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Association of Maternal Stature With Offspring Mortality, Underweight, and Stunting in Low- to Middle-Income Countries

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Abstract

Context—Although maternal stature has been associated with offspring mortality and health, the extent to which this association is universal across developing countries is unclear.

Objective—To examine the association between maternal stature and offspring mortality, underweight, stunting, and wasting in infancy and early childhood in 54 low- to middle-income countries.

Design, Setting, and Participants—Analysis of 109 Demographic and Health Surveys in 54 countries conducted between 1991 and 2008. Study population consisted of a nationally representative cross-sectional sample of children aged 0 to 59 months born to mothers aged 15 to 49 years. Sample sizes were 2 661 519 (mortality), 587 096 (underweight), 558 347 (stunting), and 568 609 (wasting) children.

Main Outcome Measures—Likelihood of mortality, underweight, stunting, or wasting in children younger than 5 years.

Results—The mean response rate across surveys in the mortality data set was 92.8%. In adjusted models, a 1-cm increase in maternal height was associated with a decreased risk of child mortality (absolute risk difference [ARD], 0.0014; relative risk [RR], 0.988; 95% confidence interval [CI], 0.987–0.988), underweight (ARD, 0.0068; RR, 0.968; 95% CI, 0.968–0.969), stunting (ARD, 0.0126; RR, 0.968; 95% CI, 0.967–0.968), and wasting (ARD, 0.0005; RR, 0.994; 95% CI, 0.993–

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Analysis and interpretation of data: Özaltın, Hill, Subramanian.

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0.995). Absolute risk of dying among children born to the tallest mothers (≥ 160 cm) was 0.073 (95% CI, 0.072–0.074) and to those born to the shortest mothers (< 145 cm) was 0.128 (95% CI, 0.126–0.130). Country-specific decrease in the risk for child mortality associated with a 1-cm increase in maternal height varied between 0.978 and 1.011, with the decreased risk being statistically significant in 46 of 54 countries (85%) ($\alpha = .05$).

Conclusion—Among 54 low- to middle-income countries, maternal stature was inversely associated with offspring mortality, underweight, and stunting in infancy and childhood.

Maternal stature is an important determinant of intrauterine growth restriction¹ and low birth weight,² birth weight and intrauterine growth restriction are predictors of subsequent mortality and growth failure.³ Because attained height reflects the health stock accumulated through social and environmental exposures during early childhood,^{4,5} maternal stature is a simple, stable, and useful marker for assessing intergenerational linkages in health. Maternal stature has been shown to predict offspring outcomes before or immediately after birth.⁶ However, evidence for whether risks associated with shorter maternal stature have a lasting influence on the offspring's health during infancy and childhood is limited, or is restricted to small nonrepresentative samples, and inconclusive. In a large, nationally representative data set from India, an inverse association between maternal stature and both child mortality and growth failure was observed.⁷ It remains unclear the extent to which this association is present across a wider range of countries. Using the largest available, nationally representative, and comparable sample from 109 surveys in 54 low- to middle-income countries, with objective measurements of maternal stature and offspring anthropometry, we investigated the potential long-term effects of maternal stature on offspring mortality, underweight, stunting, and wasting in infancy and early childhood.

METHODS

Data Sources

Data for this study came from 109 Demographic and Health Surveys (DHS) conducted in 54 low-to middle-income countries between 1991 and 2008 (Table 1).⁸ The DHS are nationally representative household sample surveys measuring indicators of population, health, and nutrition, with special emphasis on maternal and child health.⁹ The target population in most DHS surveys was all women (or in some cases ever-married women) of reproductive age (15–49 years). A complete birth and death history was collected for each eligible woman's children, including date of birth and when applicable age at death of each child. Anthropometric measurements on children were restricted to children born 5 years or less before the survey and alive at the time of the survey.⁹ Trained investigators weighed each child with a solar-powered scale accurate to within 100 g; maternal and child height were measured using an adjustable board calibrated in millimeters and theoretically accurate to 1 mm.¹⁰

Due to coverage, comparability, and data quality, DHS is the primary reliable data source for measuring child mortality and undernutrition across developing countries.^{11–13} The DHS uses extensive interviewer training, standardized measurement tools and techniques, an identical core questionnaire, and instrument pretesting to ensure standardization and comparability across diverse sites and time.¹⁰ Teams responsible for data collection are monitored during fieldwork, including spot-checking and validation of completed questionnaires.¹⁰ Country reports detail pretesting and quality assurance measures by survey (see http://www.measuredhs.com/pubs/browse_type.cfm). The DHS is modular in structure, comprising a core questionnaire, a set of country-relevant modules, and country-specific variables. The DHS provides data with standardized variables across surveys and imputed dates of key events (see <http://www.measuredhs.com/pubs/pdf/DHSG4/Recode4DHS.pdf>).

The DHS uses a multistage stratified design with probabilistic sampling with each elementary unit having a defined probability of selection.¹⁴ Every survey was stratified by urban and rural status and additionally by country-specific geographic or administrative regions. eTable 1 (available at <http://www.jama.com>) describes each survey by country and year, along with sampling characteristics, response rates, and sample sizes. Detailed sampling plans are available from survey final reports at http://www.measuredhs.com/pubs/browse_type.cfm.

Study Population and Sample Size

For the pooled mortality analysis, the study population consisted of all children (n=3 395 212) born to mothers (n = 939 140) aged 15 to 49 years (eTable 2). There were 635 709 children (19%) whose mother's height was intentionally not measured (eTable 1 shows height measurement protocol by survey). Among children whose mother's height should have been measured, 92 839 (3%) did not have a height measure in the data; these cases were excluded. We also excluded children whose mothers had recorded heights of less than 100 cm or more than 200 cm, as these were considered improbable or outliers. Furthermore, children who had missing information on the covariates included in this analysis (n = 5145, <1%) were excluded. The final analytical sample for the mortality analysis was 2 661 519 children born to 751 912 mothers surveyed between 1991 and 2008 in 54 low- to middle-income countries (eTable 2).

For the anthropometric analysis, the study population comprised children (n=829 680) born 3 to 5 years preceding the survey to mothers (n=342 229) aged 15 to 49 years and alive at the time of the survey (eTable 3). There were 71 155 children (9% of the children sample) for whom maternal height was intentionally not measured. Among children whose mother's height should have been measured, 23 677 (3%) did not have a height measure in the data and an additional 59 941 (8%) were missing data on covariates. In addition, 116 560 children (15%) had missing or biologically implausible height, 87 811 children (12%) had missing or biologically implausible weight, and 106 298 children (14%) had missing or biologically implausible weight for height. The World Health Organization (WHO) cutoffs for biological implausibility were used (eTable 3).¹⁵ The final analytical samples for the anthropometric analysis were 587 096 children born to 247 279 mothers for underweight, 558 347 children born to 234 604 mothers for stunting, and 568 609 children born to 239 628 mothers for wasting surveyed between 1991 and 2008 in 54 low- to middle-income countries (eTable 3).

Outcomes, Exposure, and Covariates

Offspring mortality was a binary variable; 1 if the child died between 0 to 59 months and 0 otherwise. Mortality by age categories was also assessed (<1 month [neonates], 1–11 months [infants], and 12–59 months [children]). Each variable was binary; 1 if the child died during that age interval and 0 otherwise. The risk set was all children alive at the beginning of the interval and the event was death during the interval.

Growth failure was defined as underweight, stunting, or wasting.³ Underweight z scores were calculated by subtracting from a child's weight the median weight for a child of that age and sex and dividing by the SD of the weight for a child of that age and sex in the WHO reference population¹⁵; stunting was measured by subtracting from a child's height the median height for a child of that age and sex and dividing by the SD of the height for a child of that age and sex in the WHO reference population¹⁵; and wasting was measured by subtracting from a child's weight the median weight for a child of that height and sex and dividing by the SD of the weight for a child of that height and sex in the WHO reference population¹⁵ (see <http://www.who.int/childgrowth/standards/en/>). Software used for z score

calculations is available at <http://www.who.int/childgrowth/software/en/>. Growth failure was defined as more than 2 SDs under WHO-growth standards¹⁵ on each dimension separately. We also calculated severe growth failure, defined as more than 3 SDs under WHO-growth standards.¹⁵

Maternal height was specified as a continuous and a categorical exposure with the following cutpoints: less than 145 cm, 145 to 149.9 cm, 150 to 154.9 cm, 155 to 159.9 cm, and 160.0 cm or more.

Sex, birth order, birth interval, birth year, and twin status of the child; mother's age at birth of the child, education, occupation, and marital status; and household wealth and urban or rural residence were included as covariates (Table 2). Household wealth was defined in terms of ownership of material possessions,¹⁶ with each child assigned a wealth score based on a combination of different household characteristics that were weighted according to a factor analysis procedure. For this procedure, *z* scores were calculated for each indicator variable and a principal components analysis was performed using these *z* scores. For each household, the values of the indicator variables were multiplied by the factor loadings and summed to produce a standardized household index value with a mean of 0 and an SD of 1. This standardized score was then divided into quintiles for each country.^{17,18} In addition, we also derived an overall wealth quintile that was comparable across countries, based on assets common across surveys, which included whether the household had electricity, radio, or bicycle, and by major source of drinking water. We conducted a factor analysis on these 5 assets, using principal components analysis, and derived overall wealth quintiles.

Analysis

Individual country files were created, combining multiple survey years, ensuring consistency of variable definitions across various survey years as well as consistency of region and primary sampling unit identifiers. These individual files were concatenated for the pooled analysis. Because prevalence of outcomes were more than 10%, we used a modified Poisson approach with robust error variance to model the binary outcomes associated with mortality and growth failure.¹⁹ We also estimated stratified models for neonates (<1 month), infants (1–11 months), and children (12–59 months) after testing for an interaction between maternal height and child's age. We also conducted an analysis by child age for the anthropometric analysis. Results are presented as change in risks (relative to 1) for a 1-cm change in maternal height and, when maternal height is specified as categories, we report both the relative risks (RRs) and absolute probabilities. Absolute risk differences were calculated by fitting a normal model with an identity link.²⁰ We also provided the absolute risk differences for maternal height categories calculated as differences in the absolute probabilities between the different maternal height categories compared with mothers in the tallest category. We accounted for clustering of children by mothers and primary sampling units in all analyses and included country and birth year fixed effects in pooled analyses. Country heterogeneity in the association between maternal stature and offspring outcomes were tested using Wald tests. Models were estimated by using STATA version 10SE.²¹ Statistical precision was ascertained by using 2-tailed Wald tests and exact *P* values, except when *P*<.05 are reported. Several ex-Soviet Republics had small numbers of respondents and events in the lowest education categories. For mortality analysis, education was not included for Kyrgyz Republic and education was included as a continuous variable in growth failure analysis for Kyrgyz Republic, Kazakhstan, Uzbekistan, and Moldova.

We conducted the following sensitivity analyses. First, to test for nonlinearity in the effect of maternal height and the appropriateness of the height categories, we conducted analyses with alternate categorizations of height. The analyses were also repeated removing the

extreme (top and bottom 1%) outliers of maternal height. Second, in some populations with very early child-bearing, height could be affected by childbearing, which itself is associated with higher mortality risks. We conducted analysis restricted to women who had their first child after the age of 20 years. Third, because several of the study covariates were measured contemporaneously, a reduced form model, including only variables likely to be determined before the outcome (ie, age of mother at birth, education, and year-born), was estimated. Fourth, we estimated the pooled model without India, which comprised 15.4% of the total sample size, and where an association between maternal height and offspring mortality and growth failure has been shown.⁷ Fifth, given issues related to relative vs absolute wealth, we estimated pooled models with and without the global wealth index. Sixth, to test for recall bias in mortality, we conducted analysis restricted to births in the last 5 years preceding the survey. Seventh, because the survey period varies between 1991 and 2008, we tested if the main results hold in a restricted sample of countries surveyed after 2000. In addition, we compared prevalence of mortality, underweight, stunting, and wasting among women who did and did not report height, as well as comparing maternal heights among children who did and did not report child anthropometric measures as sensitivity tests for missing information.

Ethical Review

The DHS data collection procedures were approved by the ORC Macro (Calverton, Maryland) institutional review board as well as by the relevant body in each country that approves research studies on human subjects. Oral informed consent for the interview or survey was obtained from respondents by interviewers. This analysis was reviewed by the Harvard School of Public Health Institutional Review Board and was considered exempt from full review because the study was based on an anonymous public use data set with no identifiable information on the survey participants.

RESULTS

Mortality

The mean response rate across surveys in the mortality data set was 92.8%, ranging from 75.1% in Brazil (1996) to 98.8% in Egypt (2008) (eTable 1). The sample size was 2 661 519 for child mortality analysis, ranging from 3770 children in Comoros to 482 378 children in India (Table 1). Of 2 661 519 children in the data set, 312 553 died between the ages of 0 to 59 months, with a mortality prevalence of 11.7% (95% confidence interval [CI], 11.7%-11.8%) (Table 1). The prevalence of child mortality varied between 3.3% (Jordan) and 24.7% (Niger). Results are reported by country in an interactive information graphic (see <http://www.jama.com>). The covariate distribution across categories of maternal height was largely overlapping (eTable 4), although there were imbalances for location (70.4% rural for <145 cm vs 64.3% for >160 cm), local wealth quintile (31.9% in poorest quintile for <145 cm vs 20.4% for >160 cm), twin (1.3% prevalence of twins for <145 cm vs 3.0% for >160 cm), occupation (55.0% working for <145 cm vs 64.3% for >160 cm), and education (14.8% secondary or higher education for <145 cm vs 25.1% for >160 cm).

In the pooled analysis, a 1-cm increase in maternal height was associated with a decreased risk in offspring mortality in unadjusted(RR,0.983;95%CI,0.982–0.984)and adjusted(RR, 0.988;95%CI, 0.987–0.988) models (Table 3). In adjusted models, compared with the tallest mothers (≥ 160 cm), each lower height category had substantially higher risk of child mortality, with children born to mothers of height shorter than 145 cm having an increased RR of 1.397(95% CI,1.373–1.422). The absolute probability of dying among children born to the tallest mothers (≥ 160 cm) was 0.073 (95% CI,0.072–0.074)and among those children born to the shortest mothers (<145 cm), absolute probability was 0.128 (95% CI, 0.126–

0.130). The association between maternal height and offspring mortality was strongest among neonates (RR, 0.982; 95% CI, 0.981–0.983), followed by infants aged 1 to 11 months (RR, 0.988; 95% CI, 0.987–0.989) and weakest for children aged 12 to 59 months (RR, 0.990; 95% CI, 0.989–0.992).

Country-specific risk of mortality by age 5 years for a 1-cm increase in maternal height ranged between 0.978 (95% CI, 0.964–0.992) for Kyrgyz Republic and 1.011 (95% CI, 0.996–1.026; $P=.14$) for Comoros. Mortality risk associated with increased height was decreased in 52 of 54 countries (96%) (ie, <1) and was statistically significant in 46 of those 54 countries (85%) ($\alpha=.05$) (Figure 1). A joint Wald test of country-specific coefficients rejected the null hypothesis of equivalence, suggesting heterogeneity in the strength of the association between maternal height and offspring mortality across countries ($\chi^2=165.37$, $P<.001$) (eTable 5). The association between maternal height and offspring mortality remained among country groupings based on the World Bank income classification and WHO geographic regions (Figure 2).

Growth Failure

The sample size for the anthropometric analysis was 587 096, 558 347, and 568 609 children for underweight, stunting, and wasting, respectively; with sample sizes varying from 944 to 68 597 children for underweight, 897 to 64 028 children for stunting, and 924 to 65 487 children for wasting, in Comoros and India, respectively (Table 1). Of children in the sample, 21.5% were underweight (95% CI, 21.4%–21.6%), 38.3% were stunted (95% CI, 38.2%–38.5%), and 8.9% had wasting (95% CI, 8.8%–9.0%). The prevalence of underweight varied from 3.4% for Armenia to 44.5% for Bangladesh; stunting from 10.7% for Moldova to 55.2% for Ethiopia; and wasting from 1.3% for Honduras to 19.7% for India (Table 1). Results are reported by country in an interactive information graphic (see <http://www.jama.com>). The covariate distribution across categories of maternal height in the anthropometric data set was largely overlapping across covariates (eTable 6), and the patterns were similar to those reported earlier for the mortality data set.

In pooled adjusted models, a 1-cm increase in height was associated with a decreased risk in underweight (RR, 0.968; 95% CI, 0.968–0.969), stunting (RR, 0.968; 95% CI, 0.967–0.968), and wasting (RR, 0.994; 95% CI, 0.993–0.995) (Table 4). Compared with the tallest mothers (≥ 160 cm), each lower height category had substantially higher risk of offspring underweight and stunting, with the risk being highest for mothers shorter than 145 cm. Analysis stratified by child's age showed no differential effect for underweight and stunting (eTable 7). An association was also observed between maternal height and severe growth failure (eTable 8). The RR for underweight, for a 1-cm increase in height, ranged from 0.930 (95% CI, 0.922–0.939) for Colombia to 0.991 (95% CI, 0.968–1.015; $P=.40$) for Uzbekistan, and was statistically significant in 50 of 54 countries (93%) (eFigure 1). For a 1-cm increase in height, the risk of stunting ranged from 0.926 (95% CI, 0.921–0.931) for Colombia to 0.993 (95% CI, 0.977–1.009; $P=.39$) for Azerbaijan, and was statistically significant in 52 of 54 countries (96%) (eFigure 2). The association between maternal height and wasting was weak and was statistically significant in only 11 of 54 countries (20%) (eFigure 3).

Sensitivity Analysis

We examined if there were substantial differences in the prevalence of mortality, underweight, stunting, and wasting among women who did and did not report maternal height, and observed considerable overlap in the prevalence distribution (eTable 9). No differences were found in maternal height among children who were measured and not measured for height or weight (eTable 10). The main results on mortality and growth failure

appeared to be robust to sensitivity tests that included removing outliers, specifying maternal height in various ways to test for nonlinearity, excluding India from the overall analysis, restricting the analysis to mothers whose first born was after age 20 years, using overall wealth quintile, restricting the analysis to births in the last 5 years, restricting the analysis to surveys conducted after 2000, and to conditioning the association on only exogenous variables (eTable 7 and eTable 11). eTable 12 shows the mutually adjusted association between maternal height, select covariates and child mortality, underweight, stunting, and wasting.

COMMENT

Using large representative samples of children and mothers from 54 low-to middle-income countries, we observed a robust inverse association between maternal height and child mortality, underweight, and stunting. Our finding is suggestive of the importance of early life factors, not only for the subsequent health of a woman (as reflected in her attained stature) but also to her offspring's health, and highlights the long-term effects of mother's poor health stock. The weak association between wasting and maternal height may be because wasting reflects acute growth failure and is more likely to be influenced by contemporaneous factors as opposed to long-term effects of maternal health.

The association of maternal height and offspring health has a biomechanical plausibility (ie, shorter women have narrower pelves that increase the likelihood of cephalopelvic disproportion and obstructed labor)^{22,23} and a biological plausibility (ie, in shorter mothers who may have lower health stock, the supply of nutrients to the fetus may be inadequate, leading to intrauterine growth restriction and low birth weight, which can influence offspring health and survival).²⁴ For mothers, limited nutrient supply at the cellular level during their development may lead to maintenance of basic metabolic functions taking precedence and resources being diverted away from growth, resulting in growth retardation and shortened stature.²⁵ Furthermore, inflammation caused by infections has deleterious long-term health consequences,²⁶ which may be transmitted to offspring. Because attained adult height reflects the stressful nutritional environment of the mother in early life,²⁷ a plausible interpretation of an association between maternal stature and offspring health also reflects the intergenerational transfer of socioeconomic adversity.

Our study relies on DHS data that in general are considered to be of high quality and are often the only source of maternal and child health surveillance in developing countries.²⁸ The comparability of the DHS data across countries and time, achieved through use of standardized questionnaires, manuals, field procedures, and technical support makes these data particularly appropriate for our study.²⁸ Notwithstanding the strengths of the DHS data, recall bias in reporting offspring birth and death histories remains a potential concern.²⁹ Furthermore, clustering of the age at death, particularly at 12 months, was a concern in country samples from sub-Saharan Africa.³⁰ Despite objective measurements, a quality analysis of height data in 81 DHS surveys also showed clustering on whole and half centimeters, with some additional heaping at multiples of 5 and 10 cm.¹³ However, with the exception of Guatemala (1998–1999) and Bolivia (1994), the low levels of missing or implausible heights in almost all DHS surveys are taken as evidence that the quality of the recorded data be considered acceptable.¹³

The study findings should also be interpreted alongside the following caveats. First, the association between maternal height and offspring mortality, underweight, and stunting could arise due to unobserved factors common to both mother and child. Second, data constraints did not allow us to study how maternal height and child health are associated; restricting our assessment to whether there is an association and the extent to which it is

common. Third, because women who may have died in childbirth are not observed, this could potentially lead to sampling bias in that causes of child mortality are linked to causes of maternal mortality with such women having a different covariate profile than those surviving. Fourth, contemporaneously measured covariates do not necessarily reflect the same covariates at the time of death of the child. In addition, although we show effect estimates pooled across countries, the assessment of the presence of an association between maternal height and offspring mortality, underweight, and stunting should be based on the consistency of the association in each country included in this study.

Our findings help resolve the mixed and inconclusive evidence observed in small nonrepresentative samples in a limited set of countries on the association between maternal height and child survival, with some suggesting a protective effect,^{31–35} while others show a null or reverse association.^{36–41} Besides confirming the overall inverse association between maternal stature and child mortality,⁴² our findings show that in more than 90% of the countries studied, children of shorter mothers were more likely to die, with robust association across different categories of country-level income as well as geographic regions. The consistent inverse association (both overall and country-specific) between maternal stature and child underweight and stunting is also novel as previous studies have been restricted to few countries, with small samples, and assessments of maternal stature largely restricted to childhood stunting.^{43–46}

In conclusion, our study provides evidence that shorter maternal stature is a risk factor for offspring mortality, underweight, and stunting in developing countries. Underscoring the policy significance of this association, for child mortality, the effect of being in the lowest height category (relative to the tallest) was approximately 70% and 80% of the size of the effect of having no education or being in the poorest income quintile, respectively. For childhood underweight and stunting, maternal height was the most important factor, with an effect size about twice that of being in the lowest education category and 1.5 times that of being in the poorest quintile. This suggests the presence of an intergenerational transmission from mother's own nutrition, disease, and socioeconomic circumstances during her childhood to her offspring's health and mortality in their infancy and childhood.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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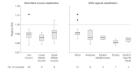
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Figure 1. Country-Specific Adjusted Change in Offspring Mortality Risks for 1-cm Increase in Maternal Height Among Children Younger Than 5 Years
Plotted on log scale; error bars are 95% confidence intervals (CIs). Wald test for equivalence of coefficients rejected ($\chi^2=165.37$, $P<.001$). See eTable 5 for relative risks and CIs by country. Tanzania refers to the United Republic of Tanzania and Guinea refers to the Republic of Guinea. An interactive information graphic is available at <http://www.jama.com>.

**Figure 2.**

Box Plots of Relative Risk for the Association Between 1-cm Increase in Maternal Height and Offspring Mortality Among Children by World Bank Income Classification and WHO Regional Classification of Countries

WHO, World Health Organization; IQR, interquartile range. Plotted on log scale. For World Bank income classification, low income indicates \$975 or less; lower middle income, \$976–\$3855; upper middle income, \$3856–\$11 905 (2008) gross national income per capita.

Boxes indicate first and third quartiles with median lines; whiskers indicate first quartile minus $1.5 \times$ IQR and third quartile + $1.5 \times$ IQR; all values outside the whiskers are shown as filled circles (outliers). An interactive information graphic is available at

<http://www.jama.com>.

Table 1

Sample Size, Weighted Percentage of Child Mortality, Underweight, Stunting, and Wasting by Country^a

Country, Survey Years	Mortality			Underweight			Stunting			Wasting		
	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)
Pooled	2 661 519	312 533 (11.7)	587 096	126 235 (21.5)	558 347	214 120 (38.3)	568 609	50 682 (8.9)				
Armenia, 2000, 2005	20 812	1093 (5.3)	2774	90 (3.4)	2699	437 (17.2)	2722	87 (3.4)				
Azerbaijan, 2006	13 095	949 (7.2)	2032	167 (8.6)	1879	502 (25.8)	1906	116 (6.9)				
Bangladesh, 1999–00, 1996–97, 2004, 2007	87 963	10 689 (12.2)	21 590	9442 (44.5)	20 222	10 109 (50.8)	20 531	3214 (15.9)				
Benin, 1996, 2001, 2006	82 123	12 072 (14.6)	19 889	4247 (21.0)	18 547	7566 (40.6)	18 952	1837 (9.6)				
Bolivia, 1994, 1998, 2003	71 221	8473 (12.0)	18 054	1286 (6.7)	17 525	5975 (32.6)	17 831	425 (2.2)				
Brazil, 1996	9338	663 (6.4)	4161	204 (4.5)	3936	579 (12.7)	3962	106 (2.6)				
Burkina Faso, 1992–93, 1998–99, 2003	72 529	13 310 (19.0)	17 752	5822 (33.2)	16 618	6968 (43.1)	16 836	3058 (18.0)				
Cambodia, 2000, 2005	8709	5140 (12.4)	7282	2594 (34.0)	6892	3285 (45.6)	7034	849 (12.4)				
Cameroon, 1998, 2004	40 376	2659 (13.0)	5010	736 (16.1)	4758	1658 (35.4)	4869	311 (6.9)				
Central African Republic, 1994–95	20 731	1152 (13.3)	2322	537 (22.9)	2224	881 (39.5)	2298	205 (8.9)				
Chad, 1996–97, 2004	33 060	5526 (17.4)	10 226	3365 (33.8)	9687	4140 (44.5)	9885	1624 (16.0)				
Colombia, 1995, 2000, 2005	84 513	3077 (3.5)	20 457	1148 (5.4)	20 244	3483 (17.1)	20 599	346 (1.5)				
Comoros, 1996	3770	426 (11.3)	944	208 (22.0)	897	348 (38.8)	924	101 (10.9)				
Congo (Brazzaville), 2005	15 901	1585 (10.4)	3941	440 (12.0)	3728	1049 (29.7)	3793	273 (7.3)				
Congo (DRC), 2007	13 975	2021 (14.1)	3545	863 (24.9)	3121	1392 (44.2)	3178	306 (9.8)				
Côte d'Ivoire, 1994, 1998–99	20 504	2769 (14.2)	4905	935 (19.9)	4753	1436 (31.4)	4878	464 (9.7)				
Dominican Republic, 1996	17 854	1333 (7.2)	3701	224 (4.8)	3614	582 (13.8)	3646	82 (2.0)				

Country, Survey Years	Mortality		Underweight		Stunting		Wasting	
	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)
Egypt, 2000, 2005, 2008	161 282	13 251 (7.9)	33 440	1848 (5.3)	31 210	7808 (24.0)	31 718	1507 (4.8)
Ethiopia, 2000, 2005	61 055	10 819 (17.7)	13 043	4912 (39.5)	12 286	6340 (55.2)	12 511	1678 (12.4)
Gabon, 2000	9965	727 (7.3)	3407	348 (8.8)	3332	971 (25.7)	3414	137 (4.1)
Ghana, 1998, 2003, 2008	34 260	3901 (10.6)	8399	1596 (18.1)	7964	2624 (31.9)	8103	747 (8.9)
Guatemala, 1995, 1998–99	35 632	3222 (8.3)	12 414	2885 (21.2)	11 979	7247 (54.4)	12 188	441 (3.5)
Guinea, 1999, 2005	28 154	5396 (19.2)	7070	1501 (21.5)	6749	2414 (35.9)	6761	688 (10.5)
Haiti, 1994–95, 2000, 2005–06	45 839	6170 (13.8)	10 795	1946 (17.5)	10 509	3218 (30.0)	10 705	778 (7.5)
Honduras, 2005	48 181	2485 (4.9)	9095	952 (8.5)	8977	3207 (29.9)	9119	128 (1.3)
India, 1998–99, 2005–06	482 378	46 624 (10.7)	68 597	26 810 (43.7)	64 028	29 173 (49.0)	65 487	11 844 (19.7)
Jordan, 1997, 2002, 2007	60 789	2122 (3.3)	15 130	826 (4.5)	14 509	1914 (11.9)	14 732	577 (3.6)
Kazakhstan, 1995, 1999	10 421	635 (6.2)	1302	72 (5.6)	1268	220 (15.3)	1294	61 (4.9)
Kenya, 1993, 1998, 2003	49 232	4804 (9.8)	14 345	2634 (18.2)	13 605	5086 (37.8)	13 858	943 (6.5)
Kyrgyz Republic, 1997	8528	721 (8.9)	960	78 (8.2)	937	297 (32.4)	964	36 (3.2)
Lesotho, 2004	7158	671 (9.0)	1429	265 (17.8)	1323	586 (42.8)	1342	67 (4.9)
Liberia, 2007	21 116	3461 (17.2)	4378	836 (18.7)	4164	1598 (38.4)	4259	312 (7.5)
Madagascar, 1997, 2003–04	31 690	3697 (12.5)	7547	2520 (35.8)	7158	3674 (53.9)	7354	904 (13.0)
Malawi, 1992, 2000, 2004	83 720	15 349 (18.8)	21 403	4094 (20.5)	19 751	10 260 (53.3)	20 135	1194 (6.3)
Mali, 1995–96, 2001, 2006	117 084	25 751 (22.4)	25 449	7876 (30.7)	24 113	9554 (39.4)	24 494	4095 (16.5)
Moldova, 2005	9629	320 (3.4)	1352	43 (3.4)	1271	136 (10.7)	1284	61 (4.6)
Morocco, 2003–04	31 854	2644 (8.1)	5544	596 (10.0)	5233	1178 (21.9)	5297	548 (10.0)

Country, Survey Years	Mortality		Underweight		Stunting		Wasting	
	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)	Sample Size	No. (Weighted %)
Mozambique, 1997, 2003	47 010	8227 (18.4)	11 401	2475 (23.5)	10 949	4996 (46.5)	11 196	721 (7.1)
Namibia, 1992, 2006–07	27 742	2030 (7.1)	6306	1225 (19.4)	6135	1964 (31.7)	6134	508 (8.2)
Nepal, 1996, 2001, 2006	67 641	9068 (13.1)	15 202	6185 (41.2)	14 692	8068 (54.7)	15 029	1848 (12.6)
Nicaragua, 1997–98, 2001	66 125	4621 (6.8)	12 826	1199 (9.4)	12 239	3619 (27.9)	12 425	312 (2.6)
Niger, 1998, 2006	34 424	7691 (24.7)	7628	2998 (42.5)	7280	3484 (51.2)	7516	1386 (19.3)
Nigeria, 2003	21 764	4243 (20.5)	4609	1228 (27.0)	4232	1766 (43.0)	4319	473 (11.3)
Peru, 1992, 1996, 2000, 2004	136 166	12 555 (8.4)	36 181	2712 (6.2)	35 225	12 611 (32.3)	35 730	599 (1.4)
Rwanda, 2000, 2005	41 957	6980 (16.9)	9791	1826 (19.0)	9420	4509 (49.1)	9582	638 (6.8)
Senegal, 2005	12 131	1619 (12.9)	2810	420 (14.1)	2749	587 (20.2)	2797	248 (8.4)
Swaziland, 2006	10 853	911 (8.2)	2032	109 (5.6)	1960	524 (27.4)	1994	48 (2.4)
Tanzania, 1996, 2004–05	46 306	5890 (13.0)	12 532	2686 (20.9)	12 123	5540 (46.1)	12 345	755 (5.6)
Togo, 1998	14 506	2068 (13.9)	3645	906 (23.4)	3490	1134 (31.0)	3608	530 (13.8)
Turkey, 1993, 1998, 2003	24 143	1932 (8.0)	10 118	630 (6.2)	9719	1895 (18.9)	9871	238 (2.5)
Uganda, 1995, 2000–01, 2006	46 219	6604 (14.7)	12 070	2225 (19.5)	11 632	4893 (43.7)	11 898	692 (6.0)
Uzbekistan, 1996	9397	551 (5.6)	1049	144 (15.0)	916	300 (34.2)	939	104 (12.3)
Zambia, 1996, 2001–02, 2007	61 335	9065 (14.8)	16 314	3210 (19.2)	15 568	7696 (49.1)	15 887	872 (5.4)
Zimbabwe, 1994, 1999, 2005–06	39 359	2771 (7.0)	8898	1111 (12.2)	8308	2639 (31.5)	8476	560 (6.5)

^aTanzania refers to the United Republic of Tanzania and Guinea refers to the Republic of Guinea.

Table 2

Frequency and Percentage Distribution of Child Mortality, Underweight, Stunting, and Wasting by Maternal, Child, and Household Covariates

Covariates	No. (%) of Participants			
	Mortality (n = 2 661 519)	Underweight (n = 587 096)	Stunting (n = 558 347)	Wasting (n = 568 609)
	Maternal			
Height, cm (continuous) ^a	156 (7.2)	156 (7.2)	156 (7.2)	156 (7.2)
≥160	715 535 (26.9)	165 204 (28.1)	156 769 (28.1)	159 329 (28.0)
155–159.9	687 642 (25.8)	154 596 (26.3)	147 145 (26.4)	149 809 (26.4)
150–154.9	673 568 (25.3)	145 513 (24.8)	138 793 (24.9)	141 488 (24.9)
145–149.9	413 693 (15.5)	86 152 (14.7)	81 958 (14.7)	83 554 (14.7)
<145	171 081 (6.4)	35 631 (6.1)	33 682 (6.0)	34 429 (6.1)
Age at birth, y				
<17	142 278 (5.4)	18 298 (3.1)	17 313 (3.1)	17 598 (3.1)
17–19	459 614 (17.3)	77 784 (13.3)	73 910 (13.2)	75 287 (13.2)
20–24	920 332 (34.6)	178 853 (30.5)	170 068 (30.5)	173 275 (30.5)
25–29	631 531 (23.7)	145 305 (24.8)	138 218 (24.8)	140 769 (24.8)
≥30	507 764 (19.1)	166 856 (28.4)	158 838 (28.5)	161 680 (28.4)
Occupation				
Not working	1 060 981 (39.9)	254 963 (43.4)	241 091 (43.2)	245 702 (43.2)
Working	1 600 538 (60.1)	332 133 (56.6)	317 256 (56.8)	322 907 (56.8)
Marital status				
Unmarried	277 426 (10.4)	48 564 (8.3)	46 569 (8.3)	47 479 (8.4)
Married	2 383 957 (89.6)	538 532 (91.7)	511 778 (91.7)	521 130 (91.7)
Education				
None	1 210 905 (45.5)	222 711 (37.9)	210 012 (37.6)	213 951 (37.6)
Primary	826 169 (31.0)	195 808 (33.4)	187 303 (33.6)	190 684 (33.5)
Secondary or higher	624 445 (23.5)	168 577 (28.7)	161 032 (28.8)	163 974 (28.8)
	Child			
Birth order				
First	711 464 (26.7)	140 849 (24.0)	133 852 (24.0)	136 375 (24.0)
Second	598 027 (22.5)	124 371 (21.2)	118 356 (21.2)	120 423 (21.2)

Covariates	No. (%) of Participants			
	Mortality (n = 2 661 519)	Underweight (n = 587 096)	Stunting (n = 558 347)	Wasting (n = 568 609)
Third	444 918 (16.7)	93 834 (16.0)	89 288 (16.0)	90 990 (16.0)
Fourth	311 953 (11.7)	68 186 (11.6)	64 843 (11.6)	66 052 (11.6)
≥Fifth	595 157 (22.4)	159 856 (27.2)	152 008 (27.2)	154 769 (27.2)
Birth interval, mo				
First child	711 464 (26.7)	140 849 (24.0)	133 852 (24.0)	136 375 (24.0)
<24	620 528 (23.3)	93 492 (15.9)	89 025 (16.0)	90 442 (15.9)
24–47	1 010 360 (38.0)	244 749 (41.7)	232 686 (41.7)	237 041 (41.7)
≥48	318 600 (12.0)	107 879 (18.4)	102 663 (18.4)	104 630 (18.4)
Sex				
Male	1 359 296 (51.1)	297 401 (50.7)	282 643 (50.6)	288 102 (50.7)
Female	1 302 223 (48.9)	289 695 (49.3)	275 704 (49.4)	280 507 (49.3)
Twin				
Not twin	2 602 444 (97.8)	575 164 (98.0)	547 150 (98.0)	557 160 (98.0)
Twin	59 075 (2.2)	11 932 (2.0)	11 197 (2.0)	11 449 (2.0)
Age category, mo				
<1	112 930 (4.3)	3443 (0.6)	3512 (0.6)	5800 (1.0)
1–12	240 838 (9.1)	124 139 (21.8)	113 721 (20.4)	122 105 (20.8)
>12	2 285 369 (86.9)	441 027 (77.6)	441 114 (79.0)	459 191 (78.2)
Age, mo ^a	22 (17.7)	28 (16.9)	28 (16.9)	28 (16.8)
Household				
Wealth quintile, within country				
First, poorest	620 912 (23.3)	140 794 (24.0)	133 539 (23.9)	136 085 (23.9)
Second	566 230 (21.3)	125 884 (21.4)	119 808 (21.5)	121 941 (21.5)
Third	538 283 (20.2)	118 173 (20.1)	112 369 (20.1)	114 475 (20.1)
Fourth	498 194 (18.7)	108 144 (18.4)	103 069 (18.5)	104 962 (18.5)
Fifth, richest	437 900 (16.5)	94 101 (16.0)	89 562 (16.0)	91 146 (16.0)
Location				
Urban	911 435 (34.2)	204 156 (34.8)	195 229 (35.0)	198 620 (34.9)
Rural	1 750 084 (65.8)	382 940 (65.2)	363 118 (65.0)	369 989 (65.1)

^aContinuous height and child age are reported as mean (SD).

Overall and Age-Stratified Unadjusted and Adjusted Changes in Risk, RR, AP, and DAP by Maternal Height for Offspring Mortality Among Children Younger Than 5 Years^d

Table 3

	No. of Events	Unadjusted			Adjusted		
		RR (95% CI) ^b	AP (95% CI)	DAP	RR (95% CI) ^b	AP (95% CI)	DAP
Mortality, 0–59 mo							
Maternal height ^c		0.983 (0.982–0.984)	0.0020 (0.0019–0.0020)		0.988 (0.987–0.988)	0.0014 (0.0013–0.0015)	
Maternal height, cm							
≥160	86 840	1 [Reference]	0.077 (0.076–0.078)	0	1 [Reference]	0.073 (0.072–0.074)	0
155–159.9	79 024	1.086 (1.074–1.098)	0.114 (0.113–0.115)	0.037	1.062 (1.051–1.072)	0.098 (0.097–0.099)	0.025
150–154.9	76 088	1.186 (1.173–1.200)	0.122 (0.121–0.123)	0.045	1.128 (1.116–1.141)	0.102 (0.101–0.103)	0.029
145–149.9	48 216	1.341 (1.323–1.360)	0.138 (0.136–0.140)	0.061	1.230 (1.213–1.246)	0.111 (0.110–0.113)	0.038
<145	22 365	1.586 (1.558–1.615)	0.166 (0.163–0.169)	0.089	1.397 (1.373–1.422)	0.128 (0.126–0.130)	0.055
Neonates, <1 mo							
Maternal height ^c		0.979 (0.978–0.980)	0.0008 (0.0008–0.0009)		0.982 (0.981–0.983)	0.0007 (0.0007–0.0008)	
Maternal height, cm							
≥160	25 492	1 [Reference]	0.026 (.0251–0.026)	0	1 [Reference]	0.023 (0.022–0.023)	0
155–159.9	25 584	1.111 (1.089–1.135)	0.041 (0.041–0.042)	0.015	1.099 (1.077–1.112)	0.034 (0.034–0.035)	0.011
150–154.9	27 170	1.232 (1.206–1.259)	0.045 (0.044–0.045)	0.019	1.195 (1.170–1.221)	0.037 (0.036–0.037)	0.014
145–149.9	18 825	1.409 (1.374–1.445)	0.051 (0.050–0.052)	0.025	1.336 (1.303–1.370)	0.041 (0.040–0.042)	0.018
<145	9349	1.718 (1.665–1.773)	0.063 (0.061–0.065)	0.037	1.584 (1.536–1.633)	0.049 (0.048–0.051)	0.026
Infants, 1–11 mo							
Maternal height ^c		0.983 (0.981–0.984)	0.0007 (0.0006–0.0007)		0.988 (0.987–0.989)	0.0005 (0.0004–0.0005)	
Maternal height, cm							

	Unadjusted				Adjusted			
	No. of Events	RR (95% CI) ^b	AP (95% CI)	DAP	RR (95% CI) ^b	AP (95% CI)	DAP	
≥160	27 873	1 [Reference]	0.026 (0.025-0.027)	0	1 [Reference]	0.025 (0.024-0.026)	0	
155-159.9	26 023	1.087 (1.067-1.108)	0.039 (0.038-0.040)	0.013	1.059 (1.039-1.079)	0.033 (0.032-0.033)	0.008	
150-154.9	25 330	1.209 (1.185-1.234)	0.042 (0.041-0.043)	0.016	1.143 (1.120-1.166)	0.035 (0.034-0.035)	0.010	
145-149.9	15 566	1.356 (1.323-1.389)	0.047 (0.046-0.048)	0.021	1.231 (1.201-1.261)	0.038 (0.037-0.038)	0.013	
<145	6980	1.587 (1.537-1.639)	0.056 (0.055-0.058)	0.030	1.385 (1.342-1.430)	0.043 (0.042-0.044)	0.018	
Children, 12-59 mo								
Maternal height ^c		0.985 (0.984-0.986)	0.0006 (0.0006-0.0007)		0.990 (0.989-0.992)	0.0004 (0.0003-0.0004)		
Maternal height, cm								
≥160	33 475	1 [Reference]	0.024 (0.023-0.024)	0	1 [Reference]	0.021 (0.021-0.022)	0	
155-159.9	27 417	1.081 (1.061-1.100)	0.035 (0.034-0.035)	0.011	1.050 (1.032-1.068)	0.027 (0.027-0.028)	0.006	
150-154.9	23 588	1.158 (1.136-1.181)	0.037 (0.036-0.037)	0.013	1.090 (1.069-1.111)	0.028 (0.028-0.029)	0.007	
145-149.9	13 825	1.326 (1.294-1.359)	0.042 (0.041-0.043)	0.018	1.192 (1.164-1.221)	0.031 (0.030-0.031)	0.010	
<145	6036	1.560 (1.509-1.613)	0.050 (0.048-0.515)	0.026	1.331 (1.287-1.375)	0.035 (0.033-0.036)	0.014	

Abbreviations: AP, absolute probabilities; CI, confidence interval; DAP, differences in AP; RR, relative risk.

^a Adjusted models were adjusted for mother's age at birth and education; child's sex, birth order, preceding birth interval, twin status, and era-born; household income, urban/rural; and country fixed effects. AP for categorical height calculated at mean values of covariates; AP for continuous height is the decrease in probability of child mortality for a 1-cm increase in height. DAP calculated as AP minus AP of reference category. Interaction coefficients from sensitivity analysis (maternal height × neonate [referent]; maternal height × infant [RR, 1.011; 95% CI, 1.009-1.013; *P*<.001]; maternal height × child [RR, 1.031; 95% CI, 1.028-1.034; *P*<.001]).

^b All coefficients are *P*<.001.

^c Per 1-cm increase.

Table 4
 Unadjusted and Adjusted Changes in Risk, RR, AP, and DAP by Maternal Height for Offspring Underweight, Stunting, and Wasting Among Children Younger Than 5 Years^a

	Unadjusted				Adjusted			
	No. of Events	RR (95% CI) ^b	AP (95% CI)	DAP	RR (95% CI) ^b	AP (95% CI)	DAP	
Underweight								
Maternal height ^c		0.964 (0.963–0.965)	0.0081 (0.0080–0.0083)		0.968 (0.968–0.969)	0.0068 (0.0067–0.0070)		
Maternal height, cm								
≥160	26 871	1 [Reference]	0.088 (0.087–0.090)	0	1 [Reference]	0.092 (0.090–0.093)	0	
155–159.9	29 142	1.272 (1.253–1.292)	0.201 (0.198–0.203)	0.113	1.241 (1.222–1.260)	0.186 (0.184–0.189)	0.094	
150–154.9	33 171	1.545 (1.520–1.570)	0.233 (0.230–0.236)	0.145	1.467 (1.444–1.490)	0.212 (0.209–0.215)	0.120	
145–149.9	24 298	1.912 (1.878–1.946)	0.292 (0.288–0.297)	0.204	1.751 (1.721–1.782)	0.256 (0.252–0.260)	0.164	
<145	12 753	2.453 (2.404–2.503)	0.391 (0.383–0.398)	0.303	2.152 (2.109–2.196)	0.326 (0.320–0.332)	0.234	
Stunting								
Maternal height ^c		0.964 (0.963–0.964)	0.0145 (0.0143–0.0147)		0.968 (0.967–0.968)	0.0126 (0.0124–0.0128)		
Maternal height, cm								
≥160	44 816	1 [Reference]	0.189 (0.187–0.191)	0	1 [Reference]	0.194 (0.192–0.196)	0	
155–159.9	50 762	1.271 (1.258–1.285)	0.423 (0.419–0.427)	0.243	1.242 (1.229–1.255)	0.393 (0.389–0.396)	0.199	
150–154.9	56 642	1.544 (1.527–1.561)	0.491 (0.487–0.495)	0.311	1.475 (1.460–1.491)	0.448 (0.444–0.452)	0.254	
145–149.9	40 877	1.922 (1.899–1.945)	0.619 (0.613–0.625)	0.439	1.779 (1.758–1.800)	0.547 (0.542–0.553)	0.353	
<145	21 023	2.393 (2.360–2.426)	0.805 (0.795–0.815)	0.625	2.132 (2.103–2.161)	0.682 (0.673–0.690)	0.488	
Wasting								
Maternal height ^c		0.990 (0.988–0.991)	0.0009 (0.0008–0.00010)		0.994 (0.993–0.995)	0.0005 (0.0004–0.0006)		
Maternal height, cm								

	Unadjusted			Adjusted			
	No. of Events	RR (95% CI) ^b	AP (95% CI)	DAP	RR (95% CI) ^b	AP (95% CI)	DAP
≥160	14 402	1 [Reference]	0.056 (0.054–0.058)	0	1 [Reference]	0.056 (0.054–0.057)	0
155–159.9	12 687	1.051 (1.026–1.076)	0.070 (0.069–0.072)	0.014	1.029 (1.005–1.054) ^d	0.064 (0.062–0.065)	0.008
150–154.9	12 361	1.100 (1.072–1.128)	0.073 (0.071–0.075)	0.017	1.050 (1.024–1.077)	0.065 (0.063–0.066)	0.009
145–149.9	7866	1.197 (1.162–1.234)	0.079 (0.077–0.081)	0.023	1.109 (1.076–1.143)	0.068 (0.664–0.070)	0.012
<145	3366	1.306 (1.256–1.358)	0.087 (0.084–0.091)	0.031	1.174 (1.129–1.222)	0.073 (0.070–0.076)	0.017

Abbreviations: AP, absolute probabilities; CI, confidence interval; DAP, differences in AP; RR, relative risk.

^a Adjusted models were adjusted for mother's age at birth, marriage, occupation, and education; child's sex, birth order, preceding birth interval, twin status, and era-born; household income, urban/rural; and country fixed effects. AP for categorical height calculated at mean values of covariates; AP for continuous height is the decrease in probability of child growth failure for a 1-cm increase in height. DAP calculated as AP minus AP of reference category.

^b All coefficients have $P < .001$.

^c Per 1-cm increase.

^d $P < .05$.