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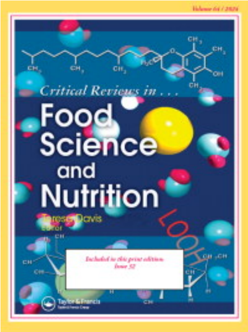

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Prevalence and key determinants of the triple burden of childhood malnutrition in Southeast Asian countries: a systematic review and meta-analysis within an adapted socio-ecological framework

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ABSTRACT

The triple burden of malnutrition (TBM) is increasing globally, but significant evidence gaps exist regarding its burden and drivers among children in Southeast Asian (SEA) countries. We systematically searched four databases (PROSPERO-CRD42023420129) and Google Scholar through February 2024. We assessed stunting and overweight prevalence among children aged 0–18 years old across four SEA countries (Indonesia, Malaysia, Thailand, and Vietnam) from recent national surveys. We conducted random-effect meta-analyses to estimate the pooled prevalence of micronutrient deficiencies, and the pooled odds ratio for TBM-associated determinants using an adapted socio-ecological framework. 176 studies were included for systematic review, with 132 studies eligible for meta-analysis. Our findings illustrate significant variation in TBM across countries, dependent on region, age, and sex. Pooled prevalence [95% CI] of anemia, iron, vitamin A, and D deficiencies were 25% [22, 29], 14% [10, 18], 6% [4, 8], and 40% [32, 48], respectively (I^2>90%). Determinants of the TBM included child-individual factors, poor early-life nutrition, and family household characteristics including maternal nutrition and education, socioeconomic, family size, sanitation, and food security. However, macro-level environmental impacts were less documented. Our findings emphasize the need for robust, timely monitoring of TBM data, including micronutrient biomarkers, and targeted policy intervention in SEA countries.

KEYWORDS

Systematic review; meta-analysis; triple burden of malnutrition; children and adolescents; Southeast Asian

Introduction

The triple burden of malnutrition (TBM) is increasing globally and inequitable, particularly affecting children and women in low- and middle-income countries (LMICs) (Müller and Krawinkel 2005; Wells et al. 2020). The TBM is characterized by the coexistence of undernutrition, hidden hunger or micronutrient deficiencies (MNDs), and overnutrition, which can manifest at multiple levels (i.e., individual, household, country) and across the life course (Bhutta, Salam, and Das 2013). Particularly in childhood, the TBM is a serious public health issue worldwide, significantly impacting countries' economies through reducing productivity and creating substantial strain on health care systems (Nugent et al. 2020). Early life severe undernutrition, including MNDs, is linked to poor growth, intellectual impairment, and increased risk of child morbidity and mortality (Bailey, West, and Black 2015). Moreover, the interplay between early undernutrition and later overnutrition heightens the risk of adulthood obesity and obesity-related non-communicable diseases (Zhou et al. 2020). This underscores that childhood as a critical period for addressing nutrition-related disease burdens and mitigating intergenerational malnutrition (Martorell 2017).

The TBM has emerged as a significant public health challenge, particularly in low- and middle-income countries (LMICs) in the Southeast Asian (SEA) region (Khadilkar et al. 2024). Rapid economic transitions and urbanization have shifted diets toward more energy-dense, micronutrient-poor processed foods and promoted sedentary lifestyles, resulting in rising rates of overnutrition, while undernutrition and MNDs persist, contributing to TBM in SEA countries (Lipoeto, Geok Lin, and Angeles-Agdeppa 2013). Recent publications in *The Lancet* have highlighted that the combined prevalence of underweight and obesity among school-aged children and adolescents was considerably high in South Asia (SA) and SEA regions (NCD Risk Factor Collaboration 2024). The prevalence of double burden of malnutrition, encompassing both undernutrition and overnutrition, at household

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level, ranged from 5% in Vietnam to 30% in Indonesia (Rachmi, Li, and Baur 2018). MNDs continue to affect a large proportion of children, with varying degrees of severity across SEA countries (Gayer and Smith 2015). *The Lancet* reported that nearly 58% of preschool children in SEA countries (Cambodia and Vietnam) have deficiencies in one of the three most common critical MNDs including iron (ID), zinc, and vitamin A (VAD), indicating an alarming level of the TBM in these regions (Stevens et al. 2022). Moreover, emerging MNDs such as Vitamin D deficiency (VDD), are also prevalent among children in SEA countries, the reported prevalence rates ranging from 0.9% to 96.4% (which could be due to measurement bias), despite ample sun exposure, with (Oktaria et al. 2022). This deficiency is often attributed to cultural practices such as wearing clothing that limits sun exposure, and urban lifestyles that reduce outdoor activity (Oktaria et al. 2022). A recent review highlighted significant gaps in vitamin D, zinc, and iron intakes among children aged 6–23 months across multiple countries in SEA, leading to an increased risk of nutritional deficiencies (White et al. 2023). Conversely, while VAD has generally declined in SEA regions primarily due to the provision of vitamin A supplementation (e.g., Indonesia and Vietnam), it still disproportionally affects populations living in poor and remote areas (Nguyen et al. 2020; Stevens et al. 2015).

There are multiple global and regional efforts, including the World Health Organization (WHO) five double-duty actions and The United Nations Sustainable Development Goal 2 (SDG-2) "Zero Hunger" and (SDG-3) "Ensure healthy lives and promote well-being for all at all ages," which aim to eradicate all forms of malnutrition (Pradeilles, Baye, and Holdsworth 2019). In addition, the Food and Agriculture Organization's (FAO) National Plans of Action for Nutrition (NPANs) provide strategic frameworks to guide national responses to malnutrition (Tee et al. 2020). Despite notable progress in reducing stunting among children under 5 in certain regions, no country has yet succeeded in reversing national increases in childhood obesity (Roberto et al. 2015; Vaivada et al. 2020). In SEA countries, NPANs from six of the eleven countries (Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Vietnam) recognize both persistent undernutrition and escalating rate of obesity and other diet-related chronic diseases. However, challenges such as limited capacity and resources, access to sensitive biomarkers, and an insufficient evidence base in some SEA countries, weakening the policy commitment to action (Haddad, Cameron, and Barnett 2015; Tee et al. 2020).

To effectively tackle all forms of malnutrition, it is essential that policies and interventions designed to address one form of malnutrition do not inadvertently exacerbate another in the long-term (Hawkes, Demaio, and Branca 2017). Despite the severity of the TBM, there remains a significant knowledge gap regarding its burden and drivers, especially among young children and adolescents in SEA countries (Chaparro, Oot, and Sethuraman 2014; Haddad, Cameron, and Barnett 2015; Mondon et al. 2024). Therefore, identifying key shared determinants offer an opportunity to develop double-duty actions that address all forms of childhood malnutrition concurrently. This study aimed to address these gaps by systematically searching four databases and the grey literature to: (1) assess the national prevalence of stunting and overweight among children aged 0–18 years old across four SEA countries (Indonesia, Malaysia, Thailand, and Vietnam) using national nutrition surveys; (2) estimate the pooled prevalence of MNDs (anemia, ID, VAD, and VDD); (3) estimate the pooled odds ratio (ORs) for determinants associated with the TBM, using an adapted socio-ecological framework developed by McLeroy and colleagues (McLeroy et al. 1988). These four Southeast Asian countries were selected based on their varying economic development, the magnitude of the TBM, and the availability of the malnutrition data, particularly concerning blood micronutrient data.

Methodology

This systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, and prospectively registered at PROSPERO (CRD42023420129).

Literature search

We conducted a comprehensive search across four databases (PubMed, Scopus, Embase (Ovid), and the Web of Science) and one search engine (Google Scholar) to identify published articles and national surveys reporting the prevalence or/and determinants of various forms of malnutrition including undernutrition, overnutrition and MNDs among children and adolescents aged 0–18 years old across four SEA countries, namely Indonesia, Malaysia, Thailand and Vietnam. The search was completed on the 26th of February 2024. The database search utilized the following keywords from three main themes: i) population (age group): infant* OR child OR children OR adolescent* OR boy* OR girl*; ii) population (countries): Indonesia* OR Malaysia* OR Thailand OR Thai OR Vietnam OR "Viet Nam" OR Vietnamese; iii) outcomes (anthropometric indicators): undernutrition OR overnutrition OR stunting OR stunted OR underweight OR overweight OR obesity OR obese OR height OR weight OR BMI OR "nutritional status"; and iv) outcomes (micronutrient blood indicators): [(blood OR serum OR plasma OR status OR concentration* OR deficienc*) AND (iron OR ferritin OR retinol OR "vitamin A" OR "vitamin D" OR h?emoglobin)] OR (an?emia). Detailed search strategies for each of the four databases are reported in Supplementary Table S1. Additionally, the Google search engine (advanced) was used to find government and non-government organization reports of national nutrition surveys assessing national prevalence of stunting or overweight and obesity. The keywords used were: (Stunting OR Overweight) AND (children) AND (Malaysia OR Thailand OR Vietnam OR Indonesia). Only the most recent surveys (2018–2020) were included.

Eligibility criteria

Inclusion and exclusion criteria were based on Population, Exposure, Comparison and Outcome (PECO) framework. We included studies reporting the prevalence or/and determinants of malnutrition among infants, young children and adolescents aged 0–18 years old from Indonesia, Malaysia, Thailand and Vietnam. Studies including populations outside these countries, participants aged above 18 years, or those diagnosed with chronic or congenital diseases affecting the child's nutritional status were excluded. The study outcomes included anthropometric growth indices for undernutrition (e.g., stunting, underweight, wasting, and thinness) and overnutrition (e.g., body mass index, waist circumference, overweight and obesity). MNDs particularly focusing on anemia, iron, retinol/vitamin A, and vitamin D. Only studies that assessed MNDs using biomarkers (e.g., serum, plasma) were included, while those based only on dietary intake were excluded. These four core MNDs were selected for analysis based on two criteria, 1) the severity of the MNDs, and 2) the availability of population-based data particularly using blood-based micronutrient biomarkers. Zinc deficiency was excluded due to the lack of available biomarker data, primarily because there are no reliable indicators, as no specific syndrome or biomarker is uniquely associated with zinc deficiency (Wieringa et al. 2015). Definitions of outcome variables were as per the original articles. The (PECO) criteria are detailed in Supplementary Table S2.

Eligible studies included observational studies (cross-sectional and longitudinal cohorts; either prospective or retrospective), and baseline data from human intervention trials. Studies were excluded if nutritional assessment was measured following an intervention study, as this would not reflect baseline prevalence or determinants. As the causes of malnutrition are highly dynamic and vary considerably over time, only studies published from 2012 onward were included to ensure relevance to current conditions affecting the TBM. Studies with small or unrepresentative samples were excluded ($n < 2{,}000$; based on the minimum sample size reported in most of the population-based studies), though no sample size restriction applied to MNDs due to the limited data. Reviews, editorials, letters, non-English articles, and conference abstracts without full text were excluded.

Study selection

Duplicates from all databases were removed prior to screening Endnote (Endnote X7.7.1, Thomson Reuters 2016). Titles and abstracts were screened by two independent reviewers (PYT and CLC) using Rayyan (http://rayyan.qcri.org), followed by eligibility assessment of full texts using Endnote. The final decision on study inclusion was reached by consensus among all reviewers. Any disagreements were resolved through discussion with additional coauthors.

Data extraction

A standardized data extraction table was utilized to extract variables of interests including: author, year of publication, study design, year of study, country/population, sample characteristics (i.e., sample size, age, and sex), exposure (determinants), outcome measures (i.e., indicators related to undernutrition, overnutrition, and MNDs), analytical methods and diagnostic criteria for malnutrition indicators, and main findings (i.e., prevalence, β coefficient, odds ratio (OR), relative risk, and prevalence ratio, where available).

Quality assessment of included studies

Risk of bias for each study included was assessed by two independent reviewers (PYT and CLC) using the Academy of Nutrition and Dietetics Quality Criteria Checklist (Academy of Nutrition and Dietetics 2022). This assessment addressed 10 validity questions, 1) clear research question, 2) no selection bias, 3) group comparability, 4) report of response rate/withdrawals, 5) blinding, 6) description of study procedure, 7) outcome, 8) appropriate use of statistical method, 9) conclusion supported by results, and 10) conflict of interest. Any disagreement was resolved through discussion, and a third reviewer was consulted if necessary. Studies were rated positive (meeting majority of criteria, including criteria 2, 3, 6, and 7), neutral (failing to meet any of criteria 2, 3, 6, or 7), or negative (failing to meet six or more criteria).

Data synthesis and statistical analysis

Prevalence of stunting and overweight from national surveys was illustrated in bar charts, stratified by country, region, age, and sex. Age was categorized into two groups: <5 and 5–18 years old, as per the age categories of preschool and school aged children/adolescents primarily reported in national surveys and reports. For prevalence data, only stunting was reported as the indicator of undernutrition, this decision was made because different anthropometric constructs and terminologies were applied to children of different age groups e.g., BMI-for-age ("thinness") are used in adolescents, while weight-for-age ("underweight") and weight-for-height ("wasted") are used in children under 5, which can result in erroneous comparisons of data.

Further, random-effect meta-analyses were conducted using STATA 18 (Stata Corporation, College Station, TX, US) to estimate the pooled prevalence (%) of MNDs with its 95% confidence intervals (CI) (anemia, ID, IDA, VAD, and VDD), and were stratified by country, region, age, and sex. Heterogeneity across the studies was evaluated using I^2. Random-effect meta-analyses were also performed to estimate the pooled odds ratio (OR) with its 95% CI for determinants associated with all forms of malnutrition. Relative risk (RR) and prevalence ratio (PR) were considered equivalent to OR. Determinants were classified into multiple-levels using the adapted socio-ecological framework defined by McLeroy and colleagues: intrapersonal (child-level individual, and diet/lifestyle-related factors), interpersonal (parental and household factors), and community levels (McLeroy et al. 1988). Due to high heterogeneity (I^2 values > 50%), the random-effects restricted maximum likelihood model was used. Sensitivity analyses were assessed using leave-one-out analysis to compare the pooled prevalence or ORs before and after eliminating one study at a time. Publication bias was assessed using funnel plot asymmetry. $p < 0.05$ was considered statistical significance.

Results

The literature search generated 18,867 records from four databases, one additional record identified through citations, and 6 records from the Google Scholar (Figure 1). After screening, 317 full-text articles were assessed for eligibility. 175 studies met the inclusion criteria for this systematic review ($n = 169$ for academic articles; and $n = 6$ for national surveys/reports). Of these, 132 studies were included in the meta-analysis ($n = 76$ for prevalence studies; and $n = 87$ for determinants studies). The studies included data from Indonesia ($n = 59$), Malaysia ($n = 23$), Thailand ($n = 26$), Vietnam ($n = 23$), and at least three SEA countries ($n = 1$), with 99 from cross-sectional studies, 18 from longitudinal studies, and 15 using baseline data from human experimental studies.

Study quality and risk of bias assessment

Among the 132 studies, 112 studies were rated as high quality (positive), while 2 studies were rated as low quality (negative) (Supplementary Table S3). Common reasons for lower ratings included lack of blinding procedure, inadequate reporting of response rates or withdrawals, and inappropriate use of statistical analysis such as no adjustment for confounding factors.

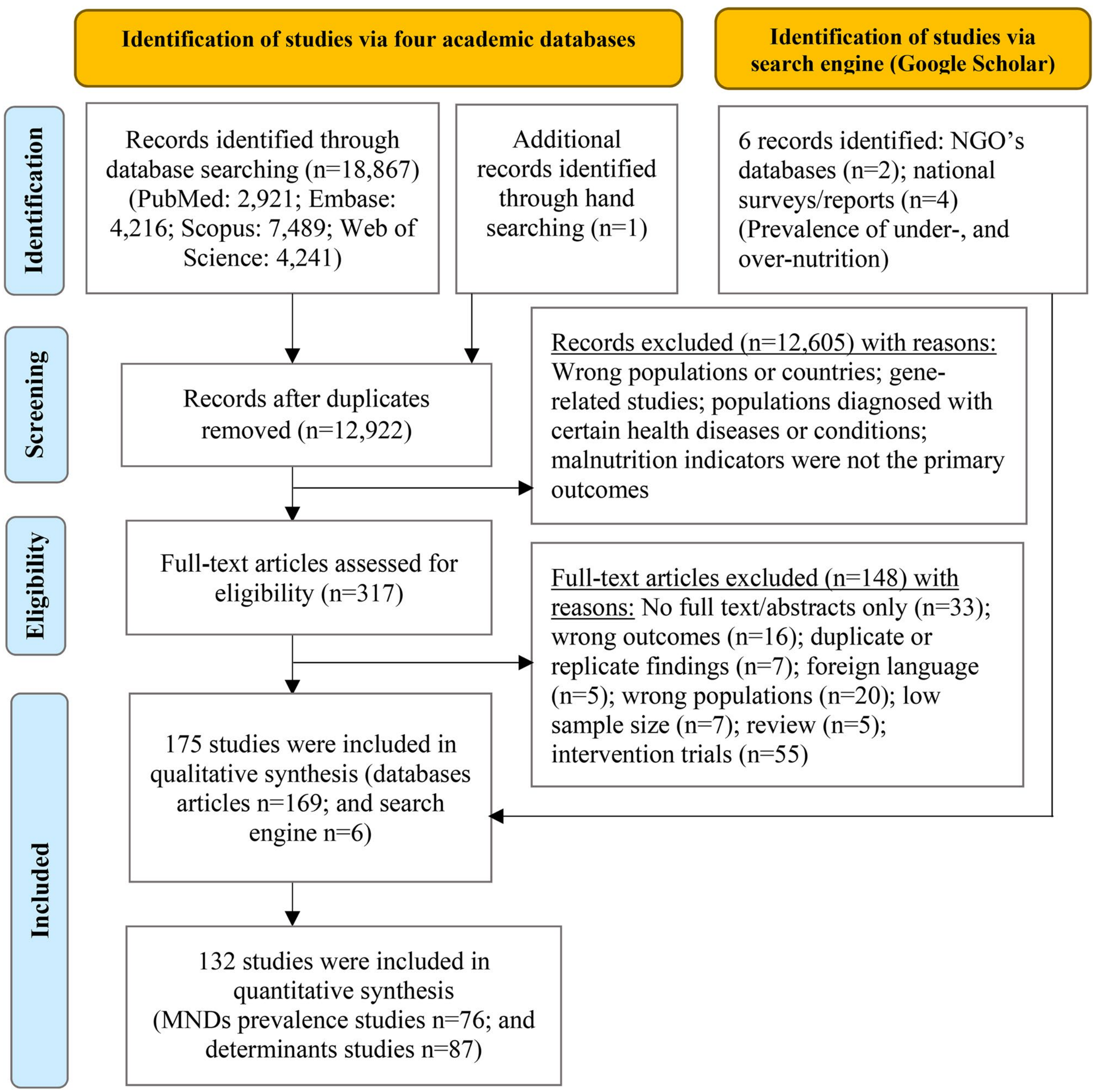

Figure 1. PRISMA flow diagram of identification and selection of studies from four academic databases and one search engine.
NGO, non-government organization.

Prevalence of child stunting and overweight

Country-specific prevalence of stunting and overweight (including obesity), stratified by age, sex, and region, were collated from recent national and NGO nutrition surveys (2018–2020) for comparison (Figure 2). Stunting was more prevalent among children aged under 5 years old (13.4–30.8%) compared to older children aged 5–18 years old (3.7–18.3%) across all four countries (WHO/UNICEF/World Bank Group 2022a, 2022b). Indonesia reported the highest prevalence of stunting at 30.8%, particularly in rural regions (34.9%), while Thailand reported the lowest prevalence at 13.4%. Prevalence of stunting varied by sex depending on country; it was higher in males in Indonesia and Thailand, but higher in females in Malaysia and Vietnam. Overweight and obesity were notably prevalent among school children (aged 5–18 years old), especially in Vietnam (41.3%) and Malaysia (29.8%) (Agency of Health Research and Development Indonesia 2019; Mai et al. 2020; Ministry of Health Malaysia 2020; National Statistical Office Thailand 2019). Higher prevalence of overnutrition was observed in males and those living in urban areas across all four countries.

Pooled prevalence of MNDs

Seventy-six published articles were included in estimation of the pooled prevalence (95% CI) of each of the four MNDs (Figure 3). The characteristics of the studies and the main findings on the prevalence of MNDs are reported in Supplementary Tables S4–S8. Overall, anemia was commonly defined as hemoglobin levels below age- and sex-specific cut offs according to WHO guidelines (World Health Organization 2011). Serum ferritin was commonly used to define ID, but other indicators such as soluble transferrin receptors, and transferrin saturation were also reported. All studies defined VAD as serum retinol <0.7 µmol/L. Definitions of VDD varied across studies, with some using cut off levels of <50 nmol/L or <30 nmol/L for 25-hydroxyvitamin D (25(OH)D) to define "insufficiency" or "deficiency." For consistency, VDD was reported as 25(OH)$D < 50$ nmol/L in this review following the majority of the studies. Sensitivity analysis using leave-one-out indicated that the overall prevalence estimates remained consistent when individual studies were omitted (Supplementary Figure S1). Funnel plot

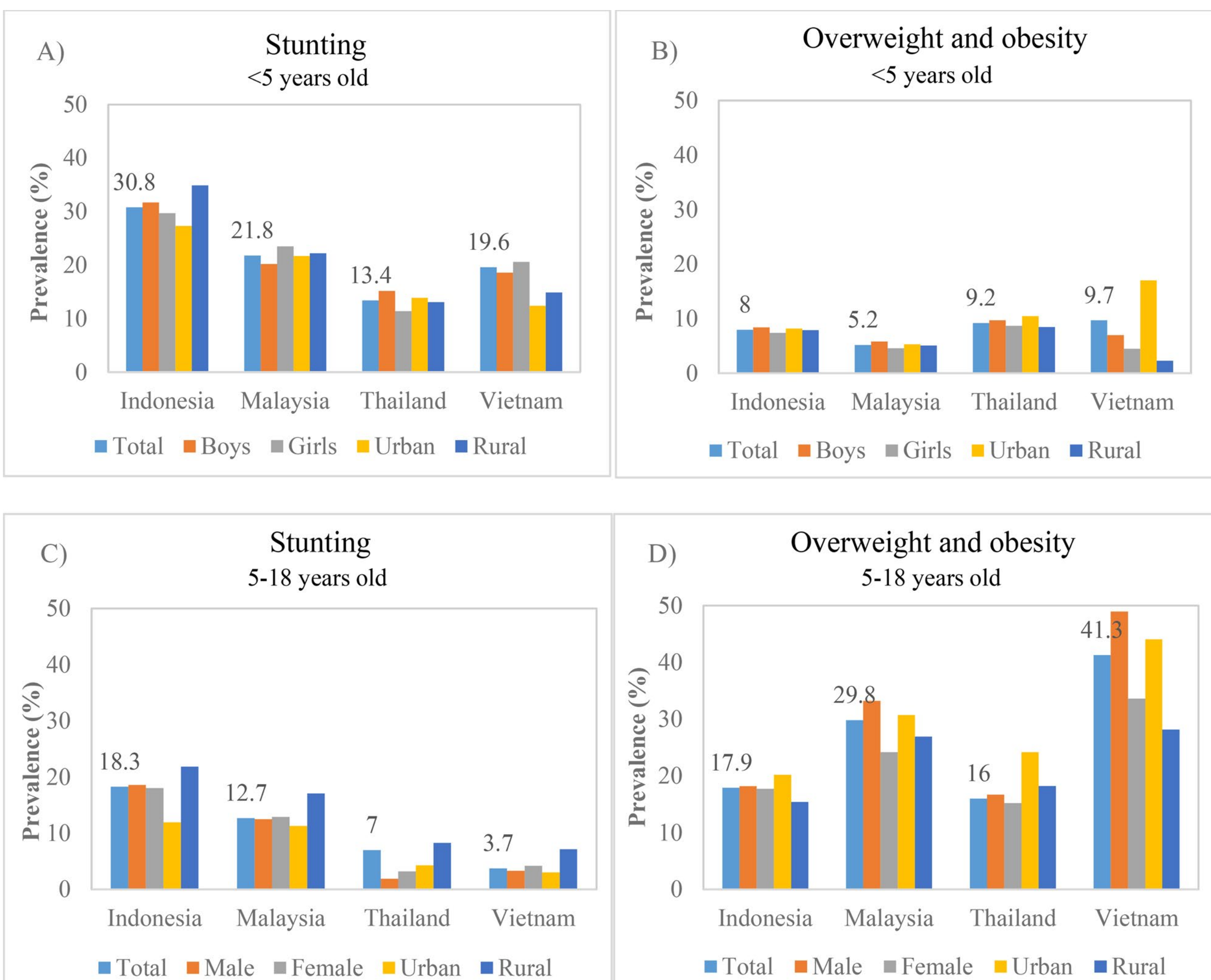

Figure 2. Total and stratified prevalence of stunting and overweight and obesity in children across four SEA countries. A) Stunting in children under 5 years old. B) Overweight and obesity in children under 5 years old. C) Stunting in children aged 5–18 years old. D) Overweight and obesity in children aged 5–18 years old. Total prevalence and prevalence stratified by sex and region were extracted from WHO/UNICEF/World Bank Group databases and national nutrition surveys (2018–2020).

analyses for publication bias are shown in Supplementary Figure S2.

Overall and country-specific pooled prevalence of MNDs

The pooled prevalence [95% CI] of MNDs in SEA children and adolescents was as follows (in descending order): VDD (40% [32, 48]); anemia (25% [22, 29]); ID (14% [10, 18]); IDA (8% [5, 11)]); and VAD (6% [4, 8]) (Figure 3). Notably high heterogeneity was observed across studies ($I^2 > 99\%$). Anemia and IDA were more prevalent in Indonesia (31% [25, 37] and 15% [8, 23]) and less prevalent in Thailand (17% [12, 22] and 5% [2, 10]) and Vietnam (22% [15, 29] and 2% [0, 5]), respectively (all $p < 0.001$) (Figure 3A and 3C). Interestingly, however, ID was more prevalent in Thailand (16% [9, 26]) and Indonesia (16% [9, 24]; $p = 0.03$) (Figure 3B). VDD and VAD were more prevalent in Malaysia (61% [43, 77] and 13% [5, 21]) and less prevalent in Thailand (19% [11, 27] and 1% [0, 2]; both $p < 0.001$), respectively (Figure 3D and 3E).

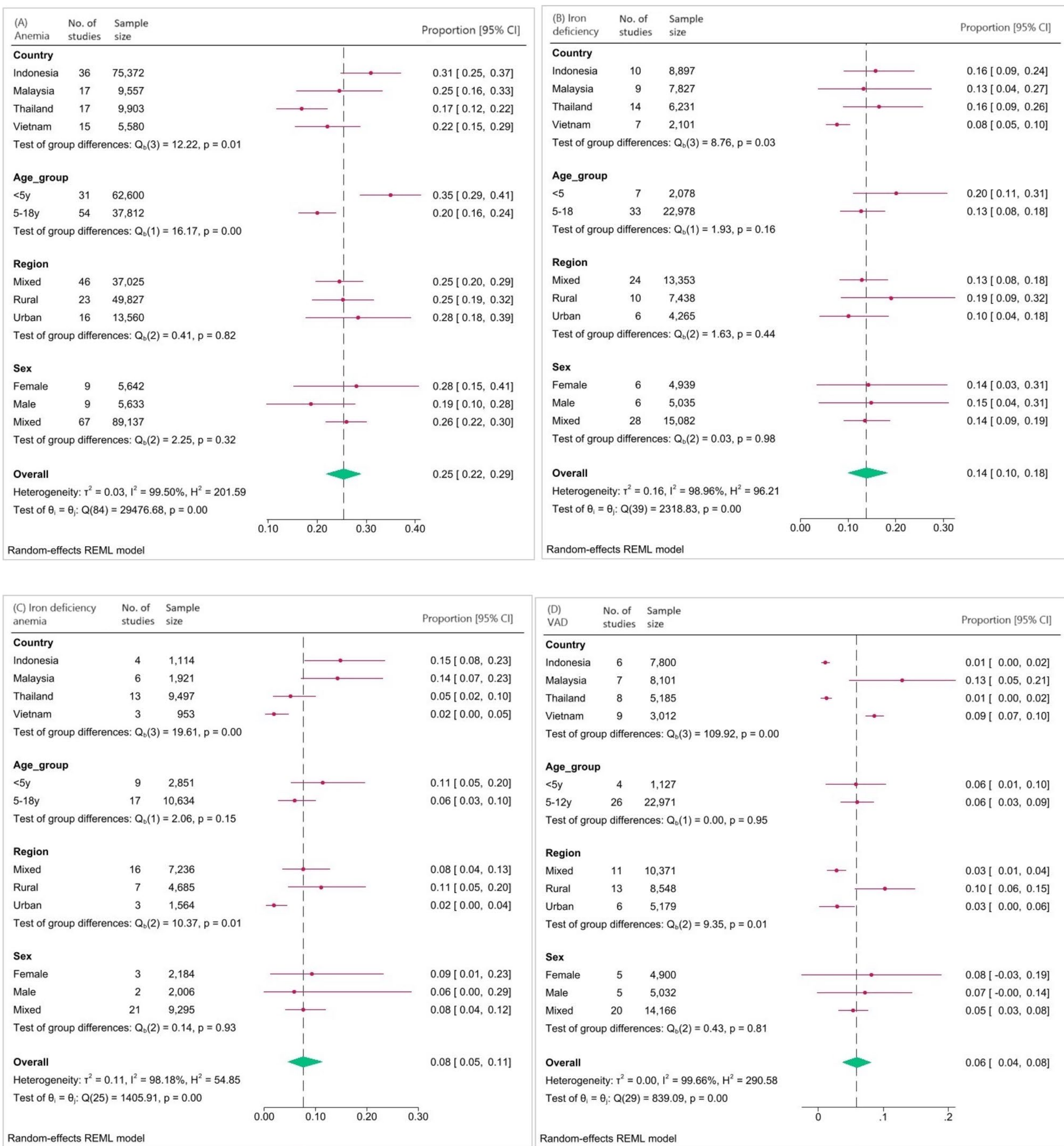

Figure 3. Forest plot of pooled and stratified prevalence of micronutrient deficiencies among SEA children. A) Anemia. B) Iron deficiency. C) Iron deficiency anemia. D) Vitamin A deficiency. E) Vitamin D deficiency.
The red dots indicate the pooled prevalence for each subgroup and the horizontal red lines indicate its 95% CI. The green diamond shows the overall pooled prevalence for each type of micronutrient deficiency.

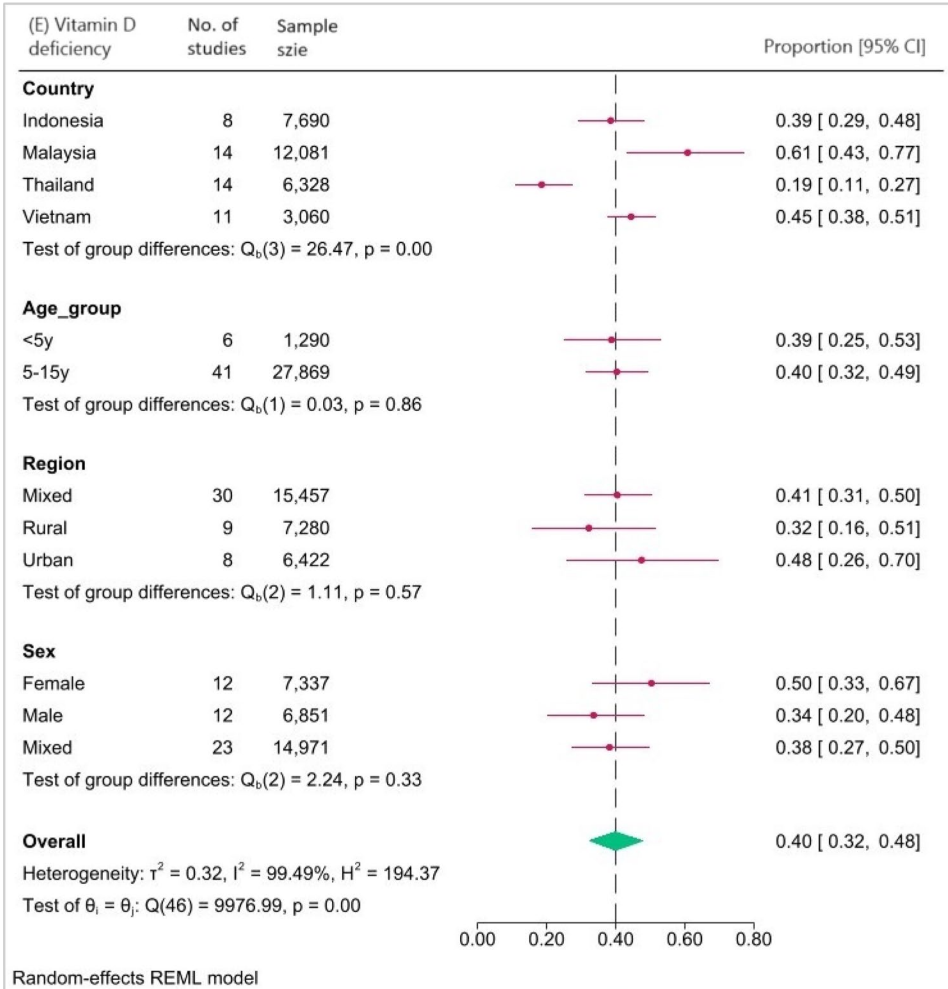

Figure 3. (Continued).

Age-, sex- and region-based inequalities

Age-stratified analyses indicated a higher prevalence of anemia among younger children aged under 5 compared to those aged 5–18 years (35% [29, 41] vs. 20% [16, 24]; $p < 0.001$) (Figure 3A). Similar patterns were observed for ID and IDA thought was not statistically significant (Figure 3B and 3C). Region-stratified analyses showed higher prevalence of IDA (11% [5, 20] vs. 2% [0, 4]; $p = 0.01$) (Figure 3C) and VAD (10% [6, 15] vs. 3% [1, 4]; $p < 0.001$) (Figure 3D) in rural regions compared to urban regions. In contrast, anemia (28% [18, 39] vs. 25% [19, 32]; $p = 0.82$) (Figure 3A) and VDD (48% [26, 70] vs. 32% [16, 51]; $p = 0.57$) (Figure 3E) were more prevalent in urban regions, although such difference was not statistically significant. Sex did not statistically influence on the prevalence of any MNDs.

Determinants of different forms of childhood malnutrition

Eighty-seven published articles ($n = 70$ cross-sectional, $n = 14$ longitudinal cohort, and $n = 3$ baseline data from human experimental studies) were included to estimate the pooled ORs (95% CI) for determinants of each form of TBM (Table 1). The study characteristics and main findings are summarized in Supplementary Table S9. Of those 87 studies, only 4 studies investigated the determinants of concurrent stunting-overweight or stunting-overweight-anemia (Andriani et al. 2023; Benedict et al. 2021; Ciptanurani and Chen 2021; Rachmi et al. 2016a). The estimated pooled ORs for determinants of malnutrition were categorized into multi-level determinants (intrapersonal, interpersonal, community) according to an adapted version of the socio-ecological framework defined by McLeroy and colleagues (McLeroy et al. 1988) (Table 1). See Supplementary Figure S3 for the results of pooled ORs generated from random-effects meta-analyses.

Child-level individual factors (*intrapersonal level*) such as male sex and increased age were consistently associated with increased odds of both undernutrition (pooled ORs: 1.30, 95% CI [1.17, 1.44]; and 1.61 [1.17, 2.06]) and overnutrition (1.47 [1.29, 1.65]; and 1.11 [1.08, 1.15]). In contrast, decreased age was associated with increased odds of anemia/IDA. Females had increased odds of VDD (7.07 [3.68, 10.47]). Poor pre-natal nutrition (i.e., low birth weight; LBW) was a significant predictor of undernutrition (2.09 [1.71, 2.49]), while being stunted at a young age was a significant predictor of overnutrition (2.35 [2.08, 2.62]) and anemia/IDA (1.56 [1.01, 2.10]). Childhood illnesses such as intestinal parasitic infection (i.e., Giardiasis or *Ascaris*) or

Table 1. Pooled odds ratio [95% CI] for determinants associated with various forms of malnutrition among SEA children using an adapted socio-ecological framework.

Level of determinants	Determinants	Overnutrition	Undernutrition	Concurrent stunting and overweight and/or anemia	Anemia or iron deficiency anemia	Vitamin A deficiency	Vitamin D deficiency
Child-individual factors (intrapersonal)	Age (Older age)	1.11 [1.08, 1.15] (#6)	1.61 [1.17, 2.06] (#10)	1.41 [1.22, 4.03] (#2)	Younger age: 1.94 [1.58, 2.30] (#2)		
	Sex (Male)	1.47 [1.29, 1.65] (#10)	1.30 [1.17, 1.44] (#12)				Female: 7.07 [3.68, 10.47] (#2)
	Anemia		2.17 [0.74, 3.61] (#2)				
	Diarrhea		1.30 [1.13, 1.48] (#2)				
	Large birth weight	1.66 [1.48, 1.86] (#1)	0.54 [0.32, 0.75] (#2)				
	Intestinal parasitic infection or inflammation		1.56 [0.72, 2.41] (#2)		3.08 [1.94, 4.22] (#5)	2.38 [1.13, 3.62] (#2)	
	Low birth weight	7.46 [6.73, 8.19] (#1)	2.09 [1.71, 2.49] (#10)				
	Overnutrition				0.51 [0.19, 0.83] (#1)		1.70 [0.14, 3.25] (#2)
	Perceived overweight	3.38 [1.75, 5.02] (#2)					
	Early life undernutrition	2.35 [2.08, 2.62] (#2)			1.56 [1.01, 2.10] (#4)		
Diet and lifestyle-related factors (intrapersonal)	Dairy consumption	0.99 [0.98, 1.00] (#2)	0.59 [0.40, 0.79]* (#2)			0.40 [0.15, 0.65] (#1)	0.36 [0.09, 0.64] (#3)
	Excessive intake of energy, sugar, oil and salt	1.20 [1.03, 1.38] (#7)					
	Inadequate nutrient intake	0.91 [0.83, 0.99] (#2)	1.47 [1.27, 1.67] (#3)		3.75 [0.91, 6.59] (#4) Adequate iron intake: 0.44 [0.27, 0.61] (#5)		
	Increased screen time	1.47 [1.16, 1.79] (#2)					
	Poor eating habit (e.g., meal skipping, eating fast)	1.75 [1.39, 2.11] (#4)					
	Sedentary lifestyle	1.07 [1.04, 1.11] (#4)					
	Shorter sunlight exposure						1.06 [0.94, 1.18] (#5)
	Smoking	1.05 [0.42, 1.69] (#2)					
Parental factors (interpersonal)	Low gestational/maternal age		1.84 [1.12, 2.57] (#2)	0.72 [0.55, 0.94] (#1)			
	Mother's marital status		Married: 0.80 [0.78, 0.81] (#2) Single/divorced: 1.57 [1.20, 1.93] (#3)				
	Mother's nutritional status	Overweight or maternal obesity: 1.31 [1.14, 1.49] (#7)	Short stature: 1.76 [1.45, 2.07] (#10)	Short stature: 1.66 [1.22, 2.58] (#1)	Anemia: 1.95 [1.65, 2.24] (#4)		
	Mother's occupation	Working: 1.47 [0.91, 2.04] (#2)	Non-working: 0.96 [0.78, 1.14] (#4)				
	No or delayed breastfeeding		4.77 [2.35, 11.88] (#4)				
	Low maternal educational level	High: 1.42 [0.47, 2.37] (#3)	1.59 [1.38, 1.90] (#10) High: 0.88 [0.34, 1.43] (#6)		1.54 [1.06, 2.01] (#2)		1.71 [1.13, 2.28] (#2)
	Parental mental distress		1.26 [1.13, 1.38] (#4)				
	Poor complementary feeding		2.19 [0.84, 3.55] (#2)		1.33 [1.00, 1.65] (#2)		
Household factors (interpersonal)	Low wealth or socioeconomic status	High: 1.70 [1.42, 1.92] (#8)	1.51 [1.29, 1.74] (#7) High: 0.57 [0.42, 0.71] (#3)		2.79 [1.26, 6.32] (#1)		
	Household food insecurity		1.47 [1.21, 1.73] (#)				
	Improved sanitation and drinking-water sources		0.52 [0.24, 0.80] (#3)				
	Large household size	0.58 [0.40, 0.77] (#3)	1.11 [1.02, 1.19] (#5)	1.26 [1.05, 1.52] (#1)			
	Low household expenditure		1.73 [1.55, 1.91] (#2)				
	One- or two-child household	1.25 [1.18, 1.32] (#2)		1.80 [1.18, 2.74] (#1)			
	Poor sanitation and drinking-water sources		1.30 [1.18, 1.41] (#13)				
Community	Region (urban)	1.38 [1.18, 1.58] (#11)	0.81 [0.72, 0.90] (#6) Rural: 1.19 [1.10, 1.28] (#7)	Rural: 1.66 [1.19, 1.32] (#1)			
	Availability of fast-food outlet in neighborhood	1.23 [1.03, 1.47] (#1)					
	No vitamin A supplementation		3.50 [2.70, 4.30] (#1)				
	Lack of access to nutrition and health service	1.21 [1.13, 1.28] (#4)	1.20 [0.70, 1.70] (#2)		2.61 [1.34, 5.10] (#1)		
	Antenatal care including supplementation		Poor antenatal care: 1.22 [1.08, 1.39] (#1)	0.49 [0.20, 0.79] (#2)			0.21 [0.06, 0.68] (#1)

Random-effect meta-analyses were performed to estimate the pooled ORs [95% CI] of each determinant associated with each form of malnutrition.
Red font indicates significantly increased odds of malnutrition, while green font indicates significantly decreased odds of malnutrition.
# indicates number of associations reported. At least ≥2 studies were required to estimate the pooled ORs.
Indicators of undernutrition include stunting, underweight and wasting; and overnutrition includes overweight and obesity.
CI, confidence interval; OR, odds ratio.

inflammation were significant predictors of anemia/IDA (3.08 [1.94, 4.22]) and VAD (2.38 [1.13, 3.62]).

Diet and lifestyle factors (*intrapersonal level*) such as increased screen time (1.47 [1.16, 1.79]), sedentary lifestyle (1.07 [1.04, 1.11]), excessive intake of energy, sugar, oil, and salt (1.20 [1.03, 1.38]), and poor eating behaviors (1.77 [1.39, 2.11]) were associated with increased odds of overnutrition. Frequent dairy consumption was protective against undernutrition, VAD and VDD (ORs ranged from 0.36 to 0.59). Other diet-related risk factors such as inadequate nutrient intake (i.e., low healthy eating index, inadequate energy and protein intake) was associated with increased odds of undernutrition (1.47 [1.27, 1.67]). Adequate intake of iron-rich foods such as meats, fruits, and vegetables were protective against anemia (0.44 [0.27, 0.61]).

For parental factors (*interpersonal level*), poor maternal nutrition was consistently associated with child undernutrition (mother's short stature: 1.76 [1.45, 2.07]) and anemia/IDA (maternal anemia: 1.95 [1.65, 2.24]). In contrast, overweight and obese mothers were more likely to have children living with overweight and obesity (1.31 [1.14, 1.49]). No or delayed breastfeeding (4.77 [2.35, 11.88]), having a single or divorced mother (1.57 [1.20, 1.93]), or parents with mental illnesses (1.26 [1.13, 1.38]) were associated with increased odds of undernutrition. Low maternal educational status was associated with increased odds of undernutrition (1.59 [1.38, 1.90]) and anemia/IDA (1.54 [1.06, 2.01]). Household factors (*interpersonal level*) such as household wealth status and household size were shared determinants of undernutrition (high wealth: 0.57 [0.42, 0.71]; and large size: 1.11 [1.02, 1.19]) and overnutrition (high wealth: 1.70 [1.42, 1.92]; and large size: 0.58 [0.40, 0.77]). Household food insecurity (1.47 [1.21, 1.73]), poor household sanitation and drinking water sources (1.30 [1.18, 1.41]), and low household expenditure (1.73 [1.55, 1.91]) were associated with increased odds of undernutrition.

For neighborhood factors (*community level*), children living in rural regions had increased odds of undernutrition (1.19 [1.10, 1.41]) and anemia/IDA (1.66 [1.19, 1.32]), while those living in urban regions had increased odds of overnutrition (1.38 [1.18, 1.58]). Lack of nutrition and health services (i.e., vaccination, and availability of child health service in neighborhood) was associated with increased odds of overnutrition (1.21 [1.13, 1.28]), VAD (2.61 [1.34, 5.10]) and undernutrition (1.20 [0.70, 1.70]. Other community factors, such as the availability of neighborhood fast-food outlet and poor antenatal care, as well as supplementation for children or during pregnancy were linked to various forms of malnutrition, though these associations were reported in only one or two studies.

Guided with an adapted socio-ecological framework, we intent to graphically depict the multiple-level determinants of TBM identified in this review (Table 1), and highlights key research gaps in Figure 4. The determinants are grouped in different ecological levels, namely intrapersonal (individual factors including diet and lifestyle related factors), interpersonal (parental and household factors), community, and macro-level. This framework illustrates the key shared determinants of TBM, particularly at the intrapersonal and interpersonal levels including the intergenerational transmission of both undernutrition (including MNDs) and overnutrition, and highlights the limited evidence on the impacts of broader determinants at the community and macro-levels.

Discussion

This systematic review comprehensively evaluated the prevalence and shared determinants of the TBM, incorporating a wide range of nutritional status indicators including MNDs among infants, young children and adolescents across four SEA countries. Despite the regional efforts in addressing TBM, our findings show a concerning trend of co-existing undernutrition, MNDs and overnutrition among SEA children, affecting each country, region, age, and sex differently. Stunting remains a significant issue among children aged under 5, particularly in rural areas. Conversely, childhood overweight is a growing concern among school children (5–18 years) in urban settings. VDD is notably widespread, particularly in Malaysia and Vietnam, despite ample sunlight exposure, with higher prevalence observed among females and urban dwellers. Anemia and IDA remain prevalent in SEA countries, particularly in Indonesia and Malaysia, predominantly affecting younger children. VAD appears to be less of a concern overall, possibly due to effective supplementation programmes, and the abundant availability of fruits and other Vitamin A-rich foods in these regions (Kang et al. 2022; Tee et al. 2020). Noticeably, its prevalence doubled in Malaysia (14%), especially among stunted and indigenous children residing in poor rural and remote areas (Al-Mekhlafi et al. 2010; Ernawati et al. 2021; Tan et al. 2023).

The TBM is a complex public health phenomenon driven by a range of socio-ecological determinants (Mahmudiono et al. 2019). Consistent with findings from other LMICs, male sex was associated with increased risk of both child stunting and overweight (Al-Taiar et al. 2021; Keino et al. 2014). Conversely, VDD was more prevalent among females, possibly due to religious and cultural practices (i.e., Islam and Hinduism) such as wearing covered-up clothes, along with certain sunlight avoidance lifestyles such as application of sunscreen, wearing hat, using umbrella and, reduced outdoor activities, particularly in urban areas (Chee et al. 2021; Oktaria et al. 2020; Oktaria et al. 2022; Poh et al. 2016; Pulungan et al. 2021; Quah et al. 2018; Senaprom et al. 2016). Moreover, stunting reportedly increased with age, particularly in children aged under 5, while the risk of overweight increases in later childhood and adolescence. Previous evidence suggested that stunted children who experienced rapid weight gain after 2 years have an increased risk of becoming overweight or obese later in life (Fall and Kumaran 2019; Langley-Evans 2009; Yasmin, Kustiyah, and Dwiriani 2019). This may be explained by the concept of early-life programming, which proposes that environmental influences experienced in utero and/or during early development including genetic condition and food environment, can lead to permanent alterations in the metabolism or physiological systems of an individual (Kwon and Kim 2017).

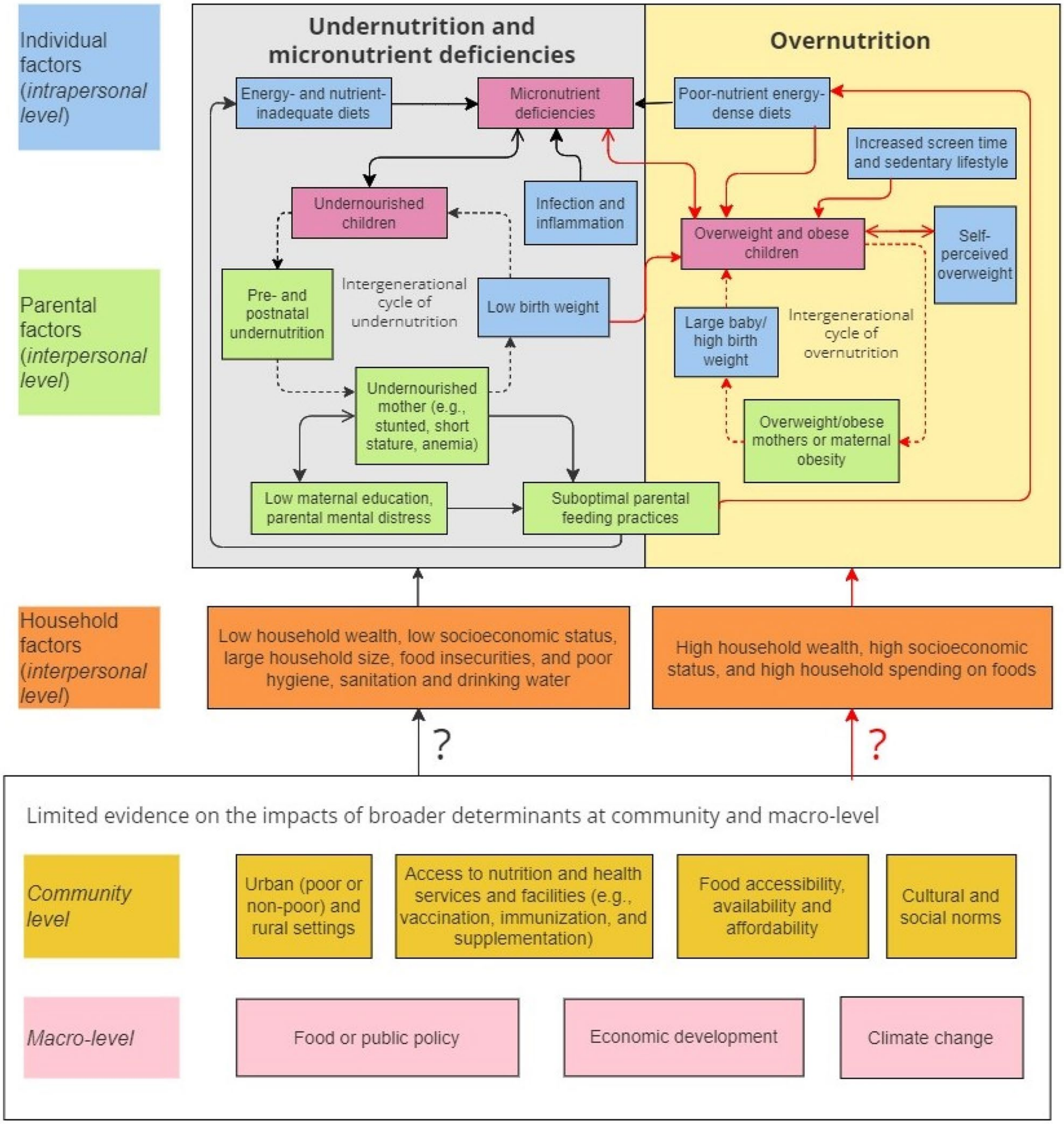

Figure 4. Determinants of various forms of childhood malnutrition and the identified research gaps in SEA countries within an adapted socio-ecological framework. This diagram provides an overview of our findings on the determinants of various forms of childhood malnutrition at multiple levels, namely individual (blue), parental (green), household (orange), community (yellow) and macro-level or public policy (pink). The black solid line (___) indicates the factors associated with undernutrition and micronutrient deficiencies, whereas the red solid line (___) indicates the factors associated with child overnutrition. The black dot line (----) indicates the intergenerational cycle of undernutrition, whereas the red dot line (----) indicates the intergenerational cycle of overnutrition. Model adapted from that of McLeroy et al. (1988).

In line with previous findings, our review also highlights the importance of poor early-life nutrition factors such as LBW, being stunted in early life, child illnesses (i.e., anemia, intestinal parasitic infection, inflammation, and diarrhea), and suboptimal breastfeeding and complementary feeding practices as significant predictors of both undernutrition (including MNDs) and overnutrition (Andriani et al. 2016; Rachmi et al. 2016a, Rachmi et al. 2016b). The intergenerational effects of maternal nutrition on child growth are also well documented. Both genetic condition and food environment including food availability and feeding practice play important role for child growth (Martorell and Zongrone 2012). Undernourished mothers are more likely to give birth to babies with LBW, increasing the risk of undernutrition in early life and overweight later in life. Conversely, overweight and obese mothers are more likely to give birth to babies with large birth weight, predisposing them to overweight and obesity in childhood and later in life (Godfrey et al. 2017). Therefore, interventions targeting the first 1,000 days of life including vaccination, institutional delivery, prenatal care and postnatal care, nutritional supplementation for both women and newborns, nutritional education and counseling for optimal feeding practices, and school feeding programmes for young children are essential in addressing the TBM (Hoffman et al. 2019; Rahman and Pingali 2024; Sotiraki et al. 2022).

Dietary shifts remain the major drivers of both undernutrition and overnutrition. The global nutrition transition, influenced by economic growth, urbanization, and trade liberalization, has increased access to highly processed, nutrient-poor foods that high in refined carbohydrates, unhealthy fats, salt and sugar, heightening the risk of TBM particularly in LMICs (Popkin and Ng 2022). Coupled with increasingly sedentary lifestyles and increased screen time, especially in urban settings, further exacerbate this issue (Do et al. 2015; Mo-Suwan et al. 2014; Nguyen et al. 2016). A meta-analysis of 28 LMICs found that, in several countries, children in urban poor areas were at greater risk of stunting and anemia compared to those in urban non-poor areas, with risk levels similar to those in rural areas (Assaf and Juan 2020). Our review corroborates these findings, showing a slight, though not statistically significant, increase in the prevalence of anemia in urban areas. This suggests that urban poor dwellers face challenges in accessing healthy foods that are comparable to those faced in rural settings, potentially due to economic constrains, limited access to food, and higher prices for nutritious foods in urban poor areas, exposing them to an elevated risk of adverse nutritional outcomes (Vilar-Compte et al. 2021).

Our review finds that nearly half of the anemic cases in Indonesia and Malaysia are attributable to ID (48–56%) whereas a smaller proportion of anemia is attributable to ID in Thailand and Vietnam (9–29%), suggesting that anemia in these regions may be influenced by other nutritional deficiencies and non-nutritional factors including genetic factors such as α- and β-thalassemia and hemoglobinopathies (Panomai et al. 2010; Porniammongkol et al. 2011; Sunuwar et al. 2023). Given the high prevalence of α-Thalassemia reported in SEA countries, particularly in Vietnam (51%) and Thailand (20%) (Goh et al. 2020), its impacts on anemia development warrants further investigation. Future research should consider nutritional and non-nutritional factors, including socioeconomic and cultural factors to better understand the underlying determinants of anemia and IDA in these regions.

Consistent with previous evidence, our study underscore the significance of family household characteristics as critical social determinants of child malnutrition, these factors include household wealth, socioeconomic status, maternal education, maternal age, family size, single parenting, access to sanitation and safe drinking water, and food security (Katoch 2022; Yaya et al. 2022). Improved household wealth, higher socio-economic level, and maternal education are linked to improved household food security and better nutritional knowledge, enabling mothers to provide better nutrition and healthcare for their children, thereby positively influencing child nutritional outcomes (Siddiqui et al. 2020; Yani et al. 2023). Conversely, poor access to sanitation and safe drinking water, and unhygienic food preparation practices, heightens the risk of infections and diarrhoeal diseases, which can exacerbate chronic malnutrition in children (Shrestha et al. 2020).

Furthermore, family size plays a dual role in determining child nutritional status. Larger family sizes are often correlated with an increased risk of child malnutrition due to economic constraints, resource scarcity, particularly foods, and lesser time and attention given to meet the child nutritional requirement (Galgamuwa et al. 2017). Increase in family size has also been associated with reduced risk of childhood overweight (Datar 2017). Single parenting, particularly among mothers without partners, may similarly impact child nutrition due to limited resources and support (Ntoimo and Odimegwu 2014). Additionally, the positive impacts of advanced maternal age on child nutritional status are notable. As older mothers tend to have more experience and knowledge about child nutrition, leading to better nutritional outcomes, and younger mothers may face socioeconomic challenges or biological immaturity that could negatively affect their children's nutrition (Finlay et al. 2011). Nonetheless, our findings indicate that the evidence gaps in these regions are immense, impeding the development of effective action plans. There is an urgent need for more research, particularly on the impacts of broader or macro-level contextual factors such as infrastructure, technology, and public policy, which remain underexplored.

Regarding micronutrient assessment, the WHO revised its guidelines in 2020, advising that ferritin should not be used alone to diagnose ID without considering additional iron biomarkers or making adjustments for inflammation (World Health Organization 2020). Serum ferritin, while serving as an iron storage protein, is also an acute-phase reactant that can become elevated in response to acute or chronic inflammatory conditions. This elevation may lead to an underestimation of the true prevalence of ID, particularly in regions where infections or inflammation are widespread (Namaste et al. 2017). Despite this, very few studies included in this review accounted for inflammation status alongside serum ferritin measurements (Suchdev et al. 2017). Additionally, there is still no international consensus on the definition of vitamin D deficiency and sufficiency, which complicates the assessment and comparison of vitamin D status across studies (Amrein et al. 2020). Global efforts such as the Vitamin D Standardization Program (VDSP) are crucial to standardize the assessment of serum 25(OH)D to ensure consistency and accuracy in future research (Wise et al. 2021).

Policy implications

Given the observed variation on TBM distribution by country and region, policy responses must be tailored to address the specific needs of different SEA countries and regions. Strategies should aim to eradicate poverty, food insecurity, and undernutrition among the disadvantaged, while preventing the emergence of childhood overweight and obesity as the socioeconomic status improves (Venegas Hargous et al. 2023). Comprehensive actions are needed to regulate the food environment, improving the availability, accessibility, and affordability of nutrient-rich foods. These should include biofortification, crop diversification, and the restriction of unhealthy food advertisement to children (Burgaz et al. 2024).

Additionally, nutrition education and behavioral interventions promoting healthy eating and an active lifestyle, tailored by specific food environment faced by the children and adolescents including parents, families, communities, and schools (e.g., healthy school canteen and school gardening programs) are highly encouraged (Chan et al. 2022; Golden and Earp 2012). Achieving these goals requires a concerted action across multiple sectors including health, education, social protection, agriculture, and rural and urban planning, to foster a healthy food (Khandelwal and Kurpad 2019; Reinhardt and Fanzo 2014). Furthermore, incorporating robust, valid micronutrient biomarkers in national surveys is crucial for collecting routine data to monitor progress and inform future nutrition programmes and policies in SEA countries.

Strengths and limitations

Our study had some notable strengths. First, this is a comprehensive systematic review that provides a robust evaluation of the pooled prevalence and determinants of the TBM among children of all age groups across four SEA countries, including a comprehensive range of nutritional status indicators including MNDs. Findings from this review fill important gaps in knowledge, provide valuable insights to inform policy, and identify priorities for effective intervention. Second, this review was conducted systematically using established PRISMA and PECO guidelines. We provided detailed documentation of our approaches to ensure transparency and replicability. Third, we excluded studies with small or unrepresentative sample size to minimize selection bias. As a result, over 98% of the studies included in this review were rated as neutral or positive quality, reinforcing the reliability of our findings. While our focus was on four SEA countries, the findings and insight generated in this review may be relevant to other SEA regions with similar socio-cultural contexts.

Nonetheless, this study had some limitations. First of all, observational studies are limited by confounding factors and hence causality should not be inferred. Second, the estimates are subject to uncertainty due to limited biomarkers data assessing micronutrient status, therefore results need to be interpreted with caution. Third, the heterogeneity across studies, in term of study design, analytical methods, and diagnostic criteria for MNDs especially for iron and vitamin D, may affect comparability and complicate interpretation. Fourth, our analysis was limited to four core MNDs, potentially mispresenting other MNDs. Last but not least, the inclusion of only English-language studies may have introduced language bias.

Conclusion

The TBM is an increasing public health challenge among children and adolescents in SEA countries, with variation in burden dependent on country, regions, and demographic factors. Our findings highlight that poor early-life nutrition, parental, and household factors including socioeconomic status, are significant predictors of the TBM. Energy-dense, nutrient poor diets, poor eating behaviors, sedentary lifestyles, increased screen time, and maternal overweight were consistently associated with overnutrition. However, evidence on macro-level societal and physical environmental factors remains scarce, indicating a need for further research. Many of the studies reviewed were observational, limiting causal inferences due to potential confounding factors. Additionally, variations in study designs, statistical techniques, analytical methods, and diagnostic criteria for MNDs particularly for iron and vitamin D, complicate comparisons across studies. Addressing these challenges is essential to ensure the reliability and validity of data to inform public health policies and interventions. Robust and timely data on malnutrition indicators from national surveys, particularly for biomarker data is essential to evaluate progress and inform nutrition programmes and policies.

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Author contributions

PYT and YYG designed and conceptualized the study; PYT and CLC conducted literature searches, data screening, selection and extraction, and quality assessment; PYT contributed to data analysis and visualization; PYT wrote the first draft of the manuscript; All authors interpreted results, edited, revised, and finalized the manuscript; YYG supervised the work and acquired funding for this work as principal investigator. All the authors read and approved the final manuscript.

Disclosure statement

The authors report there are no competing interests to declare.

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