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Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

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TITLE:

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

SUBTITLE:

Double burden of malnutrition among under-five children in South Asia

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ABSTRACT

Objectives: The extent of double burden of malnutrition among children aged under five years in South Asian countries is unknown. We aimed to explore the double burden of malnutrition among young children by household's socioeconomic status in South Asian countries.

Design: Nationally-representative cross-sectional surveys.

Settings: Latest Demographic and Health Surveys from Bangladesh, India, Pakistan, Maldives, and Nepal.

Participants: Children aged 24-59 months with valid measured information on height and weight (n=146,996).

Primary exposure and outcome measures: Information on household's socioeconomic status (e.g. wealth index, highest level of education) was collected using face-to-face interview. Underweight and overweight were defined according to definitions of World Health Organisation and International Obesity Task Force, respectively.

Results: The prevalence of underweight ranged from 19% in Maldives to 38% in India. The prevalence of overweight was between 2% and 4% in Bangladesh, India, and Nepal, whereas Pakistan (7%) and Maldives (9%) had slightly higher prevalence. Higher household wealth was inversely associated with prevalence of underweight. ORs (95% CI) for richest vs poorest households for Bangladesh, India, Maldives, Nepal and Pakistan were 0.31 (0.25-0.37), 0.36 (0.34-0.37), 0.51 (0.20-1.32), 0.38 (0.23-0.62), and 0.58 (0.41-0.82), respectively. When compared to poorest households, richest households had higher odds of having children who were overweight in Bangladesh (1.96 [1.27-3.02]) and India (1.53 [1.41-1.66]), but lower odds in Pakistan (0.22 [0.14-0.34]). The likelihood of having underweight

children decreased with increasing household education level in all five countries. Households with higher education were more likely to have overweight children only in Bangladesh (2.97 [1.88-4.68]) and India (1.37 [1.25-1.50]).

Conclusions: While the associations for household's socioeconomic status with underweight among under-five children were consistent in South Asian countries, the associations with overweight seem heterogeneous. These differences warrant different approaches for developing national nutrition programs and strategies to tackle double burden of malnutrition in this region.

Keywords:
Double burden, underweight, overweight, under-five children, South Asia

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to investigate the double burden of malnutrition among children aged under five years in South Asian countries, using nationally-representative samples.
- We used height and weight information which were measured by trained research personnel.
- Use of International Obesity Task Force (IOTF) classification to define overweight ensures cross-comparison of estimates with those from other regions.
- Even though we adjusted for several factors to examine the associations of socioeconomic status with underweight and overweight, we did not have information on dietary and lifestyle factors that could modify those associations.
- Due to smaller sample sizes in Maldives and Nepal, we could not reliably estimate the associations of socioeconomic status with underweight and overweight.

INTRODUCTION

Double burden of malnutrition implies to the presence of both undernutrition and overnutrition (overweight or obesity) within individuals, households, or populations [1]. At the individual level an undernourished child can be overweight or obese when they reach adulthood, whereas at household level coexistence of underweight and overweight children or adults can be possible. At the population level, double burden of malnutrition indicates the prevalence of both underweight and overweight in the same community, country, or region [1,2].

Double burden of malnutrition is an emerging problem in the low and middle-income countries (LMICs). Historically, these countries have huge burden of undernutrition in children [3,4], but there is also a growing burden of overnutrition in recent times, particularly due to economic growth, rapid urbanization, and adoption of western lifestyles [5–7]. South Asia is comprised mostly of LMICs, and all of them are experiencing similar trends in both childhood undernutrition and overnutrition. While South Asian countries have highest numbers of underweight children due to higher prevalence rates and large populations in younger age groups [8], the number of overweight children is also increasing rapidly [5–7]. South Asians children living in developed countries also have a much higher prevalence of overweight than any other ethnic groups - a recent study suggests [9]. However, there is no study - to the best of our knowledge - which looked at double burden of malnutrition among children aged under five years in any South Asian countries. So, the extent of this emerging public health problem in this age group in South Asian countries is still unknown.

Ensuring optimum nutrition in early years of life is an important public health agenda, particularly because both underweight and overweight in these years are associated

with wide range of morbidities in early life as well as in later life [5,10]. Health systems in South Asian countries are still focusing mainly on prevention of childhood undernutrition, but an increasing trend in overnutrition demands newer approach to tackle double burden of malnutrition among children in this region. To have better strategies to solve the problem of double burden of malnutrition among children under the age of five years, we also need to understand the socioeconomic inequalities in nutritional outcomes. While previous studies have suggested that there can be substantial differences in the burden of underweight and overweight among older children by household's wealth, education level, and area of residence [11–14], such associations are not clear for children under five years in South Asian countries. Given the nutrition status in early childhood can track into later childhood and adulthood, identifying socioeconomic groups with higher burden of underweight and overweight is crucial for tailoring public health prevention interventions.

In this study, we aimed to quantify the extent of underweight and overweight among children aged 24-59 months in South Asian countries, and to estimate their associations with household's socioeconomic status, using the latest nationally-representative surveys.

METHODS

Study design and data sources

This study is based on the latest DHS data from five South Asian countries, namely Bangladesh, India, Pakistan, Maldives, and Nepal. Other countries in the South Asian regions (e.g. Afghanistan, Bhutan, and Sri Lanka) were not included in this study because of either DHS was not conducted, or anthropometric data for children were not available. Year of survey for each included country is given in Table 1. DHS are nationally-representative household surveys which are usually conducted about every 5 years. These surveys provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition. A DHS is conducted by a national implementing agency, which can be any bona-fide governmental, non-governmental, or private-sector organization and has enough experience in the execution of surveys that are national in scope. Technical assistances throughout the whole process are provided by the DHS program [15]. DHS are usually based on two-stage stratified sampling of households. In the first stage, sampling census enumeration areas are selected using probability proportional to size (PPS) sampling technique through statistics provided by the respective national statistical office. In the second stage, households are selected through systematic random sampling from the complete listing of households within a selected enumeration area [16].

Ethical approval for each DHS is taken from the ICF Institutional Review Board as well as by a review board in the host country. More details of such ethical approval can be found in the DHS program website [https://dhsprogram.com/]. Informed consent to participate in the study is taken from the participant, or from the parent or guardian if anthropometric measurements are taken from a child. The data files are

freely available from the program website. We received authorization from the DHS program for using the relevant datasets for this analysis. The data we received were anonymized for protection of privacy, anonymity and confidentiality.

These surveys have very high response rate, usually 90% and above. Detailed questionnaires of included surveys are available in the final report of each survey. We used the children's record (coded as “KR” in DHS program) datasets which contained information about children born in the last 5 years prior to the survey (aged 0-59 months). The present analysis is based on children aged 24 – 59 months who had valid measurement of their weight and height. We excluded children aged less than 24 months because there is no available classification system for defining overweight for them.

Anthropometric measurement, and defining underweight and overweight

In DHS, height and weight of the children were measured by trained personnel using standardized instruments and procedures. Lightweight SECA scales (Hamburg, Germany) with digital screen, designed and manufactured by the United Nations Children’s Fund (UNICEF), were used to measure weight. The height/length was measured by boards, produced by Shorr Productions (Maryland, USA). In children with height less than 85 centimetres, recumbent length was measured, whereas standing height was measured for those taller than this. Body mass index (BMI) was calculated by dividing body weight (kg) by squared height (m^2).

Childhood underweight is based on the indicator weight-for-age, which is an overall indicator of population's nutritional status. A child with weight-for-age less than two standard deviations (-2 SD) from the median of the reference population is considered as underweight according to World Health Organization (WHO)

guidelines [17]. Underweight is a composite definition which can encompass stunting, wasting, or both.

To define childhood overweight, we used the age and sex-specific BMI cut-offs from the International Obesity Task Force (IOTF) classification system [18,19]. According to IOTF, a child aged between 2 years and 18 years is classified as overweight if their BMI is larger than the age and sex-specific BMI cut-off corresponding to an adult BMI of >25 kg/m^2. Our definition of childhood overweight also included those with obesity and it is referred to hereafter as "overweight" for simplicity.

Socioeconomic factors

DHS collected information on wide range variables from the selected households and the respondents from those households using face-to-face interview conducted by trained personnel. DHS collected information on socioeconomic factors like area of residence and household's wealth index. Place of residence (rural and urban) was defined according to country-specific definitions. For household's wealth index, each national implementing agency constructed a country-specific index using principal components analysis from data on household assets including durable goods (i.e. bicycles, televisions etc.) and dwelling characteristics (i.e. sanitation, source of drinking water and construction material of house etc.) [15]. This wealth index was then categorized into five groups (i.e. poorest, poorer, middle, richer, and richest) based on the quintile distribution of the sample.

Statistical analysis

We conducted all analysis following the instructions given in the DHS guide to analysis [16]. The percent distributions for characteristics of included children are described as proportions, for each DHS survey. To estimate the prevalence of childhood underweight and overweight, we used sampling weights given in each DHS dataset in order to get nationally-representative estimates. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate. We also estimated the prevalence of childhood underweight and overweight by the levels of socioeconomic factors to assess the inequalities by those factors.

To examine the associations of socioeconomic factors with prevalence of childhood underweight and overweight, we used multiple logistic regression, separately for each included country. These analyses were adjusted for child's age, sex, are of residence, household's highest education level, household's wealth index, as appropriate. Considering the two-stage stratified cluster sampling in DHS, we applied Stata's survey estimation procedures (*"svy"* command) for regression analyses [20]. The results are presented (as in tables and figures) as group-specific 95% confidence intervals (g-SCIs) for comparisons between more than two categories to allow comparisons to be made between any two categories, even if neither is the reference group [21]. Conventional 95% CIs are provided in case of two categories being compared. All analyses were performed using Stata v15.1 (Statacorp, College Station, TX, USA).

RESULTS

A total of 146,996 children aged between 24 and 59 months from five south Asian countries were included in this study. Table 1 shows the sample characteristics for each of these countries' latest DHS data. Sample population for five countries had almost equal distribution for both sex and age. In all countries except Nepal, the majority of the children were from rural area (according to the definition of specific country), and the proportions varied widely between 57% and 86%. On average less than one in every 10 households had at least one member who completed higher education. India, Nepal and Pakistan had significant number (≥33%) of households where none had formal education, whereas in Bangladesh and Maldives proportion of such households was relatively lower (<20%). The samples from original surveys were divided into quintiles based on household's wealth index, and after relevant exclusions for this study the distributions remained more or less similar (Table 1). As expected, the better part of burden for malnutrition in all countries was due to undernutrition (Figure 1). India had the highest (38%) prevalence of undernutrition among children aged 24-59 months followed by Bangladesh (37%), Nepal (29%), Pakistan (28%), and Maldives had the lowest prevalence (19%). For overweight among these children, Bangladesh, India, and Nepal had similar prevalences (between 2% and 4%) whereas Pakistan and Maldives had much higher prevalence, 7% and 9% respectively. When we looked at the combined burden of both forms of malnutrition, India and Bangladesh had much higher burden in compared to other countries. However, the prevalences for both undernutrition and overnutrition were slightly higher in India than those in Bangladesh. In Pakistan and Maldives where overweight prevalence was high, the burden of undernutrition was decreased.

There were wide variations in the prevalence of undernutrition and overweight according to household's wealth index (Figure 2) and household's highest education (Figure 3) in all countries. Between the poorest and the richest households, the burden of undernutrition decreased by more than half in all of these five countries. The prevalence of overweight almost doubled between the poorest and the richest households in Bangladesh and India, whereas such differences were not clearly evident in Maldives and Nepal. In Pakistan, rich households were less likely to have overweight children than poor households. The prevalence of undernutrition and overweight according to household's highest education level followed similar country-specific patterns observed for wealth index (Figure 3). Notably, children in households with higher education had much higher rate of overweight in Bangladesh, India, and Pakistan.

When adjusted for age, sex, area of residence, and education, there was reliable evidence for inverse relationship between wealth index and prevalence of underweight in Bangladesh, India, Nepal, and Pakistan; whereas such conclusion could not be made for Maldives possibly due to smaller number of cases (Figure 4). The adjusted ORs for richest vs. poorest households were 0.36 (95% CI 0.34-0.37) and 0.31 (95% CI 0.25-0.37) in India and Bangladesh, respectively. Richest households were more likely to have children who were overweight in compared to the poorest households in India (OR 1.53, 95% CI 1.41-1.66) and in Bangladesh (OR 1.96, 95% CI 1.27-3.02). In contrary, richest households were less likely to have overweight children in Pakistan when compared to poorest households (OR 0.22, 95% CI 0.14-0.34). The overall associations of wealth index with underweight and overweight were not significant for Maldives and Nepal.

There were significant inverse associations between household's education level and underweight in all countries expect Maldives, after adjustment for age, sex, area of residence, and wealth index (Figure 5). The ORs of underweight for higher education vs. no education were 0.48 (95% CI 0.46-0.51), 0.63 (95% CI 0.49-0.81), and 0.38 (95% CI 0.24-0.59) in India, Bangladesh, and Pakistan, respectively. Households with higher education were more likely to have overweight children when compared to households with no education in Bangladesh (OR 2.97, 95% CI 1.88-4.68), and in India (OR 1.37, 95% 1.25-1.50). Overweight in children was not associated with education level in Maldives, Nepal, and Pakistan.

Additional analyses showed that there were no appreciable sex differences for underweight and overweight prevalence (Supplementary Table S1). The prevalence for underweight and overweight differed between rural and urban areas (Supplementary Table 2), although adjusted models showed no significant association for area of residence with underweight and overweight (Supplementary Table 3). This illustrates that socioeconomic status can explain the rural-urban differences in double burden of malnutrition.

DISCUSSION

This study involving nationally-representative surveys conducted in recent times in five South Asian countries provided empirical evidence on double burden of malnutrition among children aged 24-59 months and its association with socioeconomic status factors. In South Asian countries, there is a substantial burden of undernutrition among younger children while a differential burden of overnutrition is also seen. Households with higher socioeconomic status (as measured by wealth index and education) were consistently associated with lower odds of underweight children in all countries, though the association did not reach statistical significance in Maldives. The associations between socioeconomic status and overweight were heterogeneous: both households with richest wealth and households with higher education were more likely to have overweight children in India and Bangladesh, but the evidence for such associations in other countries was not consistent.

South Asian countries have experienced striking economic growth in the last few decades which triggered unprecedented improvements in maternal mortality, infant mortality, under-five mortality, and child undernutrition [22,23]. The prevalence of childhood underweight was declined by 25-30% between 2004 and 2014 in Bangladesh, India, Pakistan, and Nepal [24]. However, the existing burden of undernutrition is still high – our study found that around one-third of under-five children in this region are underweight. Previous studies conducted in the region have found that poor socioeconomic status, lower level of parental education, younger age of mother at birth, short birth interval, and initiation of complimentary feeding are important determinants of undernutrition among under-five children [25–27]. We also observed significant nutrition disparity by household socioeconomic status. In populous countries like Bangladesh, India, and Pakistan, almost half of the

children in poorest households were underweight. In multivariable models, both household's socioeconomic status and household's highest education level were found to be strongly associated with childhood underweight in all countries. Multi-sector approach is needed to alleviate poverty and other social inequalities related to undernutrition disparity in South Asia and beyond [28].

Recent reports [29–32] from South Asian countries highlighted the rise of overweight burden in children, but mainly in older groups. Overweight among under-five children is still overlooked in current literature. In our study, we provided evidence for an increasing burden of overweight in this age group, which clustered in households with higher socioeconomic status. We used two indicator variables for household's socioeconomic status, namely wealth index and highest level of education, and found that after simultaneous adjustment for each other wealth index had better explanatory power than education level. Frequent intake of energy-dense foods and physical inactivity have been shown to be associated with overweight and obesity both in children and adults [33,34]. These lifestyle behaviors are common in the higher socioeconomic group in LMICs and therefore, both childhood and adulthood overweight are clustered in affluent households in urban areas [29,32]. Public health nutrition programmes should therefore focus on educating parent of younger children about proper feeding guidance and importance of physical activity.

South Asian countries have seen an unprecedented rise of urbanization and economic growth in recent times [35]. Previous studies [29,32,36] reported about urban-rural gap in burden of overweight and obesity, but we found no significant differences after adjustment for socioeconomic variables. This means that socioeconomic distribution of households can largely explain the observed urban-rural differences for the burden of childhood overweight. In our study, the

associations for socioeconomic status with childhood overweight were heterogeneous among countries, but it could be due to small number of overweight children in those countries. A previous study from Pakistan with a representative multistage cluster sample also found that affluent urban population was facing a rapid rise in overweight and obesity among primary school children [30].

The findings from our study highlight the importance of considering social determinants of health while developing public health interventions and policies to tackle both childhood undernutrition and overnutrition. So far, the public health interventions in South Asia focus almost completely on the prevention of undernutrition, but identifying groups with more likelihood of developing childhood overweight and obesity can help to shift the focus of intervention to those groups. We suggest the policy makers to provide more resources to tackle underweight while care should be taken for the affluent section of the society to prevent overweight.

To the best of our knowledge, no study looked at the coexistence of underweight and overweight among under-five children in South Asian countries by socioeconomic status. We used nationally-representative samples for five South Asian countries to investigate the association of double burden of malnutrition with households' socioeconomic status. Child's height and weight were measured objectively by trained field researchers using calibrated scales. We also used IOTF classification system to define overweight among these children, which helps to compare the overweight prevalence internationally. We were also able to adjust for several factors in the multivariable models. Our study lacks information on dietary and lifestyle factors, so we could not adjust for their effects on the association between socioeconomic status and double burden of malnutrition. Due to smaller sample sizes in Maldives and Nepal, we could not reliably estimate the associations. We

excluded those children who did not have anthropometric data, but DHS reports suggest that they should not vary significantly in terms of sociodemographic characteristics.

In conclusion, our study provides evidence for socioeconomic disparities for the coexistence of under and over nutrition among children aged 24-59 months in South Asian settings. These unmet inequalities for both underweight and overweight should be considered while developing national public health nutrition programmes and strategies.

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AUTHOR CONTRIBUTIONS

Conception and design: FH, MS, SA and MB

Data collection and management: FH, SS, and GA

Data analysis: FH, MS, SS

Interpretation of the results: All authors

Drafting of the article: FH and MS

Critical revision of the article for important intellectual content: All authors

Final approval of the article: All authors.

COMPETING INTERESTS STATEMENT

None declared

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This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

DATA SHARING STATEMENT

This study used data from Demographic and Health Surveys (DHS) for Bangladesh, India, Maldives, Nepal, and Pakistan, which are available from the DHS programme website.

PATIENT AND PUBLIC INVOLVEMENT

There was no patient and public involvement in the development of the research question, design of this study, recruitment to and conduct of the study.

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FIGURE LEGENDS

Figure 1: Prevalence of underweight and overweight, by country

Sampling weight provided by the Demographic and Health Survey (DHS)[16] was used to estimate country-representative prevalence. Error bars represent 95% confidence intervals

Figure 2: Prevalence of underweight and overweight, by household's wealth index

Error bars represent 95% confidence intervals

Figure 3: Prevalence of underweight and overweight, by household's highest educational attainment

Error bars represent 95% confidence intervals

Figure 4: Odds ratios of underweight and overweight, by household's wealth index

Analyses were adjusted for age, sex, area of residence, and household's highest educational attainment

Figure 5: Odds ratios of underweight and overweight, by household's highest educational attainment

Analyses were adjusted for age, sex, area of residence, and household's wealth index

TABLES

Table 1: Sample characteristics in five demographic and health survey data, by country

	Number (%)				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Year of survey	2014	2015-16	2009	2016	2012-13
Number of children	4170	138134	1339	1389	1964
Child's sex					
Male	2134 (51.2)	71698 (51.9)	672 (50.2)	715 (51.5)	1016 (51.7)
Female	2036 (48.8)	66436 (48.1)	667 (49.8)	674 (48.5)	948 (48.3)
Child's age					
2 year	1406 (33.7)	45298 (32.8)	452 (33.8)	460 (33.1)	668 (34.0)
3 year	1377 (33.0)	47506 (34.4)	464 (34.7)	479 (34.5)	641 (32.6)
4 year	1387 (33.3)	45329 (32.8)	423 (31.6)	449 (32.3)	655 (33.4)
Area of residence					
Urban	1316 (31.6)	33245 (24.1)	183 (13.7)	788 (56.7)	851 (43.3)
Rural	2854 (68.4)	104889 (75.9)	1156 (86.3)	601 (43.3)	1113 (56.7)
Household's highest education level					
No education	714 (17.1)	44950 (32.5)	221 (16.5)	514 (37.0)	1067 (54.3)
Primary	1168 (28.0)	20664 (15.0)	615 (45.9)	260 (18.7)	303 (15.4)
Secondary	1877 (45.0)	60737 (44.0)	462 (34.5)	431 (31.0)	385 (19.6)
Higher	411 (9.9)	11783 (8.5)	26 (1.9)	184 (13.2)	209 (10.6)
Wealth index					
Poorest	931 (22.3)	36404 (26.4)	330 (24.6)	351 (25.3)	443 (22.6)
Poorer	781 (18.7)	32673 (23.7)	335 (25.0)	308 (22.2)	390 (19.9)
Middle	808 (19.4)	27462 (19.9)	358 (26.7)	296 (21.3)	323 (16.4)
Richer	843 (20.2)	23044 (16.7)	201 (15.0)	276 (19.9)	419 (21.3)
Richest	807 (19.4)	18551 (13.4)	115 (8.6)	158 (11.4)	389 (19.8)

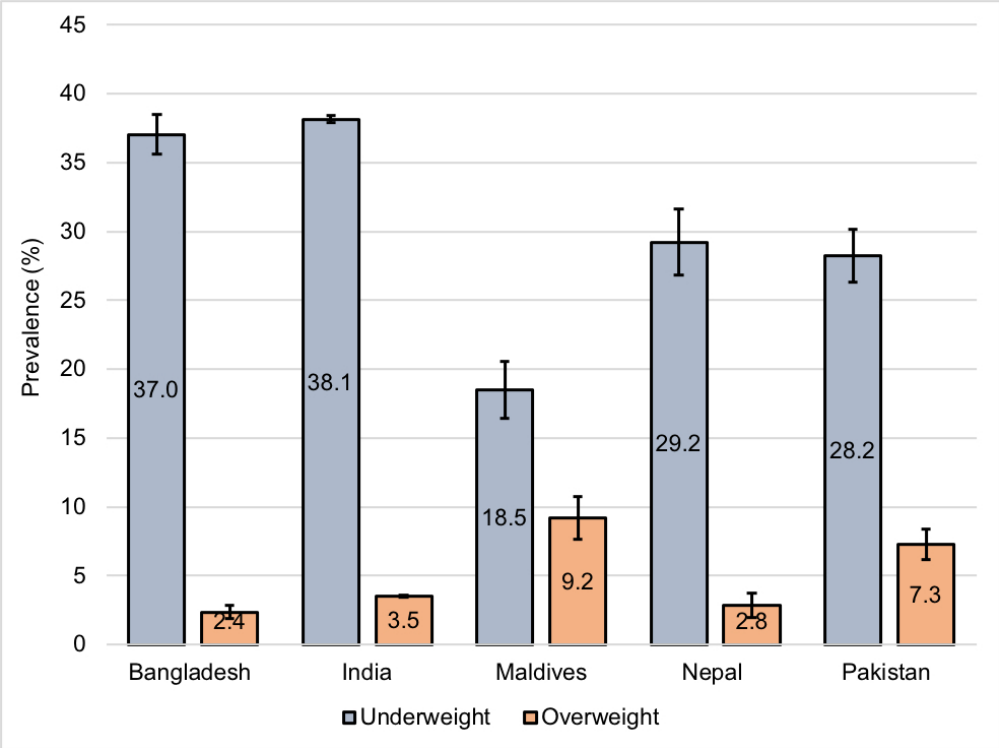

Figure 1: Prevalence of underweight and overweight, by country.
Sampling weight provided by the Demographic and Health Survey (DHS)[16] was used to estimate country-representative prevalence. Error bars represent 95% confidence intervals

83x62mm (300 x 300 DPI)

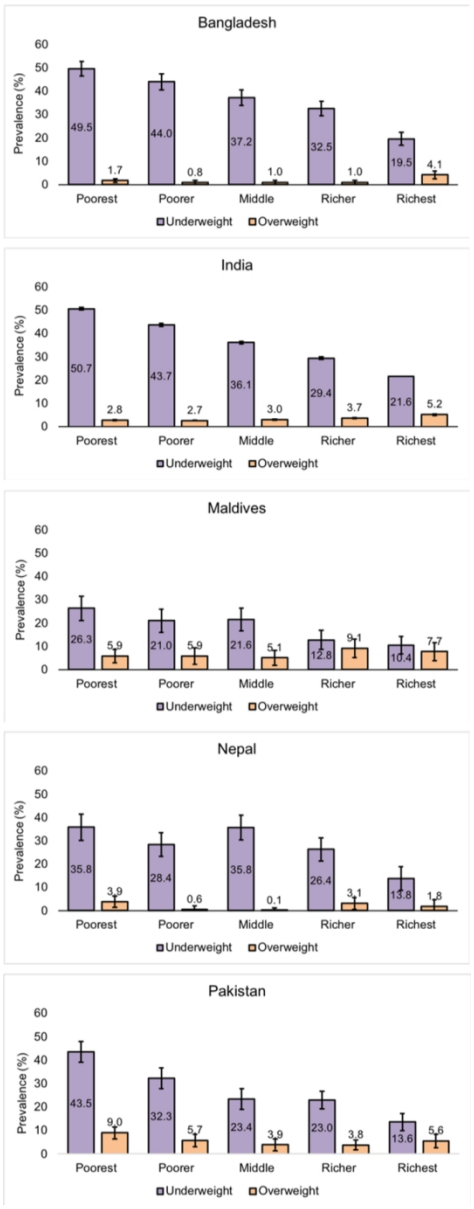

Figure 2: Prevalence of underweight and overweight, by household's wealth index
Error bars represent 95% confidence intervals

30x78mm (600 x 600 DPI)

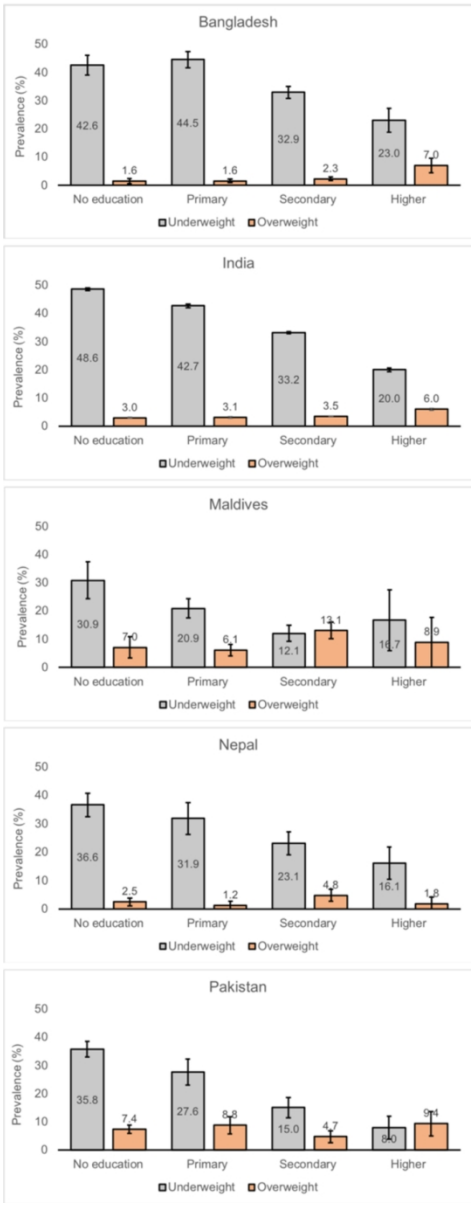

Figure 3: Prevalence of underweight and overweight, by household's highest educational attainment
Error bars represent 95% confidence intervals

30x77mm (600 x 600 DPI)

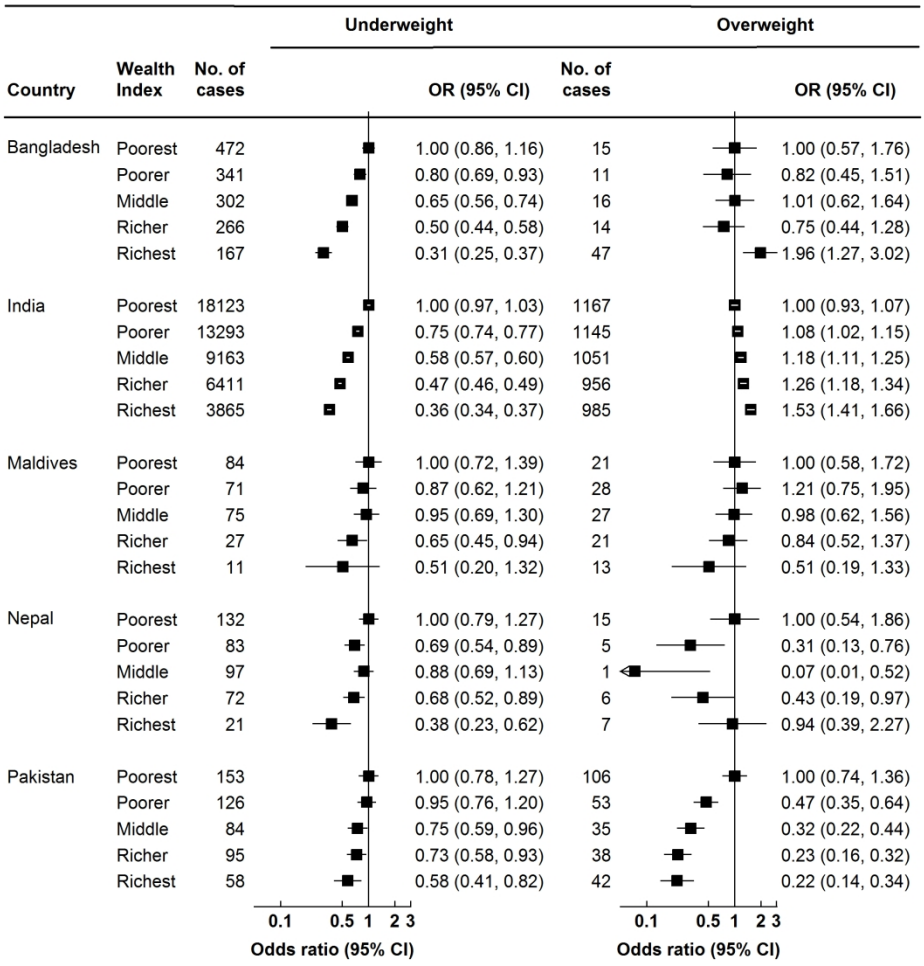

Figure 4: Odds ratios of underweight and overweight, by household's wealth index
Analyses were adjusted for age, sex, area of residence, and household's highest educational attainment

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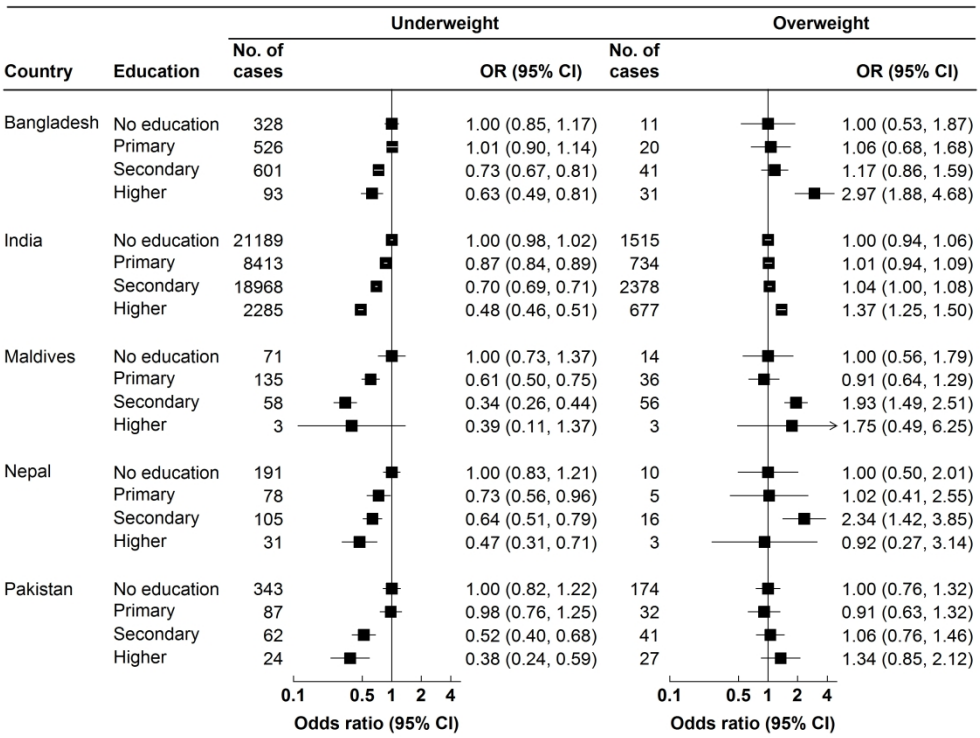

Figure 5: Odds ratios of underweight and overweight, by household's highest educational attainment
Analyses were adjusted for age, sex, area of residence, and household's wealth index

277x209mm (300 x 300 DPI)

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five south Asian countries: evidence from Demographic and Health Surveys

Fariha Binte Hossain, Md Shajedur Rahman Shawon, Md Shehab Uddin Al-Abid, Sultan Mahmood, Gourab Adhikary, Md M Islam Bulbul

Supplementary materials

Table S1: Prevalence of underweight and overweight among children aged 24-59 months, by sex

	Prevalence (95% CIs)	
	Boys	**Girls**
Underweight		
Bangladesh	35.2 (33.2-37.2)	39.0 (36.9-41.1)
India	37.4 (37.0-37.7)	38.9 (38.6-39.3)
Maldives	17.6 (14.9-20.7)	19.4 (16.6-22.6)
Nepal	29.3 (26.1-32.8)	29.1 (25.8-32.6)
Pakistan	30.6 (27.9-33.4)	25.7 (23.1-28.4)
Overweight		
Bangladesh	2.0 (1.5-2.6)	2.8 (2.1-3.6)
India	3.4 (3.2-3.5)	3.7 (3.5-3.8)
Maldives	8.3 (6.5-10.7)	10.0 (7.9-12.5)
Nepal	1.7 (1.0-3.0)	4.0 (2.7-5.7)
Pakistan	7.2 (5.8-8.9)	7.3 (5.9-9.1)

Sampling weights provided by the Demographic and Health Survey (DHS) were used to estimate country-representative prevalence. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate.

Table S2: Prevalence of underweight and overweight among children aged 24-59 months, by area of residence

	Prevalence (95% CIs)	
	Urban	**Rural**
Underweight		
Bangladesh	30.0 (27.4-32.9)	39.4 (37.7-41.1)
India	30.9 (30.4-31.4)	41.0 (40.7-41.3)
Maldives	11.5 (8.8-15.0)	21.7 (19.1-24.4)
Nepal	25.4 (22.4-28.7)	33.6 (30.1-37.4)
Pakistan	23.3 (20.2-26.7)	30.4 (28.1-32.8)
Overweight		
Bangladesh	3.9 (2.9-5.2)	1.8 (1.4-2.4)
India	4.4 (4.2-4.7)	3.1 (3.0-3.2)
Maldives	13.2 (10.2-16.8)	7.4 (5.8-9.2)
Nepal	3.1 (2.1-4.6)	2.5 (1.5-4.0)
Pakistan	6.6 (4.9-8.8)	7.6 (6.3-9.1)

Sampling weights provided by the Demographic and Health Survey (DHS) were used to estimate country-representative prevalence. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate.

Table S3: Associations of area of residence with underweight and overweight among children aged 24-59 months

	Area	No. of case	Adjusted OR (95% CIs) †
Underweight			
Bangladesh	Urban	416	1.00 (Reference)
	Rural	1132	0.94 (0.80-1.10)
India	Urban	10075	1.00 (Reference)
	Rural	40780	0.90 (0.87-0.92)
Maldives	Urban	20	1.00 (Reference)
	Rural	248	1.03 (0.46-2.31)
Nepal	Urban	204	1.00 (Reference)
	Rural	201	1.11 (0.87-1.43)
Pakistan	Urban	185	1.00 (Reference)
	Rural	331	1.01 (0.79-1.29)
Overweight			
Bangladesh	Urban	52	1.00 (Reference)
	Rural	51	0.69 (0.44-1.09)
India	Urban	1420	1.00 (Reference)
	Rural	3884	1.05 (0.98-1.13)
Maldives	Urban	25	1.00 (Reference)
	Rural	85	0.39 (0.16-0.96)
Nepal	Urban	18	1.00 (Reference)
	Rural	16	1.23 (0.57-2.66)
Pakistan	Urban	118	1.00 (Reference)
	Rural	156	0.57 (0.41-0.79)

† Adjusted for age, sex, household's highest education and household's wealth index

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	Page 1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	#3	State specific objectives, including any prespecified hypotheses	Page 6 lines 14-16
Methods			

Study design	#4	Present key elements of study design early in the paper	Page 7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	Page 7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	NA
Bias	#9	Describe any efforts to address potential sources of bias	Page 10 lines 11-15
Study size	#10	Explain how the study size was arrived at	NA
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	Page 10
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	NA
Statistical methods	#12c	Explain how missing data were addressed	NA
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	NA
Statistical methods	#12e	Describe any sensitivity analyses	Page 13 lines 10-16
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers	Page 11

		potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	NA
Participants	#13c	Consider use of a flow diagram	Page 11
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	Page 11
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	NA
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Page 11
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12
Main results	#16b	Report category boundaries when continuous variables were categorized	NA
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Page 13 lines 10-16
Discussion			
Key results	#18	Summarise key results with reference to study objectives	Page 14
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	Page 16-17
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and	Page 14-16

		other relevant evidence.	
Generalisability	#21	Discuss the generalisability (external validity) of the study results	Page 16
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

Notes:

- 3: Page 6 lines 14-16
- 9: Page 10 lines 11-15
- 12e: Page 13 lines 10-16
- 17: Page 13 lines 10-16 This checklist was completed on 09. July 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

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Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

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Secondary Subject Heading:	Public health, Nutrition and metabolism, Global health, Epidemiology
Keywords:	Double burden, underweight, overweight, under-five children, socioeconomic status, South Asia

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TITLE:

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

SUBTITLE:

Double burden of malnutrition among under-five children in South Asia

AUTHORS:

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ABSTRACT

Objectives: We aimed to investigate the socioeconomic inequalities in the burden of underweight and overweight among children in South Asia. We also examined other factors that were associated with these outcomes independently of household's socioeconomic status.

Design: Nationally-representative surveys.

Settings: Demographic and Health Surveys from Bangladesh, India, Pakistan, Maldives, and Nepal, which were conducted between 2009 and 2016.

Participants: Children aged 24-59 months with valid measurement for height and weight (n=146,996).

Primary exposure and outcome measures: Primary exposures were household's wealth index and level of education. Underweight and overweight were defined according to the World Health Organization and International Obesity Task Force definitions, respectively.

Results: Underweight prevalence was 37% in Bangladesh, 38% in India, 19% in Maldives, 29% in Nepal, and 28% in Pakistan. Bangladesh, India, and Nepal had similar overweight prevalence (between 2% and 4%) whereas Pakistan (7%) and Maldives (9%) had higher prevalence. As expected, households with higher wealth index or education had lower odds of having underweight children. Adjusted-odds ratios (ORs) of underweight for richest vs poorest households were 0.4 [95% CI:0.3-0.5], 0.5 [0.5-0.6], 0.5 [0.2-1.4], 0.5 [0.3-0.8], and 0.7 [0.5-1.1] for Bangladesh, India, Maldives, Nepal and Pakistan, respectively. Compared to poorest households, richest households were more likely to have overweight children in all countries except Pakistan, but such associations were not significant after adjustment for other factors. There were higher odds of having overweight children in households with

higher education in Bangladesh (OR 2.1 [95% CI:1.3-3.5]), India (1.2 [1.2-1.3]), and Pakistan (1.8 [1.1-2.9]) when compared to households with no education. Maternal nutritional status was consistently associated with children's nutritional outcomes after adjustments for socioeconomic status.

Conclusions: Our study provides evidence for socioeconomic inequalities for childhood underweight and overweight in South Asian countries, although the directions of associations for underweight and overweight might be different.

Keywords:

Double burden, underweight, overweight, under-five children, South Asia, Bangladesh, India, Pakistan, Nepal, Maldives

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to investigate the double burden of malnutrition among children aged under five years in South Asian countries, using nationally-representative samples.
- We used height and weight information which were measured by trained research personnel.
- Use of International Obesity Task Force (IOTF) classification to define overweight ensures cross-comparison of estimates with those from other regions.
- Although we adjusted for several child, household and maternal factors when examining the associations of socioeconomic status with underweight and overweight, we did not have information on many dietary and lifestyle factors that could modify those associations.
- We examined the effects of other factors on childhood underweight and overweight after adjustment for household's socioeconomic status.

INTRODUCTION

Double burden of malnutrition implies the presence of both undernutrition and overnutrition (overweight or obesity) either at the individual, household, or population level [1]. At the individual level, an undernourished child can be overweight or obese when they reach adulthood, whereas at household level coexistence of underweight and overweight children or adults can be possible. At the population level, double burden of malnutrition indicates the prevalence of both underweight and overweight in the same community, country, or region. Double burden of malnutrition is an emerging problem in the low and middle-income countries (LMICs) [1,2]. Historically, these countries have a considerable burden of undernutrition in children [3,4], but there is also a growing burden of overnutrition in recent times, particularly due to economic growth, rapid urbanisation, and adoption of western lifestyles [5,6].

Ensuring optimum nutrition in early years of life is an important public health agenda, mainly because both underweight and overweight in these years are associated with a wide range of morbidities in early life as well as in later life [7,8].

According to the World Report on Nutrition 2018 [9], South Asia had the highest burden of child undernutrition in the world - approximately 39% of all stunted children were from this region. While the health systems in South Asian countries are still focusing mainly on the prevention of childhood undernutrition, there has been growing evidence that the number of children with overweight and obesity is also increasing in recent years [5,10–12]. While these studies examined the burden of undernutrition or overnutrition individually, studying both outcomes together in a population will be more useful to the relevant stakeholders. So far, studies looking at the issue of the double burden of malnutrition in countries from this region focused mainly on the coexistence of overweight or obese mother and underweight or

stunted child within the same household [13–15]. To the best of our knowledge, no study looked at the double burden of malnutrition among children aged under five years in South Asian countries.

In high-income countries, overweight in children are associated with poorer socioeconomic conditions [16–18]. In LMICs, it has been shown consistently that children in poorer households are more likely to be underweight than those in richer households [15,19]. However, it is not clear whether lower socioeconomic status can also increase the likelihood of children with overweight in LMICs. While understanding the socioeconomic inequalities in nutritional outcomes is very important, identifying other factors that might influence these outcomes independently of socioeconomic status help us to develop effective public health interventions.

This study uses data from the Demographic and Health Surveys (DHS), which provide nationally-representative estimates for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition [20]. While these surveys provide the prevalence of underweight and overweight among children by socioeconomic status, it is essential to understand the associations between them by taking account of other factors that might confound such associations. In this study, we aimed to investigate the associations of household's wealth index and highest education level with the prevalence of underweight and overweight among children aged 24-59 months in five South Asian countries. Also, we explored which other factors can influence childhood underweight and overweight independently of household's socioeconomic status.

METHODS

Study design and data sources

This study is based on the latest DHS data from five South Asian countries, namely Bangladesh, India, Pakistan, Maldives, and Nepal. Other countries in the South Asian regions (e.g. Afghanistan, Bhutan, and Sri Lanka) were not included in this study because of either DHS was not conducted, or anthropometric data for children were not available. The included surveys were conducted in 2014, 2015-16, 2009, 2016, and 2012-13 for Bangladesh, India, Maldives, Nepal and Pakistan, respectively.

DHS are nationally-representative household surveys which are usually conducted about every five years. These surveys provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition. A DHS is conducted by a national implementing agency, which can be any bonafide governmental, non-governmental, or private-sector organization and has enough experience in the execution of surveys that are national in scope. Technical assistance throughout the whole process is provided by the DHS program [20].

DHS is usually based on a two-stage stratified sampling of households. In the first stage, sampling census enumeration areas are selected using probability proportional to size (PPS) sampling technique through statistics provided by the respective national statistical office. In the second stage, households are selected through systematic random sampling from the complete listing of households within a selected enumeration area [21].

Ethical approval for each DHS is taken from the ICF Institutional Review Board as well as by a review board in the host country. More details of such ethical approval can be found in the DHS program website [https://dhsprogram.com/]. Informed

consent to participate in the study is taken from the participant, or from the parent or guardian if anthropometric measurements are taken from a child. The data files are freely available from the program website. We received authorization from the DHS program for using the relevant datasets for this analysis. The data we received were anonymized for protection of privacy, anonymity and confidentiality.

These surveys have a very high response rate, usually 90% and above. Detailed questionnaires of included surveys are available in the final report of each survey. We used the children's record (coded as "KR" in DHS program) datasets which contained information about children born in the last five years prior to the survey (aged 0-59 months). The present analysis is based on children aged 24 – 59 months who had a valid measurement of their weight and height. We excluded children aged less than 24 months because most of the available classification system for defining childhood overweight starts from 24 months [22,23].

Anthropometric measurement, and defining underweight and overweight

In DHS, height and weight of the children were measured by trained personnel using standardized instruments and procedures. Lightweight SECA scales (Hamburg, Germany) with a digital screen, designed and manufactured by the United Nations Children's Fund (UNICEF), were used to measure weight. The height/length was measured by boards, produced by Shorr Productions (Maryland, USA). In children with height less than 85 centimetres, the recumbent length was measured, whereas standing height was measured for those taller than this. Body mass index (BMI) was calculated by dividing body weight (kg) by squared height (m^2).

Childhood underweight is based on the indicator weight-for-age, which is an overall indicator of the population's nutritional status. A child with weight-for-age less than two standard deviations (-2 SD) from the median of the reference population is

considered as underweight according to the World Health Organization (WHO) guidelines [24]. Underweight is a composite definition which can encompass stunting, wasting or both.

To define childhood overweight, we used the age and sex-specific BMI cut-offs from the International Obesity Task Force (IOTF) classification system [23,25]. According to IOTF, a child aged between 2 years and 18 years is classified as overweight if their BMI is larger than the age and sex-specific BMI cut-off corresponding to an adult BMI of >25 kg/m^2. Our definition of childhood overweight also included those with obesity and it is referred to hereafter as "overweight" for simplicity.

Covariates

DHS collected information on a wide range of variables from the selected households using a face-to-face interview with the respondents conducted by trained personnel. DHS collected information on socioeconomic factors like the area of residence and household's wealth index. Place of residence (rural and urban) was defined according to country-specific definitions. Household's highest education level was based on the educational attainment of the child's mother and father. For household's wealth index, each national implementing agency constructed a country-specific index using principal components analysis from data on household assets including durable goods (i.e. bicycles, televisions etc.) and dwelling characteristics (i.e. sanitation, source of drinking water and construction material of house etc.) [26]. This wealth index was then categorized into five groups (i.e. poorest, poorer, middle, richer, and richest) based on the quintile distribution of the sample.

We also included indicators of child's exposure to nutrition-sensitive interventions (focusing on the underlying determinants of malnutrition) such as receiving vitamin A

in the last six months and receiving the deworming drug in last six months [27]. Households with flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet were considered to have improved access to sanitation, whereas households with improved access to drinking water were considered if they had connection (piped), public standpipe, borehole, protected dug well or spring, or rainwater collection.

Statistical analysis

We conducted all analysis following the instructions given in the DHS guide to analysis [21]. Considering the two-stage stratified cluster sampling in DHS, we applied Stata's survey estimation procedures ("svy" command) for the estimation of proportions, means, and regression analysis [28].

The percent distributions for characteristics of included children are described as proportions, for each DHS survey. To estimate the prevalence of childhood underweight and overweight, we used sampling weights given in each DHS dataset in order to get nationally-representative estimates. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate. We also estimated the prevalence of childhood underweight and overweight by the levels of socioeconomic factors to assess the inequalities by those factors.

To examine the associations of socioeconomic factors (i.e. household's wealth index and household's highest level of education) with the prevalence of childhood underweight and overweight, we used multiple logistic regression, separately for each included country. At first, these analyses were minimally-adjusted for child's age and sex; and then they were adjsuted for the child's exposure to nutrition-sensitive interventions, area of residence, access to improved sanitation and to

improved drinking water, number of household members, number of under-five children in household, mother's age at first birth, and mother's BMI.

To explore which factors can influence the prevalence of childhood underweight and overweight after accounting for household's socioeconomic status, we estimated the odds ratios (ORs) for all child-, household- and maternal-level factors with adjustment for household's wealth index and highest level of education.

All analyses were performed using Stata v15.1 (Statacorp, College Station, TX, USA). All statistical analyses were two-sided and p-value <0.05 was considered as statistically significant.

Patient and public involvement

Patients and the public were not involved in the development of research questions, design of the study, recruitment and conduct of the study, or dissemination of the study results.

RESULTS

A total of 146,996 children aged between 24 and 59 months from five south Asian countries were included in this study. Table 1 shows the characteristics of the study population for each of these countries. There were almost equal distributions for both sex and age in all country samples. At least half of the children in all countries received vitamin A in the last six months. While Maldives and Nepal had excellent coverage (80% or more) for deworming drugs, only about one in three children received the deworming drug in India and Pakistan. Majority of the children were from the rural area except in Nepal, and the proportions varied widely between 43% and 86%. Overall, most of the households had access to improved sanitation and drinking water supply, expect the percentages of household with access to improved sanitation are particularly low in Bangladesh and India. The proportions of household with no formal education were particularly high in India, Nepal, and Pakistan. More than half of the households in Bangladesh and India had members who completed secondary or higher education. The samples from original surveys were divided into quintiles based on the household's wealth index, and after relevant exclusions, the distributions remained more or less similar for this study. India, Maldives, and Pakistan had households with a median of two children aged under five years, while Bangladesh and Nepal had a median of one child per household. Most mothers were less than 25 years old at their first birth. The prevalence of mothers with underweight was higher in Bangladesh (20%) and India (23%) than in other countries, whereas the prevalence of mothers with overweight was higher in Maldives (42%) and Pakistan (37%) than in other countries.

As expected, the prevalence of underweight was much higher than the prevalence of overweight in all five countries (Figure 1). India had the highest (38%) prevalence of underweight among children aged 24-59 months followed by Bangladesh (37%), Nepal (29%), Pakistan (28%), and Maldives had the lowest prevalence (19%). For overweight among these children, Bangladesh, India, and Nepal had similar prevalence (between 2% and 4%) whereas Pakistan and Maldives higher prevalence, 7% and 9% respectively. When we looked at the combined prevalence of both forms of malnutrition, India (42%) and Bangladesh (39%) had a much higher burden compared to other countries (Maldives [28%], Nepal [32%], Pakistan [36%]). The prevalence of underweight was particularly low in Maldives and Pakistan, but they had a higher prevalence of overweight.

The prevalence of underweight and overweight varied widely according to both the household's wealth index in all countries (Figure 2). Between the poorest and the richest households, the burden of undernutrition decreased by more than half. On the other hand, the richest households in Bangladesh and India had almost two times higher prevalence of overweight than the poorest households. Such clear differences were not evident in Maldives and Nepal, while the richest households were less likely to have overweight children compared to poorest households in Pakistan. The prevalence of underweight and overweight according to the household's highest education level followed similar country-specific patterns observed for wealth index (Figure 3). Notably, children in households with higher education had a much higher rate of overweight in Bangladesh, India, and Pakistan.

Table 2 shows the minimally-adjusted and fully-adjusted associations of household's wealth index and highest education level with the prevalence of underweight and overweight. There was strong evidence of an inverse relationship between the household's wealth index and the prevalence of underweight in children, which was not attenuated even after adjustment for a wide range of covariates except for Maldives and Pakistan. Compared to the poorest households, the richest households were less likely to have children with underweight (adjusted-OR for Bangladesh 0.4 [95% CI: 0.3-0.5], India 0.5 [0.5-0.6], Maldives 0.5 [0.2-1.4], Nepal 0.5 [0.3-0.8], and Pakistan 0.7 [0.5-1.1]. For the household's highest education level, we also observed that households with secondary or higher education were less likely to have children with underweight when compared to households with no education. The adjusted-OR for higher education vs no education was 0.7 (0.6-1.0) for Bangladesh, 0.6 (0.5-0.6) for India, 0.5 (0.1-1.7) for Maldives, 0.6 (0.4-0.9) for Nepal and 0.4 (0.3-0.7) for Pakistan.

Table 2 also shows that the richest households were more likely to have children with overweight than the poorest households in all countries except Pakistan. However, the positive associations between household's wealth index and overweight prevalence in children were not significant after adjustment for other variables. The adjusted ORs were 1.3 (0.8-2.2) for Bangladesh, 1.1 (1.0-1.2) for India, 0.5 (0.2-1.4) for Maldives, and 1.2 (0.5-2.9) for Nepal. In Pakistan, the richest households less likely to have overweight children, which remained significant after adjustment for other variables (adjusted-OR 0.1 [0.1-0.2]). Household's education level was also positively associated with the prevalence of overweight in children. When compared with households with no formal education, households with higher

education had higher odds of having overweight children in Bangladesh (OR 2.1 [1.3-3.5]), India (OR 1.2 [1.2-1.3]), and Pakistan (OR 1.8 [1.1-2.9]). Maldives and Nepal had fewer households with higher education, but the adjusted ORs for secondary vs no education were 2.3 (1.7-3.1) and 1.8 (1.1-3.1), respectively.

We then explored the associations of other factors with underweight and overweight among children after accounting for household socioeconomic status (Table 3). Factors like living in rural, improved access to sanitation and to drinking water, older maternal age at first birth, and maternal underweight were significantly associated with childhood underweight in some but not all countries. Maternal underweight was consistently found to be associated with increased odds of childhood underweight (adjusted-OR vs normal weight in Bangladesh 1.9 [1.6-2.3], in India 1.7 [1.7-1.8], in Nepal 2.1 [1.6-2.9] and in Pakistan 2.0 [1.4-2.7]). For childhood overweight, maternal overweight was found to be associated with increased odds in Bangladesh (OR 1.9 [1.2-3.0]), India (OR 1.3 [1.2-1.4]) and Pakistan (OR 1.8 [1.4-2.5]), but not in Maldives (OR 1.3 [0.9-2.0]) and Nepal (OR 0.9 [0.3-2.2]). In Pakistan, those children who received vitamin A or deworming drug in the last six months were less likely to be overweight than those who did not receive those interventions. For India and Pakistan, improved access to sanitation and drinking water were significantly associated with childhood overweight, although the directions of such associations were not consistent.

DISCUSSION

This study involving nationally-representative surveys conducted in recent times in five South Asian countries provided empirical evidence on the burden of underweight and overweight among children aged 24-59 months, and their associations with socioeconomic status factors. We found that there was a substantial burden of undernutrition among younger children in South Asian countries, while a differential burden of overnutrition was also seen. Households with higher socioeconomic status (as measured by wealth index and the highest level of education) were associated with lower odds of underweight children, although some of those associations did not reach statistical significance after adjustment for related factors. Household's socioeconomic status and childhood overweight were positively associated in all countries except Pakistan, but results from fully-adjusted models indicated that such associations could be explained by other factors. Households with higher wealth or education were less likely to have children with overweight only in Pakistan. After taking household's socioeconomic status into account, maternal nutritional status was found to be strongly associated with the child's nutritional status, whereas evidence for associations with other factors was inconsistent across countries.

South Asian countries have experienced a striking economic growth in the last few decades, which triggered unprecedented improvements in maternal mortality, infant mortality, under-five mortality, and child undernutrition [29,30]. Trends in the prevalence of childhood underweight have been declining in these countries, with almost 25-30% reduction between 2004 and 2014 in Bangladesh, India, Pakistan, and Nepal [31]. However, the existing burden of undernutrition is still high – our study found that around one-third of under-five children in this region are still underweight. Previous studies conducted in the region have found that poor

socioeconomic status, lower level of parental education, younger age of mother at birth, short birth interval, and initiation of complementary feeding are important determinants of undernutrition among under-five children [32–34]. We observed large inequalities in the prevalence of underweight in each of the included countries, which could not be explained by other factors studied here. Our study also showed that factors like maternal underweight could significantly increase the likelihood of underweight in children, while other factors like older age of mother at birth, and access to improved sanitation were also associated with lower odds of childhood underweight. These associations were statistically significant, mostly in India because of a relatively large sample size. DHS data have information on feeding practices for children aged up to two years, so we could not adjust for variables related to feeding practices [26].

There has been evidence on increasing trends of overweight in younger children in many South Asian countries, although the prevalence is still quite low compared to the prevalence of underweight. Recent reports [12,35–37] from South Asian countries highlighted the rise of overweight burden in children, but mainly in older groups. Overweight among under-five children is still overlooked in current literature. In our study, we provided evidence for an increasing burden of overweight in this age group, which clustered mainly in households with higher socioeconomic status. We found that the associations between socioeconomic status and the prevalence of childhood overweight can be heterogeneous between countries, with positive associations in most countries and inverse association in Pakistan. This highlights the need for cross-country comparisons for better understanding of double burden of malnutrition. Frequent intake of energy-dense foods and physical inactivity have been shown to be associated with overweight and obesity both in children and adults

[38,39]. These lifestyle behaviours are common in the higher socioeconomic group in LMICs, and therefore, both childhood and adulthood overweight are clustered in affluent households in urban areas [35,37]. Our study showed that mothers who were overweight had higher odds of having children with overweight when compared with mothers who were of normal weight - suggesting that public health nutrition programmes should prioritise children whose mothers are overweight. Our findings on having lower odds of overweight among children exposed to nutrition-sensitive programmes (receiving vitamin A and deworming drug) in Pakistan can be studied further to examine the efficacy of such programmes to reduce double burden of malnutrition in LMICs.

The findings from our study highlight the importance of considering not only socioeconomic inequalities but also other maternal and household level factors while developing public health interventions and policies to tackle both childhood undernutrition and overnutrition. Also, the opposite directions for associations of socioeconomic status and nutritional outcomes suggest that the concept of “one size fits all” is not applicable to tackle the emerging problem of the double burden of malnutrition. Previous studies suggested that a multi-sectoral approach is needed to alleviate poverty and other social inequalities related to the double burden of malnutrition in South Asia and beyond [40].

Our study is the first study to look at the coexistence of underweight and overweight among under-five children in South Asian countries by socioeconomic status. One of the major strengths of our study is the use of nationally-representative samples with objectively measured height and weight data from five different countries, which allowed cross-country comparisons of the results. We were also able to adjust for several factors in the multivariable models, but there are possibilities of residual

confounding due to unmeasured factors and/or imperfect assessment of measured factors. Due to smaller sample sizes in Maldives and Nepal, we could not reliably estimate the associations. Problems of reverse causation could also arise in the observed estimates due to the cross-sectional nature of the study. We used the IOTF reference to define childhood overweight instead of the WHO or Centers for Disease Control (CDC) references [22,23,25]. The IOTF classification system is based on large datasets from six regions covering different ethnicities, therefore more suitable for international comparisons [23,25]. When compared with other references, the IOTF reference yielded similar estimates for overall overweight prevalence but different estimates for obesity [41,42]. It was also found to be more specific in identifying children with overweight and obesity than other references [43]. We assessed childhood undernutrition by assessing only underweight, which is a composite measure of wasting and stunting. Previous studies have found that stunting and overweight can occur concurrently in an individual [44], therefore there may be double counting of children while studying double burden of malnutrition. Looking at children who are stunted and overweight can offer more insights into the topic, but we did not look into this issue in our study.

In conclusion, our study provides evidence for socioeconomic disparities for the coexistence of under- and over-nutrition among children aged 24-59 months in South Asian countries. It also showed that factors like maternal nutritional status was strongly associated with nutritional outcomes in children. These unmet inequalities for both underweight and overweight should be considered while developing national public health nutrition programmes and strategies.

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AUTHOR CONTRIBUTIONS

Conception and design: FH, MS, SA and MB

Data collection and management: FH, SS, and GA

Data analysis: FH, MS, SS

Interpretation of the results: All authors

Drafting of the article: FH and MS

Critical revision of the article for important intellectual content: All authors

Final approval of the article: All authors.

COMPETING INTERESTS STATEMENT

None declared

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FIGURE LEGENDS

Figure 1: Prevalence of underweight and overweight, by country

Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

Figure 2: Prevalence of underweight and overweight, by household's wealth index

Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

Figure 3: Prevalence of underweight and overweight, by household's highest level of education

Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

Table 1: Sample characteristics in five demographic and health survey data, by country

	Bangladesh	India	Maldives	Nepal	Pakistan
Year of survey	2014	2015-16	2009	2016	2012-13
Number of children	4170	138134	1339	1389	1964
Child's variables					
Sex, n (%)					
Male	2134 (51.2)	71698 (51.9)	672 (50.2)	715 (51.5)	1016 (51.7)
Female	2036 (48.8)	66436 (48.1)	667 (49.8)	674 (48.5)	948 (48.3)
Age in year, n (%)					
2-3	1406 (33.7)	45298 (32.8)	452 (33.8)	460 (33.1)	668 (34.0)
3-4	1377 (33.0)	47506 (34.4)	464 (34.7)	479 (34.5)	641 (32.6)
4-5	1387 (33.3)	45329 (32.8)	423 (31.6)	449 (32.3)	655 (33.4)
Received vitamin A in last 6 months, n (%)	2735 (66.0)	73678 (54.1)	695 (81.8)	1232 (88.8)	1252 (64.6)
Received deworming drug in last 6 months, n (%)	2153 (51.7)	43319 (31.6)	1104 (82.8)	1105 (79.8)	593 (30.3)
Household variables					
Area of residence, n (%)					
Urban	1316 (31.6)	33245 (24.1)	183 (13.7)	788 (56.7)	851 (43.3)
Rural	2854 (68.4)	104889 (75.9)	1156 (86.3)	601 (43.3)	1113 (56.7)
Access to improved sanitation, n (%)	2741 (65.7)	67441 (48.8)	1278 (95.4)	1047 (75.4)	1455 (74.1)
Access to improved drinking water, n (%)	3791 (90.9)	114018 (82.5)	1210 (90.4)	1206 (86.8)	1564 (79.6)
Wealth index, n (%)					
Poorest	931 (22.3)	36404 (26.4)	330 (24.6)	351 (25.3)	443 (22.6)
Poorer	781 (18.7)	32673 (23.7)	335 (25.0)	308 (22.2)	390 (19.9)
Middle	808 (19.4)	27462 (19.9)	358 (26.7)	296 (21.3)	323 (16.4)
Richer	843 (20.2)	23044 (16.7)	201 (15.0)	276 (19.9)	419 (21.3)
Richest	807 (19.4)	18551 (13.4)	115 (8.6)	158 (11.4)	389 (19.8)
Highest education level, n (%)					
No education	714 (17.1)	44950 (32.5)	221 (16.5)	514 (37.0)	1067 (54.3)
Primary	1168 (28.0)	20664 (15.0)	615 (45.9)	260 (18.7)	303 (15.4)
Secondary	1877 (45.0)	60737 (44.0)	462 (34.5)	431 (31.0)	385 (19.6)
Higher	411 (9.9)	11783 (8.5)	26 (1.9)	184 (13.2)	209 (10.6)
No. of household member, median (IQR)	5.0 (4.0, 7.0)	6.0 (5.0, 8.0)	8.0 (6.0, 11.0)	5.0 (4.0, 7.0)	8.0 (6.0, 11.0)
No. of under-five children, median (IQR)	1.0 (1.0, 2.0)	2.0 (1.0, 2.0)	2.0 (1.0, 2.0)	1.0 (1.0, 2.0)	2.0 (2.0, 3.0)
Maternal variables					
Mother's age at first birth, n (%)					
Less than 250 years	3056 (73.3)	50969 (36.9)	499 (37.3)	759 (54.6)	812 (41.3)
20-24 years	927 (22.2)	66287 (48.0)	649 (48.5)	531 (38.2)	812 (41.3)
25 years or above	187 (4.5)	20878 (15.1)	191 (14.3)	99 (7.1)	340 (17.3)
Mother's BMI (kg/m^2) category, n (%)					
Underweight	835 (20.1)	31127 (22.6)	94 (7.4)	228 (16.4)	224 (11.5)
Normal weight	2439 (58.6)	85490 (62.0)	639 (50.3)	937 (67.5)	1006 (51.5)
Overweight	885 (21.3)	21172 (15.4)	538 (42.3)	224 (16.1)	723 (37.0)

Table 2: Associations of household's wealth index and highest education with childhood underweight and overweight

	ORs (95% CI) *									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Underweight										
Household's wealth index										
Poorest	1.0 (0.9-1.1)	1.0 (0.8-1.2)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.8-1.3)	1.0 (0.7-1.4)	1.0 (0.8-1.2)	1.0 (0.8-1.3)	1.0 (0.8-1.2)	1.0 (0.7-1.3)
Poorer	0.8 (0.7-0.9)	0.8 (0.7-1.0)	0.7 (0.7-0.7)	0.8 (0.8-0.8)	0.8 (0.6-1.0)	0.9 (0.6-1.3)	0.6 (0.5-0.8)	0.6 (0.5-0.8)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Middle	0.6 (0.5-0.7)	0.7 (0.6-0.8)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.8 (0.6-1.0)	1.0 (0.7-1.4)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.7 (0.5-0.9)	0.8 (0.6-1.1)
Richer	0.4 (0.4-0.5)	0.6 (0.5-0.7)	0.4 (0.4-0.4)	0.6 (0.6-0.6)	0.5 (0.3-0.7)	0.7 (0.5-1.0)	0.6 (0.4-0.8)	0.7 (0.5-0.9)	0.6 (0.4-0.7)	0.9 (0.7-1.1)
Richest	0.3 (0.2-0.3)	0.4 (0.3-0.5)	0.3 (0.3-0.3)	0.5 (0.5-0.5)	0.3 (0.2-0.6)	0.5 (0.2-1.5)	0.3 (0.2-0.4)	0.4 (0.3-0.7)	0.3 (0.3-0.4)	0.7 (0.5-1.1)
Household's highest education										
No education	1.0 (0.9-1.2)	1.0 (0.9-1.2)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.7-1.3)	1.0 (0.7-1.4)	1.0 (0.8-1.2)	1.0 (0.8-1.2)	1.0 (0.9-1.1)	1.0 (0.8-1.2)
Primary	1.0 (0.9-1.1)	1.1 (0.9-1.2)	0.8 (0.7-0.8)	0.9 (0.9-0.9)	0.6 (0.5-0.7)	0.6 (0.5-0.7)	0.7 (0.6-0.9)	0.8 (0.6-1.1)	0.8 (0.7-1.1)	1.0 (0.8-1.3)
Secondary	0.6 (0.5-0.6)	0.8 (0.7-0.9)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.3 (0.2-0.4)	0.3 (0.2-0.4)	0.5 (0.4-0.7)	0.8 (0.6-1.0)	0.4 (0.3-0.5)	0.5 (0.4-0.7)
Higher	0.3 (0.3-0.4)	0.7 (0.6-1.0)	0.3 (0.3-0.3)	0.6 (0.5-0.6)	0.2 (0.1-0.8)	0.5 (0.1-1.9)	0.3 (0.2-0.5)	0.5 (0.4-0.8)	0.3 (0.2-0.4)	0.4 (0.2-0.6)
Overweight										
Household's wealth index										
Poorest	1.0 (0.6-1.7)	1.0 (0.5-1.9)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.6-1.6)	1.0 (0.6-1.8)	1.0 (0.6-1.7)	1.0 (0.5-1.9)	1.0 (0.8-1.2)	1.0 (0.7-1.5)
Poorer	0.9 (0.5-1.6)	0.8 (0.4-1.5)	1.1 (1.0-1.2)	1.0 (1.0-1.1)	1.3 (0.9-2.0)	1.4 (0.8-2.2)	0.4 (0.2-0.9)	0.4 (0.1-0.9)	0.5 (0.4-0.7)	0.4 (0.3-0.6)
Middle	1.2 (0.7-2.0)	1.0 (0.6-1.6)	1.2 (1.1-1.3)	1.0 (1.0-1.1)	1.2 (0.8-1.8)	1.1 (0.7-1.7)	0.1 (0.0-0.6)	0.1 (0.0-0.6)	0.4 (0.3-0.5)	0.3 (0.2-0.4)
Richer	1.0 (0.6-1.7)	0.7 (0.4-1.2)	1.3 (1.2-1.4)	1.0 (1.0-1.1)	1.7 (1.1-2.7)	0.9 (0.5-1.4)	0.5 (0.2-1.1)	0.5 (0.2-1.1)	0.3 (0.2-0.4)	0.2 (0.1-0.2)
Richest	3.8 (2.8-5.0)	1.4 (0.8-2.3)	1.7 (1.6-1.8)	1.2 (1.1-1.3)	1.9 (1.1-3.4)	0.5 (0.2-1.4)	1.1 (0.5-2.3)	1.0 (0.4-2.4)	0.4 (0.3-0.5)	0.1 (0.1-0.2)
Household's highest education										
No education	1.0 (0.6-1.8)	1.0 (0.5-1.9)	1.0 (1.0-1.1)	1.0 (0.9-1.1)	1.0 (0.6-1.7)	1.0 (0.5-1.9)	1.0 (0.5-1.9)	1.0 (0.5-2.1)	1.0 (0.9-1.2)	1.0 (0.7-1.3)
Primary	1.1 (0.7-1.7)	1.1 (0.7-1.7)	1.1 (1.0-1.1)	1.0 (0.9-1.1)	0.9 (0.7-1.3)	1.1 (0.7-1.5)	1.0 (0.4-2.4)	1.1 (0.4-2.7)	0.6 (0.4-0.9)	0.9 (0.6-1.4)
Secondary	1.4 (1.0-1.9)	1.1 (0.8-1.5)	1.2 (1.1-1.2)	1.0 (0.9-1.0)	2.1 (1.6-2.7)	2.1 (1.6-2.7)	2.0 (1.2-3.3)	1.9 (1.1-3.1)	0.6 (0.4-0.8)	1.3 (0.9-1.8)
Higher	5.2 (3.6-7.5)	2.0 (1.2-3.3)	1.7 (1.6-1.9)	1.2 (1.1-1.3)	2.0 (0.6-6.8)	0.6 (0.1-5.0)	0.9 (0.3-2.8)	0.6 (0.2-2.2)	0.8 (0.5-1.1)	1.6 (1.0-2.5)

* Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of household member, number of under-five children, mother's age at first birth, and mother's BMI.

Table 3: Socioeconomic status-adjusted odds ratios (ORs) of underweight and overweight by various child, household and maternal factors

	ORs (95% CI)									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight
Child's variables										
Sex										
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.2 (1.0-1.4)	1.2 (0.8-1.8)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	1.1 (0.9-1.5)	1.1 (0.7-1.7)	1.1 (0.9-1.4)	1.5 (0.7-2.9)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Age										
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.0 (0.8-1.2)	1.0 (0.6-1.6)	1.0 (1.0-1.0)	1.0 (0.9-1.0)	1.0 (0.7-1.3)	1.4 (0.9-2.3)	0.8 (0.6-1.0)	2.6 (1.1-6.5)	0.9 (0.7-1.1)	1.4 (1.0-1.9)
4-5 years	1.0 (0.9-1.2)	0.8 (0.5-1.4)	1.0 (1.0-1.0)	0.9 (0.9-1.0)	0.7 (0.5-1.0)	1.3 (0.8-2.1)	0.9 (0.7-1.2)	1.5 (0.6-4.1)	0.9 (0.7-1.2)	1.2 (0.9-1.7)
Received vitamin A in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.2 (0.7-1.8)	1.1 (1.0-1.1)	1.1 (1.0-1.1)	1.2 (0.8-2.0)	1.0 (0.5-1.9)	0.8 (0.5-1.1)	1.1 (0.3-3.8)	1.2 (1.0-1.6)	**0.5 (0.4-0.6)**
Received deworming drug in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.8-1.1)	0.9 (0.6-1.4)	1.0 (0.9-1.0)	1.1 (1.0-1.2)	1.5 (1.0-2.3)	0.8 (0.5-1.3)	1.0 (0.7-1.3)	1.4 (0.5-3.6)	0.8 (0.6-1.0)	**0.6 (0.4-0.8)**
Household variables										
Area of residence										
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	0.9 (0.8-1.1)	0.7 (0.4-1.1)	**0.9 (0.9-0.9)**	1.1 (1.0-1.1)	1.0 (0.4-2.2)	0.4 (0.2-1.0)	1.1 (0.9-1.4)	1.2 (0.6-2.6)	1.0 (0.8-1.3)	**0.6 (0.4-0.8)**
Improved access to sanitation										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.1 (0.7-1.9)	**0.8 (0.8-0.8)**	**1.2 (1.1-1.3)**	0.7 (0.4-1.3)	1.5 (0.4-4.8)	**0.7 (0.5-0.9)**	1.0 (0.4-2.5)	0.8 (0.6-1.1)	**1.6 (1.1-2.2)**
Improved access to drinking water										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.2)	1.6 (0.7-3.7)	0.9 (0.9-1.0)	**1.2 (1.1-1.2)**	1.5 (0.8-2.7)	0.9 (0.4-1.7)	1.0 (0.7-1.5)	0.9 (0.4-2.2)	1.2 (0.9-1.6)	**0.7 (0.5-0.9)**
No. of household member	1.0 (1.0-1.0)	1.0 (0.9-1.1)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.1)	1.0 (0.9-1.0)	1.1 (1.0-1.1)	0.9 (0.8-1.1)	1.0 (1.0-1.0)	1.1 (1.0-1.1)
No. of children under five	1.1 (1.0-1.2)	1.0 (0.8-1.3)	1.1 (1.1-1.1)	0.9 (0.9-1.0)	1.1 (1.0-1.2)	1.0 (0.8-1.2)	1.1 (0.9-1.2)	0.7 (0.4-1.1)	1.0 (1.0-1.1)	1.0 (0.9-1.1)
Maternal variables										
Mother's age at first birth										
Less than 20 years	1.1 (0.9-1.3)	0.6 (0.4-1.0)	1.1 (1.0-1.1)	1.0 (0.9-1.0)	1.1 (0.8-1.5)	0.7 (0.4-1.1)	0.9 (0.7-1.2)	0.5 (0.2-1.0)	1.0 (0.8-1.2)	0.8 (0.6-1.1)

20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.8 (0.5-1.1)	1.7 (0.9-3.3)	**0.8 (0.8-0.8)**	**1.3 (1.2-1.4)**	0.8 (0.5-1.3)	1.1 (0.6-1.9)	0.8 (0.5-1.4)	0.5 (0.1-2.3)	0.9 (0.7-1.3)	0.8 (0.5-1.1)
Mother's BMI category										
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	**1.9 (1.6-2.3)**	0.5 (0.2-1.1)	**1.7 (1.7-1.8)**	**0.5 (0.5-0.6)**	1.3 (0.7-2.1)	0.2 (0.1-1.0)	**2.1 (1.6-2.9)**	0.4 (0.1-1.5)	**2.0 (1.4-2.7)**	**0.4 (0.3-0.8)**
Overweight	**0.7 (0.5-0.8)**	**1.9 (1.2-3.0)**	**0.6 (0.6-0.7)**	**1.3 (1.2-1.4)**	0.7 (0.5-1.0)	1.3 (0.9-2.0)	**0.5 (0.3-0.7)**	0.9 (0.3-2.2)	**0.6 (0.5-0.8)**	**1.8 (1.4-2.5)**

*Bold cells indicate statistically significant estimates (p<0.05)

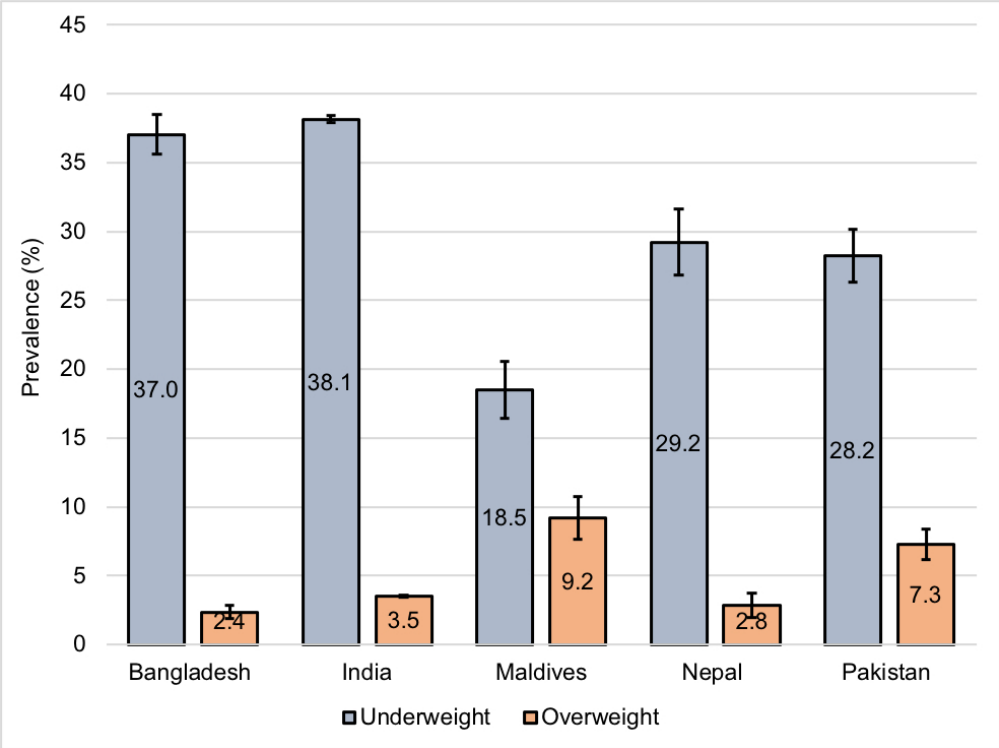
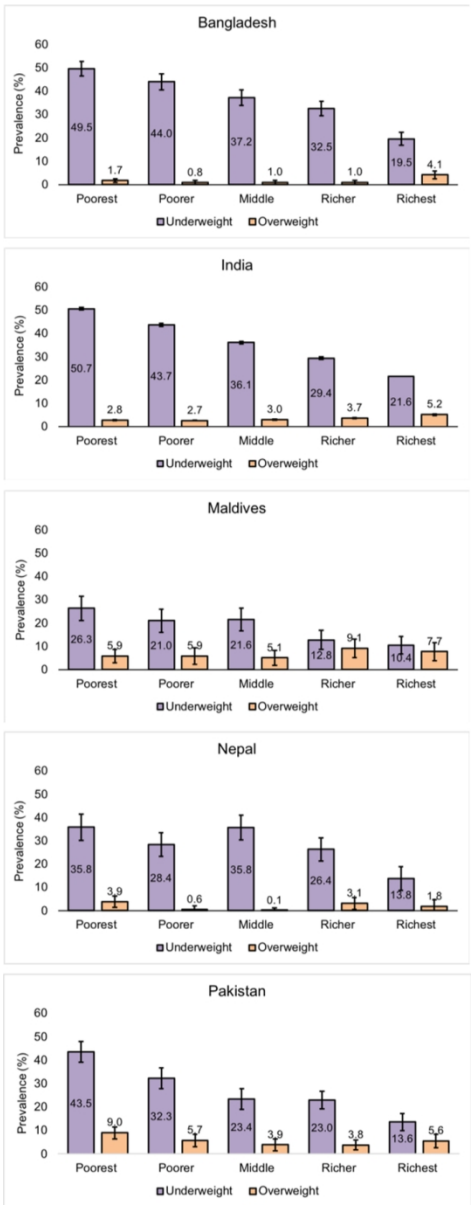


Figure 1: Prevalence of underweight and overweight, by country
Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

83x62mm (300 x 300 DPI)



Prevalence of underweight and overweight, by household's wealth index
Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

30x78mm (600 x 600 DPI)

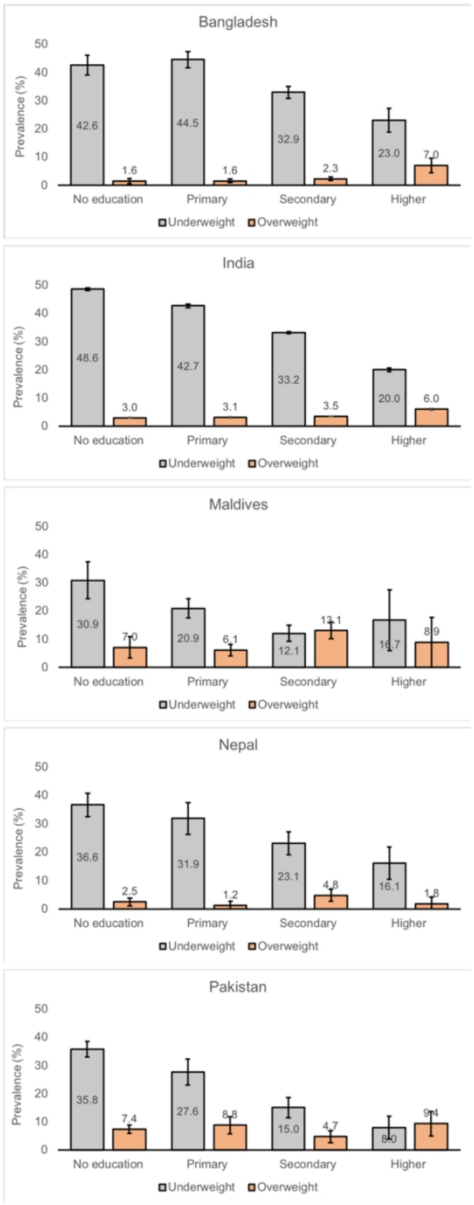


Figure 3: Prevalence of underweight and overweight, by household's highest level of education
Sampling weight provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Error bars represent 95% confidence intervals.

30x77mm (600 x 600 DPI)

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	Page 1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	#3	State specific objectives, including any prespecified hypotheses	Page 6 lines 14-16
Methods			

Study design	#4	Present key elements of study design early in the paper	Page 7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	Page 7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	NA
Bias	#9	Describe any efforts to address potential sources of bias	Page 10 lines 11-15
Study size	#10	Explain how the study size was arrived at	NA
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	Page 10
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	NA
Statistical methods	#12c	Explain how missing data were addressed	NA
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	NA
Statistical methods	#12e	Describe any sensitivity analyses	Page 13 lines 10-16
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers	Page 11

		potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	NA
Participants	#13c	Consider use of a flow diagram	Page 11
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	Page 11
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	NA
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Page 11
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12
Main results	#16b	Report category boundaries when continuous variables were categorized	NA
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Page 13 lines 10-16
Discussion			
Key results	#18	Summarise key results with reference to study objectives	Page 14
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	Page 16-17
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and	Page 14-16

		other relevant evidence.	
Generalisability	#21	Discuss the generalisability (external validity) of the study results	Page 16
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

Notes:

- 3: Page 6 lines 14-16
- 9: Page 10 lines 11-15
- 12e: Page 13 lines 10-16
- 17: Page 13 lines 10-16 This checklist was completed on 09. July 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

BMJ Open

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

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Primary Subject Heading:	Global health
Secondary Subject Heading:	Public health, Nutrition and metabolism, Global health, Epidemiology
Keywords:	Double burden, underweight, overweight, under-five children, socioeconomic status, South Asia

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TITLE:

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

SUBTITLE:

Double burden of malnutrition among under-five children in South Asia

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ABSTRACT

Objectives: We aimed to investigate the socioeconomic inequalities in the burden of underweight and overweight among children in South Asia. We also examined other factors that were associated with these outcomes independently of household's socioeconomic status.

Design: Nationally-representative surveys.

Settings: Demographic and Health Surveys from Bangladesh, India, Pakistan, Maldives, and Nepal, which were conducted between 2009 and 2016.

Participants: Children aged 24-59 months with valid measurement for height and weight (n=146,996).

Primary exposure and outcome measures: Primary exposures were household's wealth index and level of education. Underweight and overweight were defined according to the World Health Organization and International Obesity Task Force definitions, respectively.

Results: Underweight prevalence was 37% in Bangladesh, 38% in India, 19% in Maldives, 29% in Nepal, and 28% in Pakistan. Bangladesh, India, and Nepal had similar overweight prevalence (between 2% and 4%) whereas Pakistan (7%) and Maldives (9%) had higher prevalence. As expected, households with higher wealth index or education had lower odds of having underweight children. Adjusted-odds ratios (ORs) of underweight for richest vs poorest households were 0.4 [95% CI:0.3-0.5], 0.5 [0.5-0.6], 0.5 [0.2-1.4], 0.5 [0.3-0.8], and 0.7 [0.5-1.1] for Bangladesh, India, Maldives, Nepal and Pakistan, respectively. Compared to poorest households, richest households were more likely to have overweight children in all countries except Pakistan, but such associations were not significant after adjustment for other factors. There were higher odds of having overweight children in households with

higher education in Bangladesh (OR 2.1 [95% CI:1.3-3.5]), India (1.2 [1.2-1.3]), and Pakistan (1.8 [1.1-2.9]) when compared to households with no education. Maternal nutritional status was consistently associated with children's nutritional outcomes after adjustments for socioeconomic status.

Conclusions: Our study provides evidence for socioeconomic inequalities for childhood underweight and overweight in South Asian countries, although the directions of associations for underweight and overweight might be different.

Keywords:

Double burden, underweight, overweight, under-five children, South Asia, Bangladesh, India, Pakistan, Nepal, Maldives

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to investigate the double burden of malnutrition among children aged under five years in South Asian countries, using nationally-representative samples.
- We used height and weight information which were measured by trained research personnel.
- Use of International Obesity Task Force (IOTF) classification to define overweight ensures cross-comparison of estimates with those from other regions.
- Although we adjusted for several child, household and maternal factors when examining the associations of socioeconomic status with underweight and overweight, we did not have information on many dietary and lifestyle factors that could modify those associations.
- We examined the effects of other factors on childhood underweight and overweight after adjustment for household's socioeconomic status.

INTRODUCTION

Double burden of malnutrition implies the presence of both undernutrition and overnutrition (overweight or obesity) either at the individual, household, or population level [1]. At the individual level, an undernourished child can be overweight or obese when they reach adulthood, whereas at household level coexistence of undernourished and overweight children or adults can be possible. At the population level, double burden of malnutrition indicates the presence of both undernutrition and overnutrition in the same community, country, or region. Undernutrition can be assessed by underweight (low weight-for-age), wasting (low weight-for-height), and stunting (low height-for-age) [2]. Wasting and stunting reflect acute weight loss and long-term growth restriction, respectively; whereas underweight indicates wasting, stunting, or both.

Double burden of malnutrition is an emerging problem in the low and middle-income countries (LMICs), including South Asian countries [1,3]. Historically, these countries have a considerable burden of undernutrition in children [4,5], for example, according to the World Report on Nutrition 2018 [6], approximately 39% of all stunted children were from this region. But there has been growing evidence that the number of children with overweight and obesity is also increasing in recent years in South Asian countries, particularly due to economic growth, rapid urbanisation, and adoption of western lifestyles [7–10]. Ensuring optimum nutrition in early years of life is an important public health agenda, mainly because both undernutrition and overnutrition in these years are associated with a wide range of morbidities in early life as well as in later life [11,12].

Understanding the socioeconomic inequalities in nutritional outcomes is essential. The associations of socioeconomic status with undernutrition and overnutrition might

be different in LMICs to those in high-income countries. In high-income countries, overweight in children is associated with poorer socioeconomic conditions [13–15], but it is not clear whether lower socioeconomic status can increase the likelihood of children with overweight in LMICs too. It has been consistently shown that children in poorer households are more likely to be underweight than those in richer households [16,17]. Moreover, identifying other factors that might influence nutritional outcomes independently of socioeconomic status will help to develop effective public health interventions.

While many studies separately examined the burden of undernutrition or overnutrition, studying both outcomes together in a population will be more useful to the relevant stakeholders. So far, studies looking at the issue of the double burden of malnutrition in South Asian countries focused mainly on the coexistence of overweight or obese mother and underweight or stunted child within the same household [16,18,19]. While studying double burden of malnutrition, it is also essential to study the burden and underlying factors of childhood underweight, stunting and wasting because they are very different constructs of undernutrition. To the best of our knowledge, no study looked at the double burden of malnutrition among children aged under five years in South Asian countries.

This study uses data from the Demographic and Health Surveys (DHS), which provide nationally-representative estimates for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition [20]. While these surveys provide the prevalence of underweight and overweight among children by socioeconomic status, it is essential to understand the associations between them by taking account of other factors that might confound such associations. In this study, we aimed to investigate the associations of household's

wealth index and highest education level with the prevalence of underweight and overweight among children aged 24-59 months in five South Asian countries. Also, we explored which other factors can influence childhood underweight and overweight independently of household's socioeconomic status.

METHODS

Study design and data sources

This study is based on the latest DHS data from five South Asian countries, namely Bangladesh, India, Pakistan, Maldives, and Nepal. Other countries in the South Asian regions (e.g. Afghanistan, Bhutan, and Sri Lanka) were not included in this study because of either DHS was not conducted, or anthropometric data for children were not available. The included surveys were conducted in 2014, 2015-16, 2009, 2016, and 2012-13 for Bangladesh, India, Maldives, Nepal and Pakistan, respectively.

DHS are nationally-representative household surveys which are usually conducted about every five years. These surveys provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition. A DHS is conducted by a national implementing agency, which can be any bonafide governmental, non-governmental, or private-sector organization and has enough experience in the execution of surveys that are national in scope. Technical assistance throughout the whole process is provided by the DHS program [20].

DHS is usually based on a two-stage stratified sampling of households. In the first stage, sampling census enumeration areas are selected using probability proportional to size (PPS) sampling technique through statistics provided by the respective national statistical office. In the second stage, households are selected through systematic random sampling from the complete listing of households within a selected enumeration area [21].

Ethical approval for each DHS is taken from the ICF Institutional Review Board as well as by a review board in the host country. More details of such ethical approval can be found in the DHS program website [https://dhsprogram.com/]. Informed

consent to participate in the study is taken from the participant, or from the parent or guardian if anthropometric measurements are taken from a child. The data files are freely available from the program website. We received authorization from the DHS program for using the relevant datasets for this analysis. The data we received were anonymized for protection of privacy, anonymity and confidentiality.

These surveys have a very high response rate, usually 90% and above. Detailed questionnaires of included surveys are available in the final report of each survey. We used the children's record (coded as "KR" in DHS program) datasets which contained information about children born in the last five years prior to the survey (aged 0-59 months). The present analysis is based on children aged 24 – 59 months who had a valid measurement of their weight and height. We excluded children aged less than 24 months because most of the available classification system for defining childhood overweight starts from 24 months [22,23]. Flowchart of study participants included in this analysis is given in Supplementary Figure S1.

Anthropometric measurement, and defining undernutrition and overnutrition

In DHS, height and weight of the children were measured by trained personnel using standardized instruments and procedures. Lightweight SECA scales (Hamburg, Germany) with a digital screen, designed and manufactured by the United Nations Children's Fund (UNICEF), were used to measure weight. The height/length was measured by boards, produced by Shorr Productions (Maryland, USA). In children with height less than 85 centimetres, the recumbent length was measured, whereas standing height was measured for those taller than this. Body mass index (BMI) was calculated by dividing body weight (kg) by squared height (m^2).

While each indicator of child undernutrition reflects distinct aspects undernutrition, we assessed undernutrition mainly by underweight in this study. Childhood underweight indicates the overall population's nutritional status, and is a composite indicator which can encompass stunting, wasting, or both. According to the World Health Organization (WHO) guidelines [2], a child with weight-for-age less than two standard deviations (-2 SD) from the median of the reference population was considered as underweight.

To define childhood overweight, we used the age and sex-specific BMI cut-offs from the International Obesity Task Force (IOTF) classification system [23,24]. According to IOTF, a child aged between 2 years and 18 years is classified as overweight if their BMI is larger than the age and sex-specific BMI cut-off corresponding to an adult BMI of >25 kg/m^2. Our definition of childhood overweight also included those with obesity and it is referred to hereafter as "overweight" for simplicity.

Covariates

DHS collected information on a wide range of variables from the selected households using a face-to-face interview with the respondents conducted by trained personnel. DHS collected information on socioeconomic factors like the area of residence and household's wealth index. Place of residence (rural and urban) was defined according to country-specific definitions. Household's highest education level was based on the educational attainment of the child's mother and father. For household's wealth index, each national implementing agency constructed a country-specific index using principal components analysis from data on household assets including durable goods (i.e. bicycles, televisions etc.) and dwelling characteristics (i.e. sanitation, source of drinking water and construction material of house etc.) [25].

This wealth index was then categorized into five groups (i.e. poorest, poorer, middle, richer, and richest) based on the quintile distribution of the sample.

We also included indicators of child's exposure to nutrition-sensitive interventions (focusing on the underlying determinants of malnutrition) such as receiving vitamin A in the last six months and receiving the deworming drug in last six months [26]. Households with flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet were considered to have improved access to sanitation, whereas households with improved access to drinking water were considered if they had connection (piped), public standpipe, borehole, protected dug well or spring, or rainwater collection.

Statistical analysis

We conducted all analysis following the instructions given in the DHS guide to analysis [21]. Considering the two-stage stratified cluster sampling in DHS, we applied Stata's survey estimation procedures ("svy" command) for the estimation of proportions, means, and regression analysis [27].

The percent distributions for characteristics of included children are described as proportions, for each DHS survey. To estimate the prevalence of childhood underweight and overweight, we used sampling weights given in each DHS dataset in order to get nationally-representative estimates. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate. We also estimated the prevalence of childhood underweight and overweight by the levels of socioeconomic factors to assess the inequalities by those factors.

To examine the associations of socioeconomic factors (i.e. household's wealth index and household's highest level of education) with the prevalence of childhood

underweight and overweight, we used multiple logistic regression, separately for each included country. At first, these analyses were minimally-adjusted for child's age and sex; and then they were adjusted for the child's exposure to nutrition-sensitive interventions, area of residence, access to improved sanitation and to improved drinking water, number of under-five children in household, mother's age at first birth, mother's height, and mother's BMI. Missing data in the adjustment variables (usually less than 5%) were considered as separate categories so that the same children were compared in all analyses. To explore which factors can influence the prevalence of childhood underweight and overweight after accounting for household's socioeconomic status, we estimated the odds ratios (ORs) for all child-, household- and maternal-level factors with adjustment for household's wealth index and highest level of education.

All analyses were additionally conducted for childhood stunting and wasting. Stunting and wasting were defined respectively as height-for-age less than two standard deviations (-2 SD) and weight-for-height less than two standard deviations (-2 SD) from the median of the reference population [2].

All analyses were performed using Stata v15.1 (Statacorp, College Station, TX, USA). All statistical analyses were two-sided and p-value <0.05 was considered as statistically significant.

Patient and public involvement

Patients and the public were not involved in the development of research questions, design of the study, recruitment and conduct of the study, or dissemination of the study results.

RESULTS

A total of 146,996 children aged between 24 and 59 months from five south Asian countries were included in this study. Table 1 shows the characteristics of the study population for each of these countries. There were almost equal distributions for both sex and age in all country samples. At least half of the children in all countries received vitamin A in the last six months. While Maldives and Nepal had excellent coverage (80% or more) for deworming drugs, only about one in three children received the deworming drug in India and Pakistan. Majority of the children were from the rural area except in Nepal, and the proportions varied widely between 43% and 86%. Overall, most of the households had access to improved sanitation and drinking water supply, expect the percentages of household with access to improved sanitation are particularly low in Bangladesh and India. The proportions of household with no formal education were particularly high in India, Nepal, and Pakistan. More than half of the households in Bangladesh and India had members who completed secondary or higher education. The samples from original surveys were divided into quintiles based on the household's wealth index, and after relevant exclusions, the distributions remained more or less similar for this study. India, Maldives, and Pakistan had households with a median of two children aged under five years, while Bangladesh and Nepal had a median of one child per household. Most mothers were less than 25 years old at their first birth. The prevalence of mothers with underweight was higher in Bangladesh (20%) and India (23%) than in other countries, whereas the prevalence of mothers with overweight was higher in Maldives (42%) and Pakistan (37%) than in other countries.

As expected, the prevalence of underweight was much higher than the prevalence of overweight in all five countries (Figure 1 and Supplementary Table S1). India had the highest (38%) prevalence of underweight among children aged 24-59 months followed by Bangladesh (37%), Nepal (29%), Pakistan (28%), and Maldives had the lowest prevalence (19%). For overweight among these children, Bangladesh, India, and Nepal had similar prevalence (between 2% and 4%) whereas Pakistan and Maldives higher prevalence, 7% and 9% respectively. When we looked at the combined prevalence of both forms of malnutrition, India (42%) and Bangladesh (39%) had a much higher burden compared to other countries (Maldives [28%], Nepal [32%], Pakistan [36%]) (Figure 1). The prevalence of underweight was particularly low in Maldives and Pakistan, but they had a higher prevalence of overweight. Bangladesh, India, Nepal and Pakistan had high prevalence of childhood stunting (between 42% and 48%), whereas only 17% of children in Maldives were stunted (Supplementary Table S2). The prevalence of children with wasting was highest in India (18%) and lowest in Nepal (6%) (Supplementary Table S3).

The prevalence of underweight and overweight varied widely according to both the household's wealth index in all countries (Figure 2). Between the poorest and the richest households, the burden of undernutrition decreased by more than half. On the other hand, the richest households in Bangladesh and India had almost two times higher prevalence of overweight than the poorest households. Such clear differences were not evident in Maldives and Nepal, while the richest households were less likely to have overweight children compared to poorest households in Pakistan. The prevalence of underweight and overweight according to the household's highest education level followed similar country-specific patterns observed for wealth index (Figure 3). Notably, children in households with higher

education had higher burden of overweight in Bangladesh, India, and Pakistan than children in no or little education. Similar trends were observed for stunting and wasting prevalence by household's socioeconomic status (Supplementary Table S2 and S3).

Table 2 shows the minimally-adjusted and fully-adjusted associations of household's wealth index and highest education level with the prevalence of underweight and overweight. There was strong evidence of an inverse relationship between the household's wealth index and the prevalence of underweight in children, which was not attenuated even after adjustment for a wide range of covariates except for Maldives and Pakistan. Compared to the poorest households, the richest households were less likely to have children with underweight (adjusted-OR for Bangladesh 0.4 [95% CI: 0.3-0.5], India 0.5 [0.5-0.6], Maldives 0.5 [0.2-1.4], Nepal 0.5 [0.3-0.8], and Pakistan 0.7 [0.5-1.1]. For the household's highest education level, we also observed that households with secondary or higher education were less likely to have children with underweight when compared to households with no education. The adjusted-OR for higher education vs no education was 0.7 (0.6-1.0) for Bangladesh, 0.6 (0.5-0.6) for India, 0.5 (0.1-1.7) for Maldives, 0.6 (0.4-0.9) for Nepal and 0.4 (0.3-0.7) for Pakistan. Additional analyses for childhood stunting and wasting yielded similar associations with household's wealth index and highest level of education (Supplementary Table S4 and S5).

Table 2 also shows that the richest households were more likely to have children with overweight than the poorest households in all countries except Pakistan. However, the positive associations between household's wealth index and overweight prevalence in children were not significant after adjustment for other variables. The adjusted ORs were 1.3 (0.8-2.2) for Bangladesh, 1.1 (1.0-1.2) for

India, 0.5 (0.2-1.4) for Maldives, and 1.2 (0.5-2.9) for Nepal. In Pakistan, the richest households less likely to have overweight children, which remained significant after adjustment for other variables (adjusted-OR 0.1 [0.1-0.2]). Household's education level was also positively associated with the prevalence of overweight in children. When compared with households with no formal education, households with higher education had higher odds of having overweight children in Bangladesh (OR 2.1 [1.3-3.5]), India (OR 1.2 [1.2-1.3]), and Pakistan (OR 1.8 [1.1-2.9]). Maldives and Nepal had fewer households with higher education, but the adjusted ORs for secondary vs no education were 2.3 (1.7-3.1) and 1.8 (1.1-3.1), respectively.

We then explored the associations of other factors with underweight and overweight among children after accounting for household socioeconomic status (Table 3). Factors like living in rural, improved access to sanitation and to drinking water, older maternal age at first birth, low maternal height, and maternal underweight were significantly associated with childhood underweight in some but not all countries. Maternal underweight was consistently found to be associated with increased odds of childhood underweight (adjusted-OR vs normal weight in Bangladesh 1.9 [1.6-2.3], in India 1.7 [1.7-1.8], in Nepal 2.1 [1.6-2.9] and in Pakistan 2.0 [1.4-2.7]). Low maternal height was also strongly associated with childhood underweight, stunting and wasting, although the strength of associations varied by the definitions of undernutrition (Table 3 and Supplementary Table S6 and S7).

For childhood overweight, maternal overweight was found to be associated with increased odds in Bangladesh (OR 1.9 [1.2-3.0]), India (OR 1.3 [1.2-1.4]) and Pakistan (OR 1.8 [1.4-2.5]), but not in Maldives (OR 1.3 [0.9-2.0]) and Nepal (OR 0.9 [0.3-2.2]). In Pakistan, those children who received vitamin A or deworming drug in the last six months were less likely to be overweight than those who did not receive

those interventions. For India and Pakistan, improved access to sanitation and drinking water were significantly associated with childhood overweight, although the directions of such associations were not consistent.

DISCUSSION

This study involving nationally-representative surveys conducted in recent times in five South Asian countries provided empirical evidence on the burden of underweight and overweight among children aged 24-59 months, and their associations with socioeconomic status factors. We found that there was a substantial burden of undernutrition among younger children in South Asian countries, while a differential burden of overnutrition was also seen. Households with higher socioeconomic status (as measured by wealth index and the highest level of education) were associated with lower odds of underweight children, although some of those associations did not reach statistical significance after adjustment for related factors. Household's socioeconomic status and childhood overweight were positively associated in all countries except Pakistan, but results from fully-adjusted models indicated that such associations could be explained by other factors. Households with higher wealth or education were less likely to have children with overweight only in Pakistan. After taking household's socioeconomic status into account, maternal nutritional status was found to be strongly associated with the child's nutritional status, whereas evidence for associations with other factors was inconsistent across countries.

South Asian countries have experienced a striking economic growth in the last few decades, which triggered unprecedented improvements in maternal mortality, infant mortality, under-five mortality, and child undernutrition [28,29]. Trends in the prevalence of childhood underweight have been declining in these countries, with almost 25-30% reduction between 2004 and 2014 in Bangladesh, India, Pakistan, and Nepal [30]. However, the existing burden of undernutrition is still high – our study found that around one-third of under-five children in this region are still

underweight. Previous studies conducted in the region have found that poor socioeconomic status, lower level of parental education, younger age of mother at birth, short birth interval, and initiation of complementary feeding are important determinants of undernutrition among under-five children [31–33]. We observed large inequalities in the prevalence of underweight in each of the included countries, which could not be explained by other factors studied here. Our study also showed that factors like low maternal height and maternal underweight could significantly increase the likelihood of undernutrition in children, while other factors like older age of mother at birth, and access to improved sanitation were also associated with lower odds of childhood underweight. These associations were statistically significant, mostly in India because of a relatively large sample size. DHS data have information on feeding practices for children aged up to two years, so we could not adjust for variables related to feeding practices [25]. To have better insights on the assessment of childhood undernutrition, we additionally explored the burden and the underlying factors of childhood stunting and wasting.

There has been evidence on increasing trends of overweight in younger children in many South Asian countries, although the prevalence is still quite low compared to the prevalence of underweight. Recent reports [9,34–36] from South Asian countries highlighted the rise of overweight burden in children, but mainly in older groups. Overweight among under-five children is still overlooked in current literature. In our study, we provided evidence for an increasing burden of overweight in this age group, which clustered mainly in households with higher socioeconomic status. We found that the associations between socioeconomic status and the prevalence of childhood overweight can be heterogeneous between countries, with positive associations in most countries and inverse association in Pakistan. This highlights

the need for cross-country comparisons for better understanding of double burden of malnutrition. Frequent intake of energy-dense foods and physical inactivity have been shown to be associated with overweight and obesity both in children and adults [37,38]. These lifestyle behaviours are common in the higher socioeconomic group in LMICs, and therefore, both childhood and adulthood overweight are clustered in affluent households in urban areas [34,36]. Our study showed that mothers who were overweight had higher odds of having children with overweight when compared with mothers who were of normal weight - suggesting that public health nutrition programmes should prioritise children whose mothers are overweight. Our findings on having lower odds of overweight among children exposed to nutrition-sensitive programmes (receiving vitamin A and deworming drug) in Pakistan can be studied further to examine the efficacy of such programmes to reduce double burden of malnutrition in LMICs.

The findings from our study highlight the importance of considering not only socioeconomic inequalities but also other maternal and household level factors while developing public health interventions and policies to tackle both childhood undernutrition and overnutrition. Also, the opposite directions for associations of socioeconomic status and nutritional outcomes suggest that the concept of “one size fits all” is not applicable to tackle the emerging problem of the double burden of malnutrition. Previous studies suggested that a multi-sectoral approach is needed to alleviate poverty and other social inequalities related to the double burden of malnutrition in South Asia and beyond [39].

Our study is the first study to look at the coexistence of underweight and overweight among under-five children in South Asian countries by socioeconomic status. One of the major strengths of our study is the use of nationally-representative samples with

objectively measured height and weight data from five different countries, which allowed cross-country comparisons of the results. We were also able to adjust for several factors in the multivariable models, but there are possibilities of residual confounding due to unmeasured factors and/or imperfect assessment of measured factors. Due to smaller sample sizes in Maldives and Nepal, we could not reliably estimate the associations. Problems of reverse causation could also arise in the observed estimates due to the cross-sectional nature of the study. We used the IOTF reference to define childhood overweight instead of the WHO or Centers for Disease Control (CDC) references [22–24]. The IOTF classification system is based on large datasets from six regions covering different ethnicities, therefore more suitable for international comparisons [23,24]. When compared with other references, the IOTF reference yielded similar estimates for overall overweight prevalence but different estimates for obesity [40,41]. It was also found to be more specific in identifying children with overweight and obesity than other references [42]. We assessed childhood undernutrition by assessing underweight, wasting and stunting. Previous studies have found that stunting and overweight can occur concurrently in an individual [43], therefore there may be double counting of children while studying double burden of malnutrition using stunting and overweight. Looking at children who are stunted and overweight can offer more insights into the topic, but we did not look into this issue in our study.

In conclusion, our study provides evidence for socioeconomic disparities for the coexistence of under- and over-nutrition among children aged 24-59 months in South Asian countries. It also showed that factors like maternal nutritional status was strongly associated with nutritional outcomes in children. These unmet inequalities

for both underweight and overweight should be considered while developing national public health nutrition programmes and strategies.

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AUTHOR CONTRIBUTIONS

Conception and design: FH, MS, SA and MB

Data collection and management: FH, SS, and GA

Data analysis: FH, MS, SS

Interpretation of the results: All authors

Drafting of the article: FH and MS

Critical revision of the article for important intellectual content: All authors

Final approval of the article: All authors.

COMPETING INTERESTS STATEMENT

None declared

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DATA SHARING STATEMENT

This study used data from Demographic and Health Surveys (DHS) for Bangladesh, India, Maldives, Nepal, and Pakistan, which are available from the DHS programme website.

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FIGURE LEGENDS

Figure 1: Prevalence of underweight and overweight, by country

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Figure 2: Prevalence of underweight and overweight, by household's wealth index

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Figure 3: Prevalence of underweight and overweight, by household's highest level of education

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

1

Table 1: Sample characteristics in five demographic and health survey data, by country

	Bangladesh	India	Maldives	Nepal	Pakistan
Year of survey	2014	2015-16	2009	2016	2012-13
Number of children	4170	138134	1339	1389	1964
Child's variables					
Sex, n (%)					
Male	2134 (51.2)	71698 (51.9)	672 (50.2)	715 (51.5)	1016 (51.7)
Female	2036 (48.8)	66436 (48.1)	667 (49.8)	674 (48.5)	948 (48.3)
Age in year, n (%)					
2-3	1406 (33.7)	45298 (32.8)	452 (33.8)	460 (33.1)	668 (34.0)
3-4	1377 (33.0)	47506 (34.4)	464 (34.7)	479 (34.5)	641 (32.6)
4-5	1387 (33.3)	45329 (32.8)	423 (31.6)	449 (32.3)	655 (33.4)
Received vitamin A in last 6 months, n (%)	2735 (66.0)	73678 (54.1)	695 (81.8)	1232 (88.8)	1252 (64.6)
Received deworming drug in last 6 months, n (%)	2153 (51.7)	43319 (31.6)	1104 (82.8)	1105 (79.8)	593 (30.3)
Household variables					
Area of residence, n (%)					
Urban	1316 (31.6)	33245 (24.1)	183 (13.7)	788 (56.7)	851 (43.3)
Rural	2854 (68.4)	104889 (75.9)	1156 (86.3)	601 (43.3)	1113 (56.7)
Access to improved sanitation, n (%)	2741 (65.7)	67441 (48.8)	1278 (95.4)	1047 (75.4)	1455 (74.1)
Access to improved drinking water, n (%)	3791 (90.9)	114018 (82.5)	1210 (90.4)	1206 (86.8)	1564 (79.6)
Wealth index, n (%)					
Poorest	931 (22.3)	36404 (26.4)	330 (24.6)	351 (25.3)	443 (22.6)
Poorer	781 (18.7)	32673 (23.7)	335 (25.0)	308 (22.2)	390 (19.9)
Middle	808 (19.4)	27462 (19.9)	358 (26.7)	296 (21.3)	323 (16.4)
Richer	843 (20.2)	23044 (16.7)	201 (15.0)	276 (19.9)	419 (21.3)
Richest	807 (19.4)	18551 (13.4)	115 (8.6)	158 (11.4)	389 (19.8)
Highest education level, n (%)					
No education	714 (17.1)	44950 (32.5)	221 (16.5)	514 (37.0)	1067 (54.3)
Primary	1168 (28.0)	20664 (15.0)	615 (45.9)	260 (18.7)	303 (15.4)

Secondary	1877 (45.0)	60737 (44.0)	462 (34.5)	431 (31.0)	385 (19.6)
Higher	411 (9.9)	11783 (8.5)	26 (1.9)	184 (13.2)	209 (10.6)
No. of household member, median (IQR)	5.0 (4.0, 7.0)	6.0 (5.0, 8.0)	8.0 (6.0, 11.0)	5.0 (4.0, 7.0)	8.0 (6.0, 11.0)
No. of under-five children, median (IQR)	1.0 (1.0, 2.0)	2.0 (1.0, 2.0)	2.0 (1.0, 2.0)	1.0 (1.0, 2.0)	2.0 (2.0, 3.0)
Maternal variables					
Mother's age at first birth, n (%)					
Less than 250 years	3056 (73.3)	50969 (36.9)	499 (37.3)	759 (54.6)	812 (41.3)
20-24 years	927 (22.2)	66287 (48.0)	649 (48.5)	531 (38.2)	812 (41.3)
25 years or above	187 (4.5)	20878 (15.1)	191 (14.3)	99 (7.1)	340 (17.3)
Mother's BMI (kg/m^2) category, n (%)					
Underweight	835 (20.1)	31127 (22.6)	94 (7.4)	228 (16.4)	224 (11.5)
Normal weight	2439 (58.6)	85490 (62.0)	639 (50.3)	937 (67.5)	1006 (51.5)
Overweight	885 (21.3)	21172 (15.4)	538 (42.3)	224 (16.1)	723 (37.0)
Mother's height (cm) category, n (%)					
<145	518 (12.4)	15474 (11.2)	134 (10.5)	165 (11.9)	90 (4.6)
145-149.9	1228 (29.4)	36721 (26.6)	333 (26.1)	367 (26.4)	281 (14.3)
150-154.9	1432 (34.3)	47088 (34.1)	446 (34.9)	490 (35.3)	636 (32.4)
155+	992 (23.8)	38685 (28.0)	364 (28.5)	367 (26.4)	957 (48.7)

There was less than 1% missing value for variables: received vitamin A in last 6 months, received deworming drug in last 6 months, mother's height, and mother's BMI in all countries except Maldives. For Maldives, there were around 5% missing values in mother's height and mother's BMI. There was no missing value in other variables listed in this table.

Table 2: Associations of household's wealth index and highest education with childhood underweight and overweight

	ORs (95% CI) *									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Underweight										
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.8 (0.7-0.9)	0.8 (0.7-1.0)	0.7 (0.7-0.7)	0.8 (0.8-0.8)	0.8 (0.6-1.0)	0.9 (0.6-1.3)	0.6 (0.5-0.8)	0.6 (0.5-0.8)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Middle	0.6 (0.5-0.7)	0.7 (0.6-0.8)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.8 (0.6-1.0)	1.0 (0.7-1.4)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.7 (0.5-0.9)	0.8 (0.6-1.1)
Richer	0.4 (0.4-0.5)	0.6 (0.5-0.7)	0.4 (0.4-0.4)	0.6 (0.6-0.6)	0.5 (0.3-0.7)	0.7 (0.5-1.0)	0.6 (0.4-0.8)	0.7 (0.5-0.9)	0.6 (0.4-0.7)	0.9 (0.7-1.1)
Richest	0.3 (0.2-0.3)	0.4 (0.3-0.5)	0.3 (0.3-0.3)	0.5 (0.5-0.5)	0.3 (0.2-0.6)	0.5 (0.2-1.5)	0.3 (0.2-0.4)	0.4 (0.3-0.7)	0.3 (0.3-0.4)	0.7 (0.5-1.1)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	1.0 (0.9-1.1)	1.1 (0.9-1.2)	0.8 (0.7-0.8)	0.9 (0.9-0.9)	0.6 (0.5-0.7)	0.6 (0.5-0.7)	0.7 (0.6-0.9)	0.8 (0.6-1.1)	0.8 (0.7-1.1)	1.0 (0.8-1.3)
Secondary	0.6 (0.5-0.6)	0.8 (0.7-0.9)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.3 (0.2-0.4)	0.3 (0.2-0.4)	0.5 (0.4-0.7)	0.8 (0.6-1.0)	0.4 (0.3-0.5)	0.5 (0.4-0.7)
Higher	0.3 (0.3-0.4)	0.7 (0.6-1.0)	0.3 (0.3-0.3)	0.6 (0.5-0.6)	0.2 (0.1-0.8)	0.5 (0.1-1.9)	0.3 (0.2-0.5)	0.5 (0.4-0.8)	0.3 (0.2-0.4)	0.4 (0.2-0.6)
Overweight										
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.9 (0.5-1.6)	0.8 (0.4-1.5)	1.1 (1.0-1.2)	1.0 (1.0-1.1)	1.3 (0.9-2.0)	1.4 (0.8-2.2)	0.4 (0.2-0.9)	0.4 (0.1-0.9)	0.5 (0.4-0.7)	0.4 (0.3-0.6)
Middle	1.2 (0.7-2.0)	1.0 (0.6-1.6)	1.2 (1.1-1.3)	1.0 (1.0-1.1)	1.2 (0.8-1.8)	1.1 (0.7-1.7)	0.1 (0.0-0.6)	0.1 (0.0-0.6)	0.4 (0.3-0.5)	0.3 (0.2-0.4)
Richer	1.0 (0.6-1.7)	0.7 (0.4-1.2)	1.3 (1.2-1.4)	1.0 (1.0-1.1)	1.7 (1.1-2.7)	0.9 (0.5-1.4)	0.5 (0.2-1.1)	0.5 (0.2-1.1)	0.3 (0.2-0.4)	0.2 (0.1-0.2)
Richest	3.8 (2.8-5.0)	1.4 (0.8-2.3)	1.7 (1.6-1.8)	1.2 (1.1-1.3)	1.9 (1.1-3.4)	0.5 (0.2-1.4)	1.1 (0.5-2.3)	1.0 (0.4-2.4)	0.4 (0.3-0.5)	0.1 (0.1-0.2)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	1.1 (0.7-1.7)	1.1 (0.7-1.7)	1.1 (1.0-1.1)	1.0 (0.9-1.1)	0.9 (0.7-1.3)	1.1 (0.7-1.5)	1.0 (0.4-2.4)	1.1 (0.4-2.7)	0.6 (0.4-0.9)	0.9 (0.6-1.4)
Secondary	1.4 (1.0-1.9)	1.1 (0.8-1.5)	1.2 (1.1-1.2)	1.0 (0.9-1.0)	2.1 (1.6-2.7)	2.1 (1.6-2.7)	2.0 (1.2-3.3)	1.9 (1.1-3.1)	0.6 (0.4-0.8)	1.3 (0.9-1.8)
Higher	5.2 (3.6-7.5)	2.0 (1.2-3.3)	1.7 (1.6-1.9)	1.2 (1.1-1.3)	2.0 (0.6-6.8)	0.6 (0.1-5.0)	0.9 (0.3-2.8)	0.6 (0.2-2.2)	0.8 (0.5-1.1)	1.6 (1.0-2.5)

* Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table 3: Socioeconomic status-adjusted odds ratios (ORs) of underweight and overweight for various child, household and maternal factors

	ORs (95% CI)*									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight
Child's variables										
Sex										
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.2 (1.0-1.4)	1.2 (0.8-1.8)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	1.1 (0.9-1.5)	1.1 (0.7-1.7)	1.1 (0.9-1.4)	1.5 (0.7-2.9)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Age										
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.0 (0.8-1.2)	1.0 (0.6-1.6)	1.0 (1.0-1.0)	1.0 (0.9-1.0)	1.0 (0.7-1.3)	1.4 (0.9-2.3)	0.8 (0.6-1.0)	2.6 (1.1-6.5)	0.9 (0.7-1.1)	1.4 (1.0-1.9)
4-5 years	1.0 (0.9-1.2)	0.8 (0.5-1.4)	1.0 (1.0-1.0)	0.9 (0.9-1.0)	0.7 (0.5-1.0)	1.3 (0.8-2.1)	0.9 (0.7-1.2)	1.5 (0.6-4.1)	0.9 (0.7-1.2)	1.2 (0.9-1.7)
Received vitamin A in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.2 (0.7-1.8)	1.1 (1.0-1.1)	1.1 (1.0-1.1)	1.2 (0.8-2.0)	1.0 (0.5-1.9)	0.8 (0.5-1.1)	1.1 (0.3-3.8)	1.2 (1.0-1.6)	0.5 (0.4-0.6)
Received deworming drug in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.8-1.1)	0.9 (0.6-1.4)	1.0 (0.9-1.0)	1.1 (1.0-1.2)	1.5 (1.0-2.3)	0.8 (0.5-1.3)	1.0 (0.7-1.3)	1.4 (0.5-3.6)	0.8 (0.6-1.0)	0.6 (0.4-0.8)
Household variables										
Area of residence										
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	0.9 (0.8-1.1)	0.7 (0.4-1.1)	0.9 (0.9-0.9)	1.1 (1.0-1.1)	1.0 (0.4-2.2)	0.4 (0.2-1.0)	1.1 (0.9-1.4)	1.2 (0.6-2.6)	1.0 (0.8-1.3)	0.6 (0.4-0.8)
Improved access to sanitation										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.1 (0.7-1.9)	0.8 (0.8-0.8)	1.2 (1.1-1.3)	0.7 (0.4-1.3)	1.5 (0.4-4.8)	0.7 (0.5-0.9)	1.0 (0.4-2.5)	0.8 (0.6-1.1)	1.6 (1.1-2.2)
Improved access to drinking water										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.2)	1.6 (0.7-3.7)	1.2 (1.1-1.2)	0.9 (0.9-1.0)	1.5 (0.8-2.7)	0.9 (0.4-1.7)	1.0 (0.7-1.5)	0.9 (0.4-2.2)	1.2 (0.9-1.6)	0.7 (0.5-0.9)
No. of children under five	1.1 (1.0-1.2)	1.0 (0.8-1.3)	1.1 (1.1-1.1)	0.9 (0.9-1.0)	1.1 (1.0-1.2)	1.0 (0.8-1.2)	1.1 (0.9-1.2)	0.7 (0.4-1.1)	1.0 (1.0-1.1)	1.0 (0.9-1.1)

Maternal variables										
Mother's age at first birth										
Less than 20 years	1.1 (0.9-1.3)	0.6 (0.4-1.0)	1.1 (1.0-1.1)	1.0 (0.9-1.0)	1.1 (0.8-1.5)	0.7 (0.4-1.1)	0.9 (0.7-1.2)	0.5 (0.2-1.0)	1.0 (0.8-1.2)	0.8 (0.6-1.1)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.8 (0.5-1.1)	1.7 (0.9-3.3)	0.8 (0.8-0.8)	1.3 (1.2-1.4)	0.8 (0.5-1.3)	1.1 (0.6-1.9)	0.8 (0.5-1.4)	0.5 (0.1-2.3)	0.9 (0.7-1.3)	0.8 (0.5-1.1)
Mother's BMI category										
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.9 (1.6-2.3)	0.5 (0.2-1.1)	1.7 (1.7-1.8)	0.5 (0.5-0.6)	1.3 (0.7-2.1)	0.2 (0.1-1.0)	2.1 (1.6-2.9)	0.4 (0.1-1.5)	2.0 (1.4-2.7)	0.4 (0.3-0.8)
Overweight	0.7 (0.5-0.8)	1.9 (1.2-3.0)	0.6 (0.6-0.7)	1.3 (1.2-1.4)	0.7 (0.5-1.0)	1.3 (0.9-2.0)	0.5 (0.3-0.7)	0.9 (0.3-2.2)	0.6 (0.5-0.8)	1.8 (1.4-2.5)
Mother's height category										
<145 cm	3.2 (2.5-4.0)	1.2 (0.6-2.4)	2.7 (2.5-2.8)	0.9 (0.8-1.0)	4.6 (2.8-7.4)	0.7 (0.3-1.6)	3.5 (2.3-5.3)	1.5 (0.5-4.7)	2.6 (1.6-4.0)	1.2 (0.7-2.1)
145-149 cm	2.1 (1.7-2.5)	1.0 (0.6-1.7)	1.9 (1.8-2.0)	0.9 (0.8-1.0)	2.1 (1.4-3.3)	1.0 (0.6-1.7)	2.0 (1.4-2.9)	1.1 (0.4-3.0)	1.7 (1.3-2.3)	1.6 (1.1-2.2)
150-154 cm	1.5 (1.2-1.8)	1.0 (0.6-1.7)	1.4 (1.4-1.4)	1.0 (0.9-1.1)	1.9 (1.3-2.9)	0.6 (0.4-1.0)	1.5 (1.1-2.1)	1.1 (0.5-2.8)	1.3 (1.1-1.7)	0.8 (0.6-1.1)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

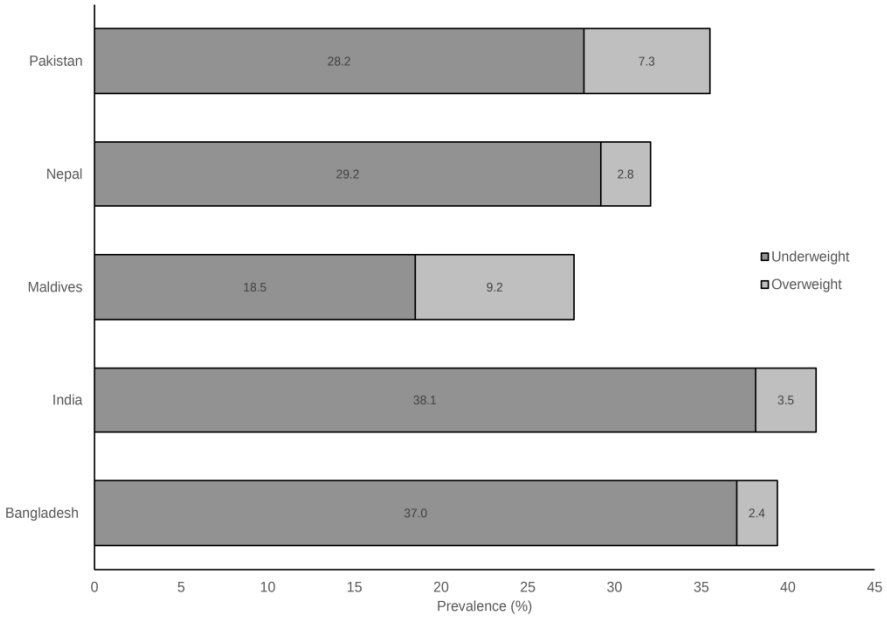

Figure 1: Prevalence of underweight and overweight, by country
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

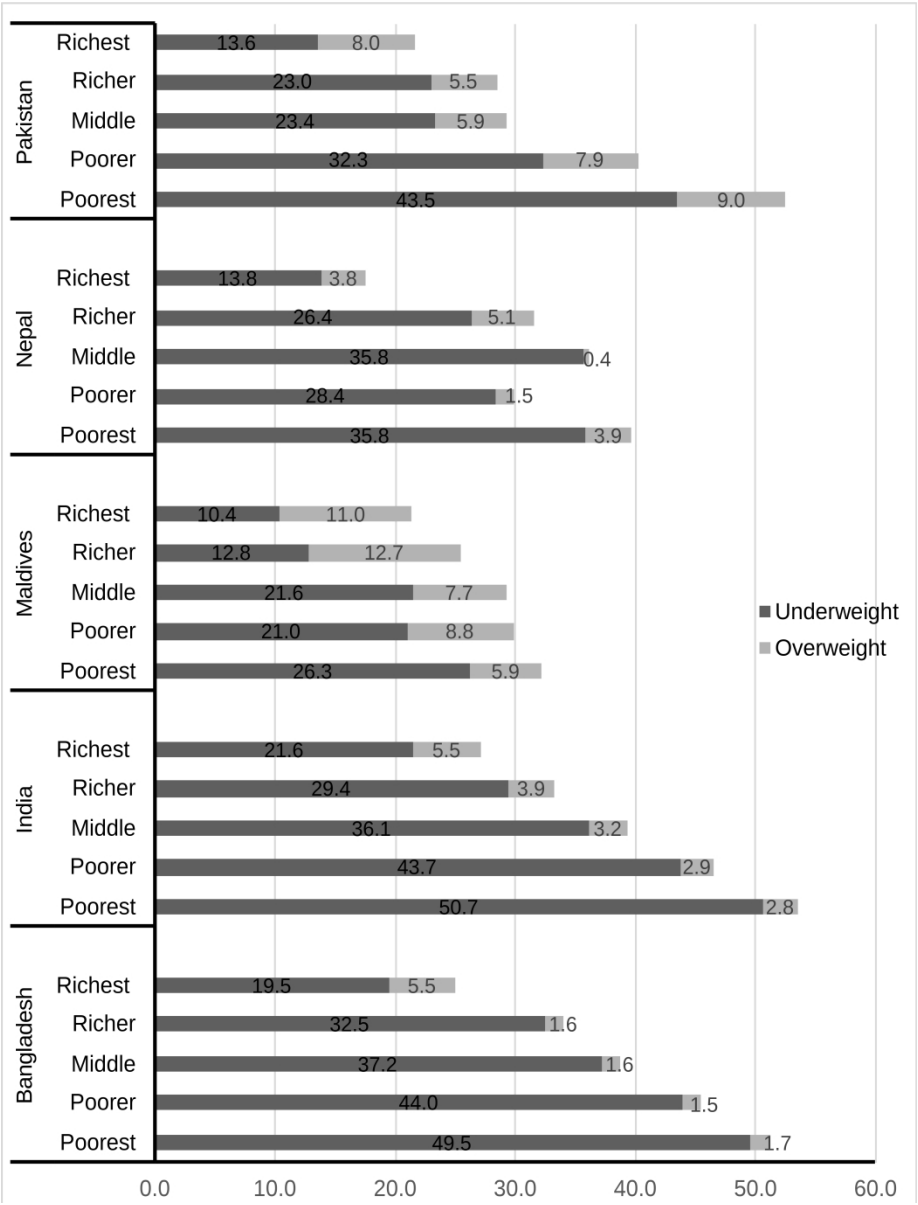

Figure 2: Prevalence of underweight and overweight, by household's wealth index
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

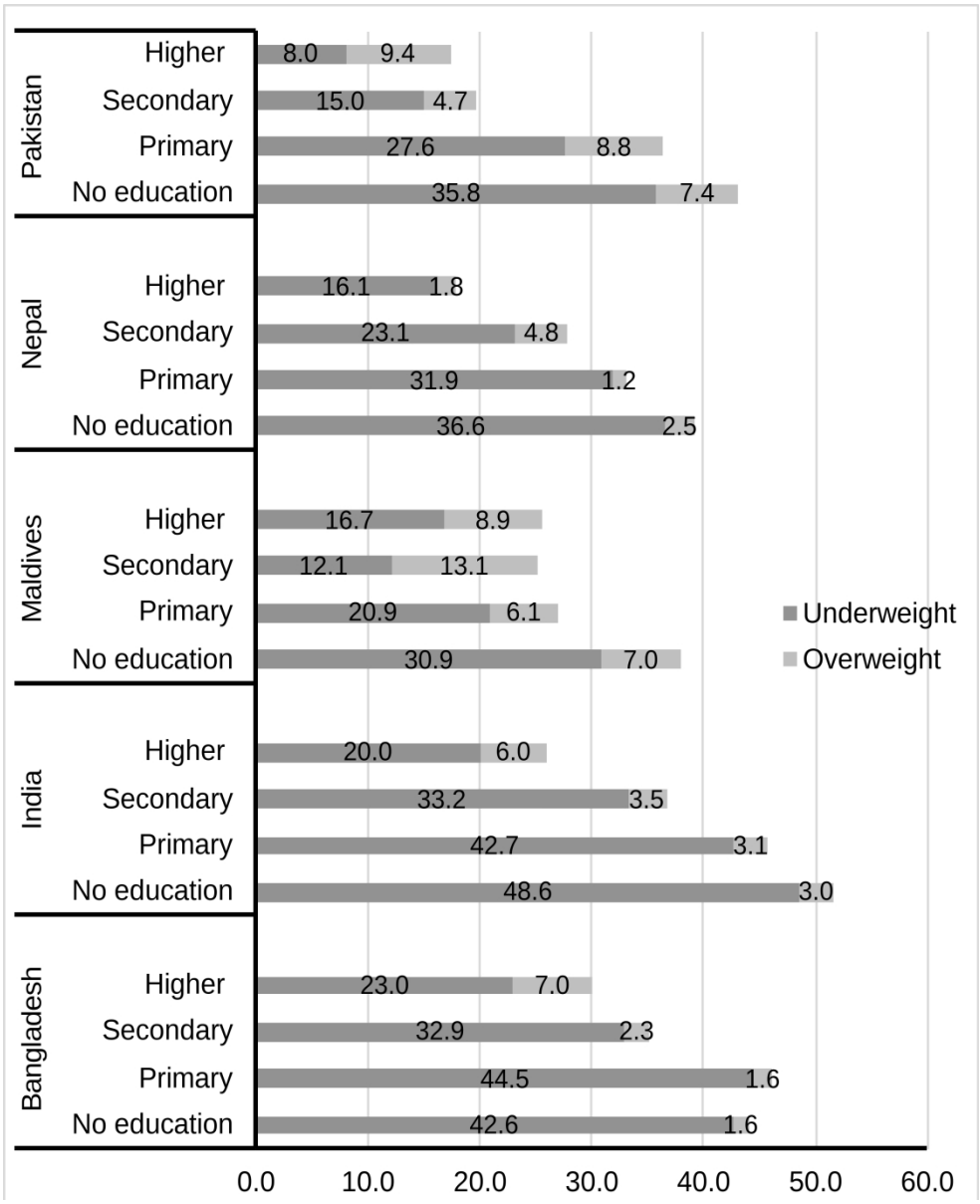

Figure 3: Prevalence of underweight and overweight, by household's highest level of education
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five south Asian countries: evidence from Demographic and Health Surveys

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Supplementary materials

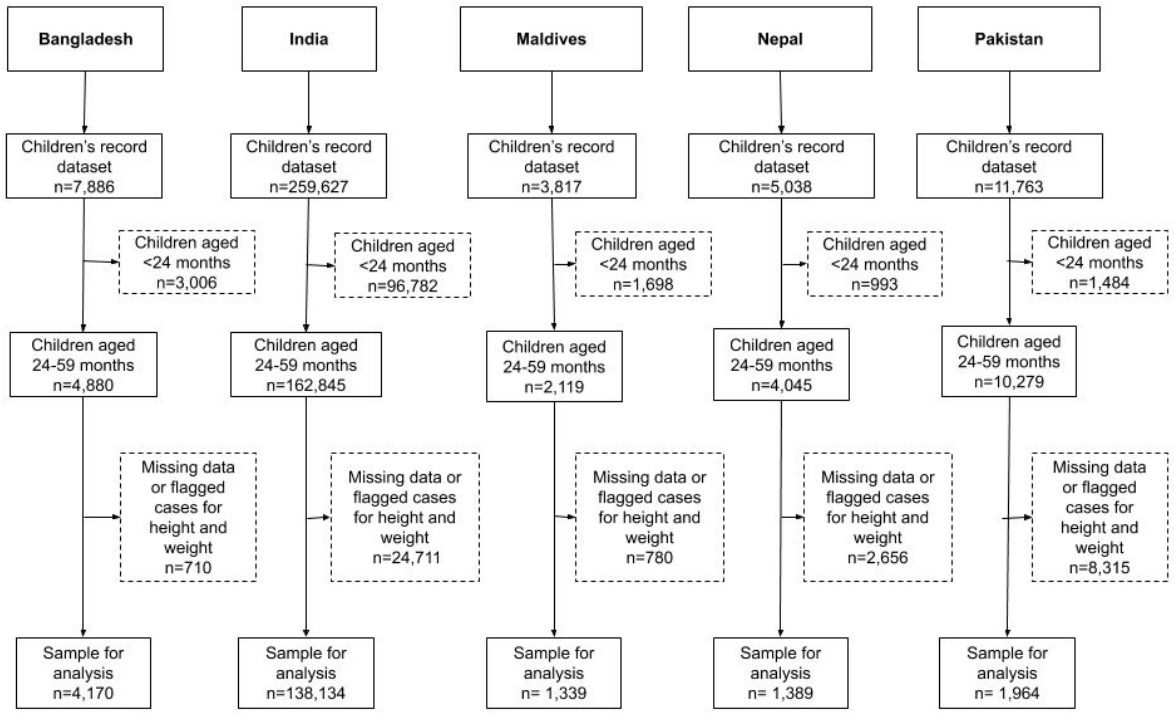

Figure S1: Flowchart of study participants included in this analysis

Table S1: Prevalence of underweight and overweight with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Bangladesh	India	Maldives	Nepal	Pakistan
			Prevalence of underweight*, % (95% CIs)		
Overall	37.0 (35.6-38.5)	38.1 (37.9-38.4)	18.5 (16.5-20.7)	29.2 (26.9-31.7)	28.2 (26.3-30.2)
Wealth index					
Poorest	49.5 (46.4-52.7)	50.7 (50.1-51.2)	26.3 (21.4-31.9)	35.8 (30.4-41.6)	43.5 (39.2-47.9)
Poorer	44.0 (40.5-47.5)	43.7 (43.2-44.3)	21.0 (16.5-26.5)	28.4 (23.6-33.8)	32.3 (28.0-36.9)
Middle	37.2 (33.9-40.6)	36.1 (35.6-36.7)	21.6 (17.1-26.8)	35.8 (30.6-41.3)	23.4 (19.3-28.1)
Richer	32.5 (29.4-35.7)	29.4 (28.8-30.0)	12.8 (9.3-17.4)	26.4 (21.7-31.7)	23.0 (19.5-26.9)
Richest	19.5 (16.9-22.4)	21.6 (21.0-22.1)	10.4 (7.2-14.8)	13.8 (9.5-19.7)	13.6 (10.4-17.7)
Household's highest education					
No education	42.6 (39.1-46.1)	48.6 (48.1-49.1)	30.9 (24.7-37.9)	36.6 (32.6-40.8)	35.8 (33.1-38.5)
Primary	44.5 (41.7-47.4)	42.7 (42.0-43.4)	20.9 (17.7-24.5)	31.9 (26.6-37.7)	27.6 (23.2-32.5)
Secondary	32.9 (30.8-35.1)	33.2 (32.8-33.6)	12.1 (9.5-15.2)	23.1 (19.3-27.5)	15.0 (11.8-19.0)
Higher	23.0 (19.0-27.6)	20.0 (19.3-20.7)	16.7 (8.5-30.2)	16.1 (11.3-22.6)	8.0 (4.8-12.9)
			Prevalence of overweight, % (95% CIs)		
Overall	2.4 (1.9-2.9)	3.5 (3.4-3.6)	9.2 (7.7-10.8)	2.8 (2.1-3.8)	7.3 (6.3-8.5)
Wealth index					
Poorest	1.7 (1.1-2.8)	2.8 (2.7-3.0)	5.9 (3.6-9.4)	3.9 (2.2-6.9)	9.0 (6.8-11.9)
Poorer	1.5 (0.8-2.6)	2.9 (2.7-3.1)	8.8 (5.9-12.9)	1.5 (0.6-3.7)	7.9 (5.7-10.9)
Middle	1.6 (1.0-2.8)	3.2 (3.0-3.4)	7.7 (5.1-11.5)	0.4 (0.1-2.3)	5.9 (3.9-8.8)
Richer	1.6 (1.0-2.7)	3.9 (3.7-4.2)	12.7 (9.1-17.3)	5.1 (3.1-8.3)	5.5 (3.8-7.9)
Richest	5.5 (4.1-7.3)	5.5 (5.2-5.9)	11.0 (7.7-15.4)	3.8 (1.8-7.8)	8.0 (5.6-11.3)
Education level					
No education	1.6 (0.9-2.7)	3.0 (2.8-3.1)	7.0 (4.2-11.7)	2.5 (1.5-4.2)	7.4 (6.0-9.0)
Primary	1.6 (1.0-2.5)	3.1 (2.9-3.4)	6.1 (4.4-8.4)	1.2 (0.4-3.5)	8.8 (6.2-12.2)
Secondary	2.3 (1.7-3.0)	3.5 (3.3-3.6)	13.1 (10.5-16.3)	4.8 (3.1-7.3)	4.7 (3.0-7.3)
Higher	7.0 (4.8-10.0)	6.0 (5.6-6.4)	8.9 (3.5-21.1)	1.8 (0.6-5.4)	9.4 (5.9-14.6)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S2: Prevalence of stunting with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Prevalence of stunting*, % (95% CI)				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Overall	41.6 (40.2-43.1)	41.8 (41.5-42.1)	16.5 (14.6-18.6)	41.6 (39.0-44.2)	48.2 (46.1-50.3)
Wealth index					
Poorest	58.8 (55.7-61.9)	56.9 (56.4-57.4)	19.6 (15.2-24.7)	58.2 (52.3-63.8)	62.3 (57.9-66.4)
Poorer	49.9 (46.4-53.4)	48.0 (47.4-48.5)	20.8 (16.3-26.2)	42.8 (37.3-48.4)	61.0 (56.3-65.5)
Middle	41.3 (38.0-44.8)	39.9 (39.3-40.5)	16.9 (12.9-21.7)	42.4 (37.0-48.0)	47.3 (42.1-52.4)
Richer	35.4 (32.3-38.7)	30.7 (30.1-31.3)	13.5 (9.9-18.2)	37.2 (31.9-42.8)	41.3 (37.0-45.7)
Richest	19.4 (16.7-22.3)	22.8 (22.2-23.4)	11.9 (8.5-16.4)	19.9 (14.7-26.4)	22.8 (18.7-27.6)
Household's highest education					
No education	51.3 (47.7-54.8)	55.0 (54.6-55.5)	21.0 (15.8-27.5)	51.6 (47.4-55.8)	58.8 (56.0-61.6)
Primary	52.5 (49.7-55.4)	47.0 (46.3-47.7)	18.5 (15.5-22.0)	41.1 (35.3-47.1)	50.3 (45.1-55.5)
Secondary	34.4 (32.3-36.6)	35.2 (34.8-35.6)	14.1 (11.3-17.3)	35.3 (30.8-40.0)	26.6 (22.5-31.2)
Higher	24.4 (20.3-29.1)	21.3 (20.5-22.0)	6.8 (2.3-18.5)	26.1 (20.0-33.4)	20.5 (15.2-27.0)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S3: Prevalence of wasting with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Prevalence of wasting*, % (95% CI)				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Overall	12.5 (11.6-13.6)	17.9 (17.7-18.1)	11.1 (9.5-12.9)	6.4 (5.2-7.8)	6.9 (5.9-8.1)
Wealth index					
Poorest	13.3 (11.3-15.6)	20.0 (19.5-20.4)	14.8 (11.0-19.5)	5.9 (3.7-9.4)	11.9 (9.4-15.1)
Poorer	15.0 (12.6-17.6)	18.6 (18.1-19.0)	13.7 (10.0-18.5)	7.4 (5.0-11.0)	5.5 (3.7-8.1)
Middle	11.8 (9.8-14.3)	17.3 (16.8-17.7)	12.5 (9.1-16.9)	6.7 (4.4-10.1)	5.4 (3.4-8.2)
Richer	12.2 (10.2-14.5)	16.8 (16.3-17.2)	6.6 (4.1-10.3)	6.4 (4.1-9.8)	4.7 (3.1-7.0)
Richest	10.3 (8.4-12.6)	15.6 (15.1-16.1)	7.8 (5.1-11.8)	4.9 (2.6-9.2)	6.1 (4.0-9.2)
Household's highest education					
No education	9.1 (7.2-11.3)	19.1 (18.8-19.5)	16.8 (12.1-22.8)	8.0 (6.0-10.7)	7.6 (6.2-9.3)
Primary	14.0 (12.2-16.1)	18.3 (17.8-18.9)	12.1 (9.6-15.1)	7.4 (4.8-11.2)	7.3 (5.0-10.5)
Secondary	13.0 (11.6-14.6)	17.7 (17.4-18.0)	8.1 (6.0-10.8)	4.6 (3.0-7.2)	5.2 (3.4-7.9)
Higher	12.5 (9.5-16.3)	14.2 (13.6-14.8)	13.2 (6.1-26.2)	3.9 (1.8-8.2)	5.1 (2.7-9.4)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S4: Associations of household's wealth index and highest education with childhood stunting

	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.7 (0.6-0.8)	0.8 (0.7-0.9)	0.7 (0.7-0.7)	0.8 (0.8-0.9)	1.2 (0.9-1.5)	1.3 (0.9-1.8)	0.5 (0.4-0.6)	0.5 (0.4-0.6)	0.9 (0.7-1.1)	0.9 (0.7-1.1)
Middle	0.5 (0.5-0.6)	0.7 (0.6-0.8)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.9 (0.6-1.1)	1.1 (0.8-1.5)	0.4 (0.4-0.6)	0.4 (0.3-0.5)	0.6 (0.5-0.8)	0.6 (0.5-0.7)
Richer	0.4 (0.3-0.5)	0.5 (0.5-0.6)	0.4 (0.3-0.4)	0.5 (0.5-0.6)	0.8 (0.5-1.1)	1.0 (0.7-1.4)	0.4 (0.3-0.5)	0.4 (0.3-0.5)	0.5 (0.4-0.6)	0.4 (0.3-0.5)
Richest	0.2 (0.2-0.2)	0.3 (0.3-0.4)	0.2 (0.2-0.3)	0.4 (0.4-0.5)	0.6 (0.3-1.1)	0.8 (0.3-2.1)	0.2 (0.1-0.2)	0.2 (0.1-0.3)	0.2 (0.2-0.3)	0.2 (0.2-0.3)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	0.9 (0.8-1.0)	0.9 (0.8-1.1)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.6 (0.5-0.8)	0.7 (0.5-0.9)	0.8 (0.6-1.0)	1.1 (0.9-1.4)
Secondary	0.4 (0.4-0.5)	0.6 (0.6-0.7)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.6 (0.4-0.7)	0.5 (0.4-0.7)	0.5 (0.4-0.7)	0.8 (0.7-1.0)	0.3 (0.3-0.4)	0.6 (0.5-0.8)
Higher	0.3 (0.2-0.3)	0.6 (0.5-0.8)	0.2 (0.2-0.2)	0.5 (0.5-0.5)	0.3 (0.1-1.1)	0.3 (0.1-1.4)	0.4 (0.3-0.5)	0.6 (0.4-0.9)	0.3 (0.2-0.4)	0.6 (0.4-0.8)

***** Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S5: Associations of household's wealth index and highest education with childhood wasting

	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Household's wealth index										
Poorest	1.0 (0.8-1.2)	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.7-1.4)	1.0 (0.7-1.5)	1.0 (0.6-1.5)	1.0 (0.6-1.6)	1.0 (0.7-1.4)	1.0 (0.6-1.6)
Poorer	1.1 (0.9-1.3)	1.1 (0.9-1.3)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.9 (0.6-1.2)	0.9 (0.6-1.3)	1.1 (0.7-1.8)	1.0 (0.6-1.5)	0.6 (0.4-1.0)	0.7 (0.5-1.2)
Middle	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.7 (0.7-0.8)	0.9 (0.9-0.9)	0.9 (0.6-1.2)	1.0 (0.7-1.5)	1.2 (0.8-1.8)	1.0 (0.6-1.5)	0.7 (0.5-1.1)	0.9 (0.6-1.4)
Richer	0.7 (0.6-0.9)	0.8 (0.6-0.9)	0.7 (0.7-0.7)	0.9 (0.9-0.9)	0.6 (0.4-1.0)	1.1 (0.7-1.7)	1.1 (0.7-1.8)	1.2 (0.7-1.8)	0.6 (0.4-0.9)	0.9 (0.6-1.4)
Richest	0.7 (0.5-0.9)	0.8 (0.6-1.1)	0.6 (0.6-0.7)	0.9 (0.8-0.9)	0.4 (0.2-0.8)	1.3 (0.3-5.0)	0.8 (0.4-1.6)	1.1 (0.5-2.5)	0.7 (0.5-1.1)	1.0 (0.6-1.8)
Household's highest education										
No education	1.0 (0.8-1.3)	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.7-1.4)	1.0 (0.6-1.6)	1.0 (0.7-1.4)	1.0 (0.7-1.4)	1.0 (0.8-1.3)	1.0 (0.7-1.5)
Primary	1.4 (1.2-1.6)	1.5 (1.2-1.7)	0.9 (0.9-0.9)	0.9 (0.9-1.0)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.9 (0.5-1.4)	1.0 (0.6-1.6)	0.8 (0.5-1.3)	1.0 (0.6-1.5)
Secondary	1.2 (1.0-1.4)	1.4 (1.2-1.6)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.5 (0.4-0.7)	0.6 (0.4-0.8)	0.6 (0.4-1.0)	0.7 (0.5-1.0)	0.9 (0.6-1.3)	1.0 (0.6-1.5)
Higher	1.1 (0.8-1.5)	1.6 (1.1-2.3)	0.7 (0.6-0.7)	0.8 (0.8-0.9)	0.7 (0.2-2.3)	1.8 (0.5-6.9)	0.4 (0.2-0.9)	0.4 (0.2-1.0)	0.9 (0.5-1.5)	0.9 (0.5-1.6)

* Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S6: Socioeconomic status-adjusted odds ratios (ORs) of stunting for various child, household and maternal factors

	OR (95% CI)*				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Child's variables					
Sex					
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.0 (0.9-1.1)	1.0 (1.0-1.0)	1.3 (1.0-1.8)	1.0 (0.8-1.2)	0.9 (0.8-1.1)
Age					
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.1 (1.0-1.3)	1.0 (1.0-1.1)	0.9 (0.6-1.2)	0.7 (0.5-0.9)	0.9 (0.7-1.1)
4-5 years	0.8 (0.7-0.9)	0.9 (0.8-0.9)	0.5 (0.4-0.8)	0.7 (0.5-0.9)	0.8 (0.6-1.0)
Received vitamin A in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.9-1.2)	1.0 (1.0-1.0)	1.1 (0.7-1.7)	0.8 (0.5-1.1)	1.1 (0.9-1.3)
Received deworming drug in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.9-1.1)	0.9 (0.9-1.0)	1.1 (0.7-1.6)	1.0 (0.8-1.3)	0.8 (0.6-1.0)
Household variables					
Area of residence					
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	0.9 (0.8-1.1)	0.9 (0.9-1.0)	0.9 (0.4-2.0)	1.0 (0.8-1.3)	0.7 (0.6-0.9)
Improved access to sanitation					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.8 (0.7-1.0)	0.9 (0.9-0.9)	0.7 (0.4-1.2)	0.6 (0.5-0.8)	1.3 (1.0-1.7)
Improved access to drinking water					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.8-1.2)	1.2 (1.1-1.2)	1.0 (0.5-1.7)	1.1 (0.8-1.5)	1.2 (1.0-1.6)
No. of children under five	1.2 (1.1-1.3)	1.1 (1.1-1.1)	1.0 (0.9-1.2)	1.1 (1.0-1.3)	1.1 (1.0-1.2)
Maternal variables					
Mother's age at first birth					
Less than 20 years	1.1 (0.9-1.3)	1.1 (1.1-1.1)	0.8 (0.6-1.2)	0.8 (0.7-1.1)	0.9 (0.7-1.1)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.6 (0.4-0.9)	0.8 (0.8-0.8)	1.0 (0.7-1.6)	0.5 (0.3-0.9)	0.8 (0.6-1.0)
Mother's BMI category					
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.3 (1.1-1.5)	1.3 (1.2-1.3)	0.9 (0.5-1.6)	1.4 (1.1-1.9)	1.7 (1.2-2.3)
Overweight	0.7 (0.6-0.8)	0.8 (0.7-0.8)	0.9 (0.7-1.2)	0.6 (0.4-0.8)	1.0 (0.8-1.2)
Mother's height category					
<145 cm	4.9 (3.9-6.3)	3.5 (3.4-3.7)	6.2 (3.6-10.7)	4.1 (2.7-6.1)	3.7 (2.2-6.2)
145-149 cm	2.5 (2.1-3.0)	2.2 (2.1-2.3)	3.3 (2.1-5.4)	2.7 (2.0-3.8)	2.3 (1.7-3.0)
150-154 cm	1.9 (1.5-2.2)	1.5 (1.5-1.6)	2.5 (1.6-4.0)	1.6 (1.2-2.2)	1.4 (1.1-1.7)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S7: Socioeconomic status-adjusted odds ratios (ORs) of wasting for various child, household and maternal factors

	OR (95% CI)*				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Child's variables					
Sex					
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.0 (0.8-1.2)	0.9 (0.8-0.9)	0.8 (0.6-1.1)	0.9 (0.6-1.4)	0.7 (0.5-1.0)
Age					
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.0 (0.8-1.2)	0.9 (0.9-0.9)	1.1 (0.7-1.7)	0.8 (0.5-1.4)	0.9 (0.6-1.4)
4-5 years	1.2 (0.9-1.5)	0.9 (0.8-0.9)	1.3 (0.9-2.0)	0.9 (0.6-1.6)	0.7 (0.5-1.1)
Received vitamin A in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.1 (0.9-1.3)	1.1 (1.1-1.1)	1.6 (0.9-2.9)	0.6 (0.3-1.0)	1.0 (0.7-1.4)
Received deworming drug in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.7-1.1)	1.0 (1.0-1.1)	1.8 (1.0-2.9)	1.1 (0.6-1.8)	0.7 (0.5-1.1)
Household variables					
Area of residence					
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	1.1 (0.9-1.4)	0.9 (0.9-1.0)	2.7 (0.9-7.8)	0.6 (0.4-0.9)	1.0 (0.6-1.5)
Improved access to sanitation					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.2 (0.9-1.4)	0.9 (0.8-0.9)	0.7 (0.4-1.4)	0.6 (0.4-1.0)	0.7 (0.5-1.1)
Improved access to drinking water					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.2 (0.9-1.6)	1.0 (1.0-1.1)	1.5 (0.7-3.2)	1.5 (0.7-3.3)	0.6 (0.4-0.9)
No. of children under five	0.9 (0.8-1.0)	0.9 (0.9-1.0)	1.1 (0.9-1.3)	0.8 (0.6-1.0)	1.0 (0.9-1.1)
Maternal variables					
Mother's age at first birth					
Less than 20 years	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.1 (0.8-1.6)	1.1 (0.7-1.7)	0.9 (0.6-1.4)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.9 (0.6-1.5)	0.9 (0.9-1.0)	0.6 (0.4-1.2)	1.1 (0.4-2.6)	1.1 (0.7-1.8)
Mother's BMI category					
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.5 (1.2-1.9)	1.4 (1.4-1.5)	1.7 (1.0-3.0)	1.7 (1.0-2.8)	1.3 (0.8-2.1)
Overweight	0.6 (0.4-0.8)	0.6 (0.6-0.6)	0.7 (0.5-1.0)	0.5 (0.2-1.1)	0.6 (0.4-0.9)
Mother's height category					
<145 cm	1.3 (1.0-1.8)	1.0 (1.0-1.1)	1.0 (0.6-1.8)	1.1 (0.6-2.2)	1.4 (0.6-3.0)
145-149 cm	1.1 (0.9-1.5)	1.1 (1.0-1.1)	0.6 (0.4-1.0)	1.0 (0.6-1.7)	0.9 (0.5-1.5)
150-154 cm	1.0 (0.8-1.3)	1.0 (1.0-1.1)	1.1 (0.7-1.7)	0.7 (0.4-1.2)	1.2 (0.8-1.8)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

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		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	Page 1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	#3	State specific objectives, including any prespecified hypotheses	Page 6 lines 14-16
Methods			

Study design	#4	Present key elements of study design early in the paper	Page 7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	Page 7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	NA
Bias	#9	Describe any efforts to address potential sources of bias	Page 10 lines 11-15
Study size	#10	Explain how the study size was arrived at	NA
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	Page 10
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	NA
Statistical methods	#12c	Explain how missing data were addressed	NA
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	NA
Statistical methods	#12e	Describe any sensitivity analyses	Page 13 lines 10-16
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers	Page 11

		potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	NA
Participants	#13c	Consider use of a flow diagram	Page 11
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	Page 11
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	NA
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Page 11
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12
Main results	#16b	Report category boundaries when continuous variables were categorized	NA
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Page 13 lines 10-16
Discussion			
Key results	#18	Summarise key results with reference to study objectives	Page 14
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	Page 16-17
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and	Page 14-16

		other relevant evidence.	
Generalisability	#21	Discuss the generalisability (external validity) of the study results	Page 16
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

Notes:

- 3: Page 6 lines 14-16
- 9: Page 10 lines 11-15
- 12e: Page 13 lines 10-16
- 17: Page 13 lines 10-16 This checklist was completed on 09. July 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai

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Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

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TITLE:

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five South Asian countries: evidence from Demographic and Health Surveys

SUBTITLE:

Double burden of malnutrition among under-five children in South Asia

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ABSTRACT

Objectives: We aimed to investigate the socioeconomic inequalities in the burden of underweight and overweight among children in South Asia. We also examined other factors that were associated with these outcomes independently of household's socioeconomic status.

Design: Nationally-representative surveys.

Settings: Demographic and Health Surveys from Bangladesh, India, Pakistan, Maldives, and Nepal, which were conducted between 2009 and 2016.

Participants: Children aged 24-59 months with valid measurement for height and weight (n=146,996).

Primary exposure and outcome measures: Primary exposures were household's wealth index and level of education. Underweight and overweight were defined according to the World Health Organization and International Obesity Task Force definitions, respectively.

Results: Underweight prevalence was 37% in Bangladesh, 38% in India, 19% in Maldives, 29% in Nepal, and 28% in Pakistan. Bangladesh, India, and Nepal had similar overweight prevalence (between 2% and 4%) whereas Pakistan (7%) and Maldives (9%) had higher prevalence. Households with higher wealth index or education had lower odds of having underweight children. Adjusted-odds ratios (ORs) of underweight for richest vs poorest households were 0.4 [95% CI:0.3-0.5], 0.5 [0.5-0.6], 0.5 [0.2-1.4], 0.5 [0.3-0.8], and 0.7 [0.5-1.1] for Bangladesh, India, Maldives, Nepal and Pakistan, respectively. Compared to poorest households, richest households were more likely to have overweight children in all countries except Pakistan, but such associations were not significant after adjustment for other factors. There were higher odds of having overweight children in households with

higher education in Bangladesh (OR 2.1 [95% CI:1.3-3.5]), India (1.2 [1.2-1.3]), and Pakistan (1.8 [1.1-2.9]) when compared to households with no education. Maternal nutritional status was consistently associated with children's nutritional outcomes after adjustments for socioeconomic status.

Conclusions: Our study provides evidence for socioeconomic inequalities for childhood underweight and overweight in South Asian countries, although the directions of associations for underweight and overweight might be different.

Keywords:

Double burden, underweight, overweight, under-five children, South Asia, Bangladesh, India, Pakistan, Nepal, Maldives

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This is the first study to investigate the double burden of malnutrition among children aged under five years in South Asian countries, using nationally-representative samples.
- We used height and weight information which were measured by trained research personnel.
- Use of International Obesity Task Force (IOTF) classification to define overweight ensures cross-comparison of estimates with those from other regions.
- Although we adjusted for several child, household and maternal factors when examining the associations of socioeconomic status with underweight and overweight, we did not have information on many dietary and lifestyle factors that could modify those associations.
- We examined the effects of other factors on childhood underweight and overweight after adjustment for household's socioeconomic status.

INTRODUCTION

Double burden of malnutrition implies the presence of both undernutrition and overnutrition (overweight or obesity) either at the individual, household, or population level [1]. At the individual level, an undernourished child can be overweight or obese when they reach adulthood, whereas at household level coexistence of undernourished and overweight children or adults can be possible. At the population level, double burden of malnutrition indicates the presence of both undernutrition and overnutrition in the same community, country, or region. Undernutrition can be assessed by underweight (low weight-for-age), wasting (low weight-for-height), and stunting (low height-for-age) [2]. Wasting and stunting reflect acute weight loss and long-term growth restriction, respectively; whereas underweight indicates wasting, stunting, or both.

Double burden of malnutrition is an emerging problem in the low and middle-income countries (LMICs), including South Asian countries [1,3]. Historically, these countries have a considerable burden of undernutrition in children [4,5], for example, according to the World Report on Nutrition 2018 [6], approximately 39% of all stunted children were from this region. But there has been growing evidence that the number of children with overweight and obesity is also increasing in recent years in South Asian countries, particularly due to economic growth, rapid urbanisation, and adoption of western lifestyles [7–10]. Ensuring optimum nutrition in early years of life is an important public health agenda, mainly because both undernutrition and overnutrition in these years are associated with a wide range of morbidities in early life as well as in later life [11,12].

Understanding the socioeconomic inequalities in nutritional outcomes in LMICs is essential to seize programme and policy opportunities to address malnutrition in both

forms. The associations of socioeconomic status with undernutrition and overnutrition might be different in LMICs to those in high-income countries. In high-income countries, overweight in children is associated with poorer socioeconomic conditions [13–15], but it is not clear whether lower socioeconomic status can increase the likelihood of children with overweight in LMICs too. It has been consistently shown that children in poorer households are more likely to be underweight than those in richer households [16,17]. Moreover, identifying other factors that might influence nutritional outcomes independently of socioeconomic status will help to develop effective public health interventions.

While many studies separately examined the burden of undernutrition or overnutrition, studying both outcomes together in a population can inform the relevant stakeholders on seizing intervention and policy opportunities to tackle childhood malnutrition in more holistic ways. So far, studies looking at the issue of the double burden of malnutrition in South Asian countries focused mainly on the coexistence of overweight or obese mother and underweight or stunted child within the same household [16,18,19]. While studying double burden of malnutrition, it is also essential to study the burden and underlying factors of childhood underweight, stunting and wasting because they are very different constructs of undernutrition. To the best of our knowledge, no study looked at the double burden of malnutrition among children aged under five years in South Asian countries.

This study uses data from the Demographic and Health Surveys (DHS), which provide nationally-representative estimates for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition [20]. While these surveys provide the prevalence of underweight and overweight among children by socioeconomic status, it is essential to understand the associations

between them taking account of other factors that might confound such associations. In this study, we aimed to investigate the associations of household's wealth index and highest education level with the prevalence of underweight and overweight among children aged 24-59 months in five South Asian countries. Also, we explored which other factors can influence childhood underweight and overweight independently of household's socioeconomic status.

METHODS

Study design and data sources

This study is based on the latest DHS data from five South Asian countries, namely Bangladesh, India, Pakistan, Maldives, and Nepal. Other countries in the South Asian regions (e.g. Afghanistan, Bhutan, and Sri Lanka) were not included in this study because of either DHS was not conducted, or anthropometric data for children were not available. The included surveys were conducted in 2014, 2015-16, 2009, 2016, and 2012-13 for Bangladesh, India, Maldives, Nepal and Pakistan, respectively.

DHS are nationally-representative household surveys which are usually conducted about every five years. These surveys provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition. A DHS is conducted by a national implementing agency, which can be any bonafide governmental, non-governmental, or private-sector organization and has enough experience in the execution of surveys that are national in scope. Technical assistance throughout the whole process is provided by the DHS program [20].

DHS is usually based on a two-stage stratified sampling of households. In the first stage, sampling census enumeration areas are selected using probability proportional to size (PPS) sampling technique through statistics provided by the respective national statistical office. In the second stage, households are selected through systematic random sampling from the complete listing of households within a selected enumeration area [21].

Ethical approval for each DHS is taken from the ICF Institutional Review Board as well as by a review board in the host country. More details of such ethical approval can be found in the DHS program website [https://dhsprogram.com/]. Informed

consent to participate in the study is taken from the participant, or from the parent or guardian if anthropometric measurements are taken from a child. The data files are freely available from the program website. We received authorization from the DHS program for using the relevant datasets for this analysis. The data we received were anonymized for protection of privacy, anonymity and confidentiality.

These surveys have a very high response rate, usually 90% and above. Detailed questionnaires of included surveys are available in the final report of each survey. We used the children's record (coded as "KR" in DHS program) datasets which contained information about children born in the last five years prior to the survey (aged 0-59 months). The present analysis is based on children aged 24 – 59 months who had a valid measurement of their weight and height. We excluded children aged less than 24 months because most of the available classification system for defining childhood overweight starts from 24 months [22,23]. Flowchart of study participants included in this analysis is given in Supplementary Figure S1.

Anthropometric measurement, and defining undernutrition and overnutrition

In DHS, height and weight of the children were measured by trained personnel using standardized instruments and procedures. Lightweight SECA scales (Hamburg, Germany) with a digital screen, designed and manufactured by the United Nations Children's Fund (UNICEF), were used to measure weight. The height/length was measured by boards, produced by Shorr Productions (Maryland, USA). In children with height less than 85 centimetres, the recumbent length was measured, whereas standing height was measured for taller children. Body mass index (BMI) was calculated by dividing body weight (kg) by squared height (m^2).

While each indicator of child undernutrition reflects distinct aspects undernutrition, we assessed undernutrition mainly by underweight in this study. Childhood underweight indicates the overall population's nutritional status, and is a composite indicator which can encompass stunting, wasting, or both. According to the World Health Organization (WHO) guidelines [2], a child with weight-for-age less than two standard deviations (-2 SD) from the median of the reference population was considered as underweight.

To define childhood overweight, we used the age and sex-specific BMI cut-offs from the International Obesity Task Force (IOTF) classification system [23,24]. According to IOTF, a child aged between 2 years and 18 years is classified as overweight if their BMI is larger than the age and sex-specific BMI cut-off corresponding to an adult BMI of >25 kg/m^2. Our definition of childhood overweight also included those with obesity and it is referred to hereafter as "overweight" for simplicity.

Covariates

DHS collected information on a wide range of variables from the selected households using a face-to-face interview with the respondents conducted by trained personnel. DHS collected information on socioeconomic factors like the area of residence and household's wealth index. Place of residence (rural and urban) was defined according to country-specific definitions. Household's highest education level was based on the educational attainment of the child's mother and father. For household's wealth index, each national implementing agency constructed a country-specific index using principal components analysis from data on household assets including durable goods (i.e. bicycles, televisions etc.) and dwelling characteristics (i.e. sanitation, source of drinking water and construction material of house etc.) [25].

This wealth index was then categorized into five groups (i.e. poorest, poorer, middle, richer, and richest) based on the quintile distribution of the sample.

We also included indicators of child's exposure to nutrition-sensitive interventions (focusing on the underlying determinants of malnutrition) such as receiving vitamin A in the last six months and receiving the deworming drug in last six months [26]. Households with flush toilet, ventilated improved pit latrine, traditional pit latrine with a slab, or composting toilet were considered to have improved access to sanitation, whereas households with improved access to drinking water were considered if they had connection (piped), public standpipe, borehole, protected dug well or spring, or rainwater collection.

Statistical analysis

We conducted all analysis following the instructions given in the DHS guide to analysis [21]. Considering the two-stage stratified cluster sampling in DHS, we applied Stata's survey estimation procedures ("svy" command) for the estimation of proportions, means, and regression analysis [27].

The percent distributions for characteristics of included children are described as proportions, for each DHS survey. To estimate the prevalence of childhood underweight and overweight, we used sampling weights given in each DHS dataset in order to get nationally-representative estimates. 95% confidence intervals (CIs) for prevalence estimates were calculated using a logit transform of the estimate. We also estimated the prevalence of childhood underweight and overweight by the levels of socioeconomic factors to assess the inequalities by those factors.

To examine the associations of socioeconomic factors (i.e. household's wealth index and household's highest level of education) with the prevalence of childhood

underweight and overweight, we used multiple logistic regression, separately for each included country. At first, these analyses were minimally-adjusted for child's age and sex; and then they were adjusted for the child's exposure to nutrition-sensitive interventions, area of residence, access to improved sanitation and to improved drinking water, number of under-five children in household, mother's age at first birth, mother's height, and mother's BMI. Missing data in the adjustment variables (usually less than 5%) were considered as separate categories so that the same children were compared in all analyses. To explore which factors can influence the prevalence of childhood underweight and overweight after accounting for household's socioeconomic status, we estimated the odds ratios (ORs) for all child-, household- and maternal-level factors with adjustment for household's wealth index and highest level of education.

All analyses were additionally conducted for childhood stunting and wasting. Stunting and wasting were defined respectively as height-for-age less than two standard deviations (-2 SD) and weight-for-height less than two standard deviations (-2 SD) from the median of the reference population [2].

All analyses were performed using Stata v15.1 (Statacorp, College Station, TX, USA). All statistical analyses were two-sided and p-value <0.05 was considered as statistically significant.

Patient and public involvement

Patients and the public were not involved in the development of research questions, design of the study, recruitment and conduct of the study, or dissemination of the study results.

RESULTS

A total of 146,996 children aged between 24 and 59 months from five south Asian countries were included in this study. Table 1 shows the characteristics of the study population for each of these countries. There were almost equal distributions for both sex and age in all country samples. At least half of the children in all countries received vitamin A in the last six months. While Maldives and Nepal had excellent coverage (80% or more) for deworming drugs, only about one in three children received the deworming drug in India and Pakistan. Majority of the children were from the rural area except in Nepal, and the proportions varied widely between 43% and 86%. Overall, most of the households had access to improved sanitation and drinking water supply, expect the percentages of household with access to improved sanitation are particularly low in Bangladesh and India. The proportions of household with no formal education were particularly high in India, Nepal, and Pakistan. More than half of the households in Bangladesh and India had members who completed secondary or higher education. The samples from original surveys were divided into quintiles based on the household's wealth index, and after relevant exclusions, the distributions remained more or less similar for this study. India, Maldives, and Pakistan had households with a median of two children aged under five years, while Bangladesh and Nepal had a median of one child per household. Most mothers were less than 25 years old at their first birth. The prevalence of mothers with underweight was higher in Bangladesh (20%) and India (23%) than in other countries, whereas the prevalence of mothers with overweight was higher in Maldives (42%) and Pakistan (37%) than in other countries.

As expected, the prevalence of underweight was much higher than the prevalence of overweight in all five countries (Figure 1 and Supplementary Table S1). India had the highest (38%) prevalence of underweight among children aged 24-59 months followed by Bangladesh (37%), Nepal (29%), Pakistan (28%), and Maldives had the lowest prevalence (19%). For overweight among these children, Bangladesh, India, and Nepal had similar prevalence (between 2% and 4%) whereas Pakistan and Maldives higher prevalence, 7% and 9% respectively. When we looked at the combined prevalence of both forms of malnutrition, India (42%) and Bangladesh (39%) had a much higher burden compared to other countries (Maldives [28%], Nepal [32%], Pakistan [36%]) (Figure 1). The prevalence of underweight was particularly low in Maldives and Pakistan, but they had a higher prevalence of overweight. Bangladesh, India, Nepal and Pakistan had high prevalence of childhood stunting (between 42% and 48%), whereas only 17% of children in Maldives were stunted (Supplementary Table S2). The prevalence of children with wasting was highest in India (18%) and lowest in Nepal (6%) (Supplementary Table S3).

The prevalence of underweight and overweight varied widely according to both the household's wealth index in all countries (Figure 2). Between the poorest and the richest households, the burden of undernutrition decreased by more than half. On the other hand, the richest households in Bangladesh and India had almost two times higher prevalence of overweight than the poorest households. Such clear differences were not evident in Maldives and Nepal, while the richest households were less likely to have overweight children compared to poorest households in Pakistan. The prevalence of underweight and overweight according to the household's highest education level followed similar country-specific patterns observed for wealth index (Figure 3). Notably, children in households with higher

education had higher burden of overweight in Bangladesh, India, and Pakistan than children in no or little education. Similar trends were observed for stunting and wasting prevalence by household's socioeconomic status (Supplementary Table S2 and S3).

Table 2 shows the minimally-adjusted and fully-adjusted associations of household's wealth index and highest education level with the prevalence of underweight and overweight. There was strong evidence of an inverse relationship between the household's wealth index and the prevalence of underweight in children, which was not attenuated even after adjustment for a wide range of covariates except for Maldives and Pakistan. Compared to the poorest households, the richest households were less likely to have children with underweight (adjusted-OR for Bangladesh 0.4 [95% CI: 0.3-0.5], India 0.5 [0.5-0.6], Maldives 0.5 [0.2-1.4], Nepal 0.5 [0.3-0.8], and Pakistan 0.7 [0.5-1.1]. For the household's highest education level, we also observed that households with secondary or higher education were less likely to have children with underweight when compared to households with no education. The adjusted-OR for higher education vs no education was 0.7 (0.6-1.0) for Bangladesh, 0.6 (0.5-0.6) for India, 0.5 (0.1-1.7) for Maldives, 0.6 (0.4-0.9) for Nepal and 0.4 (0.3-0.7) for Pakistan. Additional analyses for childhood stunting and wasting yielded similar associations with household's wealth index and highest level of education (Supplementary Table S4 and S5).

Table 2 also shows that the richest households were more likely to have children with overweight than the poorest households in all countries except Pakistan. However, the positive associations between household's wealth index and overweight prevalence in children were not significant after adjustment for other variables. The adjusted ORs were 1.3 (0.8-2.2) for Bangladesh, 1.1 (1.0-1.2) for

India, 0.5 (0.2-1.4) for Maldives, and 1.2 (0.5-2.9) for Nepal. In Pakistan, the richest households are less likely to have overweight children, which remained significant after adjustment for other variables (adjusted-OR 0.1 [0.1-0.2]). Household's education level was also positively associated with the prevalence of overweight in children. When compared with households with no formal education, households with higher education had higher odds of having overweight children in Bangladesh (OR 2.1 [1.3-3.5]), India (OR 1.2 [1.2-1.3]), and Pakistan (OR 1.8 [1.1-2.9]). Maldives and Nepal had fewer households with higher education, but the adjusted ORs for secondary vs no education were 2.3 (1.7-3.1) and 1.8 (1.1-3.1), respectively.

We then explored the associations of other factors with underweight and overweight among children after accounting for household socioeconomic status (Table 3). Factors like living in rural, improved access to sanitation and to drinking water, older maternal age at first birth, low maternal height, and maternal underweight were significantly associated with childhood underweight in some but not all countries. Maternal underweight was consistently found to be associated with increased odds of childhood underweight (adjusted-OR vs normal weight in Bangladesh 1.9 [1.6-2.3], in India 1.7 [1.7-1.8], in Nepal 2.1 [1.6-2.9] and in Pakistan 2.0 [1.4-2.7]). Low maternal height was also strongly associated with childhood underweight, stunting and wasting, although the strength of associations varied by the definitions of undernutrition (Table 3 and Supplementary Table S6 and S7).

For childhood overweight, maternal overweight was found to be associated with increased odds in Bangladesh (OR 1.9 [1.2-3.0]), India (OR 1.3 [1.2-1.4]) and Pakistan (OR 1.8 [1.4-2.5]), but not in Maldives (OR 1.3 [0.9-2.0]) and Nepal (OR 0.9 [0.3-2.2]). In Pakistan, those children who received vitamin A or deworming drug in the last six months were less likely to be overweight than those who did not receive

those interventions. For India and Pakistan, improved access to sanitation and drinking water were significantly associated with childhood overweight, although the directions of such associations were not consistent.

DISCUSSION

This study involving nationally-representative surveys conducted in recent times in five South Asian countries provided empirical evidence on the burden of underweight and overweight among children aged 24-59 months, and their associations with socioeconomic status factors. We found that there was a substantial burden of undernutrition among younger children in South Asian countries, while a differential burden of overnutrition was also seen. Households with higher socioeconomic status (as measured by wealth index and the highest level of education) were associated with lower odds of underweight children, although some of those associations did not reach statistical significance after adjustment for related factors. Household's socioeconomic status and childhood overweight were positively associated in all countries except Pakistan, but results from fully-adjusted models indicated that such associations could be explained by other factors. Households with higher wealth or education were less likely to have children with overweight only in Pakistan. After taking household's socioeconomic status into account, maternal nutritional status was found to be strongly associated with the child's nutritional status, whereas evidence for associations with other factors was inconsistent across countries.

South Asian countries have experienced a striking economic growth in the last few decades, which triggered unprecedented improvements in maternal mortality, infant mortality, under-five mortality, and child undernutrition [28,29]. Trends in the prevalence of childhood underweight have been declining in these countries, with almost 25-30% reduction between 2004 and 2014 in Bangladesh, India, Pakistan, and Nepal [30]. However, the existing burden of undernutrition is still high – our study found that around one-third of under-five children in this region are still

underweight. Previous studies conducted in the region have found that poor socioeconomic status, lower level of parental education, younger age of mother at birth, short birth interval, and initiation of complementary feeding are important determinants of undernutrition among under-five children [31–33]. We observed large inequalities in the prevalence of underweight in each of the included countries, which could not be explained by other factors studied here. In line with previous studies, our study also showed that factors like low maternal height and maternal underweight could significantly increase the likelihood of undernutrition in children, while other factors like older age of mother at birth, and access to improved sanitation were also associated with lower odds of childhood underweight. These associations were statistically significant, mostly in India because of a relatively large sample size. DHS data have information on feeding practices for children aged up to two years, so we could not adjust for variables related to feeding practices [25]. To have better insights on the assessment of childhood undernutrition, we additionally explored the burden and the underlying factors of childhood stunting and wasting. These additional analyses showed that although the burden of childhood undernutrition varied widely by the indicator of interest, the determinants of childhood undernutrition were similar.

There has been evidence on increasing trends of overweight in younger children in many South Asian countries, although the prevalence is still quite low compared to the prevalence of underweight. Recent reports [9,34–36] from South Asian countries highlighted the rise of overweight burden in children, but mainly in older groups. Overweight among under-five children is still overlooked in current literature. In our study, we provided evidence for an increasing burden of overweight in this age group, which clustered mainly in households with higher socioeconomic status. We

found that the associations between socioeconomic status and the prevalence of childhood overweight can be heterogeneous between countries, with positive associations in most countries and inverse association in Pakistan. This highlights the need for cross-country comparisons for better understanding of double burden of malnutrition. Frequent intake of energy-dense foods and physical inactivity have been shown to be associated with overweight and obesity both in children and adults [37,38]. These lifestyle behaviours are common in the higher socioeconomic group in LMICs, and therefore, both childhood and adulthood overweight are clustered in affluent households in urban areas [34,36]. Our study showed that mothers who were overweight had higher odds of having children with overweight when compared with mothers who were of normal weight - suggesting that public health nutrition programmes should prioritise children whose mothers are overweight. Our findings on having lower odds of overweight among children exposed to nutrition-sensitive programmes (receiving vitamin A and deworming drug) in Pakistan can be studied further to examine the efficacy of such programmes to reduce double burden of malnutrition in LMICs.

The findings from our study highlight the importance of considering not only socioeconomic inequalities but also other maternal and household level factors while developing public health interventions and policies to tackle both childhood undernutrition and overnutrition. Also, the opposite directions for associations of socioeconomic status and nutritional outcomes suggest that the concept of “one size fits all” is not applicable to tackle the emerging problem of the double burden of malnutrition. Previous studies suggested that a multi-sectoral approach is needed to alleviate poverty and other social inequalities related to the double burden of malnutrition in South Asia and beyond [39].

Our study is the first study to look at the coexistence of underweight and overweight among under-five children in South Asian countries by socioeconomic status. One of the major strengths of our study is the use of nationally-representative samples with objectively measured height and weight data from five different countries, which allowed cross-country comparisons of the results. We were also able to adjust for several factors in the multivariable models, but there are possibilities of residual confounding due to unmeasured factors and/or imperfect assessment of measured factors. Due to smaller sample sizes in Maldives and Nepal, we could not reliably estimate the associations. Problems of reverse causation could also arise in the observed estimates due to the cross-sectional nature of the study. We used the IOTF reference to define childhood overweight instead of the WHO or Centers for Disease Control (CDC) references [22–24]. The IOTF classification system is based on large datasets from six regions covering different ethnicities, therefore more suitable for international comparisons [23,24]. When compared with other references, the IOTF reference yielded similar estimates for overall overweight prevalence but different estimates for obesity [40,41]. It was also found to be more specific in identifying children with overweight and obesity than other references [42]. We assessed childhood undernutrition by assessing underweight, wasting and stunting. Previous studies have found that stunting and overweight can occur concurrently in an individual [43], therefore there may be double counting of children while studying double burden of malnutrition using stunting and overweight. Looking at children who are stunted and overweight can offer more insights into the topic, but we did not look into this issue in our study.

In conclusion, our study provides evidence for socioeconomic disparities for the coexistence of under- and over-nutrition among children aged 24-59 months in South Asian countries. It also showed that factors like maternal nutritional status was strongly associated with nutritional outcomes in children. These unmet inequalities for both underweight and overweight should be considered while developing national public health nutrition programmes and strategies.

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AUTHOR CONTRIBUTIONS

Conception and design: FH, MS, SA and MB

Data collection and management: FH, SS, and GA

Data analysis: FH, MS, SS

Interpretation of the results: All authors

Drafting of the article: FH and MS

Critical revision of the article for important intellectual content: All authors

Final approval of the article: All authors.

COMPETING INTERESTS STATEMENT

None declared

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DATA SHARING STATEMENT

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FIGURE LEGENDS

Figure 1: Prevalence of underweight and overweight, by country

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Figure 2: Prevalence of underweight and overweight, by household's wealth index

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Figure 3: Prevalence of underweight and overweight, by household's highest level of education

Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

1

Table 1: Sample characteristics in five demographic and health survey data, by country

	Bangladesh	India	Maldives	Nepal	Pakistan
Year of survey	2014	2015-16	2009	2016	2012-13
Number of children	4170	138134	1339	1389	1964
Child's variables					
Sex, n (%)					
Male	2134 (51.2)	71698 (51.9)	672 (50.2)	715 (51.5)	1016 (51.7)
Female	2036 (48.8)	66436 (48.1)	667 (49.8)	674 (48.5)	948 (48.3)
Age in year, n (%)					
2-3	1406 (33.7)	45298 (32.8)	452 (33.8)	460 (33.1)	668 (34.0)
3-4	1377 (33.0)	47506 (34.4)	464 (34.7)	479 (34.5)	641 (32.6)
4-5	1387 (33.3)	45329 (32.8)	423 (31.6)	449 (32.3)	655 (33.4)
Received vitamin A in last 6 months, n (%)	2735 (66.0)	73678 (54.1)	695 (81.8)	1232 (88.8)	1252 (64.6)
Received deworming drug in last 6 months, n (%)	2153 (51.7)	43319 (31.6)	1104 (82.8)	1105 (79.8)	593 (30.3)
Household variables					
Area of residence, n (%)					
Urban	1316 (31.6)	33245 (24.1)	183 (13.7)	788 (56.7)	851 (43.3)
Rural	2854 (68.4)	104889 (75.9)	1156 (86.3)	601 (43.3)	1113 (56.7)
Access to improved sanitation, n (%)	2741 (65.7)	67441 (48.8)	1278 (95.4)	1047 (75.4)	1455 (74.1)
Access to improved drinking water, n (%)	3791 (90.9)	114018 (82.5)	1210 (90.4)	1206 (86.8)	1564 (79.6)
Wealth index, n (%)					
Poorest	931 (22.3)	36404 (26.4)	330 (24.6)	351 (25.3)	443 (22.6)
Poorer	781 (18.7)	32673 (23.7)	335 (25.0)	308 (22.2)	390 (19.9)
Middle	808 (19.4)	27462 (19.9)	358 (26.7)	296 (21.3)	323 (16.4)
Richer	843 (20.2)	23044 (16.7)	201 (15.0)	276 (19.9)	419 (21.3)
Richest	807 (19.4)	18551 (13.4)	115 (8.6)	158 (11.4)	389 (19.8)
Highest education level, n (%)					
No education	714 (17.1)	44950 (32.5)	221 (16.5)	514 (37.0)	1067 (54.3)
Primary	1168 (28.0)	20664 (15.0)	615 (45.9)	260 (18.7)	303 (15.4)

Secondary	1877 (45.0)	60737 (44.0)	462 (34.5)	431 (31.0)	385 (19.6)
Higher	411 (9.9)	11783 (8.5)	26 (1.9)	184 (13.2)	209 (10.6)
No. of household member, median (IQR)	5.0 (4.0, 7.0)	6.0 (5.0, 8.0)	8.0 (6.0, 11.0)	5.0 (4.0, 7.0)	8.0 (6.0, 11.0)
No. of under-five children, median (IQR)	1.0 (1.0, 2.0)	2.0 (1.0, 2.0)	2.0 (1.0, 2.0)	1.0 (1.0, 2.0)	2.0 (2.0, 3.0)
Maternal variables					
Mother's age at first birth, n (%)					
Less than 25 years	3056 (73.3)	50969 (36.9)	499 (37.3)	759 (54.6)	812 (41.3)
20-24 years	927 (22.2)	66287 (48.0)	649 (48.5)	531 (38.2)	812 (41.3)
25 years or above	187 (4.5)	20878 (15.1)	191 (14.3)	99 (7.1)	340 (17.3)
Mother's BMI (kg/m^2) category, n (%)					
Underweight	835 (20.1)	31127 (22.6)	94 (7.4)	228 (16.4)	224 (11.5)
Normal weight	2439 (58.6)	85490 (62.0)	639 (50.3)	937 (67.5)	1006 (51.5)
Overweight	885 (21.3)	21172 (15.4)	538 (42.3)	224 (16.1)	723 (37.0)
Mother’s height (cm) category, n (%)					
<145	518 (12.4)	15474 (11.2)	134 (10.5)	165 (11.9)	90 (4.6)
145-149.9	1228 (29.4)	36721 (26.6)	333 (26.1)	367 (26.4)	281 (14.3)
150-154.9	1432 (34.3)	47088 (34.1)	446 (34.9)	490 (35.3)	636 (32.4)
155+	992 (23.8)	38685 (28.0)	364 (28.5)	367 (26.4)	957 (48.7)

There was less than 1% missing value for variables: received vitamin A in last 6 months, received deworming drug in last 6 months, mother’s height, and mother’s BMI in all countries except Maldives. For Maldives, there were around 5% missing values in mother’s height and mother’s BMI. There was no missing value in other variables listed in this table.

Table 2: Associations of household's wealth index and highest education with childhood underweight and overweight

	ORs (95% CI) *									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Underweight										
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.8 (0.7-0.9)	0.8 (0.7-1.0)	0.7 (0.7-0.7)	0.8 (0.8-0.8)	0.8 (0.6-1.0)	0.9 (0.6-1.3)	0.6 (0.5-0.8)	0.6 (0.5-0.8)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Middle	0.6 (0.5-0.7)	0.7 (0.6-0.8)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.8 (0.6-1.0)	1.0 (0.7-1.4)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.7 (0.5-0.9)	0.8 (0.6-1.1)
Richer	0.4 (0.4-0.5)	0.6 (0.5-0.7)	0.4 (0.4-0.4)	0.6 (0.6-0.6)	0.5 (0.3-0.7)	0.7 (0.5-1.0)	0.6 (0.4-0.8)	0.7 (0.5-0.9)	0.6 (0.4-0.7)	0.9 (0.7-1.1)
Richest	0.3 (0.2-0.3)	0.4 (0.3-0.5)	0.3 (0.3-0.3)	0.5 (0.5-0.5)	0.3 (0.2-0.6)	0.5 (0.2-1.5)	0.3 (0.2-0.4)	0.4 (0.3-0.7)	0.3 (0.3-0.4)	0.7 (0.5-1.1)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	1.0 (0.9-1.1)	1.1 (0.9-1.2)	0.8 (0.7-0.8)	0.9 (0.9-0.9)	0.6 (0.5-0.7)	0.6 (0.5-0.7)	0.7 (0.6-0.9)	0.8 (0.6-1.1)	0.8 (0.7-1.1)	1.0 (0.8-1.3)
Secondary	0.6 (0.5-0.6)	0.8 (0.7-0.9)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.3 (0.2-0.4)	0.3 (0.2-0.4)	0.5 (0.4-0.7)	0.8 (0.6-1.0)	0.4 (0.3-0.5)	0.5 (0.4-0.7)
Higher	0.3 (0.3-0.4)	0.7 (0.6-1.0)	0.3 (0.3-0.3)	0.6 (0.5-0.6)	0.2 (0.1-0.8)	0.5 (0.1-1.9)	0.3 (0.2-0.5)	0.5 (0.4-0.8)	0.3 (0.2-0.4)	0.4 (0.2-0.6)
Overweight										
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.9 (0.5-1.6)	0.8 (0.4-1.5)	1.1 (1.0-1.2)	1.0 (1.0-1.1)	1.3 (0.9-2.0)	1.4 (0.8-2.2)	0.4 (0.2-0.9)	0.4 (0.1-0.9)	0.5 (0.4-0.7)	0.4 (0.3-0.6)
Middle	1.2 (0.7-2.0)	1.0 (0.6-1.6)	1.2 (1.1-1.3)	1.0 (1.0-1.1)	1.2 (0.8-1.8)	1.1 (0.7-1.7)	0.1 (0.0-0.6)	0.1 (0.0-0.6)	0.4 (0.3-0.5)	0.3 (0.2-0.4)
Richer	1.0 (0.6-1.7)	0.7 (0.4-1.2)	1.3 (1.2-1.4)	1.0 (1.0-1.1)	1.7 (1.1-2.7)	0.9 (0.5-1.4)	0.5 (0.2-1.1)	0.5 (0.2-1.1)	0.3 (0.2-0.4)	0.2 (0.1-0.2)
Richest	3.8 (2.8-5.0)	1.4 (0.8-2.3)	1.7 (1.6-1.8)	1.2 (1.1-1.3)	1.9 (1.1-3.4)	0.5 (0.2-1.4)	1.1 (0.5-2.3)	1.0 (0.4-2.4)	0.4 (0.3-0.5)	0.1 (0.1-0.2)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	1.1 (0.7-1.7)	1.1 (0.7-1.7)	1.1 (1.0-1.1)	1.0 (0.9-1.1)	0.9 (0.7-1.3)	1.1 (0.7-1.5)	1.0 (0.4-2.4)	1.1 (0.4-2.7)	0.6 (0.4-0.9)	0.9 (0.6-1.4)
Secondary	1.4 (1.0-1.9)	1.1 (0.8-1.5)	1.2 (1.1-1.2)	1.0 (0.9-1.0)	2.1 (1.6-2.7)	2.1 (1.6-2.7)	2.0 (1.2-3.3)	1.9 (1.1-3.1)	0.6 (0.4-0.8)	1.3 (0.9-1.8)
Higher	5.2 (3.6-7.5)	2.0 (1.2-3.3)	1.7 (1.6-1.9)	1.2 (1.1-1.3)	2.0 (0.6-6.8)	0.6 (0.1-5.0)	0.9 (0.3-2.8)	0.6 (0.2-2.2)	0.8 (0.5-1.1)	1.6 (1.0-2.5)

* Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table 3: Socioeconomic status-adjusted odds ratios (ORs) of underweight and overweight for various child, household and maternal factors

	ORs (95% CI)*									
	Bangladesh		India		Maldives		Nepal		Pakistan	
	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight
Child's variables										
Sex										
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.2 (1.0-1.4)	1.2 (0.8-1.8)	1.0 (1.0-1.1)	1.0 (1.0-1.1)	1.1 (0.9-1.5)	1.1 (0.7-1.7)	1.1 (0.9-1.4)	1.5 (0.7-2.9)	0.9 (0.7-1.1)	1.0 (0.8-1.3)
Age										
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.0 (0.8-1.2)	1.0 (0.6-1.6)	1.0 (1.0-1.0)	1.0 (0.9-1.0)	1.0 (0.7-1.3)	1.4 (0.9-2.3)	0.8 (0.6-1.0)	2.6 (1.1-6.5)	0.9 (0.7-1.1)	1.4 (1.0-1.9)
4-5 years	1.0 (0.9-1.2)	0.8 (0.5-1.4)	1.0 (1.0-1.0)	0.9 (0.9-1.0)	0.7 (0.5-1.0)	1.3 (0.8-2.1)	0.9 (0.7-1.2)	1.5 (0.6-4.1)	0.9 (0.7-1.2)	1.2 (0.9-1.7)
Received vitamin A in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.2 (0.7-1.8)	1.1 (1.0-1.1)	1.1 (1.0-1.1)	1.2 (0.8-2.0)	1.0 (0.5-1.9)	0.8 (0.5-1.1)	1.1 (0.3-3.8)	1.2 (1.0-1.6)	0.5 (0.4-0.6)
Received deworming drug in last 6 months										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.8-1.1)	0.9 (0.6-1.4)	1.0 (0.9-1.0)	1.1 (1.0-1.2)	1.5 (1.0-2.3)	0.8 (0.5-1.3)	1.0 (0.7-1.3)	1.4 (0.5-3.6)	0.8 (0.6-1.0)	0.6 (0.4-0.8)
Household variables										
Area of residence										
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	0.9 (0.8-1.1)	0.7 (0.4-1.1)	0.9 (0.9-0.9)	1.1 (1.0-1.1)	1.0 (0.4-2.2)	0.4 (0.2-1.0)	1.1 (0.9-1.4)	1.2 (0.6-2.6)	1.0 (0.8-1.3)	0.6 (0.4-0.8)
Improved access to sanitation										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.1)	1.1 (0.7-1.9)	0.8 (0.8-0.8)	1.2 (1.1-1.3)	0.7 (0.4-1.3)	1.5 (0.4-4.8)	0.7 (0.5-0.9)	1.0 (0.4-2.5)	0.8 (0.6-1.1)	1.6 (1.1-2.2)
Improved access to drinking water										
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.8-1.2)	1.6 (0.7-3.7)	1.2 (1.1-1.2)	0.9 (0.9-1.0)	1.5 (0.8-2.7)	0.9 (0.4-1.7)	1.0 (0.7-1.5)	0.9 (0.4-2.2)	1.2 (0.9-1.6)	0.7 (0.5-0.9)
No. of children under five	1.1 (1.0-1.2)	1.0 (0.8-1.3)	1.1 (1.1-1.1)	0.9 (0.9-1.0)	1.1 (1.0-1.2)	1.0 (0.8-1.2)	1.1 (0.9-1.2)	0.7 (0.4-1.1)	1.0 (1.0-1.1)	1.0 (0.9-1.1)

Maternal variables										
Mother's age at first birth										
Less than 20 years	1.1 (0.9-1.3)	0.6 (0.4-1.0)	1.1 (1.0-1.1)	1.0 (0.9-1.0)	1.1 (0.8-1.5)	0.7 (0.4-1.1)	0.9 (0.7-1.2)	0.5 (0.2-1.0)	1.0 (0.8-1.2)	0.8 (0.6-1.1)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.8 (0.5-1.1)	1.7 (0.9-3.3)	0.8 (0.8-0.8)	1.3 (1.2-1.4)	0.8 (0.5-1.3)	1.1 (0.6-1.9)	0.8 (0.5-1.4)	0.5 (0.1-2.3)	0.9 (0.7-1.3)	0.8 (0.5-1.1)
Mother's BMI category										
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.9 (1.6-2.3)	0.5 (0.2-1.1)	1.7 (1.7-1.8)	0.5 (0.5-0.6)	1.3 (0.7-2.1)	0.2 (0.1-1.0)	2.1 (1.6-2.9)	0.4 (0.1-1.5)	2.0 (1.4-2.7)	0.4 (0.3-0.8)
Overweight	0.7 (0.5-0.8)	1.9 (1.2-3.0)	0.6 (0.6-0.7)	1.3 (1.2-1.4)	0.7 (0.5-1.0)	1.3 (0.9-2.0)	0.5 (0.3-0.7)	0.9 (0.3-2.2)	0.6 (0.5-0.8)	1.8 (1.4-2.5)
Mother's height category										
<145 cm	3.2 (2.5-4.0)	1.2 (0.6-2.4)	2.7 (2.5-2.8)	0.9 (0.8-1.0)	4.6 (2.8-7.4)	0.7 (0.3-1.6)	3.5 (2.3-5.3)	1.5 (0.5-4.7)	2.6 (1.6-4.0)	1.2 (0.7-2.1)
145-149 cm	2.1 (1.7-2.5)	1.0 (0.6-1.7)	1.9 (1.8-2.0)	0.9 (0.8-1.0)	2.1 (1.4-3.3)	1.0 (0.6-1.7)	2.0 (1.4-2.9)	1.1 (0.4-3.0)	1.7 (1.3-2.3)	1.6 (1.1-2.2)
150-154 cm	1.5 (1.2-1.8)	1.0 (0.6-1.7)	1.4 (1.4-1.4)	1.0 (0.9-1.1)	1.9 (1.3-2.9)	0.6 (0.4-1.0)	1.5 (1.1-2.1)	1.1 (0.5-2.8)	1.3 (1.1-1.7)	0.8 (0.6-1.1)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

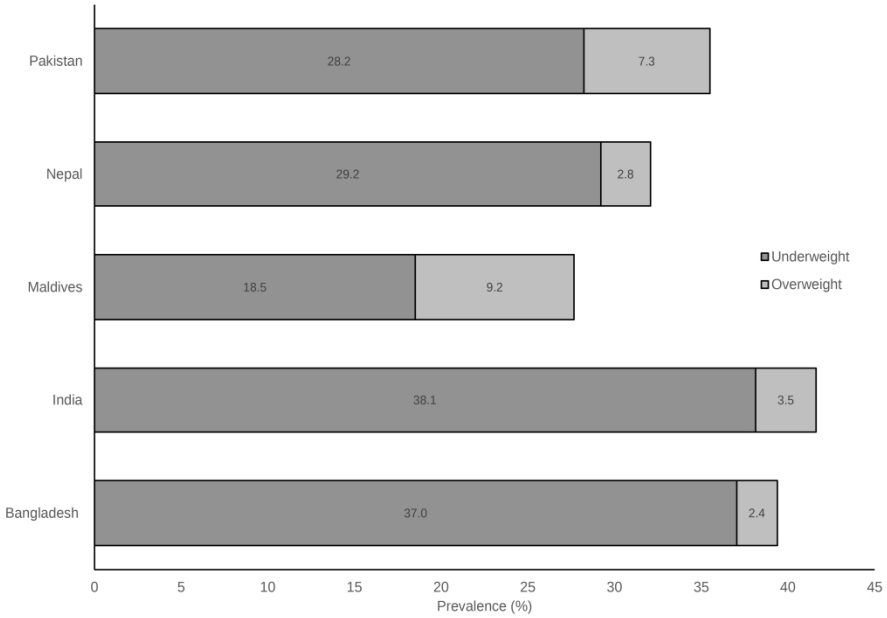

Figure 1: Prevalence of underweight and overweight, by country
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

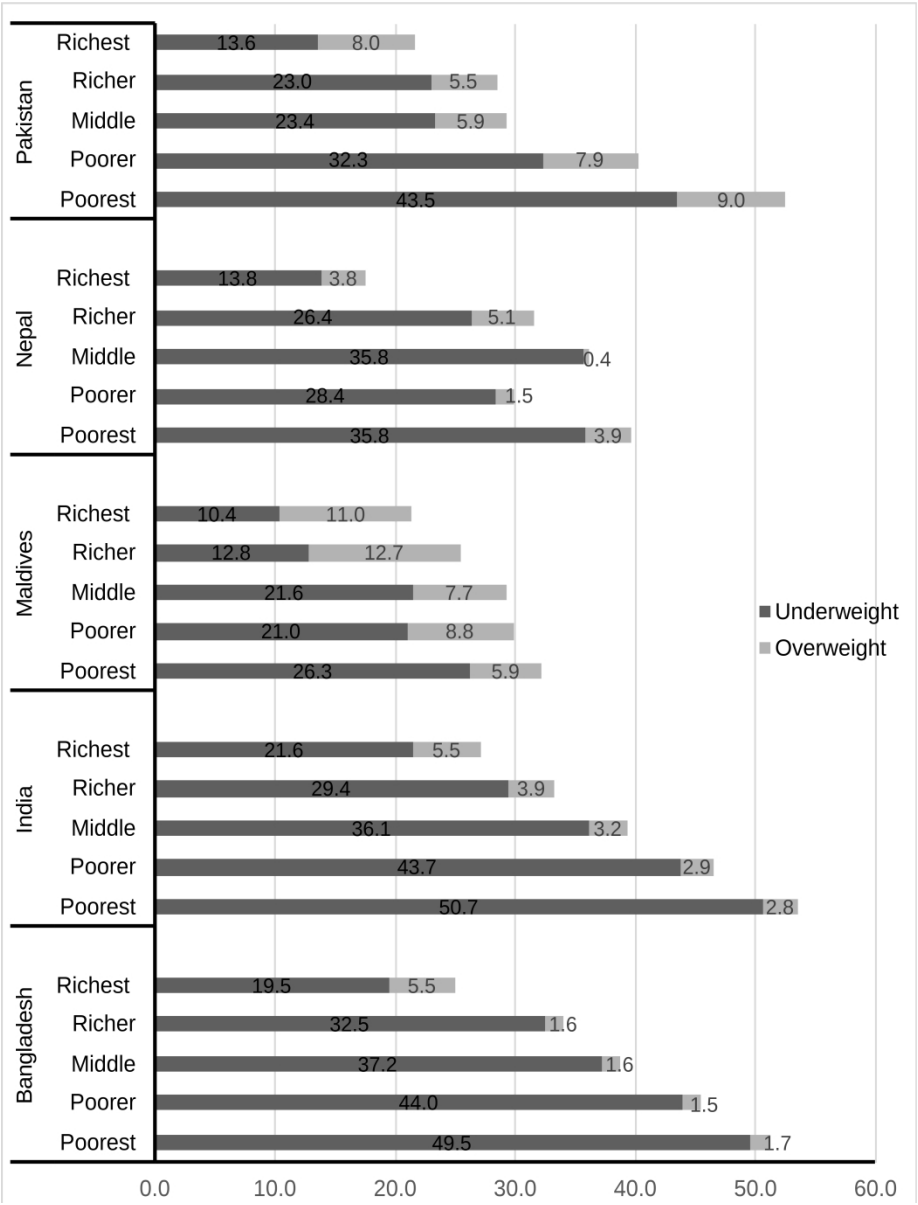

Figure 2: Prevalence of underweight and overweight, by household's wealth index
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

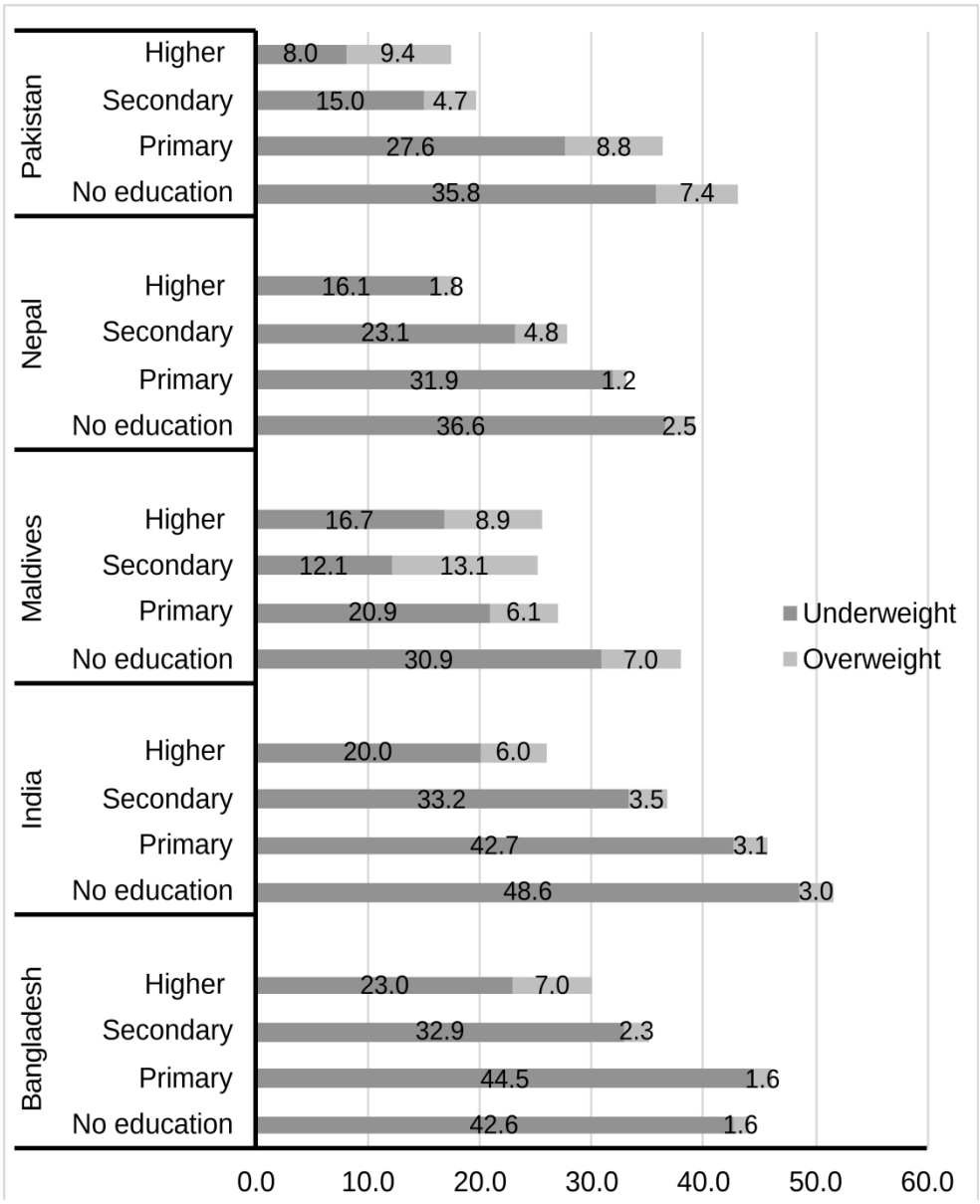

Figure 3: Prevalence of underweight and overweight, by household's highest level of education
Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence. Corresponding 95% confidence intervals of prevalence estimates are given in Supplementary Table S2.

Double burden of malnutrition in children aged 24-59 months by socioeconomic status in five south Asian countries: evidence from Demographic and Health Surveys

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Supplementary materials

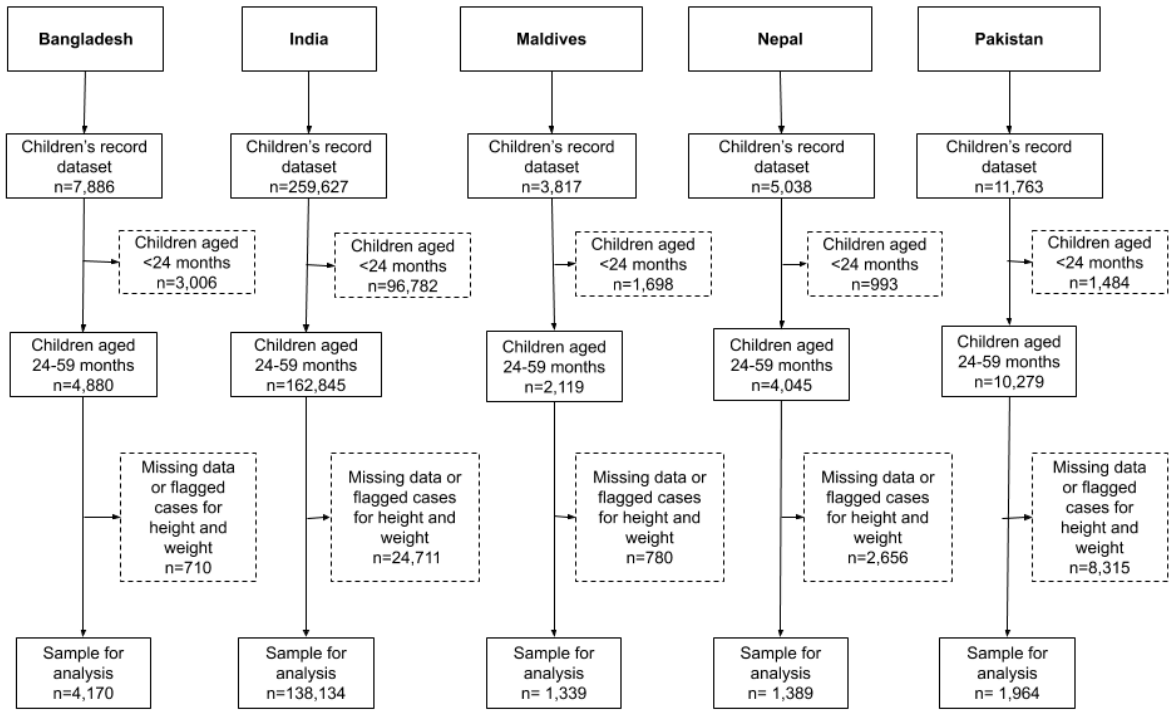

Figure S1: Flowchart of study participants included in this analysis

Table S1: Prevalence of underweight and overweight with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Bangladesh	India	Maldives	Nepal	Pakistan
			Prevalence of underweight*, % (95% CIs)		
Overall	37.0 (35.6-38.5)	38.1 (37.9-38.4)	18.5 (16.5-20.7)	29.2 (26.9-31.7)	28.2 (26.3-30.2)
Wealth index					
Poorest	49.5 (46.4-52.7)	50.7 (50.1-51.2)	26.3 (21.4-31.9)	35.8 (30.4-41.6)	43.5 (39.2-47.9)
Poorer	44.0 (40.5-47.5)	43.7 (43.2-44.3)	21.0 (16.5-26.5)	28.4 (23.6-33.8)	32.3 (28.0-36.9)
Middle	37.2 (33.9-40.6)	36.1 (35.6-36.7)	21.6 (17.1-26.8)	35.8 (30.6-41.3)	23.4 (19.3-28.1)
Richer	32.5 (29.4-35.7)	29.4 (28.8-30.0)	12.8 (9.3-17.4)	26.4 (21.7-31.7)	23.0 (19.5-26.9)
Richest	19.5 (16.9-22.4)	21.6 (21.0-22.1)	10.4 (7.2-14.8)	13.8 (9.5-19.7)	13.6 (10.4-17.7)
Household's highest education					
No education	42.6 (39.1-46.1)	48.6 (48.1-49.1)	30.9 (24.7-37.9)	36.6 (32.6-40.8)	35.8 (33.1-38.5)
Primary	44.5 (41.7-47.4)	42.7 (42.0-43.4)	20.9 (17.7-24.5)	31.9 (26.6-37.7)	27.6 (23.2-32.5)
Secondary	32.9 (30.8-35.1)	33.2 (32.8-33.6)	12.1 (9.5-15.2)	23.1 (19.3-27.5)	15.0 (11.8-19.0)
Higher	23.0 (19.0-27.6)	20.0 (19.3-20.7)	16.7 (8.5-30.2)	16.1 (11.3-22.6)	8.0 (4.8-12.9)
			Prevalence of overweight, % (95% CIs)		
Overall	2.4 (1.9-2.9)	3.5 (3.4-3.6)	9.2 (7.7-10.8)	2.8 (2.1-3.8)	7.3 (6.3-8.5)
Wealth index					
Poorest	1.7 (1.1-2.8)	2.8 (2.7-3.0)	5.9 (3.6-9.4)	3.9 (2.2-6.9)	9.0 (6.8-11.9)
Poorer	1.5 (0.8-2.6)	2.9 (2.7-3.1)	8.8 (5.9-12.9)	1.5 (0.6-3.7)	7.9 (5.7-10.9)
Middle	1.6 (1.0-2.8)	3.2 (3.0-3.4)	7.7 (5.1-11.5)	0.4 (0.1-2.3)	5.9 (3.9-8.8)
Richer	1.6 (1.0-2.7)	3.9 (3.7-4.2)	12.7 (9.1-17.3)	5.1 (3.1-8.3)	5.5 (3.8-7.9)
Richest	5.5 (4.1-7.3)	5.5 (5.2-5.9)	11.0 (7.7-15.4)	3.8 (1.8-7.8)	8.0 (5.6-11.3)
Education level					
No education	1.6 (0.9-2.7)	3.0 (2.8-3.1)	7.0 (4.2-11.7)	2.5 (1.5-4.2)	7.4 (6.0-9.0)
Primary	1.6 (1.0-2.5)	3.1 (2.9-3.4)	6.1 (4.4-8.4)	1.2 (0.4-3.5)	8.8 (6.2-12.2)
Secondary	2.3 (1.7-3.0)	3.5 (3.3-3.6)	13.1 (10.5-16.3)	4.8 (3.1-7.3)	4.7 (3.0-7.3)
Higher	7.0 (4.8-10.0)	6.0 (5.6-6.4)	8.9 (3.5-21.1)	1.8 (0.6-5.4)	9.4 (5.9-14.6)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S2: Prevalence of stunting with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Prevalence of stunting*, % (95% CI)				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Overall	41.6 (40.2-43.1)	41.8 (41.5-42.1)	16.5 (14.6-18.6)	41.6 (39.0-44.2)	48.2 (46.1-50.3)
Wealth index					
Poorest	58.8 (55.7-61.9)	56.9 (56.4-57.4)	19.6 (15.2-24.7)	58.2 (52.3-63.8)	62.3 (57.9-66.4)
Poorer	49.9 (46.4-53.4)	48.0 (47.4-48.5)	20.8 (16.3-26.2)	42.8 (37.3-48.4)	61.0 (56.3-65.5)
Middle	41.3 (38.0-44.8)	39.9 (39.3-40.5)	16.9 (12.9-21.7)	42.4 (37.0-48.0)	47.3 (42.1-52.4)
Richer	35.4 (32.3-38.7)	30.7 (30.1-31.3)	13.5 (9.9-18.2)	37.2 (31.9-42.8)	41.3 (37.0-45.7)
Richest	19.4 (16.7-22.3)	22.8 (22.2-23.4)	11.9 (8.5-16.4)	19.9 (14.7-26.4)	22.8 (18.7-27.6)
Household's highest education					
No education	51.3 (47.7-54.8)	55.0 (54.6-55.5)	21.0 (15.8-27.5)	51.6 (47.4-55.8)	58.8 (56.0-61.6)
Primary	52.5 (49.7-55.4)	47.0 (46.3-47.7)	18.5 (15.5-22.0)	41.1 (35.3-47.1)	50.3 (45.1-55.5)
Secondary	34.4 (32.3-36.6)	35.2 (34.8-35.6)	14.1 (11.3-17.3)	35.3 (30.8-40.0)	26.6 (22.5-31.2)
Higher	24.4 (20.3-29.1)	21.3 (20.5-22.0)	6.8 (2.3-18.5)	26.1 (20.0-33.4)	20.5 (15.2-27.0)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S3: Prevalence of wasting with 95% confidence intervals (95% CIs) in five South Asian countries, overall and by household's wealth index and highest education level

	Prevalence of wasting*, % (95% CI)				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Overall	12.5 (11.6-13.6)	17.9 (17.7-18.1)	11.1 (9.5-12.9)	6.4 (5.2-7.8)	6.9 (5.9-8.1)
Wealth index					
Poorest	13.3 (11.3-15.6)	20.0 (19.5-20.4)	14.8 (11.0-19.5)	5.9 (3.7-9.4)	11.9 (9.4-15.1)
Poorer	15.0 (12.6-17.6)	18.6 (18.1-19.0)	13.7 (10.0-18.5)	7.4 (5.0-11.0)	5.5 (3.7-8.1)
Middle	11.8 (9.8-14.3)	17.3 (16.8-17.7)	12.5 (9.1-16.9)	6.7 (4.4-10.1)	5.4 (3.4-8.2)
Richer	12.2 (10.2-14.5)	16.8 (16.3-17.2)	6.6 (4.1-10.3)	6.4 (4.1-9.8)	4.7 (3.1-7.0)
Richest	10.3 (8.4-12.6)	15.6 (15.1-16.1)	7.8 (5.1-11.8)	4.9 (2.6-9.2)	6.1 (4.0-9.2)
Household's highest education					
No education	9.1 (7.2-11.3)	19.1 (18.8-19.5)	16.8 (12.1-22.8)	8.0 (6.0-10.7)	7.6 (6.2-9.3)
Primary	14.0 (12.2-16.1)	18.3 (17.8-18.9)	12.1 (9.6-15.1)	7.4 (4.8-11.2)	7.3 (5.0-10.5)
Secondary	13.0 (11.6-14.6)	17.7 (17.4-18.0)	8.1 (6.0-10.8)	4.6 (3.0-7.2)	5.2 (3.4-7.9)
Higher	12.5 (9.5-16.3)	14.2 (13.6-14.8)	13.2 (6.1-26.2)	3.9 (1.8-8.2)	5.1 (2.7-9.4)

*Sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures were used to estimate country-representative prevalence.

Table S4: Associations of household's wealth index and highest education with childhood stunting

	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Household's wealth index										
Poorest	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Poorer	0.7 (0.6-0.8)	0.8 (0.7-0.9)	0.7 (0.7-0.7)	0.8 (0.8-0.9)	1.2 (0.9-1.5)	1.3 (0.9-1.8)	0.5 (0.4-0.6)	0.5 (0.4-0.6)	0.9 (0.7-1.1)	0.9 (0.7-1.1)
Middle	0.5 (0.5-0.6)	0.7 (0.6-0.8)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.9 (0.6-1.1)	1.1 (0.8-1.5)	0.4 (0.4-0.6)	0.4 (0.3-0.5)	0.6 (0.5-0.8)	0.6 (0.5-0.7)
Richer	0.4 (0.3-0.5)	0.5 (0.5-0.6)	0.4 (0.3-0.4)	0.5 (0.5-0.6)	0.8 (0.5-1.1)	1.0 (0.7-1.4)	0.4 (0.3-0.5)	0.4 (0.3-0.5)	0.5 (0.4-0.6)	0.4 (0.3-0.5)
Richest	0.2 (0.2-0.2)	0.3 (0.3-0.4)	0.2 (0.2-0.3)	0.4 (0.4-0.5)	0.6 (0.3-1.1)	0.8 (0.3-2.1)	0.2 (0.1-0.2)	0.2 (0.1-0.3)	0.2 (0.2-0.3)	0.2 (0.2-0.3)
Household's highest education										
No education	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Primary	0.9 (0.8-1.0)	0.9 (0.8-1.1)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.6 (0.5-0.8)	0.7 (0.5-0.9)	0.8 (0.6-1.0)	1.1 (0.9-1.4)
Secondary	0.4 (0.4-0.5)	0.6 (0.6-0.7)	0.5 (0.5-0.5)	0.7 (0.7-0.7)	0.6 (0.4-0.7)	0.5 (0.4-0.7)	0.5 (0.4-0.7)	0.8 (0.7-1.0)	0.3 (0.3-0.4)	0.6 (0.5-0.8)
Higher	0.3 (0.2-0.3)	0.6 (0.5-0.8)	0.2 (0.2-0.2)	0.5 (0.5-0.5)	0.3 (0.1-1.1)	0.3 (0.1-1.4)	0.4 (0.3-0.5)	0.6 (0.4-0.9)	0.3 (0.2-0.4)	0.6 (0.4-0.8)

***** Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S5: Associations of household's wealth index and highest education with childhood wasting

	Bangladesh		India		Maldives		Nepal		Pakistan	
	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted	Minimally-adjusted	Fully-adjusted
Household's wealth index										
Poorest	1.0 (0.8-1.2)	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.7-1.4)	1.0 (0.7-1.5)	1.0 (0.6-1.5)	1.0 (0.6-1.6)	1.0 (0.7-1.4)	1.0 (0.6-1.6)
Poorer	1.1 (0.9-1.3)	1.1 (0.9-1.3)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.9 (0.6-1.2)	0.9 (0.6-1.3)	1.1 (0.7-1.8)	1.0 (0.6-1.5)	0.6 (0.4-1.0)	0.7 (0.5-1.2)
Middle	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.7 (0.7-0.8)	0.9 (0.9-0.9)	0.9 (0.6-1.2)	1.0 (0.7-1.5)	1.2 (0.8-1.8)	1.0 (0.6-1.5)	0.7 (0.5-1.1)	0.9 (0.6-1.4)
Richer	0.7 (0.6-0.9)	0.8 (0.6-0.9)	0.7 (0.7-0.7)	0.9 (0.9-0.9)	0.6 (0.4-1.0)	1.1 (0.7-1.7)	1.1 (0.7-1.8)	1.2 (0.7-1.8)	0.6 (0.4-0.9)	0.9 (0.6-1.4)
Richest	0.7 (0.5-0.9)	0.8 (0.6-1.1)	0.6 (0.6-0.7)	0.9 (0.8-0.9)	0.4 (0.2-0.8)	1.3 (0.3-5.0)	0.8 (0.4-1.6)	1.1 (0.5-2.5)	0.7 (0.5-1.1)	1.0 (0.6-1.8)
Household's highest education										
No education	1.0 (0.8-1.3)	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (0.7-1.4)	1.0 (0.6-1.6)	1.0 (0.7-1.4)	1.0 (0.7-1.4)	1.0 (0.8-1.3)	1.0 (0.7-1.5)
Primary	1.4 (1.2-1.6)	1.5 (1.2-1.7)	0.9 (0.9-0.9)	0.9 (0.9-1.0)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.9 (0.5-1.4)	1.0 (0.6-1.6)	0.8 (0.5-1.3)	1.0 (0.6-1.5)
Secondary	1.2 (1.0-1.4)	1.4 (1.2-1.6)	0.8 (0.8-0.8)	0.9 (0.9-0.9)	0.5 (0.4-0.7)	0.6 (0.4-0.8)	0.6 (0.4-1.0)	0.7 (0.5-1.0)	0.9 (0.6-1.3)	1.0 (0.6-1.5)
Higher	1.1 (0.8-1.5)	1.6 (1.1-2.3)	0.7 (0.6-0.7)	0.8 (0.8-0.9)	0.7 (0.2-2.3)	1.8 (0.5-6.9)	0.4 (0.2-0.9)	0.4 (0.2-1.0)	0.9 (0.5-1.5)	0.9 (0.5-1.6)

* Minimally adjusted models were adjusted for child's age and sex; and fully-adjusted models were additionally adjusted for area of residence, receiving vitamin A and deworming drug, access to improved sanitation and drinking water, number of under-five children, mother's age at first birth, mother's height, and mother's BMI. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S6: Socioeconomic status-adjusted odds ratios (ORs) of stunting for various child, household and maternal factors

	OR (95% CI)*				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Child's variables					
Sex					
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.0 (0.9-1.1)	1.0 (1.0-1.0)	1.3 (1.0-1.8)	1.0 (0.8-1.2)	0.9 (0.8-1.1)
Age					
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.1 (1.0-1.3)	1.0 (1.0-1.1)	0.9 (0.6-1.2)	0.7 (0.5-0.9)	0.9 (0.7-1.1)
4-5 years	0.8 (0.7-0.9)	0.9 (0.8-0.9)	0.5 (0.4-0.8)	0.7 (0.5-0.9)	0.8 (0.6-1.0)
Received vitamin A in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.9-1.2)	1.0 (1.0-1.0)	1.1 (0.7-1.7)	0.8 (0.5-1.1)	1.1 (0.9-1.3)
Received deworming drug in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.0 (0.9-1.1)	0.9 (0.9-1.0)	1.1 (0.7-1.6)	1.0 (0.8-1.3)	0.8 (0.6-1.0)
Household variables					
Area of residence					
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	0.9 (0.8-1.1)	0.9 (0.9-1.0)	0.9 (0.4-2.0)	1.0 (0.8-1.3)	0.7 (0.6-0.9)
Improved access to sanitation					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.8 (0.7-1.0)	0.9 (0.9-0.9)	0.7 (0.4-1.2)	0.6 (0.5-0.8)	1.3 (1.0-1.7)
Improved access to drinking water					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.8-1.2)	1.2 (1.1-1.2)	1.0 (0.5-1.7)	1.1 (0.8-1.5)	1.2 (1.0-1.6)
No. of children under five	1.2 (1.1-1.3)	1.1 (1.1-1.1)	1.0 (0.9-1.2)	1.1 (1.0-1.3)	1.1 (1.0-1.2)
Maternal variables					
Mother's age at first birth					
Less than 20 years	1.1 (0.9-1.3)	1.1 (1.1-1.1)	0.8 (0.6-1.2)	0.8 (0.7-1.1)	0.9 (0.7-1.1)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.6 (0.4-0.9)	0.8 (0.8-0.8)	1.0 (0.7-1.6)	0.5 (0.3-0.9)	0.8 (0.6-1.0)
Mother's BMI category					
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.3 (1.1-1.5)	1.3 (1.2-1.3)	0.9 (0.5-1.6)	1.4 (1.1-1.9)	1.7 (1.2-2.3)
Overweight	0.7 (0.6-0.8)	0.8 (0.7-0.8)	0.9 (0.7-1.2)	0.6 (0.4-0.8)	1.0 (0.8-1.2)
Mother's height category					
<145 cm	4.9 (3.9-6.3)	3.5 (3.4-3.7)	6.2 (3.6-10.7)	4.1 (2.7-6.1)	3.7 (2.2-6.2)
145-149 cm	2.5 (2.1-3.0)	2.2 (2.1-2.3)	3.3 (2.1-5.4)	2.7 (2.0-3.8)	2.3 (1.7-3.0)
150-154 cm	1.9 (1.5-2.2)	1.5 (1.5-1.6)	2.5 (1.6-4.0)	1.6 (1.2-2.2)	1.4 (1.1-1.7)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Table S7: Socioeconomic status-adjusted odds ratios (ORs) of wasting for various child, household and maternal factors

	OR (95% CI)*				
	Bangladesh	**India**	**Maldives**	**Nepal**	**Pakistan**
Child's variables					
Sex					
Male	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Female	1.0 (0.8-1.2)	0.9 (0.8-0.9)	0.8 (0.6-1.1)	0.9 (0.6-1.4)	0.7 (0.5-1.0)
Age					
2-3 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
3-4 years	1.0 (0.8-1.2)	0.9 (0.9-0.9)	1.1 (0.7-1.7)	0.8 (0.5-1.4)	0.9 (0.6-1.4)
4-5 years	1.2 (0.9-1.5)	0.9 (0.8-0.9)	1.3 (0.9-2.0)	0.9 (0.6-1.6)	0.7 (0.5-1.1)
Received vitamin A in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.1 (0.9-1.3)	1.1 (1.1-1.1)	1.6 (0.9-2.9)	0.6 (0.3-1.0)	1.0 (0.7-1.4)
Received deworming drug in last 6 months					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	0.9 (0.7-1.1)	1.0 (1.0-1.1)	1.8 (1.0-2.9)	1.1 (0.6-1.8)	0.7 (0.5-1.1)
Household variables					
Area of residence					
Urban	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Rural	1.1 (0.9-1.4)	0.9 (0.9-1.0)	2.7 (0.9-7.8)	0.6 (0.4-0.9)	1.0 (0.6-1.5)
Improved access to sanitation					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.2 (0.9-1.4)	0.9 (0.8-0.9)	0.7 (0.4-1.4)	0.6 (0.4-1.0)	0.7 (0.5-1.1)
Improved access to drinking water					
No	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Yes	1.2 (0.9-1.6)	1.0 (1.0-1.1)	1.5 (0.7-3.2)	1.5 (0.7-3.3)	0.6 (0.4-0.9)
No. of children under five	0.9 (0.8-1.0)	0.9 (0.9-1.0)	1.1 (0.9-1.3)	0.8 (0.6-1.0)	1.0 (0.9-1.1)
Maternal variables					
Mother's age at first birth					
Less than 20 years	1.0 (0.8-1.3)	1.0 (1.0-1.0)	1.1 (0.8-1.6)	1.1 (0.7-1.7)	0.9 (0.6-1.4)
20-24 years	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
25 years or more	0.9 (0.6-1.5)	0.9 (0.9-1.0)	0.6 (0.4-1.2)	1.1 (0.4-2.6)	1.1 (0.7-1.8)
Mother's BMI category					
Normal weight	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
Underweight	1.5 (1.2-1.9)	1.4 (1.4-1.5)	1.7 (1.0-3.0)	1.7 (1.0-2.8)	1.3 (0.8-2.1)
Overweight	0.6 (0.4-0.8)	0.6 (0.6-0.6)	0.7 (0.5-1.0)	0.5 (0.2-1.1)	0.6 (0.4-0.9)
Mother's height category					
<145 cm	1.3 (1.0-1.8)	1.0 (1.0-1.1)	1.0 (0.6-1.8)	1.1 (0.6-2.2)	1.4 (0.6-3.0)
145-149 cm	1.1 (0.9-1.5)	1.1 (1.0-1.1)	0.6 (0.4-1.0)	1.0 (0.6-1.7)	0.9 (0.5-1.5)
150-154 cm	1.0 (0.8-1.3)	1.0 (1.0-1.1)	1.1 (0.7-1.7)	0.7 (0.4-1.2)	1.2 (0.8-1.8)
155 cm or more	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)

* Logistic regression models were adjusted for household's wealth index and highest education. Analyses were conducted using sampling weights provided by the Demographic and Health Survey (DHS) and Stata's survey estimation procedures.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cross sectionalreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	Page 1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2-3
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	#3	State specific objectives, including any prespecified hypotheses	Page 6 lines 14-16
Methods			

Study design	#4	Present key elements of study design early in the paper	Page 7
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 7
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	Page 7
	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 8-9
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	NA
Bias	#9	Describe any efforts to address potential sources of bias	Page 10 lines 11-15
Study size	#10	Explain how the study size was arrived at	NA
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 8-9
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	Page 10
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	NA
Statistical methods	#12c	Explain how missing data were addressed	NA
Statistical methods	#12d	If applicable, describe analytical methods taking account of sampling strategy	NA
Statistical methods	#12e	Describe any sensitivity analyses	Page 13 lines 10-16
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers	Page 11

		potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	NA
Participants	#13c	Consider use of a flow diagram	Page 11
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	Page 11
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	NA
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	Page 11
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 12
Main results	#16b	Report category boundaries when continuous variables were categorized	NA
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Page 13 lines 10-16
Discussion			
Key results	#18	Summarise key results with reference to study objectives	Page 14
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	Page 16-17
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and	Page 14-16

		other relevant evidence.	
Generalisability	#21	Discuss the generalisability (external validity) of the study results	Page 16
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 18

Notes:

- 3: Page 6 lines 14-16
- 9: Page 10 lines 11-15
- 12e: Page 13 lines 10-16
- 17: Page 13 lines 10-16 This checklist was completed on 09. July 2019 using https://www.goodreports.org/, a tool made by the EQUATOR Network in collaboration with Penelope.ai