*Journal of Biosocial Science* (2023), 55: 5, 873–892
doi:10.1017/S0021932022000438

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

# Height, wealth, and schooling outcomes in young women from lower- and middle-income countries

Jason Murasko

Professor, Economics, University of Houston – Clear Lake, 2700 W Bay Area Blvd, Houston, TX 77058, USA
Email: muraskoj@uhcl.edu

(Received 6 July 2022; revised 29 September 2022; accepted 16 November 2022; first published online 09 December 2022)

**Abstract**

This study evaluates a large (N > 366,000) sample of young women (15-18 years) from 64 lower- and middle-income countries for associations between height, household wealth, and schooling outcomes, with a focus on secondary school attendance. A pooled sample and regional samples (Latin America, South/Southeast Asia, East Africa, and West Africa) are evaluated. A dual purpose is to evaluate both associations between height and schooling, and potential height-wealth interactions such that height associations to schooling vary over levels of wealth. Ordered probit analysis indicates positive marginal probabilities from height on secondary school attendance in all samples, with diminishing probabilities in the Latin America and South/SE Asia samples, and flat/increasing probabilities in the African samples. For South/SE Asia and taller women in Latin America, height associations are stronger at lower household wealth. For both African samples and shorter women in Latin America, height associations are stronger at higher wealth. The findings suggest that the height-schooling relationship may derive from the influence from early-life health, and may also be affected by differences in health and education environments as suggested by variations across regions and height-wealth interactions within regions.

**Keywords:** developing; education; height; socioeconomic; women

## Introduction

Schooling has long been studied as a key input into a host of individual and social outcomes. At the individual level, schooling success has been associated with a wide array of life outcomes, including health and mortality (Cutler and Lleras-Muney 2012), wage income (Card 1999), and a number of other non-pecuniary benefits such as happiness and marriage success (Oreopoulos and Salvanes 2011). Average levels of education in populations have been linked to economic growth (Hanushek and Woessmann 2010), lower crime (Lochner 2020), and civic participation (Dee 2020). The recognized benefits of schooling to individuals and society have motivated policies to raise education levels across populations, from historical compulsory schooling laws to contemporary policies aimed at increasing enrollments at the margins of primary, secondary, and tertiary education.

Along with a long-running literature that links education attainment to various outcomes, there is the accompanying body of research that explores the determinants of educational achievement. In general, family socioeconomic status and early-life health are the dominant characteristics that are studied as schooling determinants. Their relative emphasis tends to vary depending on the population of interest. For example, in populations of higher-income countries that have high average levels of schooling, family socioeconomic status is commonly studied as a key determinant of social mobility, often with a focus on parental behaviors and investments (e.g. Heckman and Mosso 2014). In lower- and middle-income countries where the deprivation of resources in childhood and adolescence can negatively affect physical and cognitive development, the role of early-life health is more commonly studied as a schooling determinant (e.g. Currie and Vogl 2013; Glewwe and Miguel 2007; Victora et al. 2008).

Though health and socioeconomic status may vary in relative importance as determinants of schooling outcomes in different populations, it is not to say that either should be studied to the exclusion of the other. For example, while major health insults may be less common in child populations of higher-income countries, those children who do suffer from certain conditions can experience negative effects on schooling outcomes (Champaloux and Young 2015; Forrest et al. 2013; Quach et al. 2017). Also, while overall standards of living might be lower in lower- and middle-income countries, access to schooling can still be influenced by relative socioeconomic status within a country (Kim et al. 2019). In consideration of these relationships, and with a focus on populations from lower- and middle-income countries, this paper presents an analysis on the potential interactions between health and economic status in schooling outcomes.

Using height as a marker of early-life health, this study estimates associations from height and household wealth on secondary school attendance for a sample of over 366,000 young (15-18 years) women from 64 countries. Further analysis considers varying associations from height across levels of wealth. While a good number of studies have identified associations from health and socioeconomic status on schooling outcomes, none have considered the potential for an interactive effect between these variables. The section below provides reasons why such an interaction may be expected. Further, studies that look at the relationship between height and schooling in populations from lower-income countries typically focus on severe growth limitations (stunting). This analysis evaluates effects over the whole of the height distribution.

The paper proceeds with background information that motivates the associations being evaluated. The data and methods are then presented, followed by the results of the analysis. The paper concludes with a discussion of the results.

## Background

There are two critical periods of growth. The first occurs in the immediate post-natal period until around 2 years of age, during which linear growth is at its fastest relative to any other point in life. Growth inhibition during this period is likely to manifest in shorter-than-potential adult height. A second period occurs at the pre-pubertal growth spurt, after which height-growth slows considerably until final attainment. The age at which final height is attained varies by sex and resource availability. In higher-income environments, final height is often reached in the mid- to late-teens, with girls completing their growth before boys. In lower-resource environments, final height may not be reached until the early-20s (Deaton 2008). Growth inhibition during the post-natal period can be somewhat remedied by a delayed growth spurt that leaves more time for growth during the childhood-adolescent transition, but such "catch-up" growth may not fully reverse early-life growth problems (Golden 1994; Handa and Peterman 2016). Further, growth deficits can accrue after the immediate post-natal period, with one study showing about 30% of 5-year height deficits attributable to growth patterns after 24 months of age (Leroy et al. 2014).

Attained height is a product of genetic and environmental factors. The use of height as a marker for early-life health is motivated by the influence of environmental factors during the post-natal growth period. The extent to which this is appropriate depends on the relative contributions of genetics and environment to final height. Perkins et al. (2016) provide a review of the extant literature. The following points summarize their findings on the roles of genetics and environment:

1. Environmental factors are suggested to account for 20% or more of variations in attained height. Twin studies from populations in higher-income countries suggest that about 80% of

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

height is inherited, with a few studies from populations in lower-income countries suggesting less heritability. Other studies that use more comprehensive genetic analyses find around a 60% genetic component to height. Taken together, these suggest 20-40% of attained height may be influenced by environment.
2. The most important environmental factor is nutrition. Post-natal nutrition is more important that pre-natal nutrition, with protein intake playing a key role. Exposure to disease interacts with nutrition. Certain diseases (e.g. diarrheal) hinder the absorption of key nutrients, while others (e.g. respiratory diseases) may redirect energy away from growth to support the immune response. Bone growth may also be adversely affected by inflammatory diseases.
3. Height varies by socioeconomic status. Part of this variation is due to heritability, given that higher-status parents are more likely to be taller. Part of the variation is also influenced by environmental conditions in early-life that are likely to vary by socioeconomic status. This may be more pronounced in lower-income countries, as higher-income countries have a higher absolute standard of living and have more robust social programs that can help offset adverse early-life conditions.

This synthesis of previous work suggests that early-life health – characterized by nutritional status and disease exposure – can account for one-fifth or more of height variation within populations. The contribution of health to variations in height may be more pronounced in lower-income countries, where early-life insults are more prevalent and social systems are less robust in buffering their effects. These points motivate the use of attained height as a marker for early-life health.

The relationship between attained height and early-life health offers a potential explanation for the oft-found positive association between stature and educational attainment. This occurs in populations from higher-income countries (Huang et al. 2015; Meyer and Selmer 1999; Magnusson et al. 2006) as well as lower- and middle-income countries (Čvorović 2020; Maurer 2010; Murasko 2019; Victora et al. 2008). In part, that association is a reflection of intergenerational transmission of socioeconomic status. Parents of higher status are more likely to be taller, and pass that trait to their children. Further, children from higher-status families are born into environments that better facilitate linear growth and have access to resources that foster schooling outcomes.

The majority of studies that link height to education recognize the confounding role of socioeconomic status and control for that characteristic. There remains a generally robust positive association between height and education. Explanations for this vary, with some work positing that taller children may develop superior non-cognitive/social skills that drive better adult outcomes (Cinnirella et al. 2011; Persico et al. 2004). Most work, however, seeks to explain the height-education relationship as a product of superior cognitive development that accompanies the physical growth derived from a healthy early-life environment. Associations between height and cognition in childhood have been known for some time (e.g. Porter 1897). Contemporary work that evaluates populations from higher-income countries has found positive associations between height and measures of cognitive ability in pre-school children (Heinonen et al. 2008; Murasko 2013; Yang et al. 2011) and school-aged children (Ahmed et al. 2020; Case and Paxson 2008; Lawlor et al. 2005; Scholder et al. 2013). Similar findings have been shown for child populations in lower- and middle-income countries, typically with an emphasis on the effects from malnutrition and stunting (Grantham-McGregor et al. 2007; Monk and Kingdon 2010; McCoy et al. 2015; Spears 2012; Sudfeld et al. 2015). Several factors are known to affect both brain development and physical growth, including pre-natal exposures (e.g. maternal nutrition and stress) and exposures during infancy (e.g. nutritional intake and disease) (Prado and Dewey 2014; Walker et al. 2011). The dual effects from these exposures may explain findings of a height-cognition association, which in turn offers a potential explanation for the association

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

between height and education outcomes. Indeed, studies that control for measures of cognitive ability have shown them to explain a substantial part of the height-effect on adult economic outcomes (Case and Paxson 2008; Schick and Steckel 2015; Vogl 2014).

Given the associations between height and education outcomes found in a number of populations, and a focus on a height-cognition relationship as a potential mechanism for those associations, the final element that motivates the current study is a possible interaction effect between socioeconomic status and height. There are a few reasons to suggest that such an interaction effect might exist. First, the cause of shorter height, and therefore the associated consequences, may be different for lower- versus higher-status families. Shorter height may be more likely a result of less healthy early-life environments (versus inherited traits) for lower-status children, which would suggest a higher likelihood of harm to cognitive development. This would suggest a stronger height-education association for lower-status individuals. Second, productivity and resource effects may result in differential schooling outcomes for shorter children at different levels of socioeconomic status. Higher-status parents may be more productive in their child investments (time spent with children, choices of activities, etc.) or have greater access to interventions (higher quality medical care or schools) that help mitigate the negative effects associated with shorter height. This again would suggest a stronger height-education association for lower-status individuals. Though these types of productivity and resource effects are more often studied in populations from higher-income countries, there is evidence of similar patterns in lower- and middle-income countries to make them relevant to the population studied in this paper (Jeong et al. 2017).

In sum, a number of studies have identified a positive association between height and education outcomes, in both higher-income and lower-income countries. One interpretation of this finding is that height is a marker for early-life circumstances that jointly affect physical and cognitive development. Such a mechanism may be particularly relevant in lower-income environments where the potential for undernutrition and disease exposure is greater, and potentially more severe. Further, there are reasons to suggest that this mechanism may be influenced by relative socioeconomic status. This background provides context for the proceeding analysis on the association between height and secondary school attendance in young women from developing regions of the world, with an emphasis on the potential interaction effect between height and household wealth.

## Data and Methods

### *Data*

The data come from the Demographic and Health Surveys (DHS) funded by the US Agency for International Development (USAID). The DHS are nationally representative, cross-section surveys administered in countries from Sub-Saharan Africa, Northern Africa/Middle East/Europe, Latin America and the Caribbean, Central Asia, and South/Southeast Asia. Data is collected on household characteristics, anthropometry and health outcomes of women and children, women's birth and marital histories, and other lifestyle characteristics. The main sampling units within households are adolescent/adult women (15-49 years) and young children (<5 years). Surveys have been conducted since the 1980s in over 90 countries, with most countries having multiple surveys at different years with different samples. Questionnaires are standardized so that information is consistent across countries and time periods. Details about the surveys and their design can be found in ICF International (2012) and Rutstein and Rojas (2006).

The sample used in this study includes young women between the ages of 15 and 18 for whom data on height, wealth, and schooling is available. This age group is chosen for two reasons. First, the transition out of primary education and into secondary education usually takes place before these ages, thereby reducing censoring issues associated with individuals who would still be in primary school. Second, observed household wealth at these ages is likely to still be reflective

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

of conditions during childhood and adolescence, and not influenced by marriage or occupation outcomes in adulthood. The chosen ages therefore represent a period in which household wealth and schooling outcomes are assumed to be contemporaneous to each other.

Wealth and education information are available for virtually all women. Height is the limiting variable for the sample used in this study. DHS began collecting anthropometric measures of adult women in 1991, so surveys before this year are not included in the sample. Further, there are countries for which women were never measured, and countries for which they were measured in certain years but not others. The number of 15 to 18 year old women for which height, wealth, and schooling information is available comes to just over 365,000. This sample covers 176 individual surveys that represent 64 countries at various years between 1991 and 2018. The largest represented regions are Sub-Saharan Africa (42.6% of all observations, with 19.2% East Africa, 16.2% West Africa, and 7.2% Central/South Africa), South/SE Asia (30.8% of observations, mostly representing India), and Latin America and the Caribbean (21.7% of observations). The remaining 4.9% of observations are from countries in Europe, North Africa, the Middle East, and Central Asia. An appendix table lists all countries, their survey years, and sample sizes.

For those surveys that collected anthropometric information, height was measured during the interview process and recorded in centimetres. The height measure used in this study is a woman's centimetres-deviation from the average height of her birth cohort for her specific country. Surveys were pooled across each country and average heights were calculated for each birth year. A sampled woman's height was then compared to the average for her birth cohort and the deviation was calculated. This is referred to as relative height throughout the paper. As an example, the average height for women surveyed in Colombia and born in 1995 is 155.7cm. A sampled women from Colombia who was born in that year and has a height of 152cm would therefore be assigned a relative height value of -3.7cm. This measure indirectly controls for country-level unobservable characteristics (e.g., differences in population-specific genetic potential), and assumes that a woman's outcomes will be more strongly influenced by her height relative to her peers, rather than across time periods or countries.

An alternate approach would be to assign z-score values relative to a growth reference (e.g. the World Health Organization (WHO) Growth Reference (de Onis et al. 2007)). These z-scores offer a standardized height measurement for a woman based on her age. This can be appropriate given that height-growth can continue through the late-teens, and a growth reference makes it easier to make comparisons across age groups. However, a key problem for the current analysis is the variation in heights across global regions. For example, the average height for South/SE Asian women in the DHS sample is 151.4cm, as compared to 157.4cm for women from West Africa (see Table 2). This is nearly a full standard deviation difference according to the WHO Growth Reference. Having height centred at a country cohort-specific average (as described in the previous paragraph) rather than the average of a global reference makes it easier to compare effects over the height distributions of women from different regions.

Each survey also includes a wealth index that places households on a distribution relative to other households in the same survey. DHS statisticians performed a principal components analysis on a series of household responses to holdings of various physical assets (e.g. car, motorcycle, television) and the built environment (e.g. type of dwelling, water source). This is used to derive a wealth distribution for each survey, from which households are placed into quintiles that represent a household's wealth relative to other households in the country at the time of the survey. The wealth index is not relative to households in other countries or years. Details on the wealth index procedure can be found in Rutstein and Johnson (2004).

Education is provided in the DHS through two measures: years of schooling and highest level of education attended (no school, primary, secondary, and post-secondary). This analysis uses the categorical variable with a collapsed top category, yielding three categories of no schooling, highest level attained primary, and highest level attained secondary or higher. The results are presented with a focus on the outcome of secondary school attendance, as this is the level that is most

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

**Table 1.** Sample means

| Variable | Pooled | L. America | S/SE Asia | E. Africa | W. Africa |
|---|---|---|---|---|---|
| Secondary Attendance | 0.621 | 0.707 | 0.770 | 0.306 | 0.388 |
| | (0.485) | (0.455) | (0.421) | (0.461) | (0.487) |
| Height (cm) | 154.081 | 154.098 | 151.362 | 155.397 | 157.372 |
| | (6.864) | (6.477) | (5.954) | (6.676) | (6.935) |
| Wealth quintile: | | | | | |
| Lowest | 0.187 | 0.169 | 0.208 | 0.175 | 0.164 |
| | (0.390) | (0.375) | (0.406) | (0.380) | (0.370) |
| 2nd | 0.204 | 0.199 | 0.223 | 0.180 | 0.182 |
| | (0.403) | (0.399) | (0.416) | (0.384) | (0.386) |
| 3rd | 0.206 | 0.209 | 0.216 | 0.189 | 0.195 |
| | (0.404) | (0.406) | (0.411) | (0.392) | (0.396) |
| 4th | 0.203 | 0.215 | 0.194 | 0.205 | 0.207 |
| | (0.402) | (0.411) | (0.395) | (0.404) | (0.405) |
| Highest | 0.201 | 0.208 | 0.160 | 0.251 | 0.252 |
| | (0.401) | (0.406) | (0.366) | (0.434) | (0.434) |
| Age | 16.546 | 16.484 | 16.564 | 16.534 | 16.557 |
| | (1.130) | (1.113) | (1.130) | (1.137) | (1.157) |
| Urban residence | 0.379 | 0.634 | 0.278 | 0.269 | 0.399 |
| | (0.485) | (0.482) | (0.448) | (0.443) | (0.490) |
| Birth year | 1992.327 | 1990.190 | 1995.353 | 1989.561 | 1990.838 |
| | (6.294) | (5.550) | (5.266) | (6.891) | 5.586 |
| N | 366,725 | 72,498 | 146,988 | 62,576 | 45,812 |

All means adjusted for sampling weights provided by DHS. Standard deviations shown in parentheses.

contemporary to the ages of the sample. However it is useful to examine lesser outcomes as they can provide insight into the progressions that lead to secondary school, i.e. school-entry decisions which are most likely to occur in early childhood, versus the progression from primary to secondary school that occurs in adolescence. Other control variables used in the analysis are age in months, an indicator for urban residence, country identifiers, and birth year. Sample means for all analysis variables are provided in Table 1.

## Methods

The analysis begins with an evaluation of the association between relative height, wealth, and school advancement:

$$S_i = f(h(H_i), W_i, g(age_i), byear_i, c_i, c_i \times byear_i) \tag{1}$$

where $S_i$ is the categorical variable for highest level of school attendance for woman $i$, $h(H_i)$ is a second-degree polynomial of relative height, $W_i$ is a set of wealth quintile indicators (reference = lowest wealth quintile), $g(age_i)$ is a second-degree polynomial of age in months, $byear_i$ is birth year, and $c_i$ is a country identifier. Country identifiers are interacted with birth year to allow

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

**Table 2.** Schooling and height characteristics by sample

| | Height | Height by Wealth Quintile | | | | | | Highest Level of Attendance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Lowest | 2nd | 3rd | 4th | Highest | High – Low | None | Primary | Secondary + |
| Pooled | 154.1 | 152.4 | 153.2 | 153.9 | 154.7 | 156.1 | 3.8** | 12.9% | 25.0% | 62.1% |
| | (6.9) | (7.0) | (6.7) | (6.7) | (6.6) | (6.7) | | | | |
| L. America | 154.1 | 152.1 | 152.9 | 153.9 | 154.9 | 156.2 | 4.1** | 1.7% | 27.6% | 70.7% |
| | (6.5) | (6.7) | (6.4) | (6.2) | (6.2) | (6.2) | | | | |
| S/SE Asia | 151.4 | 149.6 | 150.7 | 151.4 | 152.2 | 153.5 | 3.9** | 11.2% | 11.9% | 77.0% |
| | (6.0) | (5.7) | (5.8) | (5.8) | (5.8) | (6.1) | | | | |
| E. Africa | 155.4 | 154.5 | 154.9 | 155.2 | 155.6 | 156.3 | 1.9** | 11.9% | 57.5% | 30.6% |
| | (6.7) | (6.9) | (6.7) | (6.8) | (6.6) | (6.4) | | | | |
| W. Africa | 157.3 | 156.3 | 156.5 | 157.0 | 157.6 | 158.7 | 2.4** | 39.7% | 21.5% | 38.9% |
| | (6.9) | (7.0) | (6.9) | (6.9) | (6.8) | (6.9) | | | | |

Standard deviation of height shown in parentheses. All means/percentages adjusted for sampling weights. ** = difference is significant at $p < .001$.

for varying cohort trends between countries. Height is entered as a second-degree polynomial to capture nonlinear effects (e.g. diminishing marginal returns), and age is entered as a second-degree polynomial to control for potential confounding with height given potential variations in growth rates over the 15 to 18 year age range of the sample.

A second equation is estimated that includes an interaction term between relative height and wealth:

$$S_i = f\big(h(H_i), W_i, h(H_i) \times W_i, g(age_i),\ byear_i, c_i, c_i \times byear_i\big) \tag{2}$$

Equation (2) is used to evaluate variations in height associations over wealth status. Equations (1) and (2) are estimated by ordered probit regression. Marginal effects are calculated that give the marginal probabilities of each education level associated with incremental changes in height. Marginal probabilities are evaluated at height deviations of -9cm, 0cm, and +9cm to identify any nonlinear patterns over the height distribution. These points cover approximately ±1.5 standard deviations in height for each region (see Table 1). For equation (2), the marginal probabilities from height are also evaluated at each wealth quintile, yielding estimated associations between height and schooling level over the distributions of height and household wealth, from which comparisons between the highest and lowest quintiles are made.

Both equations are estimated for the pooled sample as well as regional samples for Latin America, South/SE Asia, East Africa, and West Africa. While Sub-Saharan Africa is often treated as a singular region, Table 2 (discussed below) indicates that there are notable differences in the education and height profiles between East Africa and West Africa that motivate their separation for this analysis. All regressions adjust for women's sample weights provided with the DHS data. Standard errors are clustered at the country-level to correct for possible autocorrelation across survey years.

## Results

### *Sample Descriptions*

To provide context for the environments in which the main results should be interpreted, this section discusses the height-wealth relationships and schooling backgrounds for the samples

**Table 3.** Estimated marginal probabilities from relative height on education levels, pooled sample

| Height | Excluding Wealth Controls | | | Including Wealth Controls | | |
|---|---|---|---|---|---|---|
| | None | Primary | Secondary | None | Primary | Secondary |
| −9cm | −0.473 | −0.296 | 0.769 | −0.321 | −0.229 | 0.551 |
| | (0.090) | (0.044) | (0.073) | (0.044) | (0.043) | (0.047) |
| 0cm | −0.385 | −0.333 | 0.718 | −0.261 | −0.231 | 0.493 |
| | (0.070) | (0.041) | (0.051) | (0.026) | (0.048) | (0.038) |
| +9cm | −0.306 | −0.346 | 0.652 | −0.211 | −0.223 | 0.435 |
| | (0.056) | (0.041) | (0.045) | (0.022) | (0.056) | (0.055) |
| Δ | 0.167 | −0.050$^{ns}$ | −0.117$^{ns}$ | 0.110 | 0.006$^{ns}$ | −0.116$^{ns}$ |

N = 366,725. Marginal probabilities have been multiplied by 100. Unless otherwise superscripted, all estimates are significant at $p < .01$. Δ = difference in marginal probabilities between +9cm and -9cm of relative height. Robust standard errors shown in parentheses. $^{ns}$ = not significant ($p > .05$)

evaluated in this paper. Table 2 shows mean heights for the pooled and regional samples in the analysis, overall and across wealth quintiles. Women in West Africa are the tallest in the sample with a mean height of 157.4cm, followed by East Africa (155.4cm), Latin America (154.1cm), and South/SE Asia (151.4cm). All samples also show taller heights associated with greater household wealth. The Latin America and South/SE Asia samples show the widest differences between the highest and lowest wealth quintiles (≈ 4.0cm), with smaller differences in the Africa samples (≈ 2.0cm). At the extremes, women in the highest wealth quintile of the West Africa sample have a mean height of 158.7cm, and women in the lowest wealth quintile of the South/SE Asia sample have a mean height of 149.6cm, for a difference of 9.1cm. Also notable is that women in the lowest wealth quintile of the West Africa sample are taller than women in the highest quintiles of the Latin America and South/SE Asia samples, and equal in height to women in the highest wealth quintile in East Africa.

Table 2 also shows education levels for the pooled and regional samples. The highest rates of secondary attendance are in South/SE Asia (77%) and Latin America (71%). Lower rates are found in East Africa (31%) and West Africa (39%). There are differences in how young women track through their schooling across regions. In the Latin America sample, nearly all young women have at least some schooling, with 28% stopping before secondary school. Young women in South/SE Asia show higher rates of no schooling (11%), but for those that enter school there is a high rate of secondary attendance. West Africa shows the highest rate of no schooling among young women at 40%, while East Africa shows the highest rate of stoppage before secondary school at 58%.

### *Results from Pooled Sample*

Tables 3 and 4 show the estimation results of equations (1) and (2) for the pooled sample. Marginal probabilities are shown that give the change in the probability of each schooling level associated with an incremental change in relative height at -9cm, 0cm, and +9cm. In Table 3, marginal probabilities are shown for models estimated with wealth excluded as a control variable and with wealth included. Also shown are the differences in marginal probabilities between ±9cm along with their significance levels. In Table 4, marginal probabilities are evaluated at the lowest and highest wealth quintiles, and their differences calculated. Marginal probabilities have been multiplied by 100 in both tables.

The marginal probabilities across dependent categories will equal zero. The results are discussed here with a focus on secondary school attendance in comparison to the lower categories. From Table 3, marginal probabilities of secondary school attendance associated with incremental increases in relative height are 0.7% to 0.8% when wealth is excluded as a control, and 0.4% to

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

**Table 4.** Estimated marginal probabilities from relative height on education levels according to wealth, pooled sample

| | None | | | Primary | | | Secondary | | |
|---|---|---|---|---|---|---|---|---|---|
| | Wealth Quintile | | | Wealth Quintile | | | Wealth Quintile | | |
| Height | Lowest | Highest | Δ | Lowest | Highest | Δ | Lowest | Highest | Δ |
| −9cm | −0.406 | −0.338 | 0.068[ns] | −0.085 | −0.457 | −0.372 | 0.492 | 0.796 | 0.304[†] |
| | (0.088) | (0.065) | | (0.032) | (0.104) | | (0.071) | (0.131) | |
| 0cm | −0.346 | −0.250 | 0.096[†] | −0.111 | −0.455 | −0.344 | 0.457 | 0.705 | 0.248[†] |
| | (0.061) | (0.034) | | (0.031) | (0.092) | | (0.049) | (0.077) | |
| +9cm | −0.291 | −0.174 | 0.117 | −0.125 | −0.420 | −0.296 | 0.416 | 0.595 | 0.179[ns] |
| | (0.051) | (0.029) | | (0.037) | (0.091) | | (0.058) | (0.080) | |

N = 366,725. Marginal probabilities have been multiplied by 100. Unless otherwise superscripted, all estimates are significant at $p < .01$. Δ = difference in marginal probabilities between highest and lowest wealth quintile. Robust standard errors shown in parentheses. [†] = $p < .05$; [ns] = not significant ($p > .05$)

0.6% when wealth is included. This reflects an approximate 30% reduction in marginal probabilities associated with the inclusion of relative household wealth. There is some indication of diminishing marginal probabilities over relative height, but the differences are modest and not significant ($p > .05$). The marginal probabilities on secondary attendance are balanced about equally across the lower categories, suggesting a combination of school entry and school progress as reasons for height association to secondary schooling.

Table 4 presents the results from the height-wealth interaction model. Marginal probabilities from height are stronger at the highest wealth quintile relative to the lowest for the outcome of secondary school attendance. The differences range from 0.2% to 0.3% across the points of relative height, with the largest difference at shorter height. This suggests that incremental changes in height have a stronger association to secondary school attendance for young women in higher-wealth families relative to their lower-wealth counterparts. These wealth differences are balanced mostly with those in the middle schooling category: marginal probabilities from height on primary school attendance are negative and stronger at the highest wealth quintile by 0.3% to 0.4%. Marginal probabilities on no schooling are *lower* at the highest wealth quintile, but only by a small margin of about 0.1%.

Two robustness checks were implemented. First, the equations were estimated for the pooled sample without India, the largest contributor of observations to the sample. Second, the potential influence of early marriage was evaluated by repeating the analyses with additional controls for age at first marriage (dummy variables for 15 or younger, 16, 17, and 18, with never married being the reference category). This second check was also implemented on the regional samples discussed below. The general findings were robust to both checks.

### *Results from Regional Samples*

Table 5 shows the estimated marginal probabilities from height as estimated from equation (1) on the regional samples. For conciseness, estimates are only shown for the equation with included wealth controls. It should be noted that there were regional differences in the reduction of marginal probabilities associated with adding wealth controls. Marginal probabilities from height were most strongly affected in the South/SE Asia sample, with reductions of 40% to 60%. This is in contrast to the other regions where reductions were 20% to 30%. As with the pooled sample, adding wealth controls only affected the magnitudes of association and did not affect the pattern of marginal probabilities over points of relative height.

All regions show significant height effects on schooling outcomes. Again focusing on secondary school attendance, the strongest height effects are found in the Latin America sample, which also

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

**Table 5.** Estimated marginal probabilities from relative height on education levels, regional samples

| | Latin America ($N = 72{,}498$) | | | South/SE Asia ($N = 146{,}988$) | | |
|---|---|---|---|---|---|---|
| Height | None | Primary | Secondary | None | Primary | Secondary |
| −9cm | −0.205 | −0.975 | 1.180 | −0.368 | −0.205 | 0.573 |
| | (0.041) | (0.093) | (0.117) | (0.025) | (0.059) | (0.068) |
| 0cm | −0.096 | −0.726 | 0.822 | −0.236 | −0.156 | 0.392 |
| | (0.018) | (0.048) | (0.057) | (0.018) | (0.052) | (0.063) |
| +9cm | −0.044 | −0.477 | 0.522 | −0.141 | −0.104 | 0.245 |
| | (0.010) | (0.059) | (0.066) | (0.019) | (0.044) | (0.061) |
| Δ | 0.161 | 0.497 | −0.658 | 0.227 | 0.101 | −0.328 |
| | **East Africa ($N = 62{,}576$)** | | | **West Africa ($N = 45{,}812$)** | | |
| Height | None | Primary | Secondary | None | Primary | Secondary |
| −9cm | −0.317 | −0.142 | 0.459 | −0.414 | $0.012^{\dagger}$ | 0.402 |
| | (0.028) | (0.021) | (0.044) | (0.055) | (0.005) | (0.052) |
| 0cm | −0.237 | −0.183 | 0.420 | −0.511 | −0.016 | 0.527 |
| | (0.024) | (0.028) | (0.045) | (0.041) | (0.002) | (0.041) |
| +9cm | −0.174 | −0.192 | 0.366 | −0.589 | −0.064 | 0.653 |
| | (0.040) | (0.055) | (0.091) | (0.071) | (0.014) | (0.082) |
| Δ | 0.143 | $-0.050^{ns}$ | $-0.093^{ns}$ | $-0.175^{ns}$ | $-0.076^{ns}$ | $0.251^{\dagger}$ |

Marginal probabilities have been multiplied by 100. Unless otherwise superscripted, all estimates are significant at $p < .01$. Δ = difference in marginal probabilities between +9cm and -9cm of relative height. Robust standard errors shown in parentheses. $^{\dagger} = p < .05$; $^{ns}$ = not significant ($p > .05$).

shows the strongest diminishing marginal probabilities. The marginal probability associated with a relative height of −9cm is estimated at 1.2%, compared to 0.5% at +9cm. South/SE Asia shows a similar pattern but at reduced magnitudes. The marginal probability from height is estimated at 0.6% at −9cm and diminishes to 0.2% at +9cm. Differences between ±9cm are significant for both regional samples, and the patterns are consistent with the pooled sample. The African samples show distinct patterns. Marginal probabilities from height on secondary schooling are relatively flat in East Africa at around 0.4%. For the West Africa sample, marginal probabilities are increasing with height, from 0.4% at −9cm to 0.7% at +9cm. This difference is marginally significant ($p = 0.02$).

The balance of marginal probabilities also varies across regions and seems to relate to the overall distribution of education levels in those populations (refer to Table 2). For Latin America, where nearly all women report having some formal schooling, the positive marginal probabilities from height on secondary schooling are mostly balanced with negative probabilities on primary schooling. For West Africa, the region that shows the highest level of no formal schooling, the positive marginal probabilities from height on secondary schooling are balanced mostly with negative probabilities on no formal schooling. The samples from South/SE Asia and East Africa show more equitable balance between the marginal probabilities on secondary schooling and those at the lower levels. Recalling from Table 2, the South/SE Asia sample has secondary rates that are high and comparable to Latin America, but has higher rates of no formal schooling. East Africa has lower rates of secondary schooling, but higher rates of primary attendance and lower rates of no schooling relative to West Africa.

Tables 6a and 6b shows the results from equation (2) as estimated on the regional samples. All regions exhibit some pattern of wealth interactions, but the patterns are distinct. For the Latin

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

**Table 6a.** Estimated marginal probabilities from relative height on education levels according to wealth, regional samples

| | Latin America (N = 72,498) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | None | | | Primary | | | Secondary | | |
| | Wealth Quintile | | | Wealth Quintile | | | Wealth Quintile | | |
| Height | Lowest | Highest | Δ | Lowest | Highest | Δ | Lowest | Highest | Δ |
| −9cm | −0.442 | −0.120 | 0.322 | −0.602 | −1.868 | −1.266 | 1.044 | 1.988 | 0.944 |
| | (0.089) | (0.039) | | (0.070) | (0.270) | | (0.113) | (0.301) | |
| 0cm | −0.245 | −0.020 | 0.225 | −0.601 | −0.896 | −0.295 | 0.846 | 0.916 | 0.070$^{ns}$ |
| | (0.044) | (0.005) | | (0.051) | (0.071) | | (0.068) | (0.072) | |
| +9cm | −0.131 | −0.004 | 0.127 | −0.470 | −0.353 | 0.117$^{ns}$ | 0.601 | 0.357 | −0.244$^{\dagger}$ |
| | (0.027) | (0.001) | | (0.056) | (0.042) | | (0.073) | (0.042) | |
| | South/SE Asia (N = 146,988) | | | | | | | | |
| | None | | | Primary | | | Secondary | | |
| | Wealth Quintile | | | Wealth Quintile | | | Wealth Quintile | | |
| Height | Lowest | Highest | Δ | Lowest | Highest | Δ | Lowest | Highest | Δ |
| −9cm | −0.636 | −0.183 | 0.454 | −0.156 | −0.240 | −0.084$^{ns}$ | 0.793 | 0.423 | −0.370 |
| | (0.049) | (0.034) | | (0.050) | (0.089) | | (0.055) | (0.119) | |
| 0cm | −0.433 | −0.115 | 0.318 | −0.152 | −0.182$^{\dagger}$ | −0.030$^{ns}$ | 0.585 | 0.297 | −0.288 |
| | (0.034) | (0.025) | | (0.058) | (0.085) | | (0.079) | (0.108) | |
| +9cm | −0.270 | −0.070 | 0.200 | −0.116$^{ns}$ | −0.131$^{ns}$ | −0.015$^{ns}$ | 0.387 | 0.201$^{\dagger}$ | −0.185 |
| | (0.061) | (0.015) | | (0.065) | (0.069) | | (0.122) | (0.083) | |

Marginal probabilities have been multiplied by 100. Unless otherwise superscripted, all estimates are significant at $p < .01$. Δ = difference in marginal probabilities between highest and lowest wealth quintile. Robust standard errors shown in parentheses. $^{\dagger}$ = $p < .05$; $^{ns}$ = not significant ($p > .05$)

**Table 6b.** Estimated marginal probabilities from relative height on education levels according to wealth, regional samples

| | East Africa (N = 62,576) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | None | | | Primary | | | Secondary | | |
| | Wealth Quintile | | | Wealth Quintile | | | Wealth Quintile | | |
| Height | Lowest | Highest | Δ | Lowest | Highest | Δ | Lowest | Highest | Δ |
| −9cm | −0.142$^{ns}$ | −0.361 | −0.220$^{ns}$ | 0.055$^{ns}$ | −0.968 | −1.022 | 0.087$^{ns}$ | 1.329 | 1.242 |
| | (0.110) | (0.049) | | (0.044) | (0.079) | | (0.067) | (0.105) | |
| 0cm | −0.069$^{ns}$ | −0.182 | −0.113$^{ns}$ | 0.024$^{ns}$ | −0.953 | −0.977 | 0.045$^{ns}$ | 1.135 | 1.090 |
| | (0.068) | (0.025) | | (0.024) | (0.080) | | (0.044) | (0.096) | |
| +9cm | −0.001$^{ns}$ | −0.091 | −0.091$^{ns}$ | 0.001$^{ns}$ | −0.779 | −0.779 | 0.001$^{ns}$ | 0.870 | 0.870 |
| | (0.116) | (0.018) | | (0.039) | (0.149) | | (0.076) | (0.164) | |
| | West Africa (N = 45,812) | | | | | | | | |
| | None | | | Primary | | | Secondary | | |
| | Wealth Quintile | | | Wealth Quintile | | | Wealth Quintile | | |
| Height | Lowest | Highest | Δ | Lowest | Highest | Δ | Lowest | Highest | Δ |
| −9cm | −0.188$^{ns}$ | −0.587$^{\dagger}$ | −0.399$^{ns}$ | 0.073$^{ns}$ | −0.159 | −0.232 | 0.114$^{ns}$ | 0.746 | 0.632$^{\dagger}$ |
| | (0.106) | (0.242) | | (0.047) | (0.039) | | (0.061) | (0.279) | |
| 0cm | −0.294 | −0.726 | −0.432 | 0.107 | −0.318 | −0.425 | 0.187 | 1.043 | 0.857 |
| | (0.076) | (0.105) | | (0.031) | (0.041) | | (0.051) | (0.140) | |
| +9cm | −0.407 | −0.713 | −0.305 | 0.133 | −0.505 | −0.638 | 0.274 | 1.217 | 0.943 |
| | (0.116) | (0.059) | | (0.035) | (0.053) | | (0.089) | (0.094) | |

Marginal probabilities have been multiplied by 100. Unless otherwise superscripted, all estimates are significant at $p < .01$. Δ = difference in marginal probabilities between highest and lowest wealth quintile. Robust standard errors shown in parentheses. $^{\dagger}$ = $p < .05$; $^{ns}$ = not significant ($p > .05$)

America sample, the marginal probability from height on secondary schooling is higher for high-wealth women at short relative height (−9cm), but is lower for high-wealth women at tall relative height (+9cm). For high-wealth women, the marginal probability from height is 0.9% higher at −9cm relative to low-wealth women, and is 0.2% *lower* at +9cm. This is driven by a large wealth difference in height effects among shorter women on primary schooling, where the marginal probability from height is 1.3% lower at high wealth relative to low wealth. These results suggest that wealth differences in the association between relative height and passing through to secondary schooling are strongest for shorter women in Latin America.

High-wealth women in the South/SE Asia sample show weaker marginal probabilities from height on secondary schooling relative to their low-wealth counterparts, with somewhat stronger differences at short heights. The marginal probability from height is 0.4% lower at high-wealth for shorter women, and 0.2% lower for taller women. These wealth differences are mirrored in the patterns of no formal schooling, where low-wealth women show stronger marginal probabilities from height (0.2% to 0.5%). Wealth differences in height effects on primary schooling are small and not significant. In general, associations between relative height and secondary schooling are stronger in low-wealth women for the South/SE Asia sample, reflecting patterns of school entry rather than school progress.

The East Africa sample shows the strongest wealth differences in height effects on secondary schooling. Marginal probabilities from height are 0.9% to 1.2% higher in high-wealth women than low-wealth women. The marginal probabilities from height on secondary schooling among high-wealth women are mostly balanced with height effects on primary schooling, similar in pattern to the Latin American sample. Wealth differences in height effects are smaller and not significant for the outcome of no schooling. It is also noteworthy that height effects are not significant for low-wealth women at any schooling level. For women in East Africa, the results suggest that the association between relative height and secondary schooling manifests at higher levels of wealth, with little association at the lowest levels. They also suggest that the wealth differences relate to school progression between primary and secondary school, rather than school entry.

Women in the West Africa sample also show stronger height effects at high wealth. Marginal probabilities from height on secondary schooling are 0.6% to 0.9% higher among high-wealth women compared to low-wealth women. Unlike the other regional samples, wealth differences are larger at taller heights for West Africa. Also unlike the other regions, the marginal probabilities from height on secondary schooling are not generally balanced disproportionally with a single lower level. The exception is a wider wealth gap at primary schooling for taller women (0.6%, versus 0.3% at no schooling). The results suggest that, similar to East Africa, the association between relative height and secondary schooling is stronger for high-wealth women in West Africa. In contrast to East Africa, these wealth differences are more evenly balanced with differences at lower schooling levels, and tend to be stronger at taller heights.

## Discussion

This study evaluated a large and wide-reaching sample of young women in lower- and middle-income countries for associations between height and schooling outcomes. There were two focus areas. The first focus was on the direct association between height and secondary school attendance, which represented the schooling outcome closest to the ages of the sampled women (15 to 18 years). Taller height relative to birth cohort averages was associated with higher probability of educational attainment at or above the secondary level. This result held for pooled and regional samples. Marginal probabilities were shown to decrease over the height distributions of Latin America and South/SE Asia, but were flat for East Africa and increased with height in West Africa. Controlling for relative household wealth reduced the magnitudes of association in all samples but did not affect the patterns of association over the height distributions.

The positive associations between height and secondary school attendance were balanced with negative associations to lower attainment levels, and these were suggested to reflect the education distributions of the regional samples. In Latin America, where nearly all sampled women had some formal schooling, height was most strongly associated with progress between primary and secondary schooling. In West Africa, the region with the highest rates of no formal schooling, the positive association between height and secondary attendance was mostly balanced with a negative association between height and formal school entry. South/SE Asia and East Africa exhibited more equal balance in the associations between height and the three levels of education attainment.

One interpretation of the height-schooling associations is that early-life health, as characterized by nutritional status and disease exposure, affects both physical and cognitive development that has lasting impact on schooling success. This can manifest at younger ages, when children in certain populations face a stronger sorting mechanism into formal schooling, and at older ages as children progress through national school systems. This interpretation would be consistent with previous work that links early-life growth to cognitive outcomes, and that shows an explanatory effect from cognitive scores on empirical associations between height and adult economic outcomes. The DHS data lacks retrospective information on early-life circumstances and does not provide cognitive assessments of sample women. Therefore direct testing of this hypothesis is not possible and the interpretation remains as conjecture.

Further insight may be gained by looking at the regional variations in the height-schooling associations. If the height-schooling association is a reflection of the effects from early-life health, then it might be expected that the strongest effects would be found at shorter heights, and in particular for those in the lowest-resource populations. This was not reflected in the regional samples of this study. For the East and West Africa samples, which (on average) reflect the lowest-resource populations of the regional samples, marginal probabilities from height on schooling were flat or increasing. Indeed, the strongest height associations were identified for shorter women in the Latin America sample, which includes the highest-resource populations among the regional samples. These results may seem counterintuitive, but they may also be consistent with survivability effects. Early-life nutritional and disease insults that occur in lower-resource environments may be more likely to result in death, leaving the heights of survivors to be a stronger reflection of genetic influence. As a consequence, children in those environments who would be most at risk of poorer physical and cognitive development do not survive to adolescence, and therefore would not be represented in the samples. While a direct test of this explanation is beyond the scope of this study, it is consistent with magnitudes and patterns of marginal probabilities across regional samples, with diminishing marginal probabilities exhibited by the relatively higher-resource populations (Latin America and South/SE Asia) and flat/increasing marginal probabilities among the lower-resource populations (East and West Africa).

The second focus of this study was on potential socioeconomic differences in the height-schooling association. It was suggested in the Background section that higher-wealth families may be better able to mitigate the effects of poorer early-life health with greater access to resources and higher productivity in child investments. This would be consistent with a finding that a height-schooling association is stronger among lower-wealth women in the study sample. Such a finding was found for the South/SE Asia sample and for taller women in Latin America. For the South/SE Asia sample, wealth differences were balanced between secondary schooling and no schooling, suggesting that resource availability at higher wealth may provide an advantage by securing school entry. There were no indicated wealth interactions with height at the level of primary schooling. The wealth interactions for taller women in Latin America were modest and balanced across all education levels, though not significant at primary schooling.

For both African samples and women in Latin America who were at average height and below, the wealth-height interactions suggested that height associations to schooling were stronger among higher-wealth women. This may be explained in a few ways. First, the African samples may reflect survivability effects as discussed previously. Low-wealth in those regions would be associated with environments that carry some of the highest early-life mortality risk among the DHS-represented populations. If the low-wealth samples for those regions have selected out those whose height would have been a stronger marker of early-life health, then it would result in a weaker height-schooling association. In contrast, the sample of high-wealth women may include a higher proportion of children who were exposed to early-life health insults but survived due to greater resource availability. The inclusion of those children in the sample would result in more height variation in schooling outcomes.

A second explanation is that the results are reflective of variations in schooling opportunities. Those in low-wealth environments may have greater difficulty in school access, whether at the primary or secondary level. A lack of access would weaken any sorting mechanism since there is little outcome variation on which to sort. Again, this would be reflected in weaker height-schooling associations.

There are a few caveats to consider in drawing inferences from the results of this paper. In terms of representativeness, certain countries tend to dominate the regional samples. An appendix gives details on the numbers of observations but a general description is offered here. The most severe case is South/SE Asia, where among the seven represented countries, observations from India surveys make up 84.2% of that regional sample. The Latin America sample is represented by ten countries, with most observations (59.7%) coming from Andean countries (Bolivia, Colombia, and Peru) and the remaining observations coming from Central American and Caribbean countries. There is no representation from southern countries in South America. Each African sample has twelve countries, with East Africa a bit more balanced than West Africa. Ethiopia makes up 16.5% of the observations in the East Africa sample and Nigeria makes up 29.1% of the observations in the West African sample. Most other countries generally contribute 4-10% each. In light of these sample distributions, it is important to note that the results of this study reflect regional variations inasmuch as the country distributions in those samples can be generalizable. Further, as to the pooled sample itself, which is intended to allow a robust description of height associations to schooling outcomes in lower- and middle-income countries, its representativeness is limited to the country distributions shown in the appendix.

Secondly, the empirical methods used in this study do not provide for causal interpretations of the associations between height, socioeconomic status, and schooling outcomes. While the results are consistent with the early-life mechanism discussed above, other interpretations cannot be ruled out. One alternate explanation is that the wealth variable does not sufficiently capture relative socioeconomic status and that the associations from height and their interactions with the wealth variable are a result of measurement error. Regional variations in the height and height-wealth associations may be reflections of how socioeconomic status varies in its effect on schooling outcomes, rather than variations in the effects of early-life health and survivability. It may also be the case that some non-health factor related to height, including non-cognitive skills as referenced in the Background section, is driving the associations found in this paper. The DHS data does not have information on more conventional measures of socioeconomic status (parental education or family income) nor any information on skills. This precludes any investigation into these alternate interpretations, but offers direction for future work.

Third, findings of this study may be specific to women. Male-female differences in early-life health outcomes and schooling access may limit the generalizability of this study's findings to male populations. For example, the prevalence of early-life mortality and growth limitation tends to be higher in males, though with some regional variation (Thurstans et al. 2020). Further, while much of the world has attained relative male-female parity in primary and secondary schooling, there remain many countries – particularly in Africa – where females lag males in school attendance (UNICEF 2020). Determining the extent to which the findings of this study are comparable to male populations in similar environments is left to future work.

Finally, the marginal probabilities associated with incremental height in this study are modest, as were the wealth differences in marginal probabilities, amounting to a few percentage-points difference in schooling outcomes over multiple standard deviations in relative height and between extremes of relative wealth. Still, modest marginal improvements in early-life health outcomes may translate into meaningful effects on schooling outcomes for large populations, and consequently on population productivity. The extent to which the results of this study are economically significant depends on the underlying mechanisms of the height-schooling associations and the degree to which any causal mechanisms are malleable to intervention.

Despite these caveats, the results of this study contribute to the existing literature by providing estimates of a height-schooling association in young women from a large number of lower- and middle-income countries. It further adds to existing work by considering differential associations across levels of socioeconomic status. While the height-schooling relationship may be an artifact of the influence from early-life health circumstances, it may also be affected by differences in health and education environments, as suggested by variations across regions and height-wealth interactions within regions. The findings of this study and others should benefit from further exploration of the potential interactions between early-life development, resource environments, and education outcomes.

**Funding.** This research received no specific grant from any funding agency, commercial entity or not-for-profit organization.

**Competing Interests.** The authors have no conflicts of interest to declare.

**Ethical Approval.** The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

## References

**Ahmed A, Kramer MS, Bernard JY, Perez Trejo ME, Martin RM, Oken E and Yang S.** (2020) Early childhood growth trajectory and later cognitive ability: evidence from a large prospective birth cohort of healthy term-born children. *International Journal of Epidemiology* **49**(6), 1998–2009.

**Card D** (1999) The causal effect of education on earnings. In Ashenfelter, OC and Card, D (eds) *Handbook of Labor Economics, Volume 3, Part A*. North-Holland, Amsterdam, pp. 1801–1863.

**Case A and Paxson C** (2008) Stature and status: Height, ability, and labor market outcomes. *Journal of Political Economy* **116**(3), 499–532.

**Champaloux SW and Young DR** (2015) Childhood chronic health conditions and educational attainment: a social ecological approach. *Journal of Adolescent Health* **56**(1), 98–105.

**Cinnirella F, Piopiunik M and Winter J** (2011) Why does height matter for educational attainment? Evidence from German children. *Economics & Human Biology* **9**(4), 407–418.

**Currie J and Vogl T** (2013) Early-life health and adult circumstance in developing countries. NBER Working Paper 18371, National Bureau of Economic Research, Cambridge, MA.

**Cutler DM and Lleras-Muney A** (2012) Education and health: insights from international comparisons. NBER Working Paper 17738, National Bureau of Economic Research, Cambridge, MA.

**Čvorović J** (2020) Stature and education among Roma women: Taller stature is associated with better educational and economic outcomes. *Journal of Biosocial Science* **52**(2), 260–271.

**Deaton A** (2008) Height, health, and inequality: the distribution of adult heights in India. *American Economic Review*, **98**(2) 468–74.

**Dee TS** (2020) Education and civic engagement. In Bradley, S and Green, C (eds) *The Economics of Education (*Second *Edition).* Academic Press, Cambridge, pp. 103–108.

**de Onis MD, Onyango AW, Borghi E, Siyam A, Nishida C and Siekmann J** (2007) Development of a WHO growth reference for school-aged children and adolescents. *Bulletin of the World Health Organization* **85**(9), 660–667.

**Forrest CB, Bevans KB, Riley AW, Crespo R and Louis TA** (2013) Health and school outcomes during children's transition into adolescence. *Journal of Adolescent Health* **52**(2), 186–194.

**Glewwe P and Miguel EA** (2007) The impact of child health and nutrition on education in less developed countries. In Schultz, P and Strauss, JA (eds) *Handbook of Development Economics, Volume 4*. North-Holland, Amsterdam, pp. 3561–3606.

**Golden MHN** (1994) Is complete catch-up possible for stunted malnourished children?. *European journal of clinical nutrition* **48**(1), 58–71.

**Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B** and **International Child Development Steering Group** (2007) Developmental potential in the first 5 years for children in developing countries. *The Lancet* **369**(9555), 60–70.

**Handa S and Peterman A** (2016) Is there catch-up growth? Evidence from three continents. *Oxford Bulletin of Economics and Statistics* **78**(4), 470–500.

**Hanushek EA and Woesmann L** (2010) Education and economic growth. In Brewer, DJ and McEwan, PJ (eds) *Economics of Education*. Elsevier, Amsterdam, pp. 245–252.

**Heinonen K, Raikkonen K, Pesonen AK, Kajantie E, Andersson S, Eriksson JG, Niemelä A, Vartia T, Peltola J and Lano A** (2008) Prenatal and postnatal growth and cognitive abilities at 56 months of age: a longitudinal study of infants born at term. *Pediatrics* **121**(5), e1325–e1333.

**Huang Y, van Poppel F and Lumey LH** (2015) Differences in height by education among 371,105 Dutch military conscripts. *Economics & Human Biology* **17**, 202–207.

**Heckman JJ and Mosso S** (2014) The economics of human development and social mobility. NBER Working Paper 19925, National Bureau of Economic Research, Cambridge, MA.

**ICF International** (2012) Demographic and Health Survey Sampling and Household Listing Manual. MEASURE DHS, Calverton, Maryland, USA: ICF International.

**Jeong J, McCoy DC and Fink G** (2017) Pathways between paternal and maternal education, caregivers' support for learning, and early child development in 44 low-and middle-income countries. *Early Childhood Research Quarterly* **41**, 136–148.

**Kim SW, Cho H and Kim LY** (2019) Socioeconomic status and academic outcomes in developing countries: A meta-analysis. *Review of Educational Research* **89**(6), 875–916.

**Lawlor DA, Batty GD, Morton SM, Deary IJ, Macintyre S, Ronalds G and Leon DA** (2005) Early life predictors of childhood intelligence: evidence from the Aberdeen children of the 1950s study. *Journal of Epidemiology & Community Health* **59**(8), 656–663.

**Leroy JL, Ruel M, Habicht JP and Frongillo EA** (2014) Linear growth deficit continues to accumulate beyond the first 1000 days in low-and middle-income countries: global evidence from 51 national surveys. *The Journal of Nutrition* **144**(9), 1460–1466.

**Lochner L** (2020) Education and crime. In Bradley, S and Green, C (eds) *The Economics of Education (*Second *Edition).* Academic Press, Cambridge, pp. 109–117.

**Magnusson PK, Rasmussen F and Gyllensten UB** (2006) Height at age 18 years is a strong predictor of attained education later in life: cohort study of over 950 000 Swedish men. *International Journal of Epidemiology* **35**(3), 658–663.

**Maurer J** (2010) Height, education and later-life cognition in Latin America and the Caribbean. *Economics & Human Biology*, **8**(2), 168–176.

**McCoy DC, Zuilkowski SS and Fink G** (2015) Poverty, physical stature, and cognitive skills: Mechanisms underlying children's school enrollment in Zambia. *Developmental Psychology* **51**(5), 600.

**Meyer HE and Selmer R** (1999) Income, educational level and body height. *Annals of Human Biology*, **26**(3) 219–227.

**Monk C and Kingdon G** (2010) Health, nutrition and academic achievement: new evidence from India. *Economics Series Working Papers CSAE WPS/2010-14, University of Oxford, Department of Economics.*

**Murasko JE** (2013) Physical growth and cognitive skills in early-life: Evidence from a nationally representative US birth cohort. *Social Science & Medicine* **97**, 267–277.

**Murasko JE** (2019) Sorting by height: education and economic outcomes of women in less-developed countries. *The Journal of Development Studies* **55**(11), 2347–2364.

**Oreopoulos P and Salvanes KG** (2011) Priceless: The nonpecuniary benefits of schooling. *Journal of Economic Perspectives* **25**(1), 159-84.

**Perkins JM, Subramanian SV, Davey Smith G and Özaltin E** (2016) Adult height, nutrition, and population health. *Nutrition Reviews* **74**(3), 149–165.

**Persico N, Postlewaite A and Silverman D** (2004). The effect of adolescent experience on labor market outcomes: The case of height. *Journal of Political Economy* **112**(5), 1019–1053.

**Porter WT** (1897) The physical basis of precocity and dullness. *American Physical Education Review* **2**(3), 155–173.

**Prado EL and Dewey KG** (2014) Nutrition and brain development in early life. *Nutrition Reviews* **72**(4), 267–284.

**Quach J, Nguyen C, O'Connor M and Wake M** (2017) The cumulative effect of health adversities on children's later academic achievement. *Academic Pediatrics* **17**(7), 706–714.

**Rutstein SO and Johnson K** (2004) The DHS Wealth Index. DHS Comparative Reports No. 6. Calverton, Maryland: ORC Macro.

**Rutstein SO and Rojas G** (2006) *Guide to DHS statistics*. Calverton, Maryland, USA: ORC Macro.

**Schick A and Steckel RH** (2015) Height, human capital, and earnings: The contributions of cognitive and noncognitive ability. *Journal of Human Capital* **9**(1), 94–115.

**Scholder SVHK, Smith GD, Lawlor DA, Propper C and Windmeijer F** (2013) Child height, health and human capital: evidence using genetic markers. *European Economic Review* **57**, 1–22.

**Spears D** (2012) Height and cognitive achievement among Indian children. *Economics & Human Biology* **10**(2), 210–219.

**Sudfeld CR, Charles McCoy D, Danaei G, Fink G, Ezzati M, Andrews KG and Fawzi WW** (2015) Linear growth and child development in low-and middle-income countries: a meta-analysis. *Pediatrics* **135**(5), e1266–e1275.

**Thurstans S, Opondo C, Seal A, Wells J, Khara T, Dolan C, Briend A, Myatt M, Garenne M, Sear R and Kerac M** (2020) Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. *BMJ Global Health* **5**(12), e004030.

**United Nations International Children's Emergency Fund (UNICEF)** (2020) Gender and education. Accessed July 5, 2022. https://data.unicef.org/topic/gender/gender-disparities-in-education/

**Victora CG, Adair L, Fall C, Hallal PC, Martorell R, Richter L and Sachdev HS** (2008) Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet* **371**(9609), 340–357.

**Vogl TS** (2014) Height, skills, and labor market outcomes in Mexico. *Journal of Development Economics* **107**, 84–96.

**Walker SP, Wachs TD, Grantham-McGregor S, Black MM, Nelson CA, Huffman SL, Baker-Henningham H, Chang SM, Hamadani JD, Lozoff B, Meeks Gardner JM, Powell CA, Rahman A and Richter L** (2011) Inequality in early childhood: risk and protective factors for early child development. *The Lancet* **378**(9799), 1325–1338.

**Yang S, Tilling K, Martin R, Davies N, Ben-Shlomo Y and Kramer MS** (2011) Pre-natal and post-natal growth trajectories and childhood cognitive ability and mental health. *International Journal of Epidemiology* **40**(5), 1215–1226.

## APPENDIX: List of Country Surveys and Sample Sizes

| Region/Country | Survey Years | N |
|---|---|---|
| East Africa | | |
| Burundi (BU) | 2010-11, 2016-17 | 2,638 |
| Ethiopia (ET) | 1992, 1997, 2003, 2008 | 10,297 |
| Kenya (KE) | 1993, 1998, 2003, 2008-09, 2014 | 5,359 |
| Comoros (KM) | 1996, 2012 | 1,057 |
| Madagascar (MD) | 1997, 2003-04, 2008-09 | 3,107 |
| Malawi (MW) | 1992, 2000, 2004, 2010, 2015-16 | 7,135 |
| Mozambique (MZ) | 1997, 2003, 2011 | 4,809 |
| Rwanda (RW) | 2000, 2005, 2010, 2014-15 | 5,755 |
| Tanzania (TZ) | 1991-1992, 1996, 2004-05, 2010, 2015-16 | 6,434 |
| Uganda (UG) | 1995, 2000-01, 2006, 2011, 2016 | 3,695 |
| Zambia (ZM) | 1992, 1996, 2001-02, 2007, 2013-14 | 6,148 |
| Zimbabwe (ZW) | 1995, 1999, 2005-06, 2010-11, 2015 | 6,142 |
| West Africa | | |
| Burkina Faso (BF) | 1993, 1998-99, 2003, 2010 | 3,911 |
| Benin (BJ) | 1996, 2001, 2006, 2011-12, 2017-18 | 7,209 |
| Cote d'Ivoire (CI) | 1994, 1998-99, 2011-12 | 1,786 |
| Ghana (GH) | 1993, 1998, 2003, 2008, 2014 | 2,580 |
| Liberia (LB) | 2007, 2013, 2019-20 | 1,776 |
| Guinea (GN) | 1999, 2005, 2012, 2018 | 1,898 |

(*Continued*)

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

(Continued)

| Region/Country | Survey Years | N |
|---|---|---|
| Mali (ML) | 1995-1996, 2001, 2006, 2012-13, 2018 | 5,820 |
| Niger (NI) | 1998, 2006, 2012 | 2,248 |
| Nigeria (NG) | 2003, 2008, 2013, 2018 | 13,323 |
| Sierra Leone (SL) | 2008, 2013, 2019 | 2,002 |
| Senegal (SN) | 2005, 2010-11, 2015-16 | 2,358 |
| Togo (TG) | 1998, 2013-14 | 901 |
| Central/South Africa | | |
| Cameroon (CM) | 1998, 2004, 2011, 2018-19 | 2,721 |
| Central African Republic (CF) | 1994-95 | 218 |
| Chad (TD) | 1996-97, 2004, 2014-15 | 2,746 |
| Congo (CG) | 2005, 2011-12 | 2,158 |
| Congo Democratic Republic (CD) | 2007, 2013-14 | 2,385 |
| Gabon (GA) | 2000, 2012 | 1,310 |
| Lesotho (LS) | 2004, 2009, 2014 | 2,136 |
| Namibia (NM) | 1992, 2006-07, 2013 | 2,555 |
| Sao Tome and Principe (ST) | 2008-2009 | 432 |
| South Africa (ZA) | 2016 | 469 |
| Swaziland (SZ) | 2006-07 | 1,000 |
| Northern Africa/West Asia/Europe | | |
| Albania (AL) | 2008-09, 2017-18 | 2,651 |
| Armenia (AM) | 2000, 2005, 2015-16 | 2,357 |
| Azerbaijan (AZ) | 2006 | 1,169 |
| Egypt (EG) | 1992, 1995, 2000, 2005, 2008, 2014 | 2,129 |
| Jordan (JO) | 1997, 2002, 2007, 2012, 2017-18 | 497 |
| Moldova (MB) | 2005 | 1,121 |
| Morocco (MA) | 1992, 2003-04 | 2,749 |
| Turkey (TR) | 1993, 1998, 2003, 2013 | 1,456 |
| Central Asia | | |
| Kazakhstan (KK) | 1995, 1999 | 816 |
| Kyrgyz Republic (KY) | 1997, 2012 | 1,913 |
| Tajikistan (TJ) | 2012, 2017 | 3,096 |
| Uzbekistan (UZ) | 1996 | 767 |
| South/Southeast Asia | | |
| Bangladesh (BD) | 1996-97, 1999-00, 2004, 2007, 2011, 2014, 2017-18 | 5,994 |
| Cambodia (KH) | 2000, 2005-06, 2010-11, 2014 | 6,046 |
| India (IA) | 1998-99, 2005-06, 2015-16 | 123,695 |
| Maldives (MV) | 2009, 2016-17 | 784 |

(Continued)

https://doi.org/10.1017/S0021932022000438 Published online by Cambridge University Press

(*Continued*)

| Region/Country | Survey Years | N |
|---|---|---|
| Nepal (NP) | 1996, 2001, 2006, 2011, 2016 | 5,007 |
| Pakistan (PK) | 2012-13, 2017-18 | 297 |
| Timor-Leste (TL) | 2009-10, 2016 | 5,165 |
| Latin America and the Caribbean | | |
| Bolivia (BO) | 1994, 1998, 2003, 2008 | 6,295 |
| Brazil (BR) | 1996 | 229 |
| Colombia (CO) | 1995, 2000, 2005, 2010 | 13,074 |
| Dominican Republic (DR) | 1991, 1996, 2013 | 3,364 |
| Guatemala (GU) | 1995, 1998-99, 2014-15 | 4,941 |
| Guyana (GY) | 2009 | 747 |
| Haiti (HT) | 1994-95, 2000, 2005-06, 2012, 2016-17 | 6,863 |
| Honduras (HN) | 2005-06, 2011-12 | 7,898 |
| Nicaragua (NC) | 1998, 2001 | 5,147 |
| Peru (PE) | 1991-92, 1996, 2000, 2004-06, 2007-08, 2009, 2010, 2011, 2012 | 23,940 |
| Total | | 366,725 |

**Cite this article:** Murasko J (2023). Height, wealth, and schooling outcomes in young women from lower- and middle-income countries. *Journal of Biosocial Science* **55**, 873–892. https://doi.org/10.1017/S0021932022000438