# A systematic analysis and future projections of the nutritional status and interpretation of its drivers among school-aged children in South-East Asian countries

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## Summary

**Background** Nutrition inadequacy during childhood and adolescence can cause suboptimal growth, intergenerational effects on offspring and an increased risk of chronic diseases in adulthood. There is little information on the prevalence and drivers of malnutrition in children aged 5–19 years, in the South-East Asian setting, since most existing interventions have to date targeted undernutrition. We assessed the national prevalence of nutritional indicators, their trends, and associated risk factors among children aged 5–19 years from 11 countries of WHO South-East Asia Region (SEA Region) in order to provide evidence to guide future policy direction.

**Methods** We included 5,210,646 children for analysis from 345 studies and 25 survey datasets. A Newcastle-Ottawa Scale was used to assess the quality of the study. Bayesian regression models were used to estimate the prevalence of malnutrition between 2000 and 2030, and a series of subgroup analyses were performed to assess variation in pooled estimates by different socio-demographic and lifestyle factors. The protocol was registered with PROSPERO database (CRD42023400104).

**Findings** Overall, pooled analysis demonstrated that indicators of undernutrition in SEA is predicted to decrease between 2000 and 2030 including stunting (36.6%–27.2%), thinness (29.5%–6.2%), and underweight (29.2%–15.9%). However, a substantial increase in prevalence of overweight (6.0% in 2000–16.9% in 2030), and obesity (2.6%–9.5%) are predicted. The prevalence of micronutrient deficiencies between 2000 and 2030 is predicted to decrease–vitamin A by 84% and vitamin D by 53%. Parents' education levels and household wealth were inversely associated with malnutrition. Children's health-related behaviours, such as unhealthy dietary habits and spending more time watching TV, playing games, or using the computer, were associated with increased chance of overweight and obesity. There were no clear signs of publication bias in our study.

**Interpretation** Our analysis highlights the pattern of a double burden of malnutrition, with clear differences between different socio-demographic groups. Despite a substantial reduction in the prevalence of stunting, underweight, and anaemia since 2000, an emerging increase in overweight/obesity and micronutrient deficiencies warrants urgent attention.

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**Keywords:** Malnutrition; Micronutrient deficiencies; WHO-SEARO; Trend; Projection; Bayesian regression model

## Introduction

At present, undernutrition, including micronutrient deficiencies, still remains a high burden in several low- and middle-income countries (LMICs), while obesity is surging ahead.[1] The 'double burden' is defined in many ways, but essentially countries have to think of expanding their national programmes to address both undernutrition and overweight and obesity

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## Research in context

### Evidence before this study

For the past two decades, the "double burden of malnutrition" has been reported and emerged rapidly. For accessible evidence, we searched PubMed, Web of Science, and CINAHL, for relevant articles without date or language restrictions. All the search terms were either Medical Subject Heading terms (MeSH) or text word (tw), including nutritional status (malnutrition OR "nutrition disorders" OR anemia OR "micronutrient deficiency" OR "body mass index" OR obesity OR overweight OR underweight OR stunting OR wasting, OR "chronic malnutrition"), terms for participants (adolescent OR "school-age children" OR "young people" OR teenager) and names of country and region Bangladesh OR Bhutan OR "Korea" OR India OR Indonesia OR Maldives OR Myanmar OR Nepal OR Sri Lanka OR Thailand OR Timor-Leste OR "South Asia" OR "Southasia" OR "Southeast Asia" OR "South-east Asia"). We found that despite the evidence that double burden of malnutrition is becoming evident as children continue to suffer from undernutrition (stunting and wasting), while an emerging proportion of overweight children are also reported. Details on drivers of malnutrition in this age group and dietary intake are few and far between. Malnutrition has serious long-term impacts that transcend an individual's lifespan and pass onto the next generation. However, the limited evidence of nutrition and dietary data for older children is a major barrier to the advocacy with governments and policymakers on the importance of developing and implementing evidence-based responses for reducing the double burden of malnutrition.

### Added value of this study

This study provides the prevalence and trends of nutritional status indicators and socioeconomic and demographic risk factors associated with malnutrition at the regional and national levels among children and adolescents aged 5–19 years in South-East Asia countries. This is also the first analysis that includes both macro and micronutrient deficiencies in assessing the double burden of malnutrition. We estimated that the burden of undernutrition in the Region is projected to remain at just over one-quarter of children (27.9%) and overnutrition are predicted to be 15.6%. Micronutrient deficiencies including Vitamin A deficiency and iron deficiency anaemia is expected to decrease by 2030. Findings of our analysis suggest that undernutrition and overnutrition, are of a high magnitude in SEA.

### Implications of all the available evidence

This is the first study to analyse and interpret the prevalence and trends of nutritional status indicators at the regional and national levels among children and adolescents aged 5–19 years in SEA countries. This study provides a stark warning regarding the emergence and rising trends of overweight and obesity among 5–19 year olds in SEA Region, along with continued stunting, and micronutrient deficiencies. Prevention and management of nutritional disorders are of utmost priority for reducing the burden of child mortality and associated morbidities. Late childhood and adolescence must be recognized as an opportunistic window across the life course to address pre-existing nutritional disorders, and is a key period of sensitivity to shape nutritional factors and health-related behaviours. Double burden of malnutrition affects populations in all regions of the worlds, including high-income countries. The trends observed in this study support the need to incorporate clear strategies to address the various nutritional disorders, thus necessitating a paradigm shift from prevention and management focused on siloed malnutrition to a more holistic, double-action approach. The coexistence of both malnutrition and overweight/obesity suggests that future intervention/policy targets for maintaining healthy population weight should not focus solely on one-way prevention and treatment.

simultaneously.[2,3] National policy responses need to explore 'double-duty actions' which offer an integrated approach of interventions, programmes and policies with the ability to concomitantly prevent or reduce the risk of both undernutrition and obesity or diet-related non-communicable diseases (NCDs).[2] As effective implementation of double-duty actions are based on the rationale of shared risk factors, robust evidence to understand a range of socioeconomic and sex-specific factors associated with nutritional disorders are critical. Other cultural, social, and psychological risks applicable in the local context are also important.[3] Despite their importance, nutritional status in children aged 5–19 years and drivers of malnutrition in WHO South-East Asia Region (SEA Region) remain under-assessed and managed compared to those of infants and children under 5 years. The drivers of malnutrition in older children too are likely to center around imbalances of energy intake, poor quality diet, and inadequate physical activity.[4]

Apart from affecting the optimum growth and development of children, malnutrition has serious long-term impacts that transcend into adulthood, and can pass onto the next generation.[4] Undernourished children perpetuate an intergenerational malnutrition cycle, resulting in low birth weight babies who are stunted in childhood, and have a greater risk of developing NCDs, such as diabetes and cardiovascular diseases, especially when exposed to unhealthy diets.[3] Overweight and obesity themselves can also result in increased risk of NCDs like diabetes and hypertension later in life. Over one-fifth of SEA Regions population are children aged between 5 and 19 years.[5] Prioritizing good nutrition is critical to ensure the health of both present and future generations. Several global and regional mandates including the World Health Organization (WHO)'s Global Strategy on Diet, Physical Activity and Health (DPAH),[6] the 2016 Report on the Commission for Ending Childhood Obesity (ECHO)[7] and the Regional Strategic Action Plan to reduce the double burden of malnutrition 2016–2025[8] promote greater attention to nutrition in this age group, especially by leveraging schools as a platform. A key consequence of the double burden of malnutrition is that interventions always need to be planned and implemented considering the no harm notion; addressing one form of malnutrition should not be detrimental to subsequently tackling another type of malnutrition at the other end of the spectrum.[3] Therefore, both population level actions such as improving the food environment as well as an individualized approach are important.

However, the scarcity of nutrition and dietary data for these older children is a major barrier to the advocacy with governments and policymakers on the importance of developing and implementing evidence-based responses for reducing the double burden of malnutrition. Some countries including India,[5,6] Nepal,[7] Sri Lanka[8] and Indonesia[9,10] have recently taken initiatives to improve data availability in this age group through national-level nutrition surveys, and Global School Health Surveys. However, details on drivers of malnutrition and dietary intake are few and far between. A more detailed analysis of the nutritional status of this age group, along with identification of data trends and information gaps, will support the next steps for the prevention and treatment of malnutrition in school aged children.

We, therefore, present the data and trends on national level prevalence of nutritional status and socio-economic and demographic risk factors associated with malnutrition in 5–19 year old children in the 11 WHO SEA Region countries. The contextual factors in SEA Region which need further considerations are discussed. Interpretation of this study's findings will provide valuable insights to current progress and challenges, and identify opportunities for intervention to improve the nutritional status of children aged 5–19 years in the WHO SEA Region and also target scarce resources policy and programme areas that appear to be priorities for further malnutrition reduction.

## Methods

### Data sources, search strategy and selection criteria

We collected data on the burden (prevalence or mean) and determinants (odds ratio or risk ratio) of nutritional status indicators from nationally representative surveys and published articles. Study outcomes include underweight, overweight, obese, stunting, thinness, anaemia, and micronutrient deficiencies including vitamin A, vitamin B vitamin C, and vitamin D. We followed definitions of outcome variables as per original studies of the included papers. The protocol was registered with PROSPERO database (CRD42023400104).

We have included several international level surveys data sets including Global School-based Health Survey (GSHS), Demographic and Health Survey (DHS), and Global Health Observatory (GHO) conducted between 2000 and 2022. From the GHO database, 80 data points from three countries were obtained. A total of 15 DHS were included from five countries—Bangladesh (n = 6), Myanmar (n = 1), Maldives (n = 2), Nepal (n = 4), and Timor-Leste (n = 2) (Appendix, p2). Finally, 8 GSHS were included which covered several countries including Bangladesh, Indonesia, Maldives, Timor-Leste, and Thailand (Table S1, Appendix, p2).

Furthermore, we conducted a systematic review of research articles on nutritional status by searching PubMed, Web of Science, and CINAHL on October 5, 2021 initially and updated in February 15, 2023. We also undertook a manual search on relevant reference lists of published articles, relevant journals, and websites of international organizations. We used a combination of Medical Subject Headings and free text terms in our search strategy (Tables S2–S4, Appendix, pp3-5). All cross-sectional and follow-up studies and panel surveys conducted in any one or a combination of countries in WHO SEA Region were eligible for this study. We included studies if they provided measures on the burden and/or determinants of at least one of the nutritional status indicators among children aged 5–19 years. We excluded studies if they were qualitative in nature, letters, case series, reviews, commentaries or editorials; and only considered pregnant adolescent mothers or high-risk groups such as those with pre-existing conditions or migrants. No limitations were set for the language of publication. Four assessors independently screened titles, abstracts and full-texts based on the inclusion and exclusion criteria and disagreements were resolved by consensus or team leader. A data brief extraction form was designed in excel and pilot tested prior to tabulating the data. For eligible studies, reports, and secondary database using the agreed form, two review authors independently extracted data on author information, year of publication, survey year, country, region, settings, study design, sample size, unit of analysis, recall period, outcome variables (nutritional status by country, place of residence, household, individuals or health behaviour characteristics. When the information was unclear or full-text articles was not available, we contacted the corresponding or co-authors to collect our required information. Two authors independently completed the data entry process and which was cross-checked by another two authors. This study followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PRISMA diagram in Fig. 1) and PRISMA check list (Table S5, Appendix,

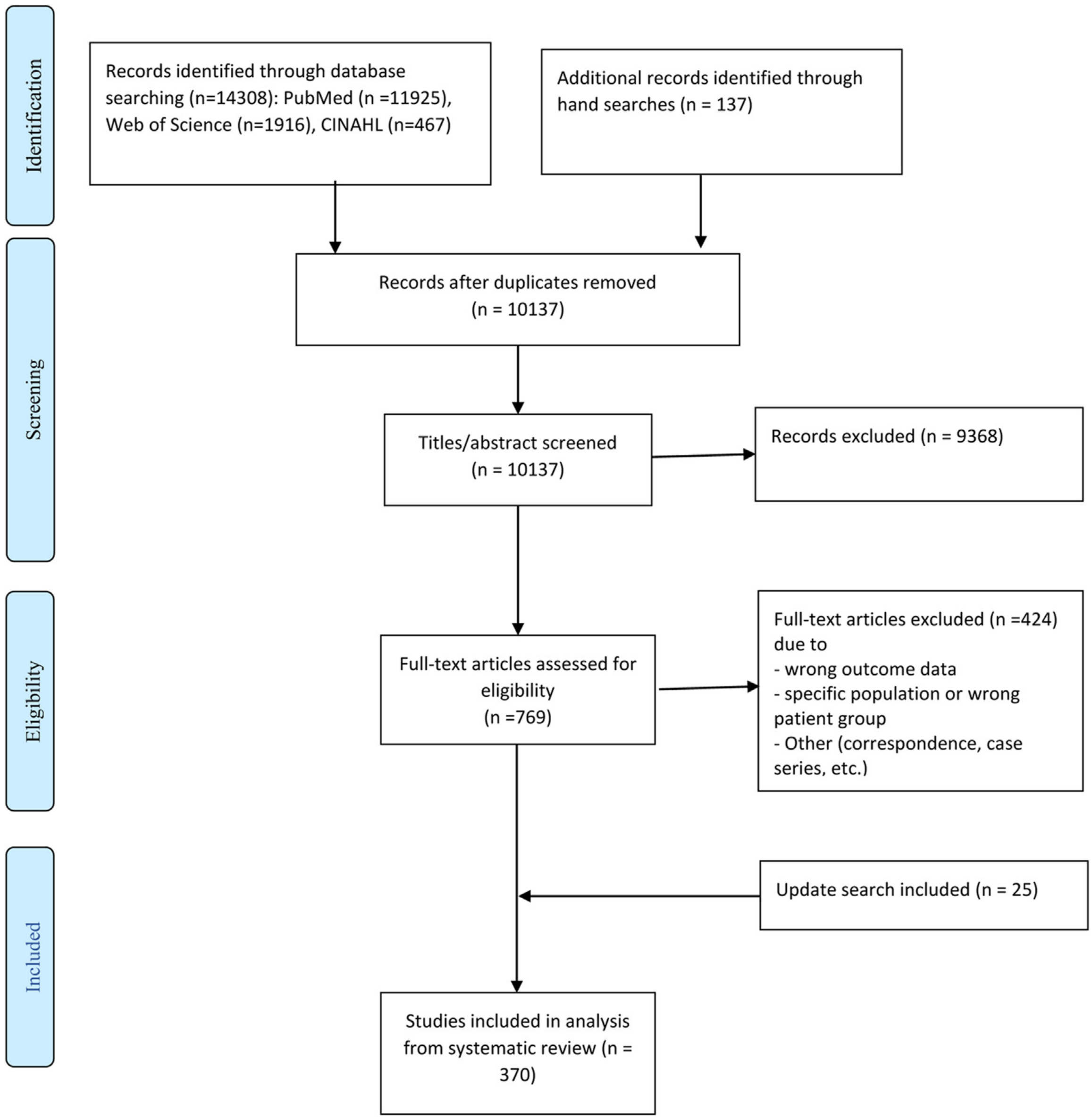


***Fig. 1:*** PRISMA flowchart of study selection.

pp6-10).[9] From the systematic review, 370 studies were included in analysis. Details of the systematic review and characteristics of included studies are summarised in the appendix (Tables S6–S7, pp11-32).

### Quality assessment in included studies

We used Newcastle–Ottawa Scale (NOS) to assess the methodological quality of all included studies.[11] The NOS consists of three domains that are used to evaluate study designs. The selection of study groups domain assesses whether the study groups were selected appropriately in order to represent the target population and if the selection of the control group was adequate. Factors such as representativeness (selection of participants), selection of control, and definition and assessment of exposure are taken into consideration when evaluating this domain. The comparability of study domain looks at whether the study groups were similar in terms of any potential confounding factors. Lastly, the ascertainment of outcome domain ensures that the assessment of the outcome was independent and blind, that the follow-up period was long enough for the outcome to occur, and that the follow-up was adequate. This system is based on a system of stars (*) awarded for each criterion that complies. Two authors independently assessed study quality based on the representativeness, the selection of the non-exposed group, ascertainment of exposure, outcome of interest not present at start; comparability of the study on the basis of study design and analysis; and finally the assessment of the outcome. All studies received a score from 0 to 10. Studies were defined as high quality, score ≥6; moderate quality, score 4–5; or low quality, score 0–3.

### Statistical analysis

Bayesian hierarchical regression model was used to estimate the trends in and projections of each nutritional status up to 2030 by country and sex. The outcome variable (prevalence of anemia, underweight, stunting, overweight, or obesity) was the logit transformation, which ensured that the predicted levels were within the possible range of 0–100%. In the long-term projection of nutritional indicator variables, we assumed that the rate of change in each country from 2000 to 2020 would continue from 2021 to 2030. The following Bayesian hierarchical regression model was used to estimate the trends in, and projections of each nutritional status up to 2030 at the country level:

$$y_{ij} \sim N\left(X\beta_{ij}, \tau^2\right)$$

$$y_{ij} = \beta_{0,ij} + \beta_{1,ij} year_{ij} + \beta_{2,ij} gender_{ij} + \beta_{3,ij} SDI_{ij} + \varepsilon_{ij}$$

$$\beta_{ij} \sim N\left(\beta_j, \sigma_i^2\right)$$

$$\beta_j \sim N\left(\beta, \sigma^2\right)$$

$$\beta \sim N(0, 10000)$$

$$\sigma_i, \sigma, \tau \sim gamma(0.0001, 0.001)$$

where $y_{ij}$ is the logit-transformed probability of each nutritional indicator (prevalence of anemia, underweight, stunting, overweight, or obesity) in the $i$th year for the $j$th country. X is the model matrix consisting of observed gender (both male and female), and socio-demographic index (SDI) values in the ith year for the $j$th country, and $\tau^2$ is the model error variance. The $\beta_{0,ij}$ quantifies random variations in nutritional indicator that are not explained by the covariates. The models were fitted using the Bayesian approach, sampling from the posterior distribution of the parameters using Gibbs Monte Carlo, a Markov Chain Monte Carlo (MCMC) method. Non-informative priors were used. The detailed description of Bayesian model are presented in Appendix (p42). A series of subgroup meta-analyses were performed to estimate the pooled prevalence of outcome variables by different characteristics such as age group, sex (male or female), level of education (primary or less, secondary or college, or higher), employment/working status (unemployed/not working or employed/working), level of income or socioeconomic status of the population (poorest, poor, average, rich, or richest), place of residence (urban or rural), dietary, and life-style variables. Firstly, we assessed the publication bias with visual inspection of funnel plots, and then we performed a quantitative analysis by using Begg-Mazumdar Kendall's tau and Egger's test for publication bias. The trim and fill analysis was also meant to be executed in the event of publication bias (namely Egger's test p-value 0.05), as well as the fail-safe number (estimated number of studies required to move the effect size from significant to insignificant). Data management was done using Stata version 17.1/MP (Stata Corp, College Station, TX, USA) and Bayesian programmes were developed in JAGS, and implemented in R 4.2.0.

### Role of the funding source

The study is supported by World Health Organization. One of the authors were from the funding agency and conceptualized the study, provided inputs into its design, interpretation and presentation of results and the writing of the paper. The authors had full access to all the data of the study and had the final responsibility of taking the decision to submit for publication. The work represents the personal opinion of the authors and not that of the organizations for whom they work.

## Results

### Prevalence of nutritional status

Overall, prevalence of indicators of malnutrition in 5–19-year-olds between the years 2000 and 2030 by region are shown in Fig. 2. Overall, undernutrition in WHO SEA Region declined between 2000 and 2020 in the following manner (Fig. 2A, and Appendix, Tables S9–S12, pp43-46): stunting (36.6%–30.1%), thinness (29.5%–10.8%), and underweight (29.2%–19.5%). This also include prevalence of anaemia (34.7%–28.3%) (Fig. 2A, and Appendix p46). However, overweight and obesity continued to increase during the same period (overweight, 6.0%–12.1%; obesity, 2.6%–6.1%) (Fig. 2A, and Appendix, Table S13 and S14, pp47-48). By 2030, the burden of stunting in the Region is projected to remain at just over one-quarter of children (27.2%) and

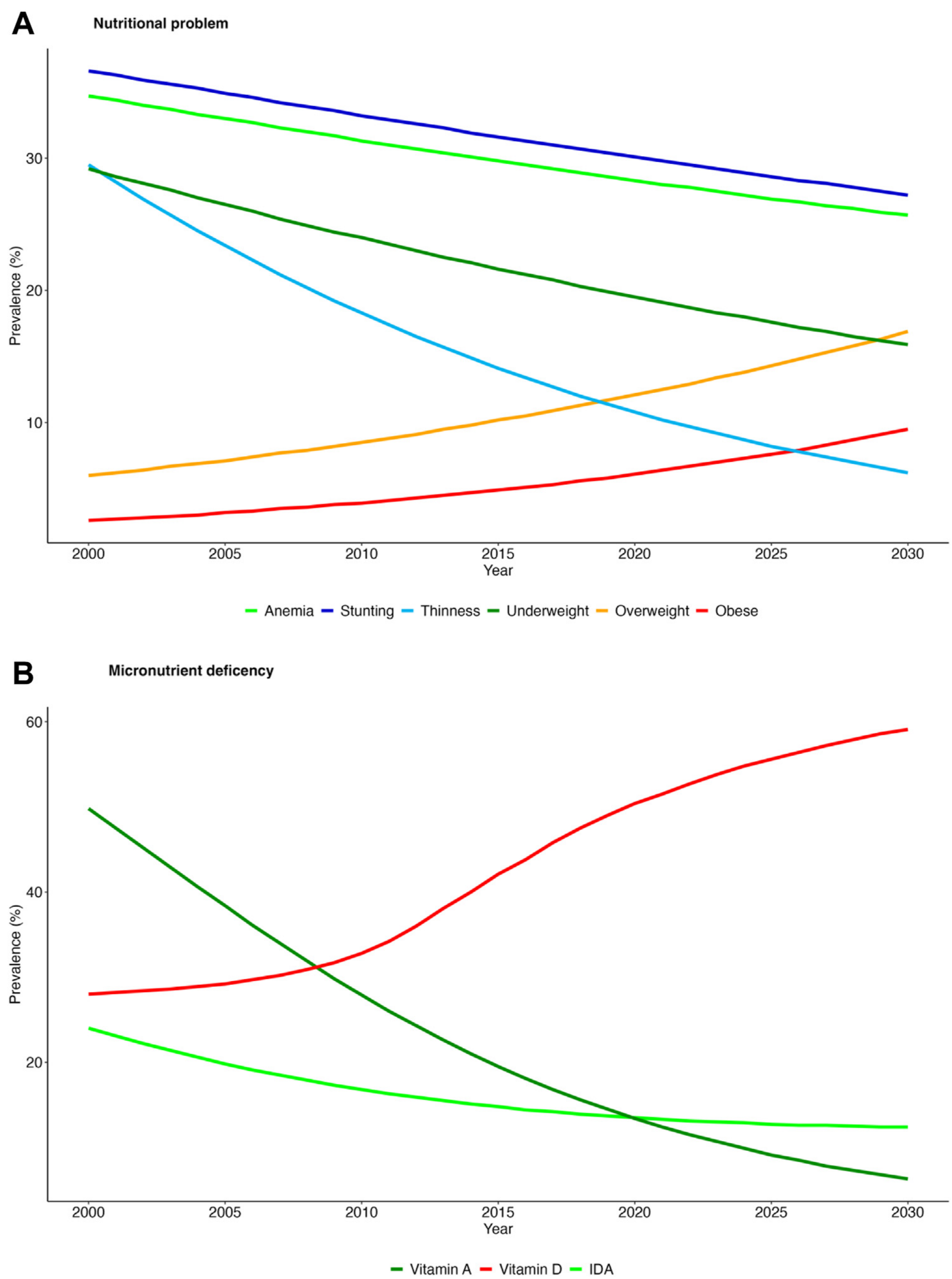


***Fig. 2:*** Prevalence of malnutrition among children and adolescents aged 5–19 years in South-East Asia, 2000–2030. (A) Indicates nutritional problems and (B) indicates micronutrient deficiencies. IDA, Iron deficiency anaemia.

the burden of overweight and obesity are predicted to be 16.9% and 9.5%, respectively. The prevalence of underweight is projected to decrease to 15.9% in 2030, while thinness will reach 6.2%. Between 2000 and 2030, the projected prevalence of micronutrient deficiencies in SEA is expected to decrease by 84% for Vitamin A deficiency (50.2%–8%) and by 53% for Iron deficiency anaemia (24.1–11.4%) (Fig. 2B).

Country and year-specific prevalence of different malnutrition indicators are presented in Fig. 3. The detailed results including sex-specific and country-specific estimates are provided in the appendix (Tables S9–S12, pp43-48). Of the 11 SEA countries, by 2030, stunting would continue to affect a fifth or more children in four countries (Bangladesh, India, Indonesia and Timor Leste), while thinness is projected to

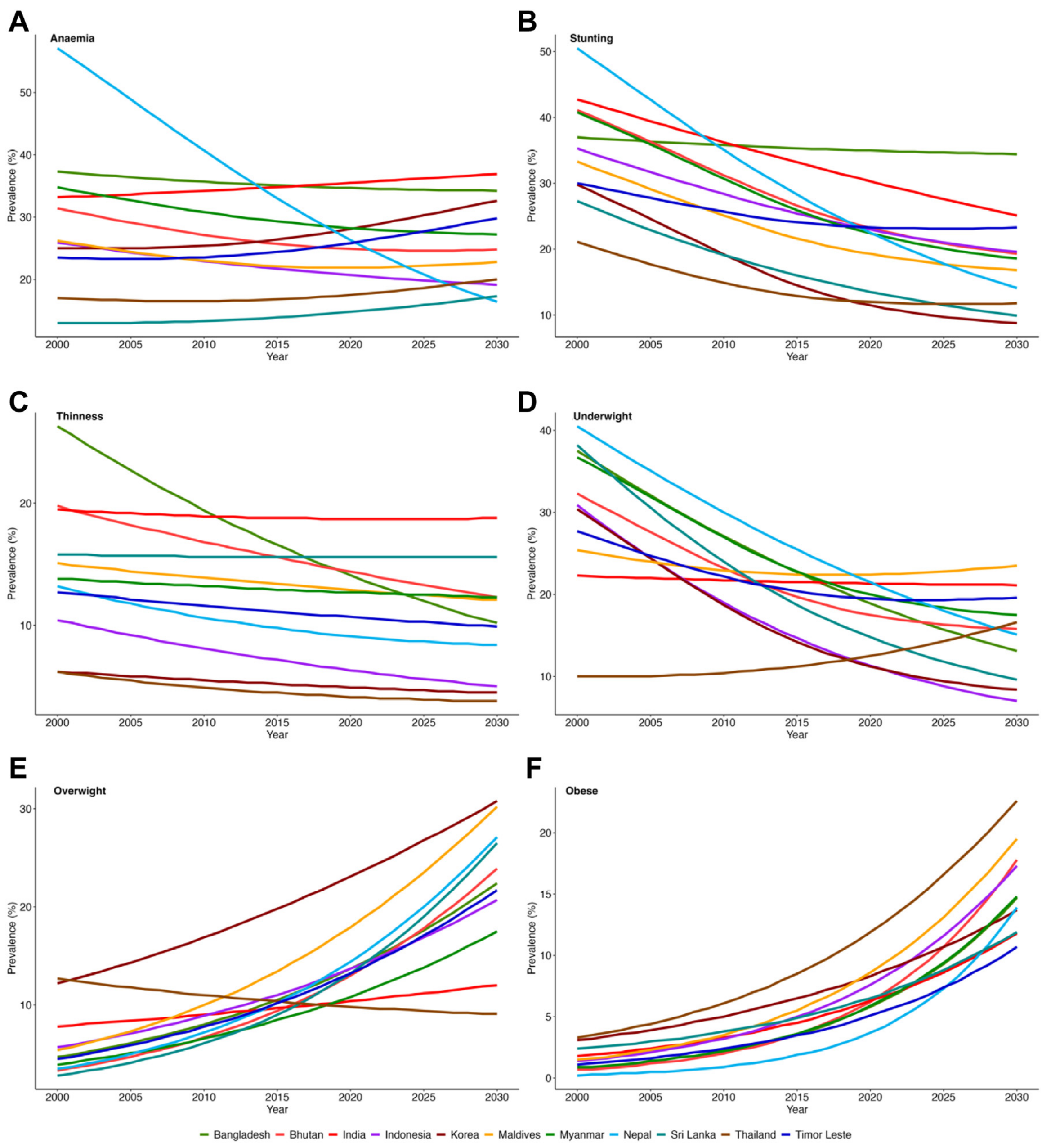


*Fig. 3:* Country-specific prevalence of nutritional status indicators among children and adolescents aged 5–19 years in South-East Asia, 2000–2030.

continue at similar levels in three countries (Bhutan, Maldives, and Myanmar), and underweight in three countries (India, Maldives, and Timor-Leste). Overweight and obesity are projected to increase markedly in almost all SEA Region countries and a fifth of children in Bangladesh, Bhutan, India, Korea, Maldives, Myanmar, Thailand, and Timor-Leste will continue to suffer from anaemia.

## Sex based inequalities

The nutritional status of both undernutrition and overnutrition reveals differences by sex (Tables S9–S12, pp43-48). Specifically, anaemia is more prevalent among female children than males across all countries, and this difference is projected to remain by 2030 (Table S12, p46). Other indicators including thinness, underweight, overweight, and obesity are observed and projected to be more among males than females in all SEA countries (Tables S9–S14, pp43-48).

### Wealth-based inequities in prevalence of overweight and obesity

The projected prevalence of overweight and obesity by wealth quintiles from 2000 to 2030 in WHO SEA Region are presented in Fig. 4 and Appendix (Table S15, p49). The prevalence of overweight and obesity are predicted to increase over the years from 2000 to 2030 across wealth quintiles. Overall, the prevalence of overweight is higher in the richest quintiles than poorest quintile in 2000 (poorest 1.7% vs richest 5.5%) and in 2030 (13.1% vs 32.8%) (Fig. 4A). Similarly for obesity, though the trajectory of obesity increased in all wealth quintiles from 2015 onwards, the highest was observed among the richest quintile as compared to the poorest quintile (Fig. 4B). The projected prevalence of overweight and obesity for the richest quintile is predicted to be substantially higher compared to the poorest quintile in all SEA Region countries (Appendix, p38). Disaggregated country data indicate a similar pattern where the prevalence of both overweight and obesity in 2030

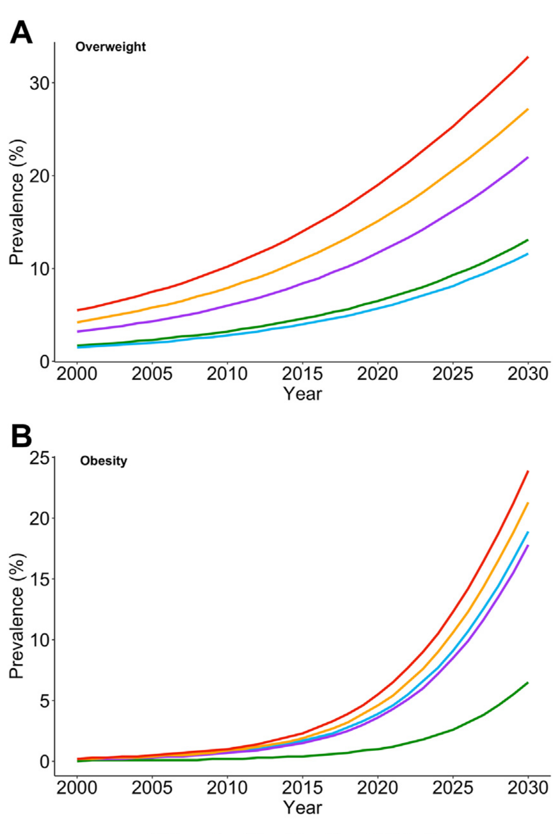


*Fig. 4:* Prevalence of overweight (A) and obesity (B) among children and adolescents aged 5–19 years in South-East Asia by wealth quintile, 2000–2030.

increases with increasing wealth quintiles in most SEA countries [Bangladesh (poorest at 20% vs richest at 61%), Indonesia (13% vs 34%), Thailand (18% vs 28%), Maldives (9% vs 26%), India (7% vs 26%), and Nepal (8% vs 20%)]. As compared to poorest quintile, the prevalence of obesity was remarkably higher in the richest group in Bangladesh (poorest at 8% vs richest at 50%), Maldives (27% vs 46%), Indonesia (10% vs 35%), and Nepal (3% vs 15%).

### Sub-group analysis of nutritional status

Pooled analysis of nutritional status indicators by socioeconomic and demographic factors are provided in Tables 1 and 2. Pooled analysis show that the prevalence of anaemia was significantly higher in female children, children whose parents had lower levels of education, and from poorer households. Similarly, a significantly higher prevalence of stunting and thinness was observed for children who had secondary or lower levels of maternal and paternal education, were from poorer households, and reported unhealthy food habits. However, females were observed to be more stunted but less thinner than males in most SEA countries across time. For underweight, only lifestyle factors (time spent on media and unhealthy food habits) were associated statistically significant with increasing prevalence, while multiple factors were significantly associated with increasing overweight/obesity, including a higher level of mother's and father's education, richer households, increasing time spent on media, high unhealthy food habits, and physical inactivity.

### Determinants of children's nutritional status

The narrative summary results of determinants analysis for each outcome by country are presented in the supplemental appendix (Table S16, pp50-51). The identified risk factors for over weight and obesity included children and adolescent who were early and mid-age, male, living in the urban area, having parents with a higher level of education or mothers who were employed, and from wealthier households. Diet-related risk factors included consumption of out of home foods or a high-fat diet, having a meal skipping habit and infrequent consumption of staple foods.[8,10,12–20] Lifestyle-related risk factors included lack of physical activities including sedentary activities, engaging in fewer outdoor games, and sleep deprivation.[8,12–20] For underweight status, the common reported risk factors were younger children, female, having a mother with a lower level of education or working/unemployed, household from a disadvantaged group, living in a rural area, and having a higher intake of vegetable and salts.[12,17,21,22] The reported risk factors for stunting among children who were female, having a parent with a lower level of education, having a large family size, with parents who were unemployed, living in a rural area, and in disadvantaged household.[12,23] Lastly, for anaemia, the risk factors identified

| Characteristics (p-values) | Pooled prevalence (95% confidence interval) | | | |
|---|---|---|---|---|
| | Anemia | Underweight | Thinness | Stunting |
| **Gender of child** | **<0.01** | **0.5** | **0.8** | **0.4** |
| Male | 24.4 (19.4–29.8) | 30.1 (23.3–37.3) | 15.2 (9.6–21.7) | 28.7 (24.4–33.2) |
| Female | 36.1 (31.4–41.1) | 25.6 (20.9–30.5) | 14.2 (9.0–20.4) | 29.5 (25.1–34.1) |
| **Maternal education** | **<0.01** | **0.1** | **<0.01** | **0.2** |
| No education | 76.8 (75.8–77.8) | 46.5 (32.3–60.9) | 1.8 (1.3–2.6) | 21.2 (14.5–28.7) |
| Primary | 50.0 (48.8–51.2) | 36.8 (29.8–44.1) | 4.0 (3.2–5.0) | 31.0 (23.7–38.8) |
| Secondary | 28.9 (27.8–30.0) | 31.7 (25.5–38.3) | 7.1 (1.1–17.5) | 32.4 (21.1–44.9) |
| Higher | 28.2 (27.1–29.3) | 25.6 (17.3–34.9) | 3.4 (2.8–4.1) | 25.2 (19.1–31.8) |
| **Paternal education** | **<0.01** | **0.2** | **<0.01** | **<0.01** |
| No education | 71.8 (70.7–72.9) | 55.4 (34.1–75.7) | 4.1 (3.2–5.1) | 35.3 (13.7–60.8) |
| Primary | 58.3 (57.1–59.5) | 54.5 (33.5–74.8) | 4.0 (3.2–5.0) | 21.3 (19.4–23.3) |
| Secondary | 50.5 (49.3–51.7) | 42.8 (29.3–56.8) | 6.9 (0.9–18.0) | 41.5 (37.9–45.3) |
| Higher | 27.2 (26.1–28.2) | 34.4 (24.1–45.4) | 1.2 (0.8–1.6) | 13.0 (10.1–16.7) |
| **Residence** | **0.9** | **0.7** | **0.8** | **0.1** |
| Urban | 23.8 (14.7–34.3) | 18.9 (8.6–32.1) | 21.6 (15.5–28.3) | 21.1 (17.0–25.8) |
| Rural | 24.3 (16.0–33.6) | 23.2 (8.8–42.0) | 19.9 (11.1–30.5) | 26.3 (21.8–31.3) |
| **Socio-economic status** | **<0.01** | **0.2** | **<0.01** | **<0.01** |
| Q1 (Poorest) | 61.3 (38.2–82.0) | 35.5 (27.1–44.3) | 4.8 (3.9–5.9) | 23.3 (14.2–33.8) |
| Q2 | 47.3 (37.8–56.9) | 29.3 (22.0–37.3) | 3.4 (2.7–4.4) | 38.8 (31.5–46.4) |
| Q3 | 50.2 (48.2–52.2) | 29.2 (22.3–36.7) | NA | 29.5 (23.1–36.3) |
| Q4 | 50.2 (48.2–52.2) | 24.6 (17.8–32.1) | 3.1 (2.4–4.1) | 43.4 (40.1–46.8) |
| Q5 (Richest) | 27.2 (18.0–37.5) | 22.3 (16.1–29.2) | 0.0 (0.0–0.2) | 18.9 (9.4–30.9) |
| **Time spent on TV/game/computer (hour/day) *** | **NA** | **<0.01** | **NA** | **<0.01** |
| 0 | NA | 1.9 (0.0–12.4) | NA | NA |
| 1–2 | 35.0 (7.9–69.1) | 28.2 (7.3–56.0) | 14.5 (12.3–16.8) | 29.8 (28.1–31.7) |
| >2 | NA | 14.1 (9.6–19.4) | NA | 22.5 (20.9–24.1) |
| **Unhealthy food habits** | **<0.9** | **<0.01** | **<0.01** | **NA** |
| Low/No | 48.7 (31.0–66.5) | 23.0 (9.7–39.8) | 11.9 (9.2–14.9) | NA |
| Moderate | 50.0 (48.0–52.0) | 13.1 (7.1–20.6) | 15.0 (13.4–16.6) | NA |
| High | NA | 47.0 (45.5–48.4) | 17.5 (15.5–19.7) | NA |

Note: Amount of time spent watching TV, playing games, or using the computer by children*. Previous literatures (Ahmad et al., 2018; Bhargava et al., 2016; Chopra et al., 2014; Ferdousi et al., 2011; Rani & Sathiyasekaran 2013; Saha et al., 2018; Laxmaiah et al., 2007; Karki et al., 2019; Ramesh K 2010), we classified unhealthy food habits into three groups such as: *high risk of unhealthy dietary habits* includes frequent intake of carbonated soft drink (>3 times a week), frequent intake locally available sold out street food items (more than 5 times a week), soft drink & fruit juice daily, eat fast food daily, eat fast food 4–7 days per week, frequently eating junk food or fast food, high junk food consumption(≥2 times/week); *moderate risk of unhealthy dietary habits* includes frequency of fruit intake 1–2 times per week, eat chocolate occasionally, eat fast food occasionally, non-vegetarian/mixed, occasionally eat junk food consumption; *low risk of unhealthy dietary habits* includes no fast food consumption, never eat fast food, vegetarian, never intake of carbonated soft drink.

***Table 1:*** **Pooled prevalence of anaemia, underweight, thinness, and stunting by different characteristics.**

from several studies included children who were from lower socioeconomic households, mid and late adolescence, had parents with a lower level of education, living in an urban area, and consuming tea/coffee.[24–28] Consumption of animal-based iron-rich food and vitamin A-rich food were found to be protective against anaemia.

### Study quality and publication bias assessments

Of the 370 included studies, only 21 studies were low quality, 87 were moderate quality and all others were high quality (Appendix Table S8, pp33-41). The funnel plots of over- and undernutrition are presented in the appendix so that the small study effects can be understood based on subjective visual inspection (Appendix Figure S1 and S2). A symmetrical arrangement of the plots in each funnel plot indicates the absence of publication bias in the data. The quantitative assessment of publication bias using Egger's test also indicated that there was no indication of publication bias in the results (p value = 0.9264 for over nutrition, and p value = 0.615 for under nutrition).

## Discussion

This study sums up the degree and trends of the double burden of malnutrition along with some of its socio-economic correlates in SEA Region countries. To our knowledge, this is the first study to analyse and interpret the prevalence and trends of nutritional status indicators at the regional and national levels among children and

| Characteristics (p-values) | Pooled prevalence (95% confidence interval) | |
|---|---|---|
| | Overweight | Obese |
| **Children's gender** | **0.9** | **0.1** |
| Male | 9.3 (7.8–10.9) | 5.6 (5.0–6.3) |
| Female | 9.2 (7.9–10.5) | 4.7 (4.1–5.3) |
| **Maternal education** | **<0.01** | **<0.01** |
| No education | 6.2 (4.2–8.4) | 0.4 (0.1–0.8) |
| Primary | 4.7 (3.3–6.4) | 0.4 (0.1–0.9) |
| Secondary | 6.7 (4.8–8.8) | 2.2 (1.3–3.2) |
| Higher | 9.3 (7.2–11.7) | 2.9 (1.4–4.9) |
| **Father education** | **0.1** | **0.5** |
| No education | 4.8 (0.8–11.9) | 4.4 (0.7–11.0) |
| Primary | 9.1 (5.4–13.7) | 6.6 (5.5–7.6) |
| Secondary | 10.1 (6.0–15.0) | 6.6 (3.3–11.0) |
| Higher | 19.5 (9.2–32.4) | 16.2 (3.4–36.0) |
| **Residence** | **0.5** | **<0.01** |
| Urban | 7.8 (2.5–15.6) | 3.2 (2.2–4.4) |
| Rural | 4.8 (1.0–11.3) | 0.5 (0.3–0.9) |
| **Socio-economic status** | **<0.01** | **<0.01** |
| Q1 (Poorest) | 3.8 (2.6–5.3) | 1.1 (0.6–1.8) |
| Q2 | 3.9 (2.4–5.7) | 1.9 (1.1–3.0) |
| Q3 | 8.2 (6.3–10.4) | 3.2 (1.9–4.7) |
| Q4 | 8.2 (6.6–9.9) | 3.1 (1.9–4.5) |
| Q5 (Richest) | 13.3 (10.6–16.2) | 5.0 (3.1–7.3) |
| **Time spent on TV/game/computer (hour/day)** | **<0.01** | **0.2** |
| 0 | 8.0 (5.2–11.4) | 4.0 (0.8–9.2) |
| 1–2 | 5.3 (4.0–6.7) | 4.1 (1.7–7.6) |
| >2 | 13.4 (7.8–20.3) | 7.7 (5.0–11.0) |
| **Unhealthy food habits** | **<0.01** | **0.2** |
| Low/No | 10.2 (7.2–13.6) | 5.2 (3.6–7.2) |
| Moderate | 14.5 (9.9–19.9) | 5.2 (2.1–9.4) |
| High | 23.4 (14.6–33.4) | 10.0 (5.4–15.8) |
| **Physical activity** | **<0.01** | **0.3** |
| Low/No | 20.8 (14.0–28.6) | 8.3 (4.1–13.7) |
| Moderate/High | 4.8 (2.5–7.7) | 5.5 (2.9–8.8) |

Note: Amount of time spent watching TV, playing games, or using the computer by children*. Previous literatures (Ahmad et al., 2018; Bhargava et al., 2016; Chopra et al., 2014; Ferdousi et al., 2011; Rani & Sathiyasekaran 2013; Saha et al., 2018; Laxmaiah et al., 2007; Karki et al., 2019; Ramesh K 2010, Appendix Table S5), we classified unhealthy food habits into three groups such as: *high risk of unhealthy dietary habits* includes frequent intake of carbonated soft drink (>3 times a week), frequent intake locally available sold out street food items (more than 5 times a week), soft drink & fruit juice daily, eat fast food daily, eat fast food 4–7 days per week, frequently eating junk food or fast food, high junk food consumption(≥2 times/week); *moderate risk of unhealthy dietary habits* includes frequency of fruit intake 1–2 times per week, eat chocolate occasionally, eat fast food occasionally, non-vegetarian/mixed, occasionally eat junk food consumption; *low risk of unhealthy dietary habits* includes no fast food consumption, never eat fast food, vegetarian, never intake of carbonated soft drink. Two major group of physical activities defined based on previous literatures (Ahmad et al., 2018; Ferdousi et al., 2011; Saha et al., 2018; Singh et al., 2020; Lisetyaningrum et al., 2021; Jain et al., 2010, Appendix Table S5): *moderate/high level of physical activities* defined if outdoor physical activity (2 h/day), physical activity (>10 min/day), duration of physical play (30–60 min/day or >60 min/day), 1–3 days/week or >3 days/week, plays outdoor daily/regular sports play, exercise duration (≥1 h/day); *no/low level of physical activities* includes range of categories including physical activity (>10 min occasionally), walking none, indoor games/no play, exercise duration (<1 h/day).

*Table 2:* **Pooled prevalence of overweight and obesity by different characteristics.**

adolescents aged 5–19 years in SEA countries. This is also the first analysis that includes both macro and micronutrient deficiencies in an analysis of the double burden of malnutrition. Our study highlights a clear pattern of a double burden of malnutrition, with little variation across countries, and increasing inequity between socioeconomic and demographic groups. Despite a substantial reduction in the prevalence of undernutrition including stunting, thinness, and underweight, and anaemia since 2000, an increase in overweight/obesity and micronutrient deficiencies warrant continued concern. By 2030, over 500 million children and adolescents will be residing in SEA Region, hence efforts to improve the nutritional status in this region is critical to achieving global nutrition targets and the sustainable development goals committed to by all nations.[5] Over 90% of the included studies in our systematic review and meta-analysis were of moderate to high quality.

Findings of our analysis suggest that under- and overnutrition are of a high magnitude in WHO SEA Region. Despite regional efforts to address undernutrition, stunting, overweight/obesity, and some micronutrient deficiencies will continue to remain public health concerns by 2030–predicted to affect over a quarter of the Regions'children aged 5–19 years. There is insufficient comparable data conducted among populations aged 5–19 years old, however previous estimates generally reflect the high burden of nutritional disorders among children under 5 years of age and adults in the region.[10] Unlike data from high income countries, and as indicated by a previous study,[17] household wealth was associated with increasing overweight/obesity. Overweight and obesity were higher in the high income quintiles, currently and also based on future projections to 2030. This is in contrast to most other parts of the world, except sub-Saharan Africa.[2] Further exploration of this pattern is vital from a public health perspective, to further analyse the disparities among the population and to plan appropriately targeted interventions. However, the inequalities of sex have not changed, with girls bearing a heavier burden especially anaemia and stunting in almost all countries. The continuing challenges of poor governance, gender discrimination, unhealthy food choices, mounting urban poverty, climate changes and lack of effective social protection systems are likely attributable for these disparities among sexes in most SEA Region countries.

This study provides a stark warning regarding the emergence and rising trends of overweight and obesity among 5–19 year olds in WHO SEA Region, along with continued stunting, and micronutrient deficiencies.[29] Adolescence is a time for catch up growth. The repercussions of inadequate catch up growth and continued stunting cause physical and neurocognitive damages, which are a major obstacle to human development. Stunted children are more likely to be susceptible to NCDs in later life, particularly if exposed to unhealthy diets. Our data where female children were stunted by less thin than males are a possible indicator of this trend, Overweight and obesity in childhood could also have significant negative consequences, including poor health such as hypertension and metabolic disorders, lower self-esteem, higher likelihood of being bullied, poor school attendance and performance, poor health in adulthood, and a lower-paid job in adulthood.[2,30] Preventing overweight and obesity has direct benefits for children's health and wellbeing, which continues across the lifecycle.

This analysis identified parents' education levels, household wealth, and lifestyle behaviours such as time spent on media and unhealthy habits, to be associated with malnutrition. While as expected, poorer socioeconomic status was identified with anaemia and stunting,[2,3] household wealth was associated with increasing overweight/obesity as identified in previous literature.[2] However, even poorer households were associated with a degree of overweight and obesity.

Overall, the identified shared risk factors are similar across the life course, mainly socioeconomic factors and lifestyle behaviours. These findings are noteworthy as it offers a novel insight to the shared drivers of malnutrition relevant for the period of middle childhood and adolescence in SEA.

The SEA Region encompasses a diverse mix of cultural, religious, ethnic groups, as well as vast wealth and health-based inequalities. Limited research in the region attempts to explore its associations with nutritional status. Some examples of factors related to sex disparities including conventional norms that females consume less food in order to prioritise male in families, time constraints due to prolonged schedule of work and/or school, and perceived body images influenced by media etc. act as major barriers to improving dietary behaviours and nutritional status.[5,31,32] Available dispersed evidence offers initial insights to individual and population-level drivers of malnutrition and micronutrient deficiencies, however, its transferability to inform policies are limited. Hence, there should be a joint effort across specialties and utilization of different research methods to better understand contextual causes of nutritional disorders across different populations and geographical regions in SEA.

Malnutrition prevention requires action throughout the life course, and school-aged children and adolescents offer an important opportunity to address childhood malnutrition in all its forms. In time, the competition for financial, human and organizational resources to address malnutrition will be considerable and strain country systems. Considering and strategizing double duty actions which have the potential to address the many facets of malnutrition at the population level is therefore a likely cost effective solution, For example, ongoing targeted social protection measures such as school meals for the disadvantaged can be retrofitted to ensure healthy food and drink options, and other actions to create a healthy food environment will benefit all and combat both undernutrition and overweight/obesity. Promoting physical activities, and providing health education are also likely to pay dividends. Individualized strategies are also important, but they are resource intensive, and considering the numbers affected, daunting to operationalize.

The strengths of our study include its large collection of data sources which allowed us to present consistent and comparable regional and national estimates on prevalence of nutritional status indicators. Current nutritional guidance largely targets maternal and early-life nutrition, but are limited to middle childhood and adolescence due to sparse evidence and resources. Our study is first of its kind to analyse a comprehensive range of risk factors and its association with malnutrition in the SEA Region from available literature. Additionally, this is one of the first studies to estimate the prevalence of a comprehensive range of nutritional status indicators among children aged 5–19 years living in SEA countries. Our findings fill a gap in knowledge by synthesizing evidence between periods of early childhood and adulthood.

Our study has some limitations. Despite our extensive efforts to identify and access data, some countries (especially Bhutan, Myanmar, and Democratic People's Republic of Korea) and indicators (micronutrient deficiencies) were relatively sparse which contribute to uncertainty. Hence, our estimates may under-represent or be unevenly distributed in countries or indicators with limited population-based data. Moreover, variations in data collection, interpretation of information in different studies and thresholds for some indicators (such as thinness, overweight and obesity) would increase the likelihood of bias. Studies focused on children and adolescents are commonly conducted in schools and this was reflected in our systematic review as two-thirds of our included studies were school-based. This may exclude those who do not attend school, further contributing to under-representation of those from poorer households or females. Moreover, measurement error is likely in the assessment of nutritional status as measurement often relies on self-recall and/or different studies utilize different diagnostic criteria. Our Bayesian model attempts to use contemporary data to predict outcomes occurring in the long term. Error surrounded in our study data or in the big sample size data projections could lead to some differences in our results compared with those that truly happen in the future. Our Bayesian model does not account for any future changes such as pandemic (COVID-19), school closure, look down, extreme poverty, treatment technologies, new health intervention that could considerably change forecasts of nutritional status among children and its consequences.

Additionally, due to lack of trend data indicating otherwise, we assume that the country and gender-specific prevalence of malnutritonal status will remain constant into the future. However, changes in lifestyle behavior such as reductions in physical activity, lack of fruits and vegitable, and greater intake of fast food may contribute to higher nutritional disorder in future. Lastly, data sources used in our study were not longitudinal in nature or based on individual participant data, and therefore, cannot provide possible causal interpretation on changing nutritional status in the same population groups from childhood to adolescence. This, coupled with the highly dynamic nature of malnutrition, may vary considerably over time within individuals, populations, and with seasonal changes.

Going forward, prevention and management of nutritional disorders are of utmost priority for reducing the burden of child mortality and associated morbidities. Late childhood and adolescence must be recognized as an opportunistic window across the life course to address pre-existing nutritional disorders, and is a key period of sensitivity to shape nutritional factors and health-related behaviours.[9] In the long-term, fostering a healthy transition into adulthood can contribute to a reduced risk of NCDs, developing a healthy reproductive biology, and ensuring continued intergenerational impact.[9] To achieve this goal, several research and policy implications are provided for consideration. The collation of all available evidence in our review identified an absence of active surveillance data across many SEA countries which comprehensively monitor and track nutritional status among children aged 5–19 years. Robust surveillance systems to collect age-, sex-, and socioeconomic disaggregated data are essential to generate empirical evidence for the development of policies and monitoring equity. Lastly, children and adolescents should be considered as a priority focus in the development of national plans or guidelines. There is a clear gap and need to include middle childhood and adolescence in global and national nutrition frameworks, and to include recommendations focused on this group in evidence-based guidelines.[33,34]

In conclusion, this study present the first attempt to systematically analyse and interpret trends of nutritional status among children and adolescents aged 5–19 years across 11 SEA countries. As the pattern of a double burden of malnutrition becomes more evident, urgent attention to implement effective double-duty actions is required. Childhood and adolescence must be acknowledged as critical periods for nutritional interventions across the life course on the global and national agendas. The trends observed in our study support the need to incorporate distinct strategies to tackle a range of nutritional disorders. Hence, a paradigm shift from a siloed undernutrition focused prevention and management to a more holistic double-action approach to double duty actions at both population and on an individual level are required. The coexistence of both undernutrition and overweight/obesity suggests that future interventions/policy targeting to maintain a healthy population weight should not just focus on prevention and treatment in one direction.

**Contributors**

de Silva A and Rahman MM conceived the study. Rahman MM, Sassa M, Islam MR performed the literature screening and data extraction. Aktar MS and Islam RA performed quality assessment. Rahman MM contributed to statistical analysis, and interpretation of data. Rahman MM, de Silva A, and Sassa M wrote the first draft of the paper. Islam MR checked for consistency of the analysis and the study. de Silva A revised it critically for important intellectual content. All authors have reviewed and approved the final manuscript.

### Data sharing statement

The data used for this study were retrieved from the Global School-based Health Survey (GSHS), Demographic and Health Survey (DHS), and Global Health Observatory (GHO) repositories, along with published papers from relevant studies. Data can be accessed through each data distribution system or through published papers referencing the data. The corresponding author is responsible for acquiring the data. Additionally, we will provide de-identified data to researchers who submit a research proposal with a statistical analysis plan. Researchers can request de-identified data by emailing mizanurrub78@gmail.com within five years of publication.

### Declaration of interests

We declare no competing interests.

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### Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lansea.2023.100244.

### References

1 World Health Organization. Fact sheets-Malnutrition. Available at: https://www.who.int/news-room/fact-sheets/detail/malnutrition. 2021.
2 Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. *Lancet*. 2020;395(10217):65–74.
3 World Health Organization. *Double-duty actions. Policy brief*. Geneva: World Health Organization; 2017.
4 Jazwiec PA, Sloboda DM. Nutritional adversity, sex and reproduction: 30 years of DOHaD and what have we learned? *J Endocrinol*. 2019;242(1):T51–T68.
5 Ministry of Health and Family Welfare (MoHFW), Government of India, UNICEF and Population Council. 2019. Comprehensive National Nutrition Survey (CNNS) National Report. New Delhi.
6 Singh AK, Maheshwari A, Sharma N, Anand K. Lifestyle associated risk factors in adolescents. *Indian J Pediatr*. 2006;73(10):901–906.
7 Ministry of Health and Population. *Nepal national micronutrient status survey, 2016*. Kathmandu, Nepal: Ministry of Health and Population, Nepal; 2018.
8 Galgamuwa LS, Iddawela D, Dharmaratne SD, Galgamuwa GLS. Nutritional status and correlated socio-economic factors among preschool and school children in plantation communities, Sri Lanka. *BMC Public Health*. 2017;17(1):377.
9 Wells JC, Sawaya AL, Wibaek R, et al. The double burden of malnutrition: aetiological pathways and consequences for health. *Lancet*. 2020;395(10217):75–88.
10 Agustina R, Wirawan F, Sadariskar A, et al. Associations of knowledge, attitude, and practices toward anemia with anemia prevalence and height-for-age Z-score among Indonesian adolescent girls. *Food Nutr Bull*. 2021;42(1):S92–S108.
11 Wells G, Shea B, O'connell D, et al. *The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses*; 2014. http://www.ohri.ca/programs/clinical_epidemiology/nos_manual.pdf.
12 Khanam SJ, Haque MA. Prevalence and determinants of malnutrition among primary school going children in the haor areas of Kishoreganj district of Bangladesh. *Heliyon*. 2021;7(9):e08077.
13 Macwana J, Mehta K, Baxi R. Predictors of overweight and obesity among school going adolescents of Vadodara city in Western India. *Int J Adolesc Med Health*. 2016;29(3).
14 Khan M, Karim M, Islam A, Islam M, Khan H, Khalilullah M. Prevalence of overweight and obesity among adolescents in Bangladesh: do eating habits and physical activity have a gender differential effect? *J Biosoc Sci*. 2019;51(6):843–856.
15 Sultana S, Rahman M, Sigel B, Hashizume M. Associations of lifestyle risk factors with overweight or obesity among adolescents: a multicountry analysis. *Am J Clin Nutr*. 2021;113(3):742–750.
16 Sultana N, Afroz S, Tomalika N, Momtaz H, Kabir M. Prevalence of childhood obesity and undernutrition among urban school children in Bangladesh. *J Biosoc Sci*. 2019;51(2):244–253.
17 Darling A, Fawzi W, Barik A, Chowdhury A, Rai R. Double burden of malnutrition among adolescents in rural West Bengal, India. *Nutrition*. 2020;79:110809.
18 Karki A, Shrestha A, Subedi N. Prevalence and associated factors of childhood overweight/obesity among primary school children in urban Nepal. *BMC Public Health*. 2019;19(1):1055.
19 Nonboonyawat T, Pusanasuwannasri W, Chanrat N, et al. Prevalence and associates of obesity and overweight among school-age children in a rural community of Thailand. *Korean J Pediatr*. 2019;62(5):179–186.
20 Mo-Suwan L, Nontarak J, Aekplakorn W, Satheannoppakao W. Computer game use and television viewing increased risk for overweight among low activity girls: fourth Thai national health examination survey 2008-2009. *Int J Pediatr*. 2014;2014:364702.
21 Ahmad S, Shukla N, Singh J, Shukla R, Shukla M. Double burden of malnutrition among school-going adolescent girls in North India: a cross-sectional study. *J Family Med Prim Care*. 2018;7(6):1417–1424.
22 Chopra A, Rao N, Gupta N, Vashisth S, Lakhanpal M. Influence of behavioral determinants on deviation of body mass index among 12-15 years old school children of Panchkula. *Epidemiol Health*. 2014;36:e2014021.
23 van Tuijl C, Madjdian D, Bras H, Chalise B. Sociocultural and economic determinants of stunting and thinness among adolescent boys and girls in Nepal. *J Biosoc Sci*. 2021;53(4):531–556.
24 Mistry S, Jhohura F, Khanam F, et al. An outline of anemia among adolescent girls in Bangladesh: findings from a cross-sectional study. *BMC Hematol*. 2017;17:13.
25 Ahankari A, Myles P, Fogarty A, Dixit J, Tata L. Prevalence of iron-deficiency anaemia and risk factors in 1010 adolescent girls from rural Maharashtra, India: a cross-sectional survey. *Public Health*. 2017;142:159–166.
26 Rakesh P, George L, Joy T, George S, BA R, KV B. Anemia among school children in ernakulam district, Kerala, India. *Indian J Hematol Blood Transfus*. 2019;35(1):114–118.
27 Bharati P, Shome S, Chakrabarty S, Bharati S, Pal M. Burden of anemia and its socioeconomic determinants among adolescent girls in India. *Food Nutr Bull*. 2009;30(3):217–226.
28 Ford N, Bichha R, Parajuli K, et al. Factors associated with anaemia among adolescent boys and girls 10-19 years old in Nepal. *Matern Child Nutr*. 2020;18:e13013.
29 Abarca-Gómez L, Abdeen ZA, Hamid ZA, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet*. 2017;390(10113):2627–2642.
30 Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5:4–85.
31 Blum LS, Khan R, Sultana M, et al. Using a gender lens to understand eating behaviours of adolescent females living in low-income households in Bangladesh. *Matern Child Nutr*. 2019;15(4):e12841.
32 Kotecha PV, Patel SV, Baxi RK, et al. Dietary pattern of schoolgoing adolescents in urban Baroda, India. *J Health Popul Nutr*. 2013;31(4):490–496.
33 Lassi ZS, Mansoor T, Salam RA, Bhutta SZ, Das JK, Bhutta ZA. Review of nutrition guidelines relevant for adolescents in low- and middle-income countries. *Ann N Y Acad Sci*. 2017;1393(1):51–60.
34 Al-Jawaldeh A, Bekele H, de Silva A, et al. A new global policy framework for adolescent nutrition? *Lancet*. 2022;399(10320):125–127.