0.0072*** (0.0027)	0.0047** (0.0024)	0.35*** (0.017)	Yes	0.53
	Round 3: 7-8 years				
(1)	0.023*** (0.0038)		0.35*** (0.017)	No	
(2)	0.0089*** (0.0030)		0.32*** (0.016)	Yes	
(3)		0.018*** (0.0034)	0.35*** (0.017)	No	
(4)		0.0050** (0.0029)	0.32*** (0.016)	Yes	
(5)	0.019*** (0.0036)	0.011*** (0.0032)	0.35*** (0.017)	No	0.13
(6)	0.0080*** (0.0031)	0.0028 (0.0030)	0.32*** (0.016)	Yes	0.28

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects.
[2]Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)
[3]p-values are from Wald tests for differences in the associations between each parent's education and height for age z-scores.

Supplementary Table 2.9 Pathways by which parental education may affect children's physical development (HAZ) at age 6-18 months (n=6,564)[1,2]

	Without mediators	Breastfeeding	Number of children born	Sickness	Water	Sanitation
Mother	0.020***	0.019***	0.018***	0.020***	0.020***	0.020***
	(0.0052)	(0.0053)	(0.0052)	(0.0052)	(0.0052)	(0.0052)
Father	0.016***	0.016***	0.016***	0.016***	0.016***	0.016***
	(0.0044)	(0.0044)	(0.0044)	(0.0043)	(0.0044)	(0.0044)
Still breastfed		-0.24***				
		(0.069)				
Number of children born			-0.033***			
			(0.013)			
Sickness[2]				-0.12***		
				(0.032)		
Water quality[3]					-0.011	
					(0.051)	
Sanitation quality[4]						0.096
						(0.064)
Constant	-4.89***	-4.64***	-4.82***	-4.81***	-4.88***	-4.86***
	(1.62)	(1.62)	(1.62)	(1.60)	(1.63)	(1.62)
R-squared	0.246	0.248	0.247	0.249	0.246	0.247

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects. Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)

[3]Sickess is an index of sickness measured as the sum of five indicators for whether the child had three or more watery stools, blood in stools, experienced vomiting, experienced a lack of appetite, all in the last 24 hours and had long-term illness.

[4]Water quality is dichotomously coded with individuals having access to safe drinking water if they obtain their water through piped water or a tubewell, public pipe or common well.

[5]Sanitation quality is dichotomously coded with individuals having access to adequate toilet facilities if they use a flush toilet, septic tank in dwelling, or a household pit latrine.

Supplementary Table 2.10 Pathways by which parental education may affect children's physical development (HAZ) at age 4-5 years (n=6,564)[1]

	Without mediators	Breastfeeding	Meals	Food shortages	Food expenditures	Water	Sanitation
Mother	0.015***	0.015***	0.015***	0.015***	0.015***	0.014***	0.015***
	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0033)
Father	0.011***	0.011***	0.011***	0.011***	0.011***	0.011***	0.011***
	(0.0030)	(0.0030)	(0.0030)	(0.0030)	(0.0029)	(0.0030)	(0.0029)
Still breastfed		-0.34***					
		(0.12)					
Number of times child ate			-0.015	-0.015			
			(0.015)	(0.015)			
Household experienced food shortages					-0.13***		
					(0.037)		
Food expenditures (logged)						0.11***	
						(0.036)	
Water quality[2]							-0.081*
							(0.043)
Sanitation quality[3]							
Constant	-7.16***	-6.95***	-7.09***	-7.09***	-7.06***	-7.62***	-7.13***
	(1.21)	(1.20)	(1.21)	(1.21)	(1.21)	(1.19)	(1.20)
R-squared	0.254	0.255	0.254	0.254	0.256	0.256	0.255

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects. Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)

[2]Water quality is dichotomously coded with individuals having access to safe drinking water if they obtain their water through piped water or a tubewell, public pipe or common well.

[3]Sanitation quality is dichotomously coded with individuals having access to adequate toilet facilities if they use a flush toilet, septic tank in dwelling, or a household pit latrine.

Supplementary Table 2.11 Pathways by which parental education may affect children's physical development (HAZ) at age 7-8 years.[1]

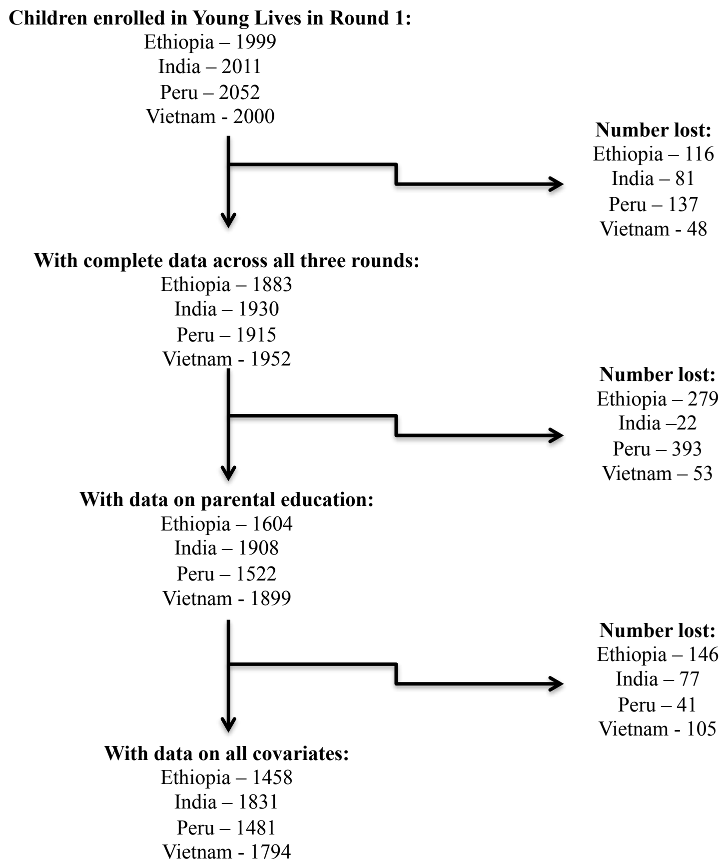
	Without mediators	Meals	Food concerns	Food shortages	Food expenditures	Water	Sanitation
Mother	0.016***	0.018***	0.016***	0.015***	0.015***	0.016***	0.016***
	(0.0038)	(0.0039)	(0.0038)	(0.0038)	(0.0038)	(0.0038)	(0.0038)
Father	0.0091***	0.0095***	0.0091***	0.0089***	0.0083**	0.0086***	0.0092***
	(0.0032)	(0.0034)	(0.0032)	(0.0032)	(0.0032)	(0.0031)	(0.0032)
Number of times child ate		-0.0072					
		(0.014)					
Worry about food			-0.019				
			(0.032)				
Food shortages (eat enough but not always what we want)				-0.048			
				(0.033)			
Food shortages (we sometimes do not eat enough)				-0.15***			
				(0.046)			
Food shortages (frequently do not eat enough)				-0.14			
				(0.11)			
Food expenditures (logged)					0.15***		
					(0.029)		
Water quality[2]						-0.11**	
						(0.049)	
Sanitation quality[3]							-0.064
							(0.042)
Constant	-6.35***	-6.20***	-6.34***	-6.20***	-7.08***	-6.32***	-6.39***
	(1.13)	(1.13)	(1.13)	(1.13)	(1.14)	(1.12)	(1.12)
Observations	6,564	6,045	6,561	6,560	6,564	6,564	6,564
R-squared	0.233	0.228	0.233	0.234	0.236	0.234	0.233

[1]Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models include survey and sentinel site fixed effects. Covariates include child's age (in months), child's sex, mother's height, wealth index, household size, and place of residence (rural/urban)

[2]Water quality is dichotomously coded with individuals having access to safe drinking water if they obtain their water through piped water or a tubewell, public pipe or common well.

[3]Sanitation quality is dichotomously coded with individuals having access to adequate toilet facilities if they use a flush toilet, septic tank in dwelling, or a household pit latrine.

Supplementary Figure 2.1



PAPER 3 SUPPLEMENTAL MATERIAL

Supplementary Table 3.1 Classification of parental education

Values	Young Lives classification			Our classification of years of schooling
	Ethiopia/India	**Peru**	**Vietnam**	
0	No education	No education	No education	0
1-8	Years of primary and secondary schooling	Years of primary and secondary schooling	Years of primary and secondary schooling	1-8
9-12				9-12
13	Post-secondary	Incomplete technical college	Post-secondary	13
14	University	Complete technical college	University	14
15	Master's education	Incomplete university	.	
16	.	Complete university	.	
17	.	Adult literacy program	.	0
18	.	Other	.	0
28	Adult literacy	.	.	0
29	Religious education	.	.	0
42-46	.	.	Graduate studies	14

Supplementary Table 3.2. Constructing the wealth index

Categories	Elements	Measurement
Housing quality (4 items)	Number of household members per rooms	Continuous variable
	Wall	Dummy variable equal to 1 if household has brick or plaster wall
	Roof	Dummy variable equal to one if house has sturdy roof
	Floor	Dummy variable equal to one if house has a floor made of finished materials e.g. cement, tile
Housing quality = Sum of 4 items/4		
Service quality (4 items)	Drinking water	Dummy variable equal to one if house has piped water
	Electricity	Dummy variable equal to one if there is a source of electricity
	Fuel	Dummy variable equal to one if the household uses either electricity, gas, or kerosene
	Sanitation	Dummy variable equal to one if household had pit latrine or flush toilet
Service quality = Sum of 4 items/4		
Consumer durables (11 items)	1. Radio 2. Refrigerator 3. Television 4. Motorcycle/scooter 5. Bicycle 6. Motor vehicle 7. Mobile phone 8. Landline phone 9. Modern bed 10. Table or chair 11. Sofa	Dummy variable for ownership of each of the 11 items
Consumer durables = Sum of 11 items/11		

Wealth index = [Housing quality + Service quality + Consumer durable]/3

Source: (37)

Supplementary Table 3.3 Parental education levels. *Proportion of parents in each level, by the other parent's educational attainment.*

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	20.70	7.48	8.79
	Primary	2.85	8.43	9.31
	Secondary +	2.45	4.11	35.89

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	30.36	14.29	11.29
	Primary	3.64	9.79	9.29
	Secondary +	1.50	3.50	16.36

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	0.65	6.36	1.74
	Primary	0.51	19.81	15.98
	Secondary +	0.14	6.87	47.94

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	39.53	6.89	13.37
	Primary	3.76	2.08	4.98
	Secondary +	3.41	2.55	23.44

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	8.43	2.81	7.70
	Primary	3.21	3.95	8.17
	Secondary +	4.35	3.95	57.43

Supplementary Table 3.4A Mean scores on Peabody Picture Vocabulary Tests at age 4-5 years, by parental education level[1]

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	19.7 (0.94)	18.9 (0.88)	25.8 (0.90)
	Primary	22.3 (1.26)	21.6 (1.39)	28.5 (1.32)
	Secondary +	32.5 (1.48)	31.7 (1.44)	38.6 (1.50)

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	16.6 (0.81)	17.7 (0.77)	19.9 (1.16)
	Primary	20.0 (0.85)	21.2 (0.81)	23.3 (1.58)
	Secondary +	25.3 (1.65)	26.4 (1.56)	28.6 (2.29)

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	15.4 (2.81)	15.7 (1.56)	24.8 (2.00)
	Primary	15.3 (2.33)	15.7 (1.10)	24.7 (1.63)
	Secondary +	29.2 (3.27)	29.6 (2.05)	38.6 (2.02)

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	20.4 (1.34)	25.2 (2.52)	26.0 (1.45)
	Primary	27.1 (3.31)	31.9 (4.48)	32.8 (3.30)
	Secondary +	32.5 (4.30)	37.4 (5.23)	38.2 (4.37)

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	23.6 (2.33)	26.8 (2.83)	32.2 (2.29)
	Primary	29.9 (1.91)	33.2 (2.48)	38.5 (2.25)
	Secondary +	33.0 (1.86)	36.2 (2.26)	41.6 (2.59)

[1]Raw PPVT scores are used. Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.4B Mean scores on Peabody Picture Vocabulary Tests at age 7-8 years, by parental education level[1]

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	56.1 (2.38)	56.5 (2.46)	68.6 (2.53)
	Primary	61.8 (2.41)	62.2 (3.19)	74.2 (2.98)
	Secondary +	74.1 (2.34)	74.4 (2.63)	86.5 (2.91)

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	58.7 (4.86)	63.7 (4.49)	78.1 (5.84)
	Primary	70.4 (4.98)	75.4 (5.99)	89.8 (7.98)
	Secondary +	85.2 (6.57)	90.2 (7.23)	105.0 (9.25)

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	29.3 (5.34)	42.8 (0.84)	51.6 (1.09)
	Primary	35.2 (5.56)	48.6 (1.34)	57.4 (1.49)
	Secondary +	46.0 (5.06)	59.4 (1.33)	68.2 (1.04)

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	50.7 (2.55)	53.0 (3.29)	59.6 (3.74)
	Primary	56.7 (2.73)	59.0 (3.75)	65.6 (3.25)
	Secondary +	62.1 (3.01)	64.4 (3.80)	71.0 (3.58)

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	69.2 (4.25)	74.4 (2.84)	82.6 (2.96)
	Primary	79.8 (3.09)	85.0 (3.69)	93.2 (3.49)
	Secondary +	89.2 (2.46)	94.3 (1.96)	103.0 (2.41)

[1]Raw PPVT scores are used. Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.5A Mean scores on Peabody Picture Vocabulary Tests at age 4-5 years, by baseline household wealth[1]

	All (n=6,005)	Ethiopia (n=1,400)	India (n=1,728)	Peru (n=1,383)	Vietnam (n=1,494
Poor	22.1	17.1	23.6	17.9	29.5
	(1.17)	(0.80)	(2.50)	(1.25)	(1.88)
Middle	26.8	18.6	24.5	26.5	36.7
	(1.21)	(0.91)	(1.69)	(1.75)	(2.07)
Wealthy	37.7	26.9	34.7	43.5	45.8
	(1.98)	(1.70)	(4.68)	(1.47)	(2.97)

[1]Raw PPVT scores are used. Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.5B Mean scores on Peabody Picture Vocabulary Tests at age 7-8 years, by baseline household wealth[1]

	All (n=6,005)	Ethiopia (n=1,400)	India (n=1,728)	Peru (n=1,383)	Vietnam (n=1,494
Poor	58.5	55.7	48.9	49.3	81.5
	(2.36)	(3.72)	(2.37)	(1.32)	(3.17)
Middle	69.6	64.4	58.4	59.1	96.0
	(2.58)	(3.91)	(3.12)	(1.73)	(2.68)
Wealthy	87.5	109.0	68.8	70.7	105.0
	(3.78)	(7.59)	(3.74)	(0.75)	(3.71)

[1]Raw PPVT scores are used. Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.6A Mean height for age z-scores (HAZ) at age 6-18 months, by parental education level[1]

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.73 (0.093)	-1.75 (0.11)	-1.40 (0.089)
	Primary	-1.53 (0.085)	-1.54 (0.089)	-1.19 (0.070)
	Secondary +	-1.27 (0.078)	-1.29 (0.073)	-0.94 (0.057)

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.88 (0.18)	-1.70 (0.17)	-1.61 (0.15)
	Primary	-1.53 (0.22)	-1.35 (0.21)	-1.26 (0.19)
	Secondary +	-1.41 (0.21)	-1.23 (0.19)	-1.13 (0.16)

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	-2.25 (0.51)	-2.29 (0.31)	-1.97 (0.28)
	Primary	-1.69 (0.41)	-1.73 (0.074)	-1.41 (0.084)
	Secondary +	-1.13 (0.38)	-1.16 (0.11)	-0.85 (0.097)

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.61 (0.12)	-1.51 (0.14)	-1.17 (0.14)
	Primary	-1.51 (0.14)	-1.42 (0.16)	-1.08 (0.15)
	Secondary +	-1.41 (0.10)	-1.32 (0.13)	-0.98 (0.11)

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.82 (0.19)	-1.79 (0.24)	-1.41 (0.18)
	Primary	-1.29 (0.13)	-1.26 (0.14)	-0.87 (0.10)
	Secondary +	-1.36 (0.13)	-1.33 (0.11)	-0.94 (0.10)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.6B Mean height for age z-scores (HAZ) at age 4-5 years, by parental education level[1]

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.86 (0.057)	-1.81 (0.076)	-1.59 (0.057)
	Primary	-1.78 (0.074)	-1.73 (0.095)	-1.51 (0.075)
	Secondary +	-1.40 (0.064)	-1.36 (0.062)	-1.14 (0.054)

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.80 (0.099)	-1.57 (0.12)	-1.54 (0.099)
	Primary	-1.53 (0.12)	-1.30 (0.16)	-1.27 (0.12)
	Secondary +	-1.37 (0.12)	-1.14 (0.16)	-1.11 (0.10)

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	-2.13 (0.38)	-2.31 (0.12)	-2.03 (0.11)
	Primary	-1.93 (0.37)	-2.11 (0.091)	-1.83 (0.12)
	Secondary +	-1.15 (0.36)	-1.33 (0.071)	-1.05 (0.075)

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.87 (0.068)	-1.68 (0.12)	-1.56 (0.086)
	Primary	-1.82 (0.065)	-1.62 (0.10)	-1.51 (0.077)
	Secondary +	-1.62 (0.062)	-1.43 (0.076)	-1.31 (0.062)

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	-2.03 (0.20)	-1.97 (0.18)	-1.70 (0.14)
	Primary	-1.51 (0.16)	-1.46 (0.12)	-1.18 (0.10)
	Secondary +	-1.45 (0.16)	-1.40 (0.11)	-1.13 (0.12)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.6C Mean height for age z-scores (HAZ) at age 7-8 years, by parental education level[1]

All (n=6,005)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.63 (0.063)	-1.59 (0.059)	-1.35 (0.050)
	Primary	-1.43 (0.066)	-1.40 (0.069)	-1.16 (0.055)
	Secondary +	-1.13 (0.065)	-1.10 (0.053)	-0.86 (0.050)

Ethiopia (n=1,400)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.47 (0.088)	-1.38 (0.082)	-1.25 (0.083)
	Primary	-1.19 (0.12)	-1.10 (0.14)	-0.97 (0.098)
	Secondary +	-1.13 (0.12)	-1.04 (0.094)	-0.91 (0.081)

Vietnam (n=1,383)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.81 (0.30)	-1.94 (0.11)	-1.64 (0.092)
	Primary	-1.50 (0.32)	-1.63 (0.082)	-1.34 (0.083)
	Secondary +	-0.89 (0.31)	-1.02 (0.079)	-0.72 (0.080)

India (n=1,728)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.67 (0.085)	-1.60 (0.084)	-1.42 (0.078)
	Primary	-1.51 (0.10)	-1.44 (0.10)	-1.27 (0.10)
	Secondary +	-1.22 (0.10)	-1.15 (0.11)	-0.97 (0.095)

Peru (n=1,494)

		Father		
		No education	Primary	Secondary +
Mother	No education	-1.85 (0.19)	-1.66 (0.14)	-1.40 (0.13)
	Primary	-1.37 (0.14)	-1.18 (0.093)	-0.93 (0.080)
	Secondary +	-1.33 (0.15)	-1.14 (0.082)	-0.88 (0.097)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.7 Mean height for age z-scores (HAZ) at age 7-8 years, by baseline wealth index[1]

	6-18 months					4-5 years					7-8 years				
	All	**Ethiopia**	**India**	**Peru**	**Vietnam**	**All**	**Ethiopia**	**India**	**Peru**	**Vietnam**	**All**	**Ethiopia**	**India**	**Peru**	**Vietnam**
Height for age z-score															
Poor	-1.68	-1.84	-1.71	-1.7	-1.47	-1.86	-1.76	-1.92	-2.05	-1.69	-1.56	-1.43	-1.74	-1.56	-1.48
	(0.091)	(0.25)	(0.15)	(0.13)	(0.18)	(0.059)	(0.10)	(0.066)	(0.11)	(0.17)	(0.056)	(0.084)	(0.086)	(0.10)	(0.15)
Middle	-1.35	-1.67	-1.27	-1.34	-1.18	-1.55	-1.54	-1.65	-1.59	-1.39	-1.28	-1.28	-1.44	-1.2	-1.16
	(0.069)	(0.17)	(0.14)	(0.13)	(0.083)	(0.045)	(0.12)	(0.071)	(0.097)	(0.075)	(0.039)	(0.080)	(0.067)	(0.093)	(0.052)
Wealthy	-0.91	-1.11	-1.05	-0.73	-0.73	-1.08	-1.13	-1.34	-0.89	-0.89	-0.82	-0.95	-1.05	-0.61	-0.63
	(0.060)	(0.13)	(0.083)	(0.100)	(0.12)	(0.055)	(0.100)	(0.050)	(0.077)	(0.14)	(0.052)	(0.064)	(0.088)	(0.080)	(0.11)
Stunting															
Poor	0.4	0.48	0.42	0.4	0.31	0.44	0.4	0.47	0.51	0.37	0.33	0.27	0.4	0.31	0.31
	-0.026	-0.062	-0.039	-0.048	-0.057	(0.025)	(0.037)	(0.034)	(0.048)	(0.068)	(0.023)	(0.030)	(0.037)	(0.041)	(0.065)
Middle	0.31	0.47	0.3	0.27	0.21	0.32	0.33	0.36	0.33	0.25	0.23	0.23	0.29	0.2	0.2
	-0.019	-0.024	-0.033	-0.042	-0.019	(0.017)	(0.039)	(0.023)	(0.045)	(0.022)	(0.015)	(0.027)	(0.024)	(0.035)	(0.027)
Wealthy	0.19	0.29	0.21	0.13	0.12	0.17	0.21	0.24	0.1	0.13	0.12	0.14	0.17	0.072	0.083
	-0.017	-0.038	-0.023	-0.028	-0.022	(0.014)	(0.025)	(0.021)	(0.017)	(0.027)	(0.011)	(0.017)	(0.025)	(0.013)	(0.018)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.8 ECD by levels of parental education[1]

	All	Ethiopia	India	Peru	Vietnam
Mother's education					
None	0.57	0.057	0.86	0.78	0.82
	(0.062)	(0.021)	(0.018)	(0.097)	(0.025)
Primary	0.68	0.26	0.88	0.77	0.89
	(0.042)	(0.076)	(0.024)	(0.037)	(0.026)
Secondary or more	0.9	0.58	0.91	0.93	0.97
	(0.018)	(0.11)	(0.027)	(0.021)	(0.0090)
Father's education					
None	0.59	0.036	0.85	0.67	0.82
	(0.062)	(0.010)	(0.021)	(0.18)	(0.023)
Primary	0.61	0.18	0.87	0.77	0.9
	(0.052)	(0.066)	(0.029)	(0.045)	(0.019)
Secondary or more	0.85	0.42	0.91	0.91	0.95
	(0.025)	(0.10)	(0.019)	(0.024)	(0.010)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.9 ECD by levels by baseline wealth index[1]

	All	Ethiopia	India	Peru	Vietnam
Poor	0.63	0.041	0.86	0.75	0.85
	(0.054)	(0.013)	(0.021)	(0.044)	(0.020)
Middle	0.72	0.052	0.88	0.88	0.96
	(0.051)	(0.018)	(0.027)	(0.029)	(0.013)
Rich	0.85	0.57	0.9	0.95	0.97
	(0.034)	(0.11)	(0.024)	(0.022)	(0.0073)

[1]Robust standard errors corrected for a clustered survey design are in parentheses.

Supplementary Table 3.10 Associations between parental education, household wealth, and children's cognitive status by age, controlling for concurrent stunting and past stunting (n=6,005)[1]

Age 4-5 years	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)	
Mother's education	0.035***	0.034***	0.034***						0.028***	0.028***	0.028***	
	(0.0041)	(0.0040)	(0.0040)						(0.0038)	(0.0037)	(0.0037)	
Father's education					0.026***	0.026***	0.025***		0.019***	0.018***	0.018***	
					(0.0034)	(0.0033)	(0.0033)		(0.0030)	(0.0029)	(0.0030)	
Wealth index	0.94***	0.89***	0.87***		1.01***	0.96***	0.95***		0.80***	0.76***	0.75***	
	(0.11)	(0.10)	(0.10)		(0.11)	(0.11)	(0.11)		(0.11)	(0.10)	(0.10)	
Stunt(2)[2]		-0.15***	-0.11***			-0.15***	-0.11***			-0.14***	-0.11***	
		(0.031)	(0.032)			(0.030)	(0.031)			(0.030)	(0.031)	
Stunt(1)[2]			-0.095***				-0.090***				-0.086***	
			(0.023)				(0.024)				(0.024)	
Constant	-3.23***	-2.79***	-2.82***		-3.23***	-2.79***	-2.81***		-3.28***	-2.85***	-2.88***	
	(0.32)	(0.32)	(0.32)		(0.33)	(0.33)	(0.33)		(0.32)	(0.32)	(0.32)	
R-squared	0.393	0.397	0.399		0.389	0.393	0.394		0.399	0.402	0.403	
p-values[2]												
Mother's vs. Father's									*0.04*	*0.03*	*0.03*	
Stunt(2) vs. Stunt(1)			*0.67*				*0.59*				*0.57*	
Age 7-8 years	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Mother's education	0.028***	0.028***	0.027***	0.027***					0.022***	0.022***	0.022***	0.022***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0034)	(0.0034)	(0.0034)
Father's education					0.023***	0.022***	0.022***	0.022***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.97***	0.97***	0.95***	1.07***	1.01***	1.01***	1.00***	0.91***	0.86***	0.85***	0.84***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Stunt(3)[2]		-0.18***	-0.15***	-0.13***		-0.18***	-0.15***	-0.13***		-0.18***	-0.15***	-0.13***
		(0.028)	(0.028)	(0.028)		(0.028)	(0.028)	(0.028)		(0.028)	(0.028)	(0.028)
Stunt(2)[2]			-0.051*	-0.025			-0.049*	-0.025			-0.047*	-0.024
			(0.026)	(0.027)			(0.026)	(0.026)			(0.026)	(0.027)
Stunt(1)[2]				-0.096***				-0.091***				-0.088***
				(0.027)				(0.028)				(0.028)

Constant	-3.24***	-2.77***	-2.70***	-2.82***	-3.24***	-2.78***	-2.71***	-2.82***	-3.28***	-2.83***	-2.77***	-2.87***
	(0.49)	(0.48)	(0.48)	(0.48)	(0.49)	(0.48)	(0.49)	(0.48)	(0.49)	(0.48)	(0.49)	(0.48)
R-squared	0.363	0.368	0.368	0.370	0.361	0.366	0.367	0.368	0.368	0.372	0.373	0.374
p-values[3]												
Mother's vs. Father's									*0.27*	*0.25*	*0.25*	*0.23*
Stunt(3) vs. Stunt(2)			*0.02*	*0.02*			*0.02*	*0.01*			*0.02*	*0.02*
Stunt(3) vs. Stunt(1)				*0.35*				*0.28*				*0.28*
Stunt(2) vs. Stunt(1)				*0.10*				*0.11*				*0.12*
Stunt(3) vs. Stunt 2) vs. Stunt(1)				*0.05*				*0.05*				*0.05*

[1]Parental education is measured in years of schooling. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(1)=Stunted at age 6-18 months; Stunt(2)=Stunted at age 4-5 years; Stunt(3)=Stunted at age 7-8 years.

[3]p-values are from significance tests for differences in associations.

Supplementary Table 3.11 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 4-5 years and concurrent stunting at 4-5 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.034***	0.033***	0.033***					0.028***	0.028***	0.027***	0.027***
	(0.0041)	(0.0040)	(0.0041)	(0.0040)					(0.0038)	(0.0037)	(0.0037)	(0.0037)
Father's education					0.026***	0.026***	0.025***	0.025***	0.019***	0.018***	0.018***	0.018***
					(0.0034)	(0.0033)	(0.0032)	(0.0032)	(0.0030)	(0.0029)	(0.0029)	(0.0029)
Wealth index	0.94***	0.89***	0.85***	0.85***	1.01***	0.96***	0.92***	0.91***	0.80***	0.76***	0.73***	0.73***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)
Stunt(2)[2]		-0.15***	-0.15***	-0.078*		-0.15***	-0.14***	-0.073*		-0.14***	-0.14***	-0.073*
		(0.031)	(0.031)	(0.045)		(0.030)	(0.030)	(0.043)		(0.030)	(0.030)	(0.044)
ECD			0.17***	0.21***			0.18***	0.22***			0.16***	0.20***
			(0.045)	(0.052)			(0.046)	(0.052)			(0.045)	(0.051)
ECD*Stunt(2)[2]				-0.097**				-0.10**				-0.096**
				(0.043)				(0.042)				(0.042)
Constant	-3.23***	-2.79***	-2.85***	-2.86***	-3.23***	-2.79***	-2.85***	-2.87***	-3.28***	-2.85***	-2.91***	-2.93***
	(0.32)	(0.32)	(0.32)	(0.33)	(0.33)	(0.33)	(0.34)	(0.34)	(0.32)	(0.32)	(0.33)	(0.33)
R-squared	0.393	0.397	0.400	0.400	0.389	0.393	0.396	0.396	0.399	0.402	0.404	0.405
p-values[3]												
Stunt(2) vs. ECD			*0.00*	*0.00*			*0.00*	*0.00*			*0.00*	*0.00*
Mother's vs. Father's									*0.04*	*0.03*	*0.04*	*0.05*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.
[2]Stunt(2)=Stunting at age 4-5 years.
[3]p-values are from significance tests for differences in associations**.**

Supplementary Table 3.12 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 4-5 years and past stunting at 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.034***	0.033***	0.033***					0.028***	0.028***	0.027***	0.027***
	(0.0041)	(0.0041)	(0.0041)	(0.0041)					(0.0038)	(0.0037)	(0.0038)	(0.0038)
Father's education					0.026***	0.026***	0.025***	0.025***	0.019***	0.018***	0.017***	0.017***
					(0.0034)	(0.0033)	(0.0033)	(0.0033)	(0.0030)	(0.0030)	(0.0030)	(0.0030)
Wealth index	0.94***	0.90***	0.86***	0.86***	1.01***	0.97***	0.93***	0.93***	0.80***	0.77***	0.74***	0.74***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)
Stunt(1)[2]		-0.14***	-0.13***	-0.12**		-0.13***	-0.13***	-0.12**		-0.13***	-0.12***	-0.11**
		(0.024)	(0.024)	(0.048)		(0.024)	(0.024)	(0.048)		(0.024)	(0.024)	(0.048)
ECD			0.17***	0.17***			0.18***	0.19***			0.16***	0.16***
			(0.046)	(0.054)			(0.046)	(0.054)			(0.045)	(0.054)
ECD* Stunt(1)[2]				-0.019				-0.017				-0.016
				(0.055)				(0.055)				(0.055)
Constant	-3.23***	-3.12***	-3.17***	-3.17***	-3.23***	-3.12***	-3.18***	-3.18***	-3.28***	-3.17***	-3.22***	-3.22***
	(0.32)	(0.32)	(0.32)	(0.32)	(0.33)	(0.33)	(0.33)	(0.33)	(0.32)	(0.32)	(0.32)	(0.32)
R-squared	0.393	0.397	0.399	0.399	0.389	0.392	0.395	0.395	0.399	0.402	0.404	0.404
p-value[3]												
Stunt(1) vs. ECD			*0.00*	*0.00*			*0.00*	*0.00*			*0.00*	*0.00*
Mother's vs. Father's									*0.04*	*0.03*	*0.05*	*0.05*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(1)=Stunting at age 6-18 months.

[3]p-values are from significance tests for differences in associations between mother's and father's education and children's cognitive status.

Supplementary Table 3.13 Associations between parental education, household wealth, and children's cognitive status at age 4-5 years, controlling for early investments in child development (ECD) at 7-8 years and concurrent stunting at 4-5 years and past stunting at 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.035***	0.034***	0.034***	0.033***					0.028***	0.028***	0.028***	0.027***
	(0.0041)	(0.0040)	(0.0040)	(0.0041)					(0.0038)	(0.0037)	(0.0037)	(0.0037)
Father's education					0.026***	0.026***	0.025***	0.025***	0.019***	0.018***	0.018***	0.017***
					(0.0034)	(0.0033)	(0.0033)	(0.0033)	(0.0030)	(0.0029)	(0.0030)	(0.0029)
Wealth index	0.94***	0.89***	0.87***	0.84***	1.01***	0.96***	0.95***	0.90***	0.80***	0.76***	0.75***	0.72***
	(0.11)	(0.10)	(0.10)	(0.10)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.10)	(0.10)	(0.10)
Stunt(2)[2]		-0.15***	-0.11***	-0.11***		-0.15***	-0.11***	-0.11***		-0.14***	-0.11***	-0.11***
		(0.031)	(0.032)	(0.032)		(0.030)	(0.031)	(0.031)		(0.030)	(0.031)	(0.031)
Stunt(1)[2]			-0.095***	-0.091***			-0.090***	-0.086***			-0.086***	-0.082***
			(0.023)	(0.024)			(0.024)	(0.025)			(0.024)	(0.024)
ECD				0.16***				0.18***				0.16***
				(0.045)				(0.046)				(0.045)
Constant	-3.23***	-2.79***	-2.82***	-2.87***	-3.23***	-2.79***	-2.81***	-2.88***	-3.28***	-2.85***	-2.88***	-2.93***
	(0.32)	(0.32)	(0.32)	(0.32)	(0.33)	(0.33)	(0.33)	(0.34)	(0.32)	(0.32)	(0.32)	(0.32)
R-squared	0.393	0.397	0.399	0.401	0.389	0.393	0.394	0.397	0.399	0.402	0.403	0.405
p-values[3]												
Stunt(2) vs. Stunt(1)			*0.67*	*0.64*			*0.59*	*0.56*			*0.57*	*0.54*
Stunt(2) vs. ECD				*0.00*				*0.00*				*0.00*
Stunt(1) vs. ECD				*0.00*				*0.00*				*0.00*
Mother's vs. Father's									*0.04*	*0.03*	*0.03*	*0.04*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(1)=HAZ at age 6-18 months.

[3]p-values are from significance tests for differences in association.

Supplementary Table 3.14 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and concurrent stunting at 7-8 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.028***	0.028***	0.027***					0.022***	0.022***	0.022***	0.022***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0034)	(0.0035)	(0.0035)
Father's education					0.023***	0.023***	0.022***	0.022***	0.017***	0.017***	0.016***	0.016***
					(0.0028)	(0.0027)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.99***	0.98***	0.98***	1.07***	1.03***	1.02***	1.02***	0.91***	0.87***	0.87***	0.86***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Stunt(3)[2]		-0.13***	-0.13***	0.13**		-0.13***	-0.12***	0.15**		-0.13***	-0.12***	0.14**
		(0.026)	(0.026)	(0.066)		(0.026)	(0.026)	(0.065)		(0.026)	(0.026)	(0.064)
SCH			0.16***	0.31***			0.16***	0.31***			0.16***	0.30***
			(0.057)	(0.061)			(0.057)	(0.065)			(0.057)	(0.062)
SCH*Stunt(3)[2]				-0.28***				-0.29***				-0.28***
				(0.068)				(0.067)				(0.066)
Constant	-3.24***	-2.85***	-2.98***	-3.11***	-3.24***	-2.86***	-2.98***	-3.13***	-3.28***	-2.91***	-3.03***	-3.17***
	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.51)
R-squared	0.363	0.366	0.367	0.368	0.361	0.364	0.365	0.366	0.368	0.370	0.371	0.372
p-values[3]												
Stunt(3) vs. SCH			*0.00*	*0.01*			*0.00*	*0.01*			*0.00*	*0.01*
Mother's vs. Father's									*0.27*	*0.25*	*0.25*	*0.26*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(3)=HAZ at age 7-8 years.

[3]p-values are from significance tests for differences in association between mother's and father's education.

Supplementary Table 3.15 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and past stunting at 4-5 years (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.028***	0.028***	0.027***					0.022***	0.022***	0.022***	0.022***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0034)	(0.0035)	(0.0035)
Father's education					0.023***	0.023***	0.022***	0.022***	0.017***	0.017***	0.016***	0.016***
					(0.0028)	(0.0027)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.99***	0.98***	0.98***	1.07***	1.03***	1.02***	1.02***	0.91***	0.87***	0.87***	0.86***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Stunt(2)[2]		-0.13***	-0.13***	0.13**		-0.13***	-0.12***	0.15**		-0.13***	-0.12***	0.14**
		(0.026)	(0.026)	(0.066)		(0.026)	(0.026)	(0.065)		(0.026)	(0.026)	(0.064)
SCH			0.16***	0.31***			0.16***	0.31***			0.16***	0.30***
			(0.057)	(0.061)			(0.057)	(0.065)			(0.057)	(0.062)
SCH*Stunt(2)[2]				-0.28***				-0.29***				-0.28***
				(0.068)				(0.067)				(0.066)
Constant	-3.24***	-2.85***	-2.98***	-3.11***	-3.24***	-2.86***	-2.98***	-3.13***	-3.28***	-2.91***	-3.03***	-3.17***
	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.51)
R-squared	0.363	0.366	0.367	0.368	0.361	0.364	0.365	0.366	0.368	0.370	0.371	0.372
p-values[3]												
Stunt(2) vs. SCH			*0.00*	*0.01*			*0.00*	*0.01*			*0.00*	*0.01*
Mother's vs. Father's									*0.27*	*0.25*	*0.25*	*0.26*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Household wealth index is mean-centered. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(2)=Stunting at age 4-5 years.

[3]p-values are from significance tests for differences in association between mother's and father's education.

Supplementary Table 3.16 Associations between parental education, household wealth, and children's cognitive status at age 7-8 years, controlling for school enrollment (SCH) at 7-8 years and past stunting at 6-18 months (n=6,005)[1]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mother's education	0.028***	0.027***	0.027***	0.027***					0.022***	0.022***	0.022***	0.022***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)					(0.0035)	(0.0035)	(0.0035)	(0.0035)
Father's education					0.023***	0.022***	0.022***	0.022***	0.017***	0.016***	0.016***	0.016***
					(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	1.03***	0.99***	0.98***	0.98***	1.07***	1.03***	1.02***	1.02***	0.91***	0.87***	0.87***	0.87***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Stunt(1)		-0.15***	-0.14***	-0.0011		-0.14***	-0.14***	0.00062		-0.14***	-0.14***	0.0061
		(0.027)	(0.027)	(0.046)		(0.028)	(0.028)	(0.047)		(0.028)	(0.028)	(0.048)
SCH			0.18***	0.25***			0.18***	0.25***			0.17***	0.25***
			(0.054)	(0.063)			(0.055)	(0.065)			(0.055)	(0.065)
SCH* Stunt(1)				-0.16***				-0.15***				-0.15***
				(0.050)				(0.051)				(0.051)
Constant	-3.24***	-3.23***	-3.34***	-3.42***	-3.24***	-3.23***	-3.35***	-3.42***	-3.28***	-3.27***	-3.39***	-3.46***
	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)	(0.49)	(0.49)	(0.50)	(0.50)
R-squared	0.363	0.367	0.368	0.368	0.361	0.365	0.366	0.366	0.368	0.371	0.372	0.372
p-values												
Stunt(1) vs. SCH			*0.00*	*0.00*			*0.00*	*0.00*			*0.00*	*0.00*
Mother's vs. Father's									*0.27*	*0.23*	*0.23*	*0.23*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. School enrollment is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

[2]Stunt(1)=Stunting at age 6-18 months

[3]p-values are from significance tests for differences in association between mother's and father's education.

Supplementary Table 3.17. Associations between parental education, household wealth, children's cognitive status at ages 7-8 years, controlling for school enrollment (SCH) at 7- years, early investments in child development (ECD) at 4-5 years and stunting at 7-8 years 5 years and 6-18 months (n=6,005)[1]

Mother's education	(1)	(2)	(3)	(4)	(5)	
Mother's education	0.028***	0.028***	0.027***	0.027***	0.027***	0.
	(0.0035)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0
Wealth index	1.03***	0.97***	0.97***	0.95***	0.95***	0
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(
Stunt(3)[2]		-0.18***	-0.15***	-0.13***	-0.13***	-0
		(0.028)	(0.028)	(0.028)	(0.029)	(
Stunt(2)[2]			-0.051*	-0.025	-0.021	-
			(0.026)	(0.027)	(0.027)	(
Stunt(1)[2]				-0.096***	-0.096***	-0.
				(0.027)	(0.027)	(
SCH					0.15***	0
					(0.057)	(
ECD						0
						(
Constant	-3.24***	-2.77***	-2.70***	-2.82***	-2.94***	-2
	(0.49)	(0.48)	(0.48)	(0.48)	(0.49)	(
R-squared	0.363	0.368	0.368	0.370	0.371	
p-values[3]						
Stunt(3) vs. Stunt(2)			*0.02*	*0.02*	*0.02*	
Stunt(3) vs. Stunt(1)				*0.35*	*0.40*	
Stunt(2) vs. Stunt(1)				*0.10*	*0.08*	
Stunt(3) vs. Stunt(2) vs. Stunt(1)				*0.05*	*0.05*	
SCH vs. ECD						

Father's education	(7)	(8)	(9)	(10)	(11)	
Father's education	0.023***	0.022***	0.022***	0.022***	0.022***	0.
	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0028)	(0
Wealth index	1.07***	1.01***	1.01***	1.00***	0.99***	0
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(
Stunt(3)[2]		-0.18***	-0.15***	-0.13***	-0.13***	-0
		(0.028)	(0.028)	(0.028)	(0.028)	(
Stunt(2)[2]			-0.049*	-0.025	-0.021	-
			(0.026)	(0.026)	(0.026)	(
Stunt(1)[2]				-0.091***	-0.091***	-0.
				(0.028)	(0.028)	(
SCH					0.15***	0
					(0.058)	(
ECD						0
						(
Constant	-3.24***	-2.78***	-2.71***	-2.82***	-2.94***	-2

	(0.49)	(0.48)	(0.49)	(0.48)	(0.49)	(0.49)
R-squared	0.361	0.366	0.367	0.368	0.369	0.371
p-values[3]						
Stunt(3) vs. Stunt(2)			*0.02*	*0.01*	*0.01*	*0.01*
Stunt(3) vs. Stunt(1)				*0.28*	*0.32*	*0.31*
Stunt(2) vs. Stunt(1)				*0.11*	*0.09*	*0.10*
Stunt(3) vs. Stunt(2) vs. Stunt(1)				*0.05*	*0.04*	*0.05*
SCH vs. ECD						*0.77*

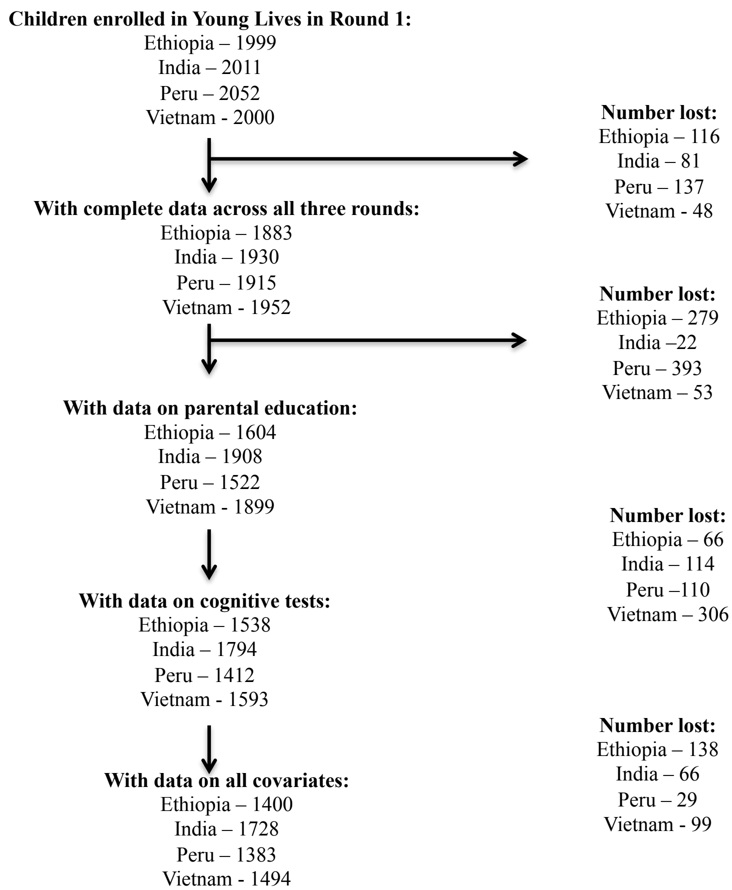
Both parents' education	(13)	(14)	(15)	(16)	(17)	(18)
Mother's education	0.022***	0.022***	0.022***	0.022***	0.022***	0.021***
	(0.0035)	(0.0034)	(0.0034)	(0.0034)	(0.0034)	(0.0034)
Father's education	0.017***	0.016***	0.016***	0.016***	0.016***	0.016***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Wealth index	0.91***	0.86***	0.85***	0.84***	0.84***	0.81***
	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)
Stunt(3)[2]		-0.18***	-0.15***	-0.13***	-0.13***	-0.13***
		(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Stunt(2)[2]			-0.047*	-0.024	-0.020	-0.019
			(0.026)	(0.027)	(0.027)	(0.026)
Stunt(1)[2]				-0.088***	-0.088***	-0.085***
				(0.028)	(0.028)	(0.028)
SCH					0.15**	0.14**
					(0.057)	(0.058)
ECD						0.15***
						(0.052)
Constant	-3.28***	-2.83***	-2.77***	-2.87***	-2.99***	-3.00***
	(0.49)	(0.48)	(0.49)	(0.48)	(0.49)	(0.49)
R-squared	0.368	0.372	0.373	0.374	0.375	0.376
p-values[3]						
Mother's vs. Father's	*0.27*	*0.25*	*0.25*	*0.23*	*0.23*	*0.28*
Stunt(3) vs. Stunt(2)			*0.02*	*0.02*	*0.02*	*0.02*
Stunt(3) vs. Stunt(1)				*0.28*	*0.32*	*0.31*
Stunt(2) vs. Stunt(1)				*0.12*	*0.10*	*0.11*
Stunt(3) vs. Stunt(2) vs. Stunt(1)				*0.05*	*0.05*	*0.05*
SCH vs. ECD						*0.92*

[1]Parental education is measured in years. Cognitive status is measured as standardized scores on the Peabody Picture Vocabulary Test, normalized separately for each country and survey round. Household wealth index is measured at baseline (age 6-18 months) and is mean-centered. Early investments in childhood development are operationalized as attendance in either preschool or crèches. School attendance is operationalized as a binary variable. Results are from ordinary least squares models. Robust standard errors adjusted for clustered sampling are presented in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Models are age and sex adjusted and include survey and sentinel site fixed effects. All models are fully adjusted for place of residence (urban/rural), household size, and mother's height.

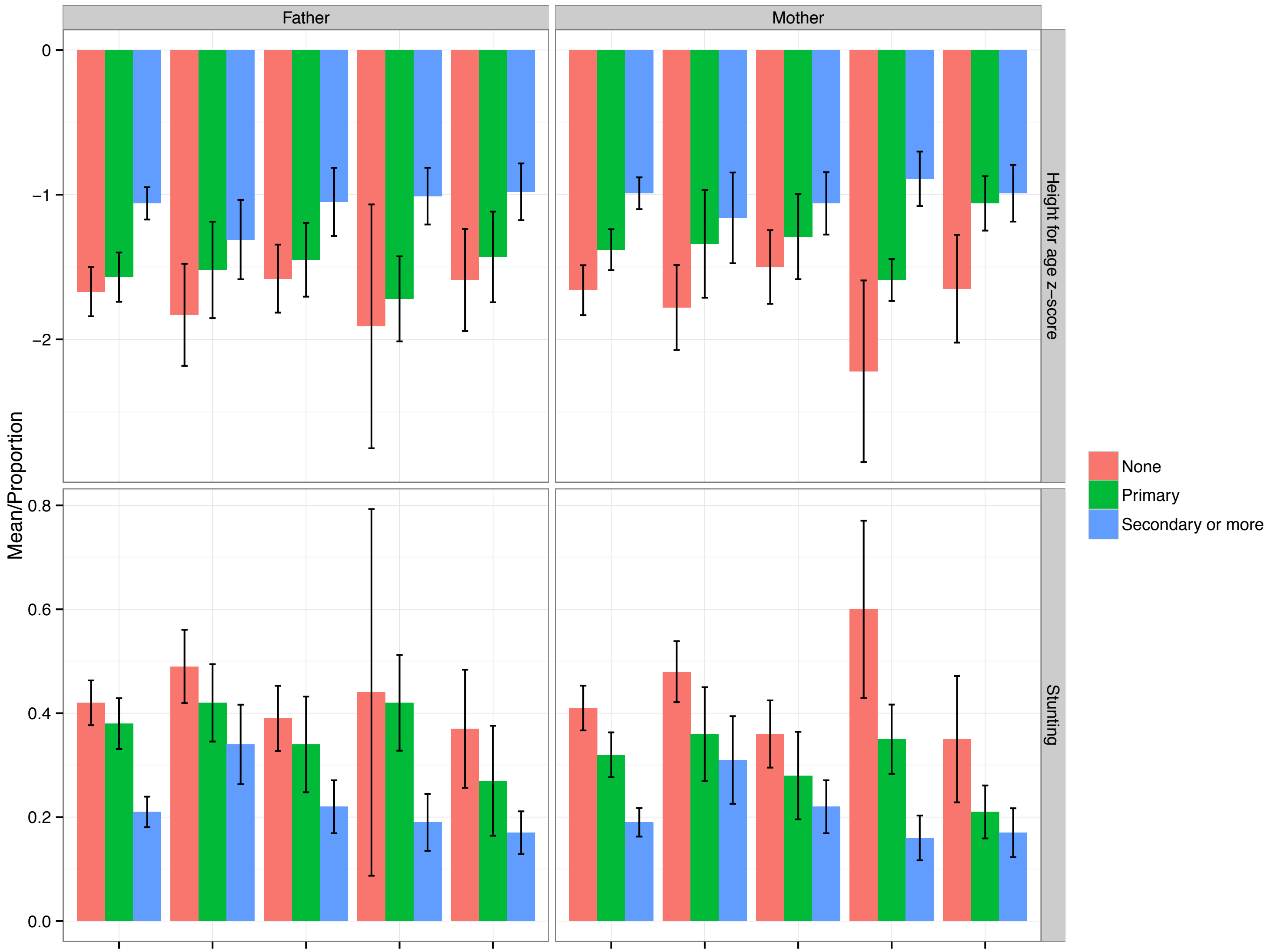
[2]Stunt(1)=Stunting at age 6-18 months; Stunt(2)=Stunting at age 4-5 years; Stunt(3)=Stunting at 7-8 years.

[3]p-values are from significance tests for differences in association between mother's and father's education.

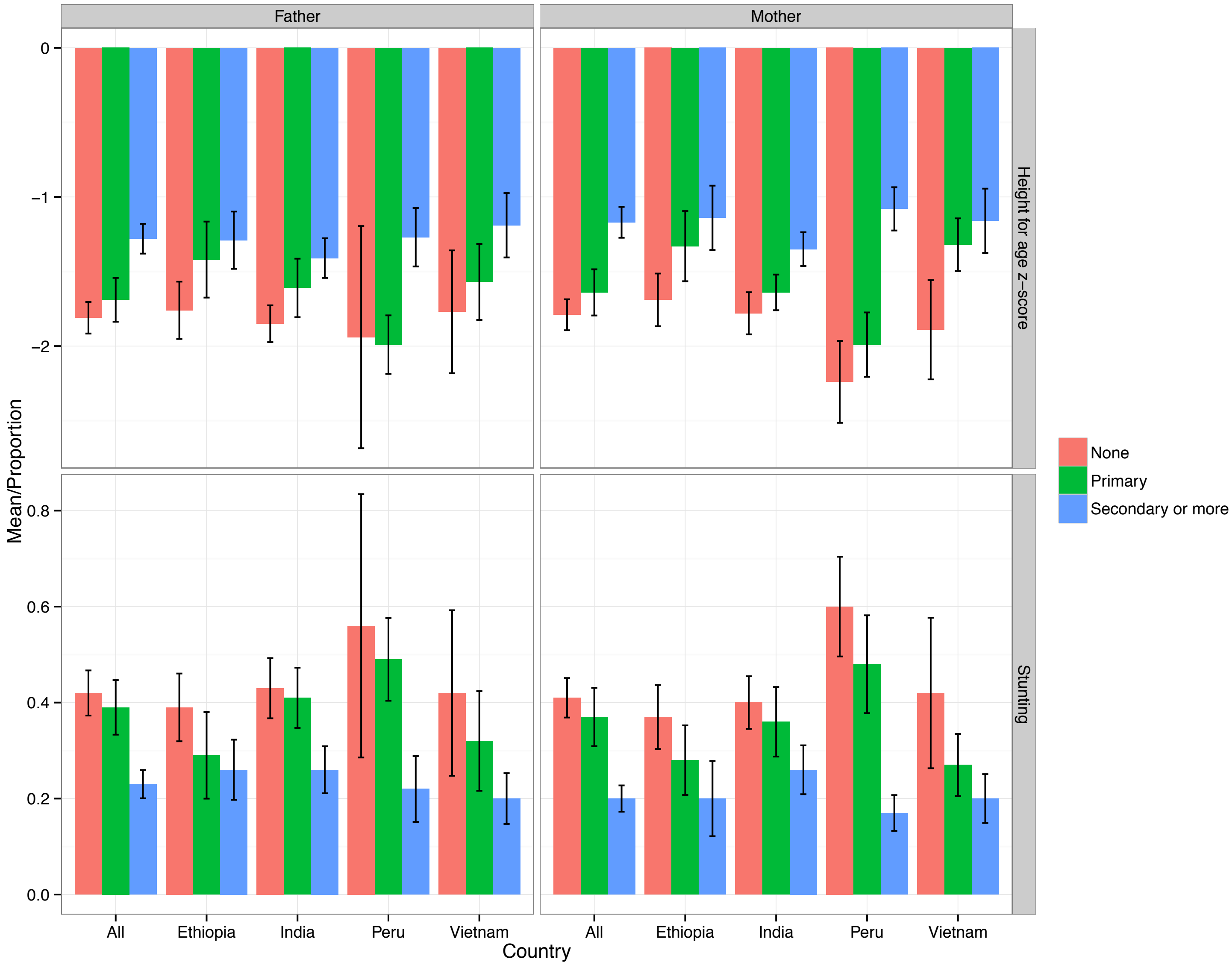
Supplementary Figure 3.1



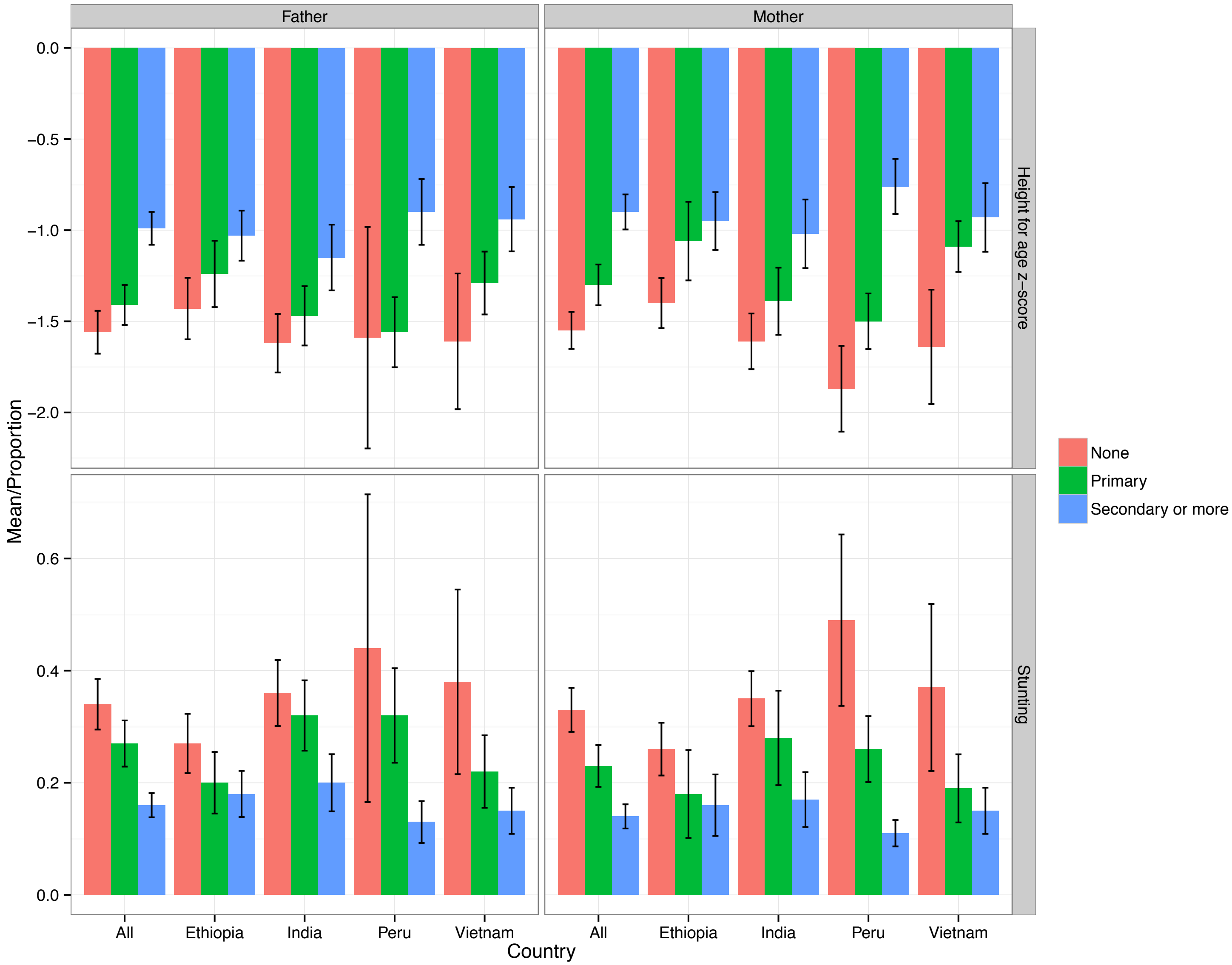
Supplementary Figure 3.2A Physical growth by parental education at age 6-18 months.



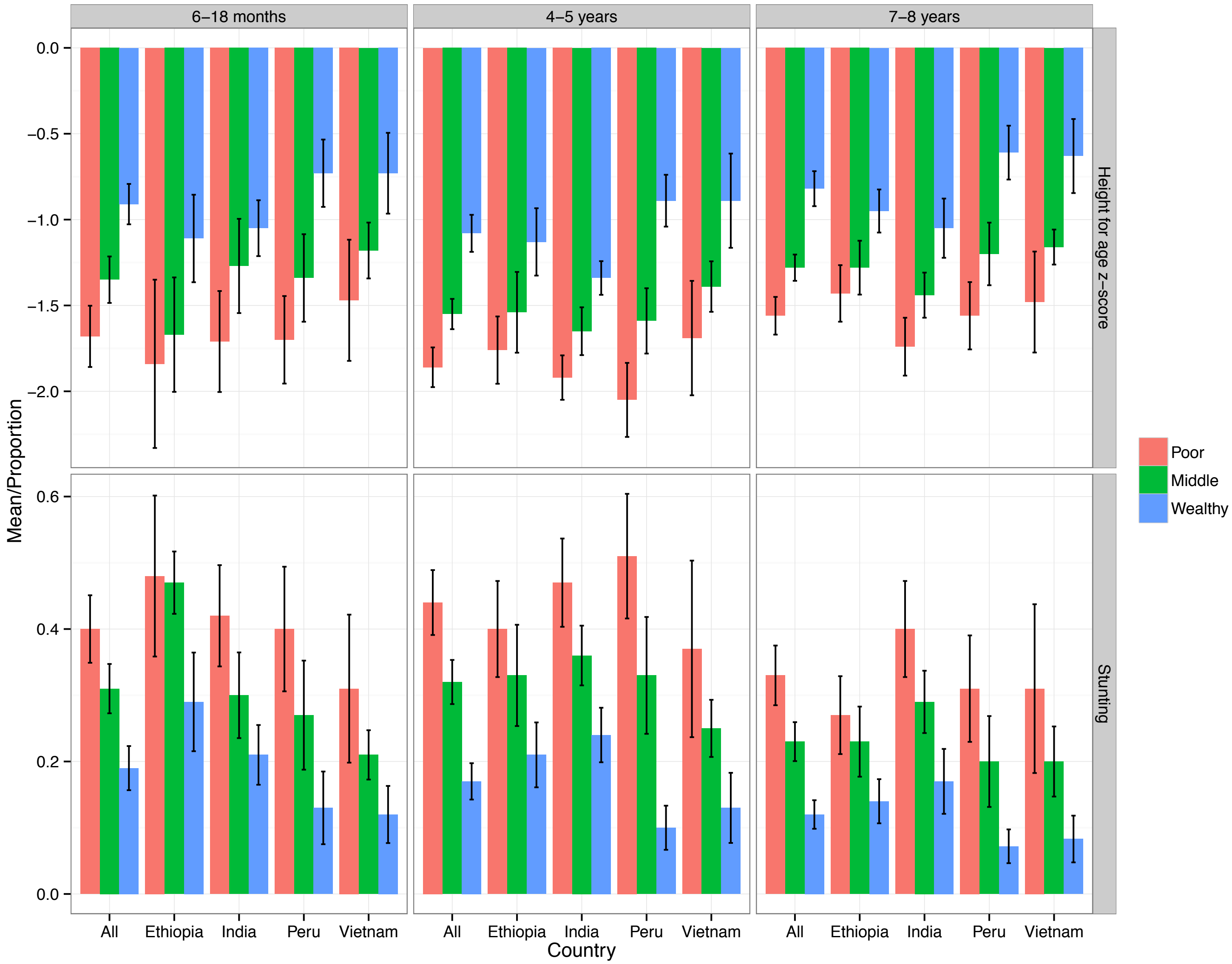
Supplementary Figure 3.2B Physical growth by parental education at age 4-5 years.



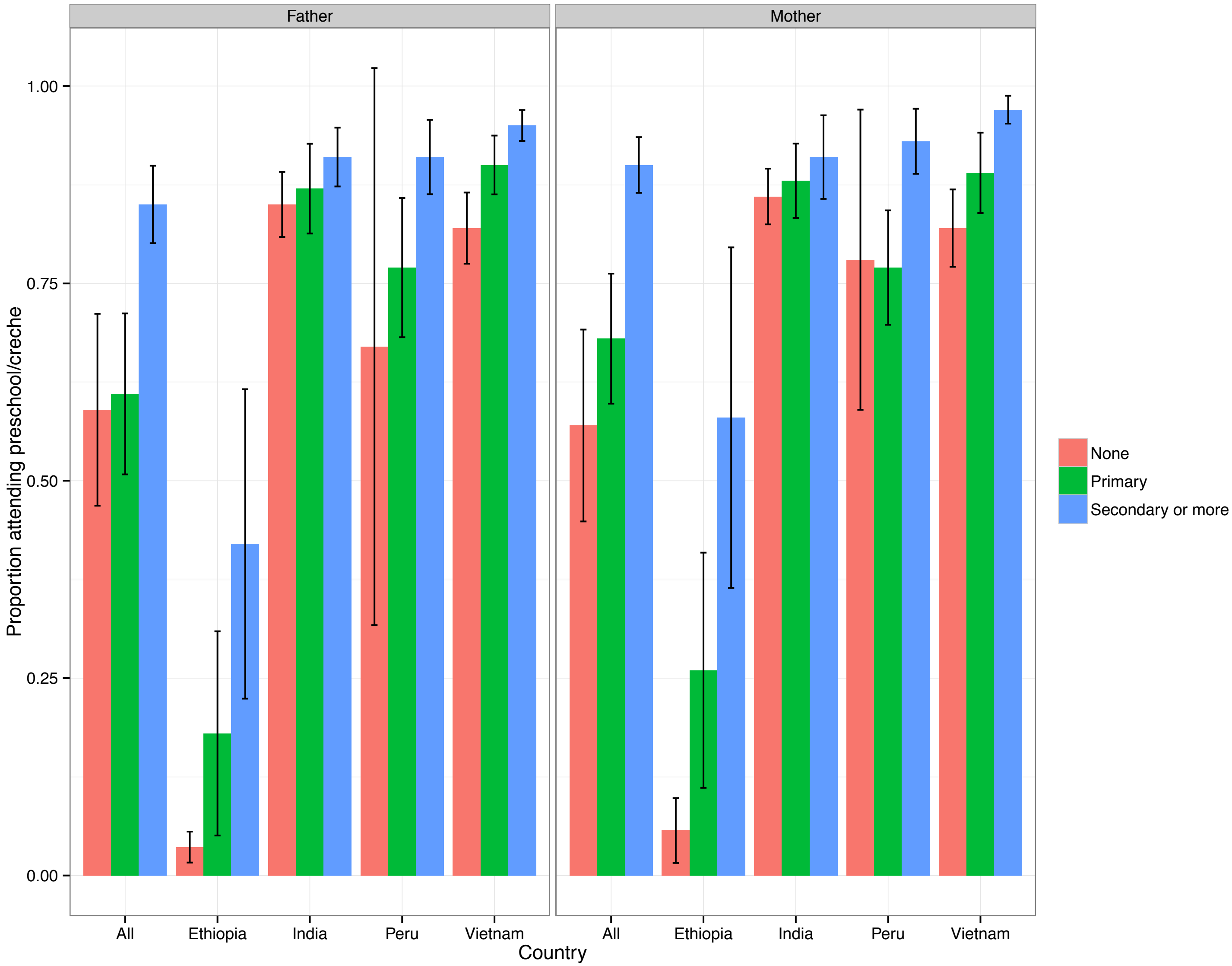
Supplementary Figure 3.2C Physical growth by parental education at age 7-8 years.



Supplementary Figure 3.3 Physical growth by baseline wealth index



Supplementary Figure 3.4 Proportion attending preschool/crèches at age 4-5 years by parental education



Supplementary Figure 3.5 Proportion attending preschool/crèches at age 4-5 years by baseline household wealth.