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Relative importance of 13 correlates of child stunting in South Asia: Insights from nationally representative data from Afghanistan, Bangladesh, India, Nepal, and Pakistan

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ABSTRACT

Optimal growth and development in early childhood is determined by a complex interplay of child, maternal, household, environmental, and socioeconomic factors that influence nutritional intake, but interventions to reduce child undernutrition sometimes target specific risk factors in isolation. In this analysis, we assess the relative importance of 13 correlates of child stunting selected based on a collective review of existing multi-factorial frameworks: complementary feeding, breastfeeding, feeding frequency, dietary diversity, maternal height, body mass index (BMI), education, age at marriage, child vaccination, access to improved drinking source and sanitation facilities, household indoor air quality, and household wealth. The analytic sample consisted of nationally representative cross-sectional surveys from the most recent Demographic and Health Surveys for Bangladesh (2014), India (2005), Nepal (2011), and Pakistan (2013), and from the National Nutrition Survey for Afghanistan (2013). In the mutually adjusted logistic regression model for 3,159 infants aged 6–8 months, short maternal stature (OR: 2.93; 95% CI: 1.93–4.46) and lack of complementary foods (OR: 1.47; 95% CI: 1.12–1.93) were associated with significantly higher risk of stunting. For 18,586 children aged 6–23 months, the strongest correlates of child stunting were: maternal height (OR: 3.37, 95% CI: 2.82–4.03), household wealth (OR: 2.25, 95% CI: 1.72–2.94), maternal BMI (OR: 1.59, 95% CI: 1.27–2.00), minimum dietary diversity (OR: 1.48, 95% CI: 1.27–1.72), maternal education (OR: 1.36, 95% CI: 1.18–1.56), and age at marriage (OR: 1.17, 95% CI: 1.05–1.30). Full vaccination and minimum dietary frequency were also found to be important for severe stunting for children of this age group. Some differences were found in the relative ordering and statistical significance of the correlates in country-specific analyses. Our findings indicate that comprehensive strategies incorporating a broader progress on socioeconomic conditions as well as investments in nutrition specific programs are needed to improve child undernutrition in South Asia.

1. Introduction

In 2015, about 25% of children under five years of age in low and middle income countries (LMICs) were stunted (UNICEF, 2015). Stunting, a linear growth failure in infancy or early childhood, has severe short- and long-term consequences. For instance, stunting is associated with increased morbidity and mortality from infections (Aguayo and Menon, 2016; Black et al., 2008), reduced stature in adulthood (Stein et al., 2010), increased risk of maternal, perinatal, and neonatal mortality (Özaltin et al., 2010), and increased risk of chronic diseases as adults (Gluckman et al., 2007). Stunting is associated with poorer cognition (Prendergast and Humphrey, 2014) and school performances in children (Martorell et al., 2010), and reduced earnings in adults (Hoddinott et al., 2013).

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Given its public health importance, child undernutrition is analyzed and approached using several complex conceptual models and frameworks, all of which support for multi-factorial interventions with differing emphasis on the basic, underlying and immediate factors at the household, environmental, socioeconomic, and cultural domains (Bhutta et al., 2008; Black et al., 2013; UNICEF, 2013). However, in many instances, interventions to prevent child undernutrition try to address a specific risk factor or a set of factors in isolation. For instance, nutrition-specific interventions that address the immediate determinants of fetal and child nutrition, including micronutrient intake and feeding practices, are likely to be implemented without addressing the social and structural factors, such as women's education, household poverty, and social exclusion (Black et al., 2013; Bryce et al., 2008; Ruel et al., 2013).

Moreover, empirical research on a selective set of risk factors on child growth and development are valuable for assessing the role of specific determinants, but do not allow an examination of the *relative* importance of multiple factors on children's health and nutrition outcomes (Bhutta et al., 2008). Existing studies focused on LMICs have identified child feeding practices, maternal nutrition, and household wealth as key determinants of the nutritional status for pre-school age children (Espo et al., 2002; Jones et al., 2008; Kanjilal et al., 2010; Smith and Haddad, 2015). These findings have important policy and programme implications at the national level, but the relative significance of the same set of risk factors may substantially vary when the focus is on the outcome of stunting, a measure of chronic undernutrition, as opposed to general nutritional status; the first two years of life, when most child stunting happens in LMICs, as opposed to children under age of five; and by different countries.

Therefore, we use the most recent nationally representative data from Afghanistan, Bangladesh, India, Nepal and Pakistan (home to over 95% of stunted children in South Asia) to investigate the relative and joint importance of a set of 13 correlates of stunting and severe stunting in infants and young children aged 6–23 months old. A comprehensive set of 13 correlates was selected based on a collective review of the existing multi-factorial frameworks that consider risk factors ranging from child's feeding practices (complementary feeding, breastfeeding, feeding frequency, dietary diversity) to maternal and household socioeconomic indicators (maternal height, body mass index, education, age at marriage, child vaccination, household access to improved drinking source and sanitation facilities, household indoor air quality, and household wealth). We focus on the critical “window of opportunity” – from conception through the first two years of life – during which linear growth faltering is most sensitive to environmentally modifiable factors (Black et al., 2008). In addition to the pooled estimates for South Asia, we provide country-specific analyses to aid national policies and programmes in averting child stunting.

2. Methods

2.1. Survey data

Data for Afghanistan (2013) come from the National Nutrition Survey (NNS), and data for Bangladesh (2014), India (2005), Nepal (2011), and Pakistan (2013) come from the latest Demographic and Health Survey (DHS). Both NNS and DHS are nationally representative household surveys that collect detailed health and nutrition information from children and their mothers following a stratified two-stage survey design. Survey weights are included to make estimates representative at the national and regional levels

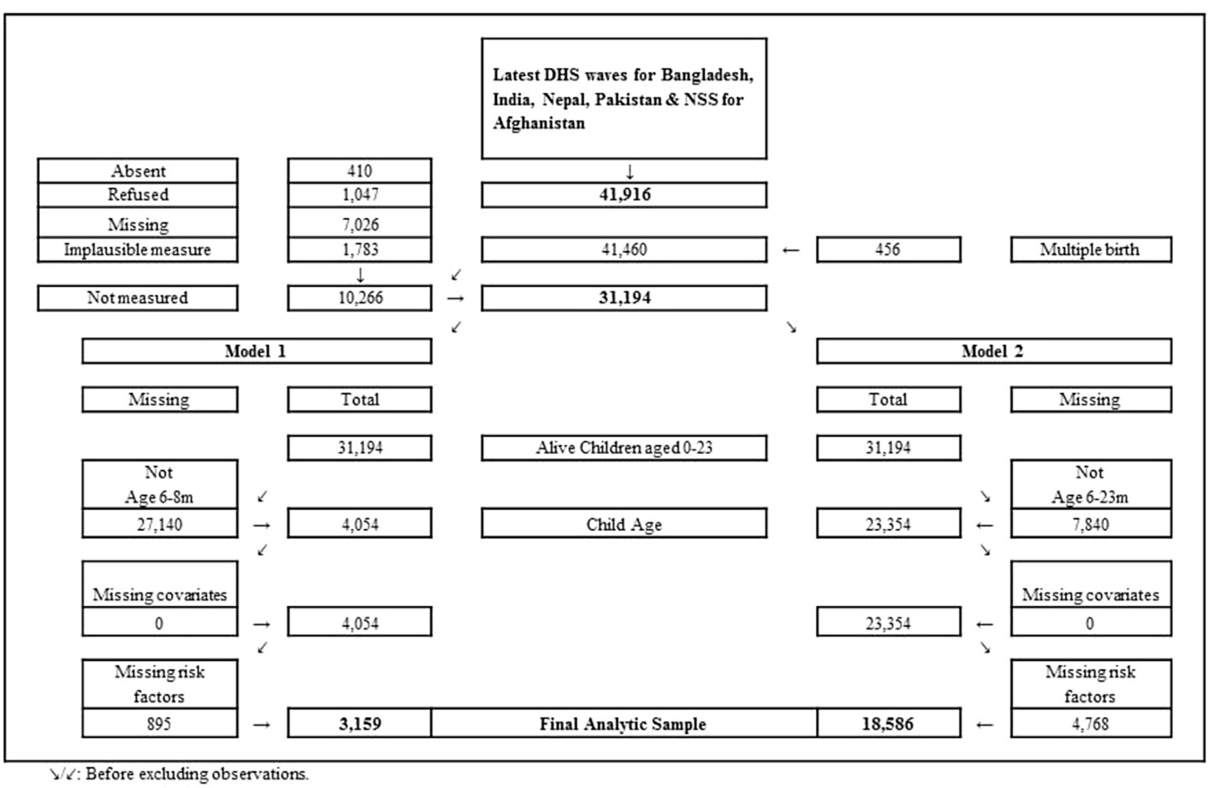

Fig. 1. Final analytic sample for stunting and severe stunting analyses for infants aged 6–8 months (Model 1) and children aged 6–23 months (Model 2) in South Asia.

(Afghanistan NNS, 2013; Measure DHS, 2012).

2.2. Study population and sampling size

The original sample included 41,916 children aged 6–23 months. We excluded 456 children who were born in non-singleton births and an additional 10,266 children who were not measured for various reasons (absent, refused, and missing for other reasons) or had implausible anthropometry, defined by height-for-age z-score (HAZ) below or above six standard deviations (SD) of the median of the World Health Organization (WHO) Child Growth Standards (de Onis, 2006). We then stratified the sample into two age groups because risk factors relevant for each age group differed. In the first model (Model 1 hereafter), we analyzed data for 3,159 infants aged 6–8 months. In the second model (Model 2), we included data from 18,586 children aged 6–23 months (Fig. 1).

2.3. Outcomes

Stunting is an objective and clinically relevant measure of chronic child undernutrition, and was defined as HAZ below −2 SD of the median for their age and sex according to the WHO Child Growth Standards (de Onis, 2006). Severe stunting, defined as HAZ below −3 SD of the median, was considered as a secondary outcome for Model 2.

2.4. Independent variables

We considered a comprehensive set of 13 correlates that has shown varying degrees of association with stunting in different settings (Bhutta et al., 2008; Bhutta et al., 2013; UNICEF, 2013) (eTable 1). Timely introduction of complementary foods, continued breastfeeding, minimum feeding frequency, and minimum dietary diversity were defined closely adhering to the UNICEF and WHO infant and young child feeding (IYCF) indicators (WHO, 2008, 2010). **Timely introduction of complementary foods** was defined for infants 6–8 months old as having received solid, semi-solid or soft foods the previous day of the interview. **Continued breastfeeding** was defined for all children aged 6–23 months. The definition of **minimum feeding frequency** varied by age and breastfeeding status: for breastfed children, it was defined as two times if 6–8 months, and three times for 9–23 months; for non-breastfed, it was defined as four times for all children 6–23 months old. Based on the dietary diversity score used in the previously published literature (Ruel and Menon, 2002), **minimum dietary diversity** was defined for children aged 6–23 months as having received foods from four or more of the following food groups: 1) grains, roots and tubers; 2) legumes and nuts; 3) dairy products (milk, yogurt, cheese); 4) flesh foods (meat, fish, poultry and liver/organ meats); 5) eggs; 6) vitamin-A rich fruits and vegetables; and 7) other fruits and vegetables.

Several maternal variables were also considered. **Mother's education** was categorized in three levels: no schooling, primary, and secondary or higher. **Mother's height** was measured by trained field investigators and was categorized in four groups: <145, 145–149.9, 150–154.9, and 155 + cm. Of note, height measures below 100 cm or above 200 cm were excluded (Özaltin et al., 2010). **Mother's BMI** was calculated from the objectively measured height and weight, and was grouped in <18.5, 18.5–25, and 25 + kg/m^2. **Mothers' age at marriage** was defined dichotomously for married or cohabitating mothers, using the age of 18 years as cutoff.

Finally, the following proxy variables for household socioeconomic conditions were included. Child's **full vaccination** was defined as having received 8 vaccines (measles, BCG, DPT 3, and Polio 3). **Household indoor pollution** was defined as *high air quality* if non-solid fuels were used for cooking and *poor air quality* if solid fuels were used (Corsi et al., 2016). The **source of drinking water** was defined as *safe* if water sources were available in the household (piped into dwelling or yard/plot, public tap/standpipe, tube well or borehole, protected well or spring, rain water, and bottled water), and *unsafe* otherwise. **Household sanitation facility** was defined as *improved* if households had access to flush to piped sewer system, septic tank, or pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet, and *unimproved* otherwise. We included the **household wealth index**, as reported by the NSS and DHS, which was constructed as a weighted sum of household assets by using the first factor resulting from a principal component analysis (PCA) on those assets as weights. The resulting wealth index was used to construct cut offs to rank households into wealth quintiles, based on the weighted frequency distribution of households (Rutstein et al., 2004).

2.5. Statistical analysis

The following logistic regression models were conducted to evaluate the association between selected variables and stunting by pooling the data from five South Asian countries and then for each country separately. A different set of correlates was considered for 6–8 months old infants (Model 1) and 6–23 months old children (Model 2) due to clinical relevance and technical reasons (eTable 1). For instance, the timely introduction of complementary foods was included only in Model 1 since complementary feeding is recommended to be given at six months of age (WHO, 2002). On the other hand, the child's vaccination status was included only in Model 2 since full vaccination is required to be given in the first two years of age. For technical reasons, minimum feeding frequency was excluded from Model 1 due to high correlation with timely introduction of complementary foods; and continued breastfeeding and minimum dietary diversity were excluded from Model 1 because of the small sample sizes and stunting cases for this age group in country-specific models that resulted in lack of statistical power and unstable estimation. For Afghanistan-specific analysis, data on mother's age at marriage and child's full vaccination were not available. For this reason, the pooled analyses were presented for results including and excluding Afghanistan. For Model 2, we also estimated the fully-adjusted models for the secondary outcome of severe stunting. Based on these models, the relative significance of each correlate was compared and ordered by its strength of magnitude.

As a sensitivity analysis, we re-estimated the fully-adjusted models after removing type of drinking water, sanitation facility, and indoor air quality since these assets were considered in the estimation of DHS wealth quintiles and may have issues of multicollinearity. All analyses accounted for the cluster survey design, and were further adjusted for age and sex of the child, birth order, and place of residency (urban/rural). The country fixed effects was included in the pooled analysis. All statistical tests were two-sided and $p < 0.05$ was considered to determine statistical significance. We used Stata (version 13.1) for all analyses procedures.

3. Results

3.1. South Asia

Among 3,159 infants aged 6–8 months in South Asia, 25.9% (n = 696) were stunted (Table 1a). In Model 1 (excluding Afghanistan), we found that infants whose mothers' attained height was <145 cm had three times higher odds of being stunted (OR: 2.93, 95% CI: 1.93–4.46) than those with taller mothers (155 + cm), and those who were not given complementary foods

Table 1a
Risk factors for stunting for infants aged 6–8 months (Model 1), count data and weighted percentage in South Asia (pooled sample) and by country.

	South Asia (n = 3,159)		Afghanistan 2013 (n = 341)		Bangladesh 2014 (n = 345)		India 2005 (n = 2,067)		Nepal 2011 (n = 122)		Pakistan 2013 (n = 284)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Stunted	696	25.9	95	26.0	53	16.9	463	25.1	23	18.8	62	25.0
Child age												
6 months	1,020	24.0	81	23.6	117	34.5	684	32.6	38	33.7	100	33.3
7 months	1,082	47.6	150	48.2	106	29.9	692	33.4	36	34.1	98	36.2
8 months	1,057	28.4	110	28.2	122	35.6	691	34.1	48	32.2	86	30.4
Child sex												
Male	1,619	47.8	166	47.6	178	53.1	1,068	51.2	51	38.9	156	52.4
Female	1,540	52.2	175	52.4	167	46.9	999	48.8	71	61.1	128	47.6
Birth order												
First	942	20.3	59	19.9	124	33.6	657	30.2	46	40.1	56	22.7
Second	868	18.5	62	18.2	114	32.1	597	27.9	35	26.5	60	21.3
Third	1,349	61.1	220	61.9	107	34.3	813	41.9	41	33.4	168	56.1
Place of residency												
Rural	2,129	65.4	287	64.9	228	72.4	1,344	77.6	102	94.1	168	66.4
Urban	1,030	34.6	54	35.1	117	27.6	723	22.4	20	5.9	116	33.6
No timely introduction of complementary foods	1,391	37.5	134	37.0	130	40.4	983	51.7	36	39.0	108	36.5
Mothers' height (cm)												
<145	345	2.3	6	1.8	53	16.3	257	14.2	19	13.0	10	1.5
145–149.9	780	13.7	43	13.2	101	28.7	546	27.6	36	27.0	54	19.9
150–154.9	1,052	29.5	99	29.4	121	35.4	701	32.7	45	40.5	86	30.9
155+	982	54.5	193	55.6	70	19.6	563	25.5	22	19.5	134	47.8
Mother's BMI (kg/m^2)												
<18.5	885	15.1	46	14.3	89	23.6	701	40.1	19	19.8	30	15.9
18.5–24.9	1,910	58.9	231	58.9	215	63.9	1,189	54.7	91	69.7	184	63.1
≥25.0	364	26.0	64	26.7	41	12.5	177	5.2	12	10.5	70	21.0
Mother's education												
No schooling	1,335	82.7	302	84.2	51	19.8	780	47.5	48	40.3	154	56.8
Primary	480	9.2	28	8.9	105	27.3	272	13.4	23	16.3	52	20.5
Secondary or Higher	1,344	8.1	11	6.9	189	52.9	1,015	39.1	51	43.4	78	22.7
Age at marriage												
<18 y	1,473	61.0	N/A	N/A	252	70.3	1,004	61.3	71	57.9	146	48.5
≥18 y	1,345	38.9	N/A	N/A	93	29.7	1,063	38.7	51	42.1	138	51.5
Drinking water source not safe	605	25.7	116	26.2	10	2.7	364	12.9	21	11.4	94	37.8
Sanitary facility not improved	2,022	58.1	236	57.6	178	53.3	1,443	78.4	79	70.9	86	36.2
Household indoor air quality												
High quality	859	41.1	88	41.9	39	13.4	606	17.3	20	15.2	106	36.0
Poor quality	2,300	58.9	253	58.1	306	86.6	1,461	82.7	102	84.8	178	64.0
Household wealth quintile												
Q1 (lowest)	608	15.6	73	15.3	74	21.3	368	25.5	35	21.1	58	16.1
Q2	586	16.1	67	15.9	71	21.1	366	21.9	22	16.0	60	24.1
Q3	643	12.6	59	12.3	71	20.5	420	19.7	29	30.3	64	24.2
Q4	673	15.5	67	15.4	65	16.4	473	18.7	16	15.3	52	22.2
Q5 (highest)	649	40.2	75	41.2	64	20.6	440	14.1	20	17.3	50	13.4

Table 1b
Risk factors for stunting for children aged 6–23 months (Model 2), count data and weighted percentage in South Asia (pooled sample) and by country.

	South Asia (n = 18,586)		Afghanistan 2013 (n = 3,644)		Bangladesh 2014 (n = 1,980)		India 2005 (n = 10,868)		Nepal 2011 (n = 618)		Pakistan 2013 (n = 1,476)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Stunted	7,140	38.8	1,511	38.7	652	31.9	4,234	43.5	187	29.2	556	39.6
Severe stunted	3,362	18.3	741	18.3	221	10.8	2,015	21.2	71	11.3	314	20.6
Child age												
6–11 months	6,736	40.9	1,476	41.0	693	34.8	3,797	34.6	220	34.0	550	35.0
12–23 months	11,850	59.1	2,168	59.0	1,287	65.2	7,071	65.4	398	66.0	926	65.0
Child sex												
Male	9,661	50.1	1,883	50.1	1,006	52.7	5,712	52.8	292	45.1	768	49.8
Female	8,925	49.9	1,761	49.9	974	47.3	5,156	47.2	326	54.9	708	50.2
Birth order												
First	5,319	16.8	573	16.5	770	37.7	3,424	30.1	214	35.2	338	22.7
Second	4,858	17.1	561	16.9	625	32.0	3,213	28.1	161	25.7	298	18.9
Third	8,409	66.1	2,510	66.6	585	30.3	4,231	41.8	243	39.1	840	58.4
Place of residency												
Rural	12,691	75.5	3,117	75.5	1,353	74.6	6,854	75.3	497	91.2	870	70.3
Urban	5,895	24.5	527	24.5	627	25.4	4,014	24.7	121	8.8	606	29.7
No continued breastfeeding	2,300	5.5	185	5.3	94	5.5	1,629	12.3	28	4.6	364	24.3
No minimum feeding frequency	8,128	19.8	750	19.1	691	37.8	5,837	57.0	148	22.8	702	50.0
No minimum diet diversity	15,248	70.1	2,629	69.8	1,675	85.1	9,243	89.1	455	74.3	1,246	85.0
Mothers' height (cm)												
<145	1,683	2.8	98	2.6	247	12.6	1,198	11.7	72	10.8	68	4.1
145–149.9	4,241	11.2	412	10.9	589	29.0	2,822	27.0	182	31.6	236	16.1
150–154.9	6,224	31.8	1,161	31.8	684	34.8	3,676	33.5	221	36.0	482	32.3
155+	6,438	54.2	1,973	54.7	460	23.6	3,172	27.7	143	21.6	690	47.5
Mother's BMI (kg/m^2)												
<18.5	5,254	12.4	414	11.9	554	26.4	3,951	43.4	129	24.3	206	18.0
18.5–24.9	10,912	62.4	2,435	62.6	1,142	59.6	6,027	51.3	442	68.1	866	57.2
≥25.0	2,420	25.2	795	25.6	284	14.0	890	5.3	47	7.6	404	24.8
Mother's education												
No schooling	8,539	82.0	3,142	82.8	267	14.7	4,087	47.4	257	44.2	786	55.5
Primary	2,837	13.1	405	13.0	554	28.0	1,514	13.9	114	17.9	250	16.9
Secondary or Higher	7,210	5.0	97	4.2	1,159	57.2	5,267	38.7	247	37.9	440	27.6
Age at Marriage												
<18 y	7,557	59.4	N/A	N/A	1,430	72.0	5,167	59.6	352	58.1	608	41.5
≥ 18 y	7,385	40.6	N/A	N/A	550	28.0	5,701	40.4	266	41.9	868	58.5
Not fully vaccinated	8,412	59.3	N/A	N/A	728	36.2	6,554	64.5	212	34.3	918	60.8
Drinking water source not safe	3,794	25.8	1,135	26.0	60	2.9	1,920	13.6	131	16.5	548	46.4
Sanitation facility not improved	11,992	61.8	2,544	61.6	1,076	56.5	7,456	76.9	404	66.2	512	43.0
Household indoor air quality												
High quality	4,928	28.9	699	29.1	260	15.4	3,322	19.5	97	14.7	550	31.6
Poor quality	13,658	71.1	2,945	70.9	1,720	84.6	7,546	80.5	521	85.3	926	68.4
Household wealth quintile												
Q1 (lowest)	3,548	16.1	756	15.9	435	23.0	1,874	25.1	191	25.3	292	20.5
Q2	3,503	18.2	751	18.1	356	18.8	1,971	22.2	117	17.8	308	20.2
Q3	3,762	18.4	745	18.3	399	19.3	2,210	19.6	116	24.6	292	19.8
Q4	3,998	17.4	693	17.4	415	20.0	2,476	18.2	104	18.1	310	23.7
Q5 (highest)	3,775	29.9	699	30.2	375	18.8	2,337	14.9	90	14.1	274	15.8

had 1.47 times higher odds of being stunted (95% CI: 1.12–1.93) than their counterparts. When Afghanistan was included in the pooled analysis, no single factor remained statistically significant (Table 2, Fig. 2).

Among 18,586 children aged 6–23 months, 38.8% (n = 7,140) were stunted and 18.3% (n = 3,362) were severely stunted (Table 1b). In Model 2 (excluding Afghanistan), the significant correlates of stunting, ranked from the strongest effect sizes, were: short maternal stature (OR: 3.37, 95% CI: 2.82–4.03), poorest wealth quintile (OR: 2.25, 95% CI: 1.72–2.94), maternal underweight (OR: 1.59, 95% CI: 1.27–2.00), not meeting the minimum dietary diversity (OR: 1.48, 95% CI: 1.27–1.72), no maternal education (OR: 1.36, 95% CI: 1.18–1.56), and mother's age at marriage (OR: 1.17, 95% CI: 1.05–1.30). When Afghanistan was included, lack of continued breastfeeding (OR: 2.02, 95% CI: 1.37–2.97) was also found to be significant, while maternal underweight and age at marriage were no longer significant (Table 3, Fig. 3).

Finally, short maternal stature (OR: 3.15, 95% CI: 2.55–3.90), poorest wealth quintile (OR: 3.07, 95% CI: 2.20–4.28), no maternal education (OR: 1.48, 95% CI: 1.25–1.76), maternal underweight (OR: 1.41, 95% CI: 1.05–1.90), not meeting the minimum dietary diversity (OR: 1.37, 95% CI: 1.11–1.70), not being fully vaccinated (OR: 1.22, 95% CI: 1.06–1.41), mother's age at marriage (OR: 1.16, 95% CI: 1.01–1.33) and infrequent feeding (OR: 1.14, 95% CI: 1.01–1.29) were found to be significantly associated with severe stunting for children aged 6–23 months (Fig. 4, eTable 3).

3.2. Afghanistan

In the Afghanistan sample, there were 341 infants aged 6–8 months and 26% of them were stunted (Table 1a). None of the correlates were found to be significantly associated with stunting in Model 1 (Table 2). Of 3,644 children aged 6–23 months, 38.7% were stunted and 18.3% were severely stunted (Table 1b). In Model 2, no maternal education (OR: 3.01, 95% CI: 1.53–5.93), short maternal stature (OR: 2.61, 95% CI: 1.41–4.84), poorest wealth quintile (OR: 2.28, 95% CI: 1.48–3.50), lack of continued breastfeeding (OR: 2.08, 95% CI: 1.35–3.21), and not meeting the minimum dietary diversity (OR: 1.34, 95% CI: 1.04–1.72) were found to have significant associations with stunting (Table 3). Consistent results were found for severe stunting, but dietary diversity and maternal education were not statistically significant (eTable 3).

3.3. Bangladesh

There were 345 infants aged 6–8 months in the Bangladesh sample and 16.9% of them were stunted (Table 1a). In Model 1, we did not find any statistically significant association between stunting and the chosen correlates (Table 2). Among 1,980 children aged 6–23 months, 31.9% were stunted and 10.8% were severely stunted (Table 1b). In Model 2, we found significant associations between stunting and short maternal stature (OR: 3.42, 95% CI: 2.03–5.76), maternal underweight (OR: 2.05, 95% CI: 1.27–3.30), lowest wealth quintile (OR: 1.98, 95% CI: 1.08–3.63), mother's lack of education (OR: 1.78, 95% CI: 1.17–2.70), and not meeting the minimum dietary diversity (OR: 1.58, 95% CI: 1.11–2.24) (Table 3). For severe stunting, only maternal stature and wealth quintile remained to be significant correlates (eTable 3).

3.4. India

India contributed the largest sample to the pooled analysis, with a total of 2,067 infants aged 6–8 months and 10,868 children aged 6–23 months, and had the highest prevalence of stunting of 25.1% and 43.5%, respectively (Table 1a and Table 1b). In Model 1, short maternal stature (OR: 3.39, 95% CI: 2.10–5.45) and failure to introduce complementary foods (OR: 1.50, 95% CI: 1.11–2.04) were found to be significantly associated with higher risk of stunting for infants aged 6–8 months (Table 2). For Model 2, the risk of stunting was significantly higher for children with mothers of shorter height (OR: 3.43, 95% CI: 2.82–4.18), in the poorest wealth quintile (OR: 2.26, 95% CI: 1.67–3.05), with underweight mothers (OR: 1.56, 95% CI: 1.20–2.03), not meeting the minimum dietary diversity (OR: 1.52, 95% CI: 1.26–1.82), and with uneducated mothers (OR: 1.36, 95% CI: 1.17–1.57) (Table 3). In addition to these correlates, not being fully vaccinated and infrequent feeding were also found to significantly increase the risk of severe stunting among children aged 6–23 months (eTable 3).

3.5. Nepal

Among 122 infants aged 6–8 months, only 23 cases (18.8%) of stunting were detected (Table 1a), and all the correlates, except for maternal height, were found to be not significantly associated with stunting (Table 2). Among 618 children aged 6–23 months, 29.2% were stunted (Table 1b), and short maternal stature (OR: 5.58, 95% CI: 2.52–12.40) and lowest wealth quintile (OR: 5.26, 95% CI: 1.35–20.50) were found to be significant correlates of stunting (Table 3) and severe stunting (eTable 3).

3.6. Pakistan

There were 284 infants aged 6–8 months and 1,476 children aged 6–23 months in the Pakistan sample, and the prevalence of stunting was 25% and 39.6%, respectively (Table 1a, Table 1b). In Model 1, no maternal education was significantly associated with higher risk of stunting (Table 2). In Model 2, short maternal stature (OR: 3.56, 95% CI: 1.24–10.20), mothers' age at marriage (OR: 1.71, 95% CI: 1.10–2.67), unimproved drinking water source (OR: 1.63, 95% CI: 1.00–2.68), and infrequent feeding (OR: 1.59, 95% CI: 1.05–2.42) were found to be significantly associated with stunting (Table 3). For severe stunting, only short maternal stature remained statistically significant (eTable 3).

3.7. Sensitivity analysis

In the sensitivity analysis with types of drinking water, sanitation, and household air quality removed for the concerns of multicollinearity with household wealth index, the ranking and magnitude of significant correlates of stunting remained largely consistent with larger effect sizes associated with household wealth index (eTable 2).

4. Discussion

Despite numerous conceptual frameworks emphasizing the importance of multiple risk factors, ranging from broad socioeconomic conditions to feeding practices, in determining optimal growth and development in early childhood, surprisingly little has been done to compare, order, and rank the relative importance of diverse correlates of child stunting at the national- and regional-levels. In our pooled analysis, we found that short maternal stature and lack of complementary feeding were associated with significantly higher risk of stunting for infants aged 6–8 months. For children aged 6–23 months, short maternal stature, household wealth quintile, maternal underweight, failure to meet the minimum dietary diversity, lack of maternal education, and mother's age at marriage were found to be the strongest correlates of child stunting. Not being fully vaccinated and not meeting the minimum feeding frequency were also found to be significant correlates of

Table 2
Fully adjusted[d] odds ratios (ORs) and 95% confidence intervals (CIs) of risk factors for stunting among infants aged 6–8 months (Model 1) in South Asia (pooled sample) and by country.

	South Asia		Afghanistan[a,c] 2013	Bangladesh 2014	India 2005	Nepal[a, b] 2011	Pakistan[a, b] 2013
	Excludes Afghanistan	Includes Afghanistan[a]					
No timely introduction of complementary foods	1.47 (1.12–1.93)	1.30 (0.67–2.53)	1.29 (0.57–2.90)	1.61 (0.78–3.29)	1.50 (1.11–2.04)	1.09 (0.19–6.18)	1.28 (0.39–4.23)
Mother's height (ref: 155 + cm)							
<145 cm	2.93 (1.93–4.46)	3.32 (0.90–12.30)	3.48 (0.54–22.50)	1.97 (0.63–6.09)	3.39 (2.10–5.45)	9.15 (1.53–54.70)	2.26 (0.46–11.00)
145–149 cm	1.94 (1.36–2.77)	1.37 (0.45–4.16)	1.41 (0.39–5.11)	2.36 (0.82–6.76)	2.01 (1.34–3.01)		
150–154 cm	1.42 (1.00–2.02)	1.44 (0.66–3.13)	1.43 (0.56–3.67)	0.69 (0.22–2.10)			
Mother's BMI (ref: 25 + kg/m^2)							
< 18.5 kg/m^2	1.48 (0.72–3.02)	1.20 (0.29–4.95)	1.24 (0.25–6.22)	4.60 (0.64–32.90)	2.27 (0.89–5.79)	1.14 (0.10–13.50)	0.24 (0.02–3.44)
18.5–25 kg/m^2	1.38 (0.68–2.80)	1.42 (0.51–3.94)	1.49 (0.49–4.59)	4.49 (0.63–31.70)	2.06 (0.83–5.16)	1.16 (0.14–9.41)	0.32 (0.08–1.21)
Mother's education (ref: secondary or higher)							
No education	1.34 (0.93–1.93)	3.19 (0.50–20.40)	1.80 (0.23–14.00)	1.13 (0.32–3.96)	1.46 (0.98–2.16)	0.73 (0.16–3.30)	7.39 (1.71–31.90)
Any primary	0.99 (0.66–1.49)	2.43 (0.24–24.90)		0.95 (0.39–2.35)	1.10 (0.68–1.77)		
Mother's age at marriage < 18y	1.08 (0.82–1.43)	0.98 (0.55–1.75)		1.24 (0.51–3.01)	1.13 (0.83–1.54)	1.36 (0.35–5.25)	0.41 (0.12–1.43)
Drinking water source not safe	0.99 (0.70–1.40)	0.49 (0.24–1.03)	0.46 (0.20–1.08)		0.93 (0.63–1.37)	2.49 (0.56–11.10)	2.05 (0.52–8.16)
Sanitation facility not improved	1.16 (0.80–1.69	1.47 (0.42–5.09)	1.51 (0.35–6.52)	0.76 (0.31–1.87)	1.03 (0.66–1.60)	3.73 (0.85–16.40)	1.50 (0.34–6.56)
Household air quality poor	0.89 (0.55–1.45)	0.70 (0.23–2.06)	0.70 (0.20–2.43)	0.37 (0.10–1.42)	0.97 (0.55–1.73)	1.01 (0.13–7.65)	0.36 (0.05–2.55)
Wealth quintile (ref: Q5)							
Q1 (lowest)	1.78 (0.87–3.66)	1.86 (0.43–8.03)	1.88 (0.34–10.50)	2.58 (0.52–12.80)	1.59 (0.78–3.25)	1.00 (0.09–10.90)	0.67 (0.02–28.00)
Q2	1.51 (0.76–2.99)	0.82 (0.18–3.73)	0.80 (0.14–4.68)	3.13 (0.78–12.50)	1.41 (0.70–2.84)	4.37 (0.43–44.60)	0.28 (0.01–5.82)
Q3	1.32 (0.70–2.50)	2.30 (0.57–9.26)	2.36 (0.45–12.30)	3.97 (0.93–17.00)	1.24 (0.63–2.42)	1.24 (0.13–12.00)	0.15 (0.01–2.01)
Q4 (highest)	0.75 (0.40–1.39)	0.93 (0.20–4.43)	0.91 (0.15–5.72)	1.03 (0.27–3.97)	0.72 (0.41–1.28)	0.50 (0.04–6.78)	0.52 (0.05–5.12)

[a] The reference group for education was changed to *primary or higher* in separate analyses for Afghanistan, Nepal, and Pakistan.
[b] Mother's height was recoded in two groups (<149.9 cm and ≥150 cm) in separate analyses for Nepal and Pakistan.
[c] In Afghanistan, *age at marriage* was not available.
[d] Fully-adjusted models were estimated including all risk factors and controlling for age and sex of the child, birth order, place of residence (urban/rural), and the country fixed effects.

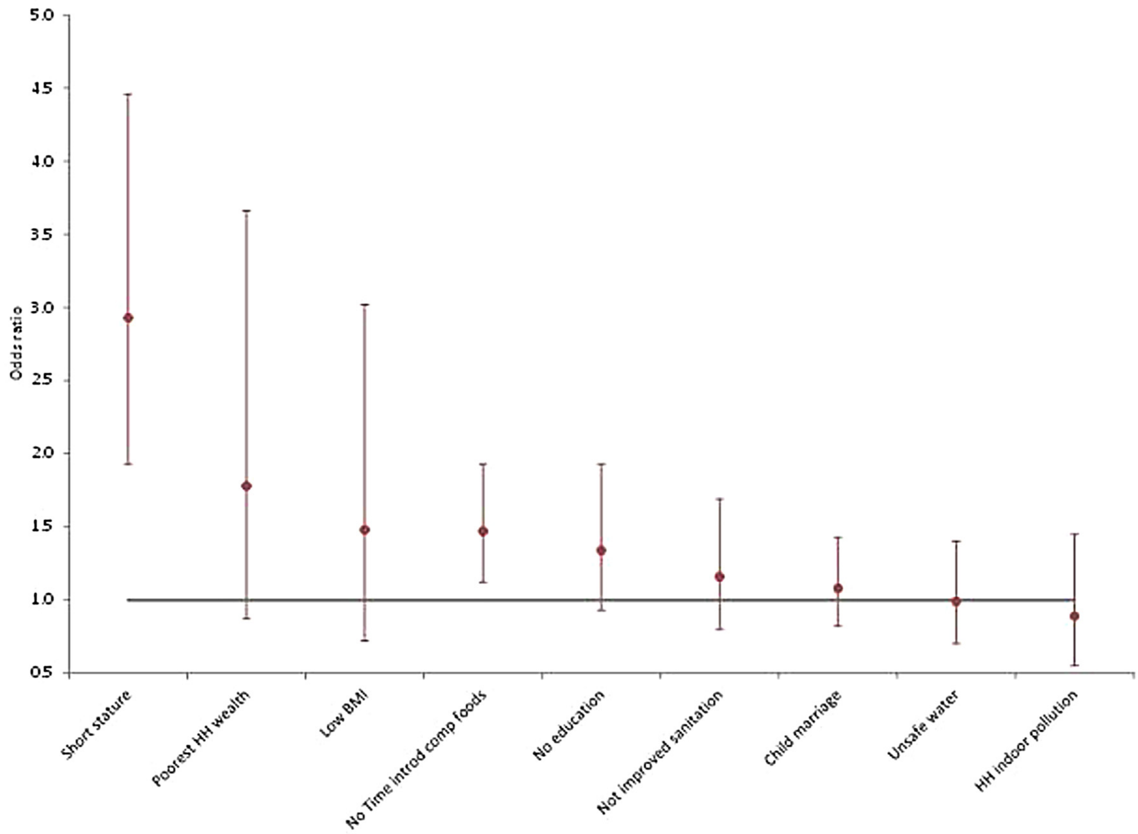

Fig. 2. Fully adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of risk factors for stunting among infants aged 6–8 months in South Asia (pooled sample, excluding Afghanistan).

severe stunting among children aged 6–23 months. Our findings indicated that the overall socioeconomic conditions at the child, maternal, and household levels as well as children's dietary diversity should be comprehensively addressed to optimally reduce the risk of stunting for children during the 1,000 days "window of opportunity" (Black et al., 2008).

Although largely consistent with the pooled analysis, there were some notable differences in the statistical significance and magnitude of the associations between stunting and the correlates in the country-specific analyses for children 6–23 months. Indeed, findings for India were almost identical to the pooled analysis since it contributed to almost 60% of the sample in the pooled model. The same set of factors were found to be important in Afghanistan and Bangladesh, except maternal age at marriage was not statistically significant in both countries while continued breastfeeding was important for Afghanistan. In Nepal, only maternal height and household wealth were found to be significantly associated with being stunted. In Pakistan, safety of drinking water and meeting the minimum feeding frequency were found to be important. The country-specific analyses provided empirical evidence as to which specific aspects of child feeding and socioeconomic determinants should be prioritized in each country.

We have used the most comprehensive and highest quality dataset available for the five South Asian countries, but there are important issues to consider in interpreting the results. First, we used cross-sectional data that limited our ability to temporally order the occurrence of each measure and the outcome. Additionally, inferences of causality cannot be made as our analyses may be confounded by omitted variables. The coefficient estimates from our models should not be interpreted as "independent effects" of stunting as they may be biased from over-adjustment for mediators and/or inadequate adjustment for important confounders. For instance, a part of the association between socioeconomic factors, such as household wealth and maternal education, and child stunting is likely to be mediated through more "proximal" determinants such as child feeding practices. Hence, including both in the same model will lead to be an underestimation of the true effect of the more fundamental macro risk factors. At the same time, household socioeconomic factors may influence both feeding practices and stunting outcome, and not controlling for such endogeneity will lead to biased coefficient estimates. There are more appropriate methods, including instrumental variable analysis or ideally randomized controlled trials, to accurately estimate the independent effect of the primary exposure of interest on the outcome. However, the primary purpose of this study was *not* to examine the specific causal nature of a single determinant of child stunting. Instead, the novelty of this analysis is in comparing the relative contribution of diverse correlates of child undernutrition that have been identified in existing multi-factorial frameworks and prior empirical studies.

Secondly, the sample sizes and stunting cases for infants aged 6–8 months were relatively small for the country-specific analyses, with the exception for India. For Model 1, not all the correlates related to child feeding practices (i.e., minimum feeding frequency, continued breastfeeding, and minimum dietary diversity) could be included due to unstable estimation. Moreover, none of the correlates were significantly associated with stunting among infants aged 6–8 months in Afghanistan and Bangladesh, and only maternal height was found to be significant for Nepal, and maternal education for Pakistan. The lack of statistical significance in these

Table 3
Fully adjusted[b] odds ratios (ORs) and 95% confidence intervals (CIs) of risk factors for stunting among children aged 6–23 months (Model 2) in South Asia (pooled sample) and by country.

	South Asia		Afghanistan[a] 2013	Bangladesh 2014	India 2005	Nepal 2011	Pakistan 2013
	Excludes Afghanistan	Includes Afghanistan					
No Continued breastfeeding	0.86 (0.73–1.01)	2.02 (1.37–2.97)	2.08 (1.35–3.21)	0.71 (0.40–1.28)	0.93 (0.78–1.11)	1.86 (0.55–6.31)	0.54 (0.31–0.93)
No Minimum feeding frequency	1.05 (0.95–1.17)	1.13 (0.88–1.45)	1.13 (0.86–1.50)	0.79 (0.61–1.02)	1.06 (0.94–1.19)	0.97 (0.50–1.90)	1.59 (1.05–2.42)
No Minimum diet diversity	1.48 (1.27–1.72)	1.34 (1.06–1.68)	1.34 (1.04–1.72)	1.58 (1.11–2.24)	1.52 (1.26–1.82)	1.08 (0.63–1.83)	1.30 (0.69–2.43)
Mother's height (ref: 155 + cm)							
<145 cm	3.37 (2.82–4.03)	2.65 (1.56–4.49)	2.61 (1.41–4.84)	3.42 (2.03–5.76)	3.43 (2.82–4.18)	5.58 (2.52–12.40)	3.56 (1.24–10.20)
145–149 cm	2.20 (1.93–2.50)	1.76 (1.34–2.31)	1.74 (1.29–2.37)	3.26 (2.26–4.71)	2.10 (1.82–2.44)	2.19 (1.18–4.06)	2.32 (1.38–3.91)
150–154 cm	1.36 (1.20–1.54)	1.33 (1.09–1.62)	1.33 (1.07–1.66)	1.36 (0.92–2.02)	1.43 (1.25–1.65)	1.10 (0.60–2.03)	1.10 (0.69–1.76)
Mother's BMI (ref: 25 + kg/m^2)							
< 18.5 kg/m^2	1.59 (1.27–2.00)	1.12 (0.81–1.55)	1.10 (0.76–1.59)	2.05 (1.27–3.30)	1.56 (1.20–2.03)	2.39 (0.70–8.15)	1.37 (0.63–2.95)
18.5–25 Kg/m^2	1.37 (1.10–1.70)	1.22 (0.94–1.58)	1.22 (0.92–1.61)	1.65 (1.11–2.47)	1.34 (1.03–1.73)	2.03 (0.64–6.47)	1.24 (0.69–2.26)
Mother's education (ref: secondary or higher)							
No education	1.36 (1.18–1.56)	2.78 (1.60–4.81)	3.01 (1.53–5.93)	1.78 (1.17–2.70)	1.36 (1.17–1.57)	1.23 (0.58–2.62)	1.40 (0.69–2.85)
Any primary	1.12 (0.96–1.29)	1.69 (0.94–3.03)	1.82 (0.88–3.78)	1.20 (0.90–1.60)	1.14 (0.97–1.35)	1.26 (0.55–2.90)	1.06 (0.46–2.45)
Mother's age at marriage < 18y	1.17 (1.05–1.30)	1.15 (0.98–1.36)		1.18 (0.86–1.62)	1.12 (0.99–1.26)	0.95 (0.58–1.56)	1.71 (1.10–2.67)
Child not fully vaccinated	1.10 (0.98–1.23)	1.02 (0.85–1.22)		0.94 (0.70–1.27)	1.11 (0.98–1.26)	1.75 (0.85–3.59)	1.14 (0.68–1.92)
Drinking water source not safe	1.04 (0.89–1.21)	0.97 (0.78–1.20)	0.97 (0.76–1.23)	1.35 (0.84–2.18)	0.93 (0.79–1.10)	0.71 (0.38–1.31)	1.63 (1.00–2.68)
Sanitation facility not improved	1.13 (0.98–1.30)	1.05 (0.81–1.35)	1.05 (0.79–1.39)	0.86 (0.67–1.10)	1.13 (0.95–1.34)	0.59 (0.31–1.13)	1.65 (0.95–2.86)
Household air quality poor	1.03 (0.86–1.24)	0.74 (0.53–1.02)	0.73 (0.50–1.06)	0.84 (0.48–1.46)	1.07 (0.87–1.31)	1.95 (0.60–6.29)	0.84 (0.43–1.64)
Wealth quintile (ref: Q5)							
Q1 (lowest)	2.25 (1.72–2.94)	2.28 (1.55–3.36)	2.28 (1.48–3.50)	1.98 (1.08–3.63)	2.26 (1.67–3.05)	5.26 (1.35–20.50)	1.92 (0.48–7.66)
Q2	1.70 (1.32–2.19)	2.26 (1.54–3.33)	2.27 (1.47–3.50)	2.05 (1.25–3.36)	1.63 (1.22–2.18)	2.48 (0.55–11.30)	1.55 (0.43–5.56)
Q3	1.60 (1.25–2.03)	1.98 (1.38–2.84)	1.98 (1.32–2.96)	1.98 (1.19–3.29)	1.69 (1.28–2.23)	2.60 (0.69–9.85)	0.66 (0.21–2.10)
Q4 (highest)	1.45 (1.19–1.78)	1.56 (1.13–2.16)	1.56 (1.08–2.24)	1.35 (0.87–2.10)	1.50 (1.21–1.87)	0.82 (0.22–3.07)	1.65 (0.64–4.26)

[a] In Afghanistan, *mother's age at marriage* and *full vacination* were not available.
[b] Fully-adjusted models were estimated including all risk factors and controlling for age and sex of the child, birth order, place of residence (urban/rural), and the country fixed effects.

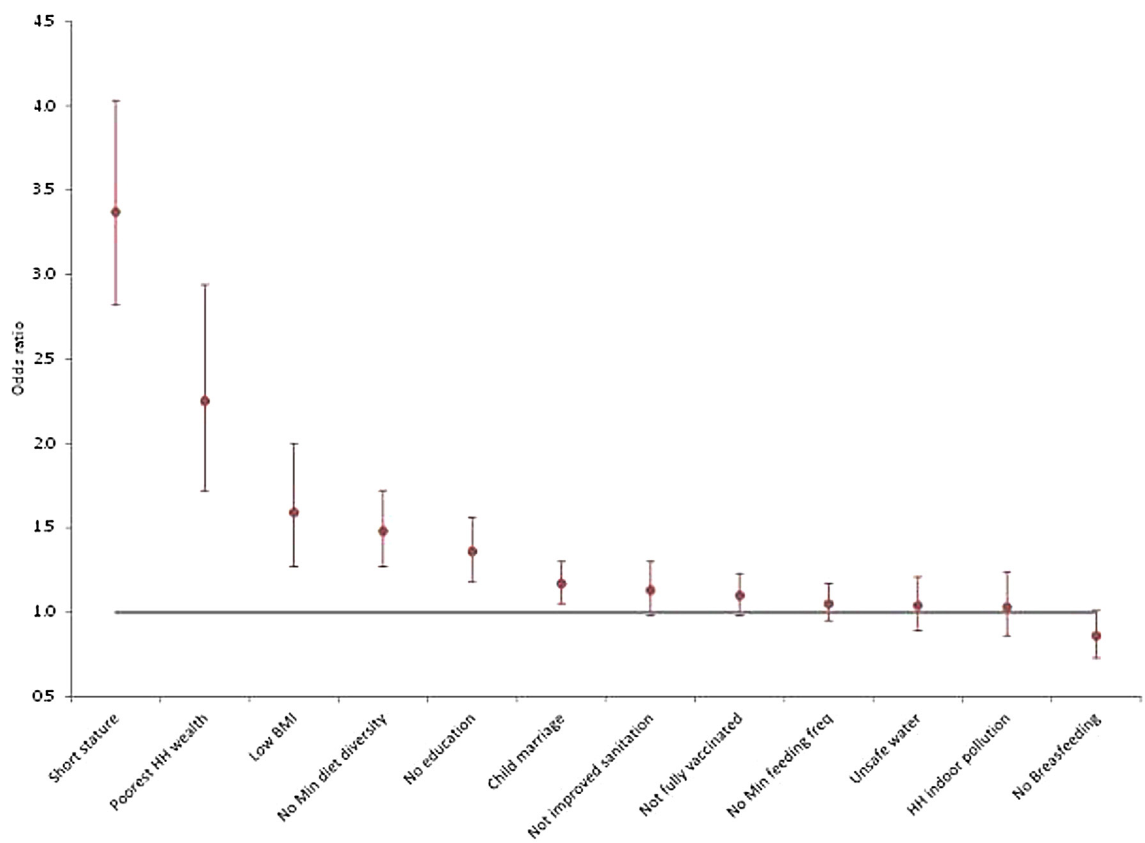

Fig. 3. Fully adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of risk factors for stunting among children aged 6–23 months in South Asia (pooled sample, excluding Afghanistan).

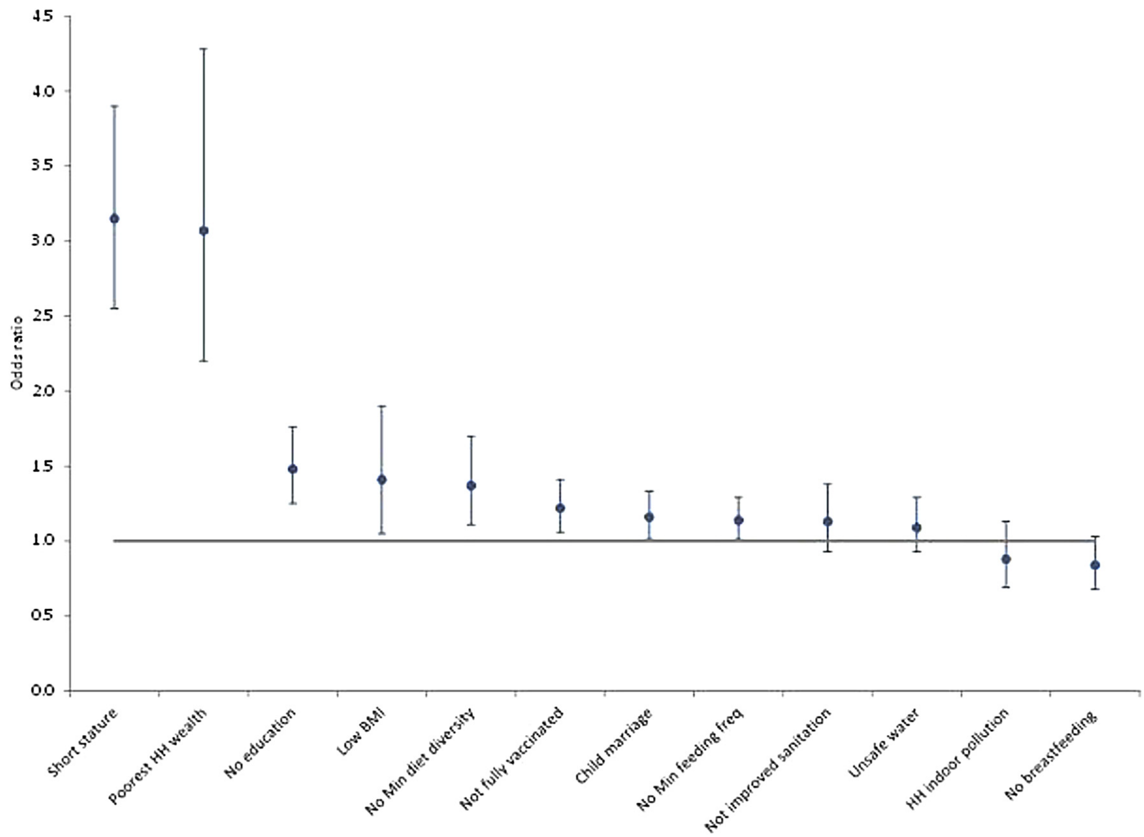

Fig. 4. Fully adjusted odds ratios (ORs) and 95% confidence intervals (CIs) of risk factors for severe stunting among children aged 6–23 months in South Asia (pooled sample).

country-specific analyses may due to inadequate power. Lastly, majority of the correlates were self-reported by mothers, and therefore measurement error could have potentially biased the estimates. However, factors such as wealth index and education level have generally been demonstrated to be valid when collected through population based surveys (Filmer and Pritchett, 2001).

Despite these potential limitations, our cross-sectional analysis provides comprehensive evidence on the relative importance of multiple correlates of child stunting, and enriches the existing assessments of determinants of nutritional status among pre-school age children in LMICs (Espo et al., 2002; Jones et al., 2008; Kanjilal et al., 2010; Smith and Haddad, 2015). For instance, child feeding has been increasingly recognized as a key determinant of child nutrition, with greater than two-thirds of malnutrition related child deaths estimated to be associated with inappropriate feeding practices (Black et al., 2008). Complementary feeding is recommended to be given at six months of age (WHO, 2002), and failure to do so has been shown to leave children vulnerable to irreversible outcomes of stunting (Gross et al., 2000; Saha et al., 2008). Yet, almost 40% of infants in our pooled sample were not given complementary foods in between 6 and 8 months of age, which was significantly associated with increased risk of stunting. Moreover, not meeting the minimum dietary diversity was also found to be important for stunting among 6–23 months old children, which is consistent with a prior review reporting that dietary diversity was positively associated with height-for-age in many LMICs (Arimond and Ruel, 2004).

In addition to factors directly related to children's feeding practices, maternal height, a marker of mother's early life nutritional and environmental conditions that has intergenerational consequences on nutrition and health (Özaltin et al., 2010; Subramanian et al., 2009), was also found to be one of the strongest predictors of child stunting and severe stunting in South Asia. Moreover, the consistent findings on the importance of maternal underweight, education and household wealth index further support that the overall environmental and socioeconomic conditions influence child nutrition through pathways involving food insecurity and inadequate access to care and dietary resources for children (Ruel et al., 2013). Overall, our analysis found that the top five risk factors identified for stunting and underweight for children aged 6–59 months in a recent study in India (i.e., short maternal stature, mothers having no education, households in lowest wealth quintile, poor dietary diversity in young children, and maternal underweight) (Corsi et al., 2016) are also applicable for infants and children aged 6–23 months across five South Asian countries, albeit the variations in the ranking and significance of the correlates by each country must be noted.

An important policy implication of our research is to further emphasize that interventions focused on specific risk factors alone are inadequate, and instead a multi-factorial framework approach should be employed, to address child stunting in South Asia. For instance, comprehensive strategies focused on a broader progress on maternal and household socioeconomic factors as well as investments in nutrition specific programs to promote dietary diversity and appropriate complementary feeding are needed to improve stunting rates at the population level (Bhutta et al., 2008; Bhutta et al., 2013; Black et al., 2008; Ruel et al., 2013).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2017.06.017.

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Supplementary Material

eTable 1. Summary of 13 risk factors for stunting for infants aged 6-8 months (Model 1) and children aged 6-23 months (Model 2) in South Asia

	Covariates and Exposures	Model 1 Age 6-8m	Model 2 Age 6-23m
1	Timely introduction of complementary foods (Y/N)	√	
2	Continued breastfeeding (Y/N)		√
3	Minimum feeding frequency (Y/N)		√
4	Minimum diet diversity (Y/N)		√
5	Mother's height (<145, 145-149.9, 150-154.9, 155+ cm)	√	√
6	Mother's BMI (<18.5, 18.5-24.9, ≥25.0 kg/m^2)	√	√
7	Mother's education (no schooling, primary, secondary or higher)	√	√
8	Mother's age at marriage (<18, ≥18 years)	√	√
9	Child fully vaccinated (Y/N)		√
10	Access to safe drinking water (Y/N)	√	√
11	Access to improved sanitation facilities (Y/N)	√	√
12	Household indoor pollution (high/poor quality)	√	√
13	Household wealth (quintiles)	√	√

eTable 2. Sensitivity analysis of fully-Adjusted[*] (but excluding type of drinking water source, sanitation facility, and household air quality) odds ratios (ORs) and 95% confidence intervals (CIs) for risk factors of stunting among children aged 6-8 months (Model 1) and 6-23 months (Model 2) in South Asia (Pooled sample) and by country

	South Asia		Afghanistan[3] 2013		Bangladesh 2014		India 2006		Nepal 2011		Pakistan 2013	
	Model 1	**Model 2**	**Model[1] 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model[1,2] 1**	**Model 2**	**Model[1,2] 1**	**Model 2**
No timely introduction of complementary foods	1.48 (1.13 - 1.94)		1.2 (0.56 - 2.60)		1.68 (0.83 - 3.40)		1.5 (1.11 - 2.03)		1.05 (0.16 - 6.85)		1.36 (0.45 - 4.10)	
No continued breastfeeding		0.86 (0.73 - 1.01)		2.05 (1.34 - 3.14)		0.72 (0.40 - 1.28)		0.93 (0.78 - 1.11)		1.71 (0.51 - 5.74)		0.53 (0.31 - 0.90)
No minimum feeding frequency		1.05 (0.95 - 1.17)		1.13 (0.86 - 1.50)		0.78 (0.60 - 1.01)		1.06 (0.95 - 1.19)		0.99 (0.50 - 1.96)		1.62 (1.08 - 2.42)
No minimum diet diversity		1.48 (1.27 - 1.73)		1.32 (1.03 - 1.70)		1.58 (1.11 - 2.24)		1.52 (1.27 - 1.83)		1.04 (0.61 - 1.77)		1.2 (0.63 - 2.29)
Mother's height (ref: 150+ cm)												
< 145 cm	2.95 (1.95 - 4.45)	3.37 (2.82 - 4.03)	3.11 (0.44 - 22.1)	2.62 (1.41 - 4.86)	2.01 (0.62 - 6.48)	3.37 (2.00 - 5.68)	3.39 (2.11 - 5.44)	3.44 (2.83 - 4.18)	7.58 (1.47 - 39.1)	5.2 (2.37 - 11.4)	2.65 (0.63 - 11.2)	3.43 (1.18 - 10.0)
145-149 cm	1.94 (1.35 - 2.77)	2.2 (1.93 - 2.50)	1.56 (0.44 - 5.50)	1.77 (1.31 - 2.41)	2.26 (0.74 - 6.93)	3.25 (2.26 - 4.66)	2.01 (1.34 - 3.01)	2.11 (1.82 - 2.44)		2.17 (1.17 - 4.03)		2.29 (1.39 - 3.79)
150-154 cm	1.42 (1.00 - 2.02)	1.36 (1.20 - 1.54)	1.49 (0.56 - 3.99)	1.33 (1.06 - 1.66)	0.65 (0.21 - 2.03)	1.35 (0.91 - 2.00)	1.87 (1.26 - 2.77)	1.44 (1.25 - 1.65)		1.13 (0.61 - 2.09)		1.05 (0.67 - 1.65)
Mother's BMI (ref: 25+ kg/m^2)												
< 18.5 kg/m^2	1.48 (0.72 - 3.04)	1.61 (1.28 - 2.01)	1.39 (0.27 - 7.25)	1.1 (0.76 - 1.59)	4.49 (0.59 - 34.2)	2 (1.23 - 3.23)	2.27 (0.89 - 5.80)	1.57 (1.20 - 2.04)	1.75 (0.19 - 16.5)	2.42 (0.68 - 8.62)	0.23 (0.018 - 2.99)	1.4 (0.65 - 3.01)
18.5-25 kg/m^2	1.38 (0.67 - 2.83)	1.38 (1.11 - 1.71)	1.33 (0.44 - 4.00)	1.2 (0.90 - 1.58)	4.31 (0.57 - 32.5)	1.63 (1.09 - 2.44)	2.07 (0.82 - 5.17)	1.34 (1.04 - 1.74)	1.86 (0.30 - 11.4)	2.03 (0.62 - 6.72)	0.4 (0.11 - 1.47)	1.28 (0.71 - 2.33)
Mother's education (ref: secondary or higher)												
No education	1.35 (0.94 - 1.95)	1.37 (1.20 - 1.57)	2.01 (0.24 - 17.3)	2.9 (1.50 - 5.62)	1.06 (0.31 - 3.67)	1.77 (1.16 - 2.70)	1.46 (0.99 - 2.17)	1.38 (1.19 - 1.59)	0.81 (0.16 - 4.05)	1.1 (0.55 - 2.19)	6.59 (1.61 - 27.0)	1.38 (0.69 - 2.76)
Any primary	1 (0.67 - 1.50)	1.13 (0.97 - 1.30)		1.77 (0.86 - 3.66)	0.9 (0.38 - 2.10)	1.18 (0.89 - 1.56)	1.1 (0.68 - 1.78)	1.15 (0.97 - 1.36)		1.12 (0.52 - 2.41)		1.01 (0.44 - 2.31)
Mother's age at marriage <18y	1.08 (0.82 - 1.43)	1.17 (1.05 - 1.30)			1.24 (0.51 - 3.03)	1.17 (0.86 - 1.60)	1.13 (0.83 - 1.54)	1.12 (1.00 - 1.26)	1.47 (0.45 - 4.81)	0.91 (0.55 - 1.48)	0.49 (0.14 - 1.70)	1.65 (1.07 - 2.52)
Child not fully vaccinated		1.1 (0.98 - 1.24)				0.94 (0.70 - 1.27)		1.11 (0.98 - 1.26)		1.71 (0.83 - 3.53)		1.12 (0.66 - 1.91)
Wealth quintile (ref: Q5)												

Q1 (lowest)	1.82 (1.01 - 3.26)	2.51 (2.00 - 3.14)	1.36 (0.22 - 8.57)	1.95 (1.31 - 2.91)	1.25 (0.36 - 4.38)	1.71 (0.99 - 2.96)	1.58 (0.87 - 2.85)	2.53 (1.97 - 3.24)	2.72 (0.16 - 45.2)	5.19 (1.85 - 14.6)	0.76 (0.035 - 16.5)	3.45 (1.08 - 11.0)
Q2	1.52 (0.88 - 2.64)	1.87 (1.51 - 2.31)	0.67 (0.11 - 4.25)	1.94 (1.31 - 2.88)	1.83 (0.64 - 5.26)	1.78 (1.10 - 2.88)	1.4 (0.79 - 2.48)	1.83 (1.44 - 2.32)	8.2 (0.69 - 96.7)	2.94 (0.91 - 9.48)	0.23 (0.015 - 3.67)	2.2 (0.74 - 6.55)
Q3	1.32 (0.78 - 2.24)	1.73 (1.42 - 2.12)	1.99 (0.32 - 12.4)	1.71 (1.17 - 2.49)	2.31 (0.75 - 7.11)	1.76 (1.09 - 2.82)	1.23 (0.70 - 2.15)	1.88 (1.50 - 2.36)	2.74 (0.24 - 31.0)	3.11 (1.08 - 8.94)	0.12 (0.0086 - 1.68)	0.82 (0.28 - 2.37)
Q4 (highest)	0.75 (0.43 - 1.32)	1.53 (1.28 - 1.84)	0.83 (0.13 - 5.39)	1.4 (0.98 - 1.99)	0.65 (0.20 - 2.08)	1.26 (0.82 - 1.94)	0.72 (0.42 - 1.25)	1.61 (1.32 - 1.96)	0.88 (0.067 - 11.6)	0.99 (0.32 - 3.11)	0.51 (0.054 - 4.90)	1.7 (0.71 - 4.07)

[1] The reference group for education was changed to *primary or higher* in separate analyses for Afghanistan, Nepal, and Pakistan.

[2] The groups in mother's height was recoded in two groups (<149.9cm and >=150cm) in separate analyses for Nepal and Pakistan.

[3] In Afghanistan, age at marriage and full vaccination was not available.

* Fully-adjusted models were estimated including all risk factors and controlling for age and sex of the child, birth order, place of residence (urban/rural), and the country fixed effects.

eTable 3. Fully adjusted[1] and Sensitivity analysis[2] odds ratios (ORs) and 95% confidence intervals (CIs) for risk factors of severe stunting among children aged 6-23 months (Model 2) in South Asia (Pooled sample) and by country

	South Asia[3]		Afghanistan 2013		Bangladesh 2014		India 2006		Nepal 2011		Pakistan 2013	
	Full model[1]	**Sensitivity[2]**	**Full model**	**Sensitivity**	**Full model**	**Sensitivity**	**Full model**	**Sensitivity**	**Full model**	**Sensitivity**	**Full model**	**Sensitivity**
No continued breastfeeding	0.84 (0.68 - 1.03)	0.84 (0.68 - 1.03)	2.24 (1.36 - 3.69)	2.28 (1.40 - 3.71)	1.05 (0.54 - 2.05)	1.04 (0.54 - 2.02)	0.97 (0.79 - 1.20)	0.98 (0.79 - 1.21)	0.57 (0.15 - 2.16)	0.59 (0.16 - 2.16)	0.32 (0.15 - 0.71)	0.32 (0.15 - 0.71)
No minimum feeding frequency	1.14 (1.01 - 1.29)	1.14 (1.01 - 1.29)	1.33 (0.93 - 1.89)	1.34 (0.94 - 1.91)	0.8 (0.51 - 1.25)	0.81 (0.52 - 1.27)	1.15 (1.01 - 1.31)	1.15 (1.01 - 1.31)	1.41 (0.61 - 3.24)	1.38 (0.61 - 3.10)	1.53 (0.90 - 2.60)	1.54 (0.91 - 2.59)
No minimum diet diversity	1.37 (1.11 - 1.70)	1.37 (1.11 - 1.70)	1.22 (0.89 - 1.66)	1.2 (0.88 - 1.64)	1.38 (0.81 - 2.35)	1.36 (0.80 - 2.32)	1.4 (1.11 - 1.77)	1.4 (1.11 - 1.76)	1.56 (0.70 - 3.45)	1.45 (0.65 - 3.25)	1.35 (0.62 - 2.94)	1.33 (0.59 - 3.01)
Mother's height (ref: 155+ cm)												
< 145 cm	3.15 (2.55 - 3.90)	3.16 (2.55 - 3.91)	2.4 (1.29 - 4.48)	2.39 (1.28 - 4.45)	7.37 (3.67 - 14.8)	7.38 (3.69 - 14.8)	2.94 (2.33 - 3.70)	2.94 (2.34 - 3.71)	2.79 (1.00 - 7.76)	2.69 (0.96 - 7.56)	4.68 (1.57 - 13.9)	4.41 (1.50 - 12.9)
145-149 cm	2.02 (1.70 - 2.40)	2.02 (1.70 - 2.40)	1.51 (1.04 - 2.20)	1.51 (1.03 - 2.20)	4.48 (2.34 - 8.57)	4.43 (2.33 - 8.41)	1.93 (1.61 - 2.31)	1.93 (1.61 - 2.31)	1.52 (0.60 - 3.86)	1.49 (0.60 - 3.72)	2.03 (0.95 - 4.33)	1.98 (0.93 - 4.22)
150-154 cm	1.35 (1.14 - 1.60)	1.35 (1.14 - 1.60)	1.04 (0.79 - 1.39)	1.03 (0.78 - 1.37)	1.73 (0.89 - 3.38)	1.73 (0.89 - 3.36)	1.37 (1.15 - 1.64)	1.37 (1.15 - 1.64)	0.36 (0.13 - 1.00)	0.37 (0.14 - 1.04)	1.45 (0.83 - 2.51)	1.39 (0.80 - 2.41)
Mother's BMI (ref: 25+ kg/m^2)												
< 18.5 kg/m^2	1.41 (1.05 - 1.90)	1.42 (1.05 - 1.91)	1.18 (0.76 - 1.81)	1.13 (0.74 - 1.73)	1.39 (0.64 - 3.02)	1.44 (0.66 - 3.14)	1.15 (0.81 - 1.64)	1.14 (0.81 - 1.61)	0.94 (0.48 - 1.81)	0.92 (0.48 - 1.78)	0.91 (0.36 - 2.35)	0.97 (0.38 - 2.49)
18.5-25 kg/m^2	1.34 (1.00 - 1.79)	1.34 (1.01 - 1.79)	1.16 (0.82 - 1.64)	1.12 (0.80 - 1.57)	1.53 (0.78 - 3.00)	1.56 (0.79 - 3.06)	1 (0.71 - 1.41)	0.99 (0.70 - 1.39)			2.16 (1.10 - 4.23)	2.25 (1.16 - 4.37)
Mother's education (ref: secondary or higher)												
No education	1.48 (1.25 - 1.76)	1.49 (1.26 - 1.76)	1.73 (0.75 - 4.00)	1.61 (0.71 - 3.68)	1.65 (0.98 - 2.76)	1.72 (1.03 - 2.86)	1.53 (1.28 - 1.83)	1.51 (1.27 - 1.81)	1.41 (0.41 - 4.89)	1.28 (0.39 - 4.21)	1.38 (0.56 - 3.40)	1.36 (0.54 - 3.39)
Any primary	1.18 (0.98 - 1.42)	1.19 (0.99 - 1.42)	1.25 (0.52 - 3.04)	1.18 (0.49 - 2.81)	1.31 (0.83 - 2.05)	1.36 (0.88 - 2.11)	1.22 (1.00 - 1.50)	1.21 (0.99 - 1.49)	1.26 (0.33 - 4.78)	1.11 (0.32 - 3.86)	0.91 (0.37 - 2.23)	0.86 (0.34 - 2.19)
Mother's age at marriage <18y	1.16 (1.01 - 1.33)	1.16 (1.01 - 1.33)			1.22 (0.75 - 2.01)	1.22 (0.74 - 2.00)	1.11 (0.96 - 1.28)	1.11 (0.96 - 1.28)	0.57 (0.27 - 1.19)	0.56 (0.27 - 1.15)	1.79 (0.99 - 3.24)	1.74 (0.97 - 3.12)
Child not fully vaccinated	1.22 (1.06 - 1.41)	1.23 (1.06 - 1.42)			0.72 (0.44 - 1.18)	0.73 (0.44 - 1.20)	1.29 (1.11 - 1.51)	1.29 (1.10 - 1.51)	1.94 (0.83 - 4.55)	1.9 (0.81 - 4.44)	1.21 (0.67 - 2.16)	1.18 (0.65 - 2.13)
Drinking water	1.09		1.13		1.08		1.02		1.71		1.32	

source not safe	(0.93 - 1.29)		(0.85 - 1.49)		(0.50 - 2.32)		(0.85 - 1.23)		(0.75 - 3.90)		(0.78 - 2.23)	
Sanitation facility not improved	1.13 (0.93 - 1.38)		0.83 (0.57 - 1.20)		1.4 (0.90 - 2.18)		1 (0.80 - 1.26)		0.78 (0.31 - 2.00)		1.27 (0.66 - 2.45)	
Household air quality poor	0.88 (0.69 - 1.13)		0.69 (0.44 - 1.09)		1.04 (0.48 - 2.29)		0.8 (0.61 - 1.04)		0.63 (0.13 - 2.98)		1.44 (0.56 - 3.69)	
Wealth quintile (ref: Q5)												
Q1 (lowest)	3.07 (2.20 - 4.28)	3.14 (2.35 - 4.21)	3.1 (1.58 - 6.08)	2.29 (1.40 - 3.77)	2.8 (1.15 - 6.79)	3.28 (1.50 - 7.19)	4.01 (2.75 - 5.86)	3.51 (2.53 - 4.87)	3.06 (0.42 - 22.5)	2.61 (0.48 - 14.3)	1.07 (0.23 - 4.92)	1.93 (0.46 - 8.14)
Q2	2.17 (1.57 - 3.01)	2.19 (1.65 - 2.90)	3.65 (1.92 - 6.93)	2.7 (1.64 - 4.45)	1.52 (0.64 - 3.60)	1.72 (0.79 - 3.74)	2.97 (2.04 - 4.32)	2.59 (1.88 - 3.55)	2 (0.24 - 17.0)	1.43 (0.25 - 8.17)	0.61 (0.14 - 2.64)	0.96 (0.25 - 3.67)
Q3	2.06 (1.51 - 2.79)	2.05 (1.56 - 2.69)	2.28 (1.26 - 4.12)	1.74 (1.08 - 2.79)	1.68 (0.74 - 3.78)	1.81 (0.87 - 3.74)	2.94 (2.06 - 4.18)	2.56 (1.88 - 3.49)	1.89 (0.28 - 13.0)	1.28 (0.25 - 6.59)	0.46 (0.13 - 1.57)	0.61 (0.18 - 2.11)
Q4 (highest)	1.68 (1.28 - 2.20)	1.67 (1.29 - 2.17)	1.48 (0.84 - 2.61)	1.23 (0.74 - 2.05)	1.05 (0.48 - 2.30)	1.08 (0.48 - 2.43)	2.28 (1.69 - 3.08)	2.1 (1.58 - 2.80)	0.63 (0.12 - 3.27)	0.5 (0.085 - 2.92)	0.72 (0.24 - 2.17)	0.86 (0.29 - 2.56)

[1] Model adjusted for drinking water source, access to sanitary facilities, and household air quality.
[2] Model excluding drinking water source, access to sanitary facilities, and household air quality.
[3] In Afghanistan, age at marriage and full vaccination was not available.
* Fully-adjusted models were estimated including all risk factors and controlling for age and sex of the child, birth order, place of residence (urban/rural), and the country fixed effects.