Mal J Nutr 31(3): 351-364, 2025

Prevalence and socioeconomic determinants of malnutrition among secondary school students in northern mountainous Vietnam

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ABSTRACT

Introduction: Malnutrition remains a critical public health issue, especially in rural and mountainous areas of Vietnam, where socioeconomic and geographic disparities are pronounced. Secondary school students are particularly vulnerable due to increased nutritional needs during growth and development. This study aimed to assess the prevalence of malnutrition and its associated factors among secondary school students in northern mountainous Vietnam. **Methods:** A community-based cross-sectional study was conducted at Bao Ai Secondary School, Yen Bai Province, from September to October 2022. A total of 460 secondary school students aged 10–15 years were included. Nutritional status was assessed using the World Health Organization growth standards, and stunting, thinness, and overweight prevalences were determined. Socioeconomic, demographic, and behavioural data were collected through structured questionnaires and analysed using chi-square tests and logistic regression models. **Results:** Stunting was more prevalent in females, while thinness and overweight were higher in males, though these differences were not statistically significant. Dao ethnic group had the highest malnutrition rates, with stunting at 9.4% and thinness at 10.8%. Low maternal education was a key predictor of stunting, while household economic status showed no significant association. These findings highlighted the need for targeted interventions addressing gender and ethnic disparities in nutrition. **Conclusion:** This study underscored the need for targeted interventions addressing age- and gender-specific nutritional vulnerabilities. Findings highlighted importance of school-based nutrition programmes and maternal education initiatives to mitigate malnutrition risks. Culturally sensitive strategies and multi-sectoral collaboration are essential to reduce malnutrition in underserved communities.

Keywords: adolescents, ethnic disparities, malnutrition, nutritional status, Vietnam

INTRODUCTION

Malnutrition is a pressing public health issue in developing countries, exacerbated by socioeconomic and geographic challenges. Secondary school students are vulnerable due to their heightened nutritional needs during growth. In Vietnam, despite economic progress, malnutrition persists in rural and marginalised

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doi: https://doi.org/10.31246/mjn-2024-0135

regions, disproportionately affecting ethnic minorities (Le *et al.,* 2023; Rocha *et al.,* 2022).

Northern mountainous Vietnam, home to diverse ethnic groups, faces health disparities due to geographic isolation, poverty, and limited access to education and healthcare. Stunting prevalence among children under five is 29.8%–34.1%, higher than the national average of 19.6%. Underweight prevalence ranges from 24.9%–29.3%, compared to 12.2% nationally (Le *et al.*, 2023; UNICEF, 2020). Previous studies predominantly focused on children under five or primary school students, with limited attention to secondary school students aged 10–15 years (Mondon *et al.*, 2024; Truong *et al.*, 2022). This age group faces unique nutritional challenges due to puberty, compounded by restricted health services and sociocultural barriers, as well as limited healthcare access.

The double burden of malnutrition – coexistence of undernutrition (stunting and thinness) and overnutrition (overweight and obesity) – is evident in Vietnam. Dietary transitions towards processed, energy-dense foods are increasing obesity risks, especially among adolescents (Nguyen & Trevisan, 2020). Rural communities face economic disparities, thus limiting diverse, nutrient-rich foods (Nkosinathi *et al.*, 2019). Malnutrition also affects cognitive performance and academic outcomes, perpetuating poverty cycles (Di Prima *et al.*, 2022).

Schools are key platforms for nutrition education and feeding programmes. However, in the northern region, logistical and financial constraints limit their effectiveness (Wang *et al.*, 2021). Therefore, a multi-sectoral approach is needed, integrating healthcare, education, and community engagement. Moreover, culturally sensitive interventions aligned with local dietary habits and socioeconomic conditions are essential (Di Prima *et al.*, 2022; Rocha *et al.*, 2022).

This study aimed to: (i) assess the prevalences of stunting, thinness, and overweight among secondary school students; (ii) identify socioeconomic and demographic risk factors for malnutrition, and (iii) recommend targeted, culturally appropriate interventions.

METHODOLOGY

Study design and setting

A cross-sectional study was conducted at Bao Ai Secondary School, Yen Binh District, Yen Bai Province, from September to October 2022.

Study population

Inclusion criteria:

- Enrolled at Bao Ai Secondary School.
- Willing to participate.

Exclusion criteria:

- Students unable to complete the questionnaire due to insufficient literacy.
- Absent on data collection days.

Sample size

A stratified random sampling method was used to select participants from the enrolled student population. Sample size was calculated based on a 38% malnutrition prevalence from the 2019–2020 National Nutrition Survey, using a proportion formula with a 5% margin of error and a 95% confidence level. An initial sample size of 362 was calculated. With a 20% non-response rate, the sample size was increased to 435. Ultimately, 460 students participated, enhancing representativeness due to higher-than-expected participation.

Data collection

Data were collected using a structured questionnaire covering anthropometric

measurements and socioeconomic, demographic, and behavioural factors.

Measurement standards

- Age determination: Age was calculated by subtracting the date of birth from the survey date and categorised following the World Health Organization (WHO) standards (1995). Age was rounded down (e.g., 11–11.99 years = 11 years).
- Height measurement: Recorded in centimetres (cm) and rounded to the nearest whole number.
- Weight measurement: Recorded in kilograms (kg) and rounded to the nearest whole number.
- Nutritional status assessment: Nutritional status was evaluated using the WHO (2007) growth standards (Table 2, Figure 1, and Table 3 combined overweight and obesity under "overweight") (De Onis *et al.*, 2007).
  - Stunting: Z-score for height-for-age (HAZ) <-2 standard deviation (*SD)*
  - Thinness: Body mass index (BMI)-for-age z-score (BAZ) <-2*SD*
  - Normal weight: BAZ between -2*SD* and +1*SD*
  - Overweight: BAZ>+1*SD*
  - Obesity: BAZ>+2*SD*
  - Students classified as having both forms of malnutrition simultaneously met the criteria for stunting (HAZ<-2*SD*) and thinness (BAZ<-2 *SD*).
- Physical activity assessment: Participants reported their daily moderate-to-vigorous physical activity (MVPA) duration. Following WHO recommendations (WHO, 2020), physical activity was categorised as:
  - <60 minutes/day: Insufficient activity
  - ≥60 minutes/day: Sufficient activity
- Sleep duration assessment: Participants reported their average sleep duration per night. Based on adolescent sleep guidelines, it was categorised as:
  - <8 hours/day: Inadequate sleep
  - ≥8 hours/day: Adequate sleep

Height and weight measurement instruments

Height and weight of participants were measured using the Akiko TZ 120 health scale (Yongkang, Jinhua, Zhejiang Province, China). Trained health staff and school nurses received a one-day refresher training session prior to conducting measurements. Tools were calibrated using standard weights (10 kg and 20 kg) and a fixed-height rod. The scale was zeroed before each use, with duplicate measurements for 10% of the sample. Discrepancies exceeding 0.5 kg or 0.5 cm prompted re-measurement.

Data processing and analysis

Collected data were cleaned and coded for statistical analysis before entering into the Jamovi software v2.3.8 (Sydney, New South Wales, Australia). Descriptive statistics summarised prevalences for stunting, thinness, normal, and overweight by age, gender, and ethnicity. The "both forms" category (n=4) was reported descriptively. Fisher's Exact Test examined associations between nutritional status and categorical variables, including age, gender, and ethnicity, to assess differences in malnutrition prevalence across these groups. Logistic regression models produced crude *OR* with 95% *CI*. A p<0.05 indicated statistical significance.

Ethical considerations

The Ethical Review Committee, School of Preventive Medicine and Public Health, Hanoi Medical University, Hanoi 100000, Vietnam provided the ethical approval to conduct this study. The

Table 1. Sociodemographic characteristics of the students (*N*=460)

Characteristic	*Frequency (n)*	*Percentage (%)*
Gender		
Male	233	50.8
Female	227	49.2
Age (years)		
11	98	21.3
12	137	29.8
13	96	20.9
14	115	25.0
15	14	3.0
Ethnicity		
Kinh	143	31.1
Tay	92	20.0
Dao	139	30.2
Nung	76	16.5
Others (Thai, Cao Lan, San Diu...)	10	2.2

study participants were reassured by the researchers that their names would not be recorded or mentioned in this study. Written informed consent from each participant was obtained before data collection by explaining the purpose and methods of the study, as well as the risks and benefits of participation in the study. For participants under 18 years of age, consent was obtained from their parents or legal guardians.

RESULTS

Table 1 presents the sociodemographic characteristics of the study participants (*N*=460). Gender distribution was nearly equal, with males comprising 50.8% (*n*=233) and females 49.2% (*n*=227). The age distribution revealed that the largest proportion of participants was 12 years old (29.8%), followed by those aged 14 (25.0%), 11 (21.3%), 13 (20.9%), and a smaller group of 15-year-olds (3.0%). Ethnicity was diverse, with Kinh (31.1%) and Dao (30.2%) as the largest groups, followed by Tay (20.0%), Nung (16.5%), and other ethnicities (e.g., Thai, Cao Lan, San Diu) (2.2%). This demographic distribution highlighted a balanced gender composition and a concentration of participants in younger age brackets, with substantial ethnic heterogeneity.

Table 2 outlines the distribution of malnutrition status by age among the study population. Stunting prevalence was highest at age 13 (11.5%) and lowest at age 11 (4.1%). Thinness was most prominent at age 14 (12.2%) and absent at age 15. The co-occurrence of stunting and thinness was minimal (0.8%), with sporadic cases in ages 12–14 years. The majority of participants were classified as normal (77.4%), with proportions ranging from 74.0% (age 13) to 92.9% (age 15). Overweight status peaked at age 11 (12.2%) but was absent at age 15. These findings indicated age-specific variations, with higher malnutrition (stunting and thinness) at ages 13–14 years and greater overweight prevalence in younger participants.

Figure 1 presents the distribution of nutritional status by gender. Stunting was higher in females (8.8%) than males (5.6%), while thinness (9.0% vs. 7.1%) and overweight (8.6% vs. 4.8%) were more prevalent in males.

Table 2. Malnutrition status distribution among students by age group (*N*=460)

Nutritional status	n (%)					
	11 years (n=98)	*12 years (n=137)*	*13 years (n=96)*	*14 years (n=115)*	*15 years (n=14)*	*Total (n=460)*
Stunting	4 (4.1)	10 (7.3)	11 (11.5)	7 (6.1)	1 (7.1)	33 (7.2)
Thinness	6 (6.1)	9 (6.6)	8 (8.3)	14 (12.2)	0 (0.0)	37 (8.1)
Both forms†	0 (0.0)	2 (1.5)	1 (1.0)	1 (0.8)	0 (0.0)	4 (0.8)
Normal	76 (77.6)	108 (78.8)	71 (74.0)	87 (75.7)	13 (92.9)	355 (77.2)
Overweight	12 (12.2)	8 (5.8)	5 (5.2)	6 (5.2)	0 (0.0)	31 (6.7)

†Students classified as both stunted (HAZ<-2 SD) and thin (BAZ<-2 SD)

These differences were not statistically significant (Fisher's Exact Test, $p>0.05$). The co-occurrence of stunting and thinness was minimal and similar across genders (0.8% in males, 0.9% in females). Most participants fell within the normal category, with females (78.4%) slightly surpassing males (76.0%). Overweight was notably higher in males (8.6%) compared to females (4.8%). These findings highlighted gender-based differences in malnutrition, with females experiencing a higher stunting prevalence and males exhibiting higher thinness and overweight prevalences.

Table 3 presents the distribution of nutritional status among students by ethnicity. Stunting was most prevalent among the Dao ethnic group (9.4%) and least among the Nung (3.9%) and Tay groups (4.3%). Thinness showed a similarly high prevalence in the Dao (10.8%) and Kinh (10.5%) groups, with the highest occurrence in the "others" category (20.0%), while lowest in the Nung group (1.3%). The co-occurrence

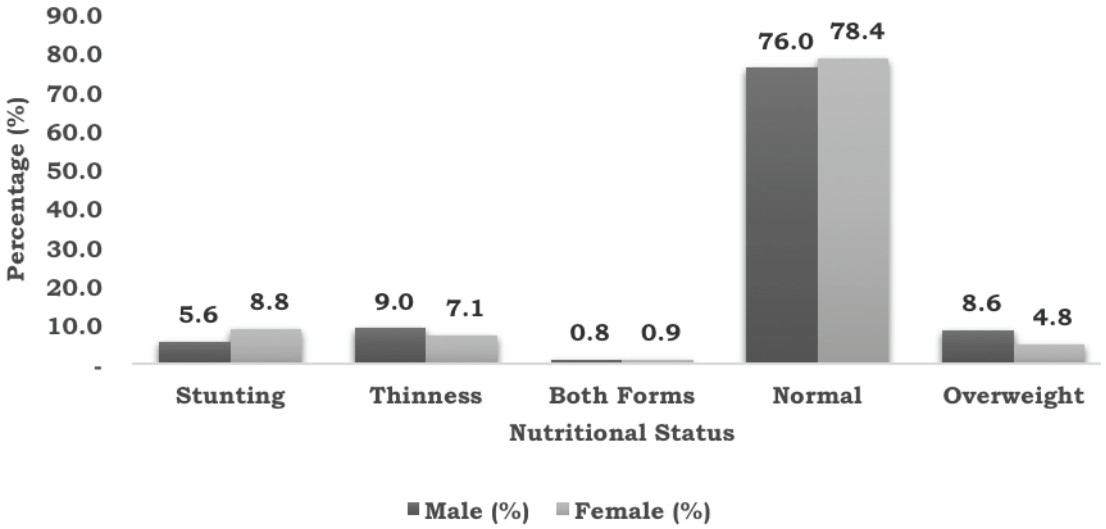

Figure 1. Distribution of nutritional status by gender
No statistically significant difference was observed between males and females (Fisher's exact test, $p>0.05$). Fisher's exact test was used due to small expected cell counts in the "Both forms" category.
"Both forms" indicates the co-occurrence of stunting and thinness in the same individual.

Table 3. Nutritional status distribution among students by ethnic group (*N*=460)

Nutritional status	*n (%)*					
	Kinh (n=143)	*Tay (n=92)*	*Dao (n=139)*	*Nung (n=76)*	*Others (n=10)*	*Total (n=460)*
Stunting	12 (8.4)	4 (4.3)	13 (9.4)	3 (3.9)	1 (10.0)	33 (7.2)
Thinness	15 (10.5)	4 (4.3)	15 (10.8)	1 (1.3)	2 (20.0)	37 (8.1)
Both forms†	1 (0.7)	0 (0.0)	2 (1.4)	1 (1.3)	0 (0.0)	4 (0.8)
Normal	105 (73.4)	78 (84.8)	101 (72.6)	65 (85.6)	7 (70.0)	356 (77.2)
Overweight	10 (7.0)	7 (7.6)	8 (5.8)	6 (7.9)	0 (0.0)	31 (6.7)

†Students classified as both stunted (HAZ<-2 *SD*) and thin (BAZ<-2 *SD*)
No statistically significant difference was found across ethnic groups (Fisher's exact test, $p>0.05$); Fisher's exact test was used due to small expected cell counts in categories such as "Both forms" and the "Others" ethnic group.

of stunting and thinness was minimal, with small proportions seen in the Dao (1.4%) and Nung (1.3%) groups. Normal nutritional status was highest in the Nung (85.6%) and Tay (84.8%) groups. At the same time, overweight prevalence was comparable across groups, ranging from 5.8% (Dao) to 7.9% (Nung), except for the absence of overweight cases in the "others" category. These findings highlighted ethnic disparities, with the Dao and "others" groups exhibiting higher malnutrition burdens, particularly stunting and thinness. No statistically significant differences were found across ethnic groups for stunting, thinness, normal, and overweight categories (Fisher's Exact Test, $p>0.05$).

Table 4 explores the relationship between household, family, and lifestyle characteristics with malnutrition status using univariate logistic regression. Compared to students from 'not poor' households, those from 'poor/near poor' households had a higher prevalence of malnutrition (5.9% vs. 9.3%), but this difference was not statistically significant (*OR*=1.41, 95% *CI*: 0.834–2.39, $p=0.199$). Families with mothers who were illiterate or with primary school education showed significantly higher odds of malnutrition compared to those with secondary school or higher education (*OR*=1.88, 95% *CI*: 1.09–3.23, $p=0.026$). No significant associations were found for the number of children in the family (reference: 3 or more children; *OR*=1.31, $p=0.349$), main family income source [reference: Others (Labour/ Business/State Salary); *OR*=1.41, $p=0.195$], physical activity (reference: ≥60 minutes/day; *OR*=1.35, $p=0.248$), or daily sleep duration (reference: ≥8 hours/day; *OR*=0.70, $p=0.218$), with *p*-values exceeding 0.05.

DISCUSSION

This study highlighted the persistent challenge of malnutrition among secondary school students in northern mountainous Vietnam, where socioeconomic and cultural disparities are pronounced. The results indicated a stunting prevalence of 7.2% and thinness prevalence of 8.1%, with stunting peaking at age 13 and thinness highest at age 14. This emphasises the critical importance of addressing nutritional deficits during early adolescence, a rapid growth and development period. Compared to recent national data from the General Nutrition Survey (GNS) 2020, stunting prevalence (7.2%) was lower than undernutrition (stunting and/or thinness) (17.3%) among female adolescents aged 10–18 years, though this national figure included urban

Table 4. Associations between household, family, and lifestyle characteristics and malnutrition status (*N*=460)

Characteristics	*Malnutrition, n (%)*		*OR*	*95% CI*	*p-value*
	Yes	*No*			
Household condition					
Poor/Near poor	27 (18.4)	120 (81.6)	1.41	0.834 - 2.39	0.199
Not poor	43 (13.7)	270 (86.3)	1		
Number of children in family					
1-2 children	51 (16.3)	262 (83.7)	1.31	0.74 - 2.31	0.349
≥ 3 children	19 (12.9)	128 (87.1)	1		
Mother's education level					
Illiterate/Primary school	25 (21.9)	89 (78.1)	1.88	1.09 - 3.23	0.026*
Secondary school or higher	45 (13.0)	301 (87.0)	1		
Main family income source					
Farming	28 (18.3)	125 (81.7)	1.41	0.83 - 2.39	0.195
Others (Labour/Business/State Salary)	42 (13.7)	265 (86.3)	1		
Physical activity duration					
< 60 minutes/day	30 (17.8)	139 (82.3)	1.35	0.77 – 2.33	0.248
≥ 60 minutes/day	40 (13.7)	251 (86.3)	1		
Daily sleep duration					
< 8 hours/day	21 (12.5)	147 (87.5)	0.70	0.38-1.26	0.218
≥ 8 hours/day	49 (16.8)	243 (83.2)	1		

Logistic regression was used to calculate odds ratio (*OR*), 95% confidence intervals (*CI*), and *p*-values

*5% significance level ($p<0.05$, statistically significant)

areas where undernutrition is typically lower (Tan *et al.*, 2025). The prevalence of thinness in this study (8.1%) aligned more closely with the national trends for this age group. Overweight prevalence in our study (6.7%) was notably lower than the national figure of 27.1% (19.0% overweight, 8.1% obese) for children aged 5–19 years, reflecting the lower obesity risk in rural, mountainous regions compared to urban areas, where it reaches 26.8%. Gender differences were observed, with females more prone to stunting (8.8%), while males exhibited higher rates of thinness (9.0%) and overweight (8.6%). However, these differences were based on observed percentages and may not be statistically significant. Among ethnic groups, students from the Dao community demonstrated the highest prevalence of stunting (9.4%) and thinness (10.8%). This pattern may be influenced by multiple socio-cultural and environmental factors unique to the Dao population.

Traditional Dao diets, like those of many ethnic minorities in northern mountainous Vietnam, are high in carbohydrates (e.g., rice, corn, cassava) and low in protein, relying on small quantities of pork, chicken, or tofu, consumed infrequently. Meals commonly lack dietary diversity, with vegetables such as bamboo shoots, mustard greens, or wild plants included more for satiety than nutritional value. Dairy products, fruits, and fortified foods are rarely consumed due to cost, availability, or cultural unfamiliarity.

Meals are usually eaten twice daily, often with minimal variation throughout the week. These factors, combined with food taboos (e.g., avoidance of eggs or certain meats during illness or pregnancy), contribute to persistent micronutrient deficiencies and poor growth outcomes in Dao adolescents. Cultural beliefs and food taboos may further restrict dietary diversity, particularly among adolescent girls.

Determinants of malnutrition

Although household economic status was not significantly associated with malnutrition in our analysis *(p*=0.199), students from "poor" or "near poor" households showed a higher proportion of malnutrition. This trend aligns with findings from other regions, such as northern Uganda, where economic constraints are often linked to undernutrition (Omona *et al.*, 2020). While the association in this study was not statistically significant, the observed trend suggests that financial hardship may still play a role and warrants further investigation using larger or multi-site datasets. Additionally, some subgroups in the logistic regression analysis, such as "≥3 children in family" (19 malnourished cases), "illiterate/primary school" maternal education (25 cases), and "<8 hours/day" sleep duration (21 cases), had relatively small numbers of malnourished children. These small-sized subgroups may affect the stability of the estimated odds ratios and contribute to wider confidence intervals, potentially limiting the precision of these findings.

Findings from other regions also highlighted the impact of maternal education on child nutrition. For example, a study in East Nusa Tenggara Province, Indonesia, reported that low maternal education significantly contributed to stunting among children under five (Suratri *et al.*, 2023). These findings align with the national trends in Vietnam, where ethnic minority adolescents face significant dietary challenges (Tan *et al.*, 2025). In our study, maternal education emerged as a substantial determinant, with secondary school students of mothers who attained only primary or no education facing substantially higher risks of malnutrition (*OR*=1.88, *p*=0.026). Notably, this association may contribute more to overweight than underweight, as lower maternal education often correlates with limited health knowledge and poorer food choices, such as increased reliance on cheap, energy-dense ultra-processed foods, which are increasingly available even in rural areas. This may elevate overweight risk, particularly among males (8.6% vs. 4.8% in females), while undernutrition persists due to systemic barriers like limited dietary diversity. This underscores the critical role of maternal education in breaking intergenerational cycles of poor nutritional outcomes, a trend observed globally.

Ethnic disparities in malnutrition, as observed in the Dao group, align with findings from other populations where ethnicity significantly influences nutritional outcomes. A study in Nepal found that disadvantaged ethnic groups, including Dalits and Janajatis, exhibited significantly higher rates of malnutrition and risk of malnutrition compared to more advantaged groups, mainly due to socioeconomic constraints, dietary limitations, and healthcare access disparities (Subedi *et al.*, 2023). Similarly, in Vietnam, findings are consistent with national research showing that ethnic minorities, including the Dao, often experience lower diet quality and reduced access to essential health services, regardless of reported income levels (Le *et al.*, 2023; Nguyen, Nguyen & Nguyen, 2022). These communities often rely on subsistence agriculture with limited market access,

resulting in low dietary diversity and seasonal food insecurity. Disposable income is typically constrained, reducing their ability to purchase protein-rich or fortified foods. In addition, remote locations hinder access to healthcare facilities and nutrition services, while language barriers and low literacy rates limit the effectiveness of health communication. Traditional beliefs may also influence food taboos, especially for children and women. These factors contribute to persistent disparities in nutritional outcomes compared to the Kinh and other majority groups. Addressing these disparities requires culturally sensitive and locally tailored interventions that respect and integrate traditional food practices, beliefs, and socioeconomic conditions, while also accounting for language barriers and logistical challenges to healthcare access.

This study also aligns with global evidence on the double burden of malnutrition, a phenomenon where undernutrition coexists with rising overweight and obesity rates. This dual challenge has been observed among ethnic minority secondary school students in mountainous areas of Vietnam, where socioeconomic changes and shifts in dietary behaviour contribute to imbalanced nutritional outcomes (Truong *et al.*, 2022). A recent study on school-aged children in these regions identified significant associations between malnutrition and nutritional habits, including frequent consumption of energy-dense, nutrient-poor foods and limited dietary diversity (Truong *et al.*, 2022). Consistent with this evidence, our study found that overweight prevalence was higher among younger adolescents (12.3% among 11-year-olds), particularly males, which may reflect early exposure to processed, calorie-dense foods and reduced physical activity. In Vietnam, rapid urbanisation and dietary shifts towards Westernised, convenience-orientated foods have been linked to increased obesity and poor dietary quality among youth and adults (Umberger, Rupa & Zeng, 2020). These changing food environments increase access to ultra-processed snacks and beverages, contributing to overnutrition in some groups, while undernutrition persists in others due to socioeconomic constraints.

Strategies for addressing malnutrition

The findings of this study have important implications for public health policy and practice. Research indicates that early-life risk factors, including a family history of obesity and maternal BMI, are positively associated with BMI trajectories throughout childhood and adolescence, underscoring the need for early interventions (Börnhorst *et al.*, 2023). Thus, targeted interventions should address age-specific vulnerabilities, particularly during early adolescence. Culturally tailored nutrition programmes, school-based interventions, and maternal education initiatives remain essential to addressing ethnic and gender disparities in malnutrition. However, implementing these strategies, especially in remote and underserved areas, faces several barriers. Limited funding for school nutrition programmes, inadequate teacher training on health promotion, and poor infrastructure (e.g., lack of kitchen, storage, or transport for food supplies) can hinder programme effectiveness (Hoffman *et al.*, 2018). Teachers and health staff may also lack the time or expertise to deliver nutrition content. Acknowledging these challenges is vital for developing realistic, sustainable, and context-specific solutions.

Gender-specific strategies are essential. Studies have shown that sugar-containing beverages and free

sugars increase the risk of overweight and obesity in secondary school students and adolescents, with potential variations in impact between genders (Fidler Mis *et al.*, 2017). Evidence indicates that consumption of ultra-processed foods (UPF) varies significantly across sociodemographic groups, with gender, economic status, and ethnicity playing key roles. In Vietnam, adolescents from higher-income families often consume more UPF, such as instant noodles, sugary drinks, and packaged snacks, due to greater disposable income and exposure to convenience-orientated diets. Males may consume more frequently due to larger portions and looser dietary supervision. In contrast, ethnic minority adolescents typically follow simpler meal patterns, with 2–3 daily meals based on rice, boiled vegetables, and fermented products. However, the increased availability of cheap UPF is shifting eating habits even in remote areas. A study in rural Bangladesh found that boys had significantly higher odds of consuming ultra-processed and deep-fried foods than girls, and secondary school students from wealthier households were more likely to consume ready-to-eat processed foods (Islam *et al.*, 2022). Implementing these targeted, gender-specific, and culturally sensitive strategies can effectively address the multifaceted challenges of malnutrition across diverse populations.

Maternal education should be a focal point of intervention strategies. In Vietnam, informal maternal education plays a crucial role in child health, but formalising these efforts with culturally and linguistically inclusive approaches could amplify their impact. Community-based training initiatives, mobile health (mHealth) tools, and multilingual materials can improve maternal literacy and nutrition awareness, particularly in ethnic minorities (Suratri *et al.*, 2023). Thus, programmes that empower women through education and awareness about nutrition and health should incorporate visual-based learning, multilingual materials, and community health workers fluent in local dialects to ensure accessibility for populations with diverse language and literacy levels. These tailored strategies can maximise the cascading benefits for children's well-being (Nguyen *et al.*, 2022). Furthermore, economic empowerment initiatives and poverty alleviation programmes are critical to reducing household-level vulnerabilities contributing to malnutrition. Enhancing access to clean water and sanitation should also be prioritised to prevent nutrition-related illnesses.

Schools represent a critical platform for delivering cost-effective and sustainable nutritional interventions. To enhance their impact, policymakers should integrate nutrition education into school curricula and implement teacher training programmes focused on adolescent health and nutrition. Allocating resources for locally sourced school meal programmes can improve dietary diversity while supporting community agriculture. In addition, establishing sustainable funding models, such as government-non-profit partnerships or district-level nutrition budgets, can help ensure programme continuity. Healthcare providers should collaborate with schools to offer regular nutrition counselling for students and parents.

At the policy level, multi-sectoral collaboration is essential to address malnutrition effectively. Governments, non-governmental organisations, and community stakeholders must work together to overcome structural and systemic barriers to nutrition

equity. Evidence suggests that such collaborations can improve health outcomes and reduce health inequalities (Alderwick *et al.*, 2021). Policies should aim to improve infrastructure, increase funding for nutrition programmes in rural schools, and strengthen healthcare systems to ensure regular growth monitoring and interventions for at-risk adolescents. Lessons from Ethiopia's National Information Platform for Nutrition (NiPN) highlighted how multi-sectoral collaboration—integrating agriculture, health, and education sectors—can enhance nutrition governance and data-driven policymaking (Zerfu *et al.*, 2024). Similarly, in Southeast Asia, the Dekthai Kamsai programme in Thailand successfully reduced both stunting and obesity among school-aged children through a multi-sectoral school-based intervention that integrated dietary guidelines, physical activity promotion, and anthropometric monitoring, supported by collaboration across health, education, and community sectors. While context-specific, such integrated approaches could be adapted to address the double burden of malnutrition in Vietnam's northern mountainous regions. By fostering collaborations across sectors and implementing comprehensive policies, it is possible to create an environment that supports nutrition equity and addresses the multifaceted challenges of malnutrition.

Strengths and limitations

This study has several notable strengths. It provided valuable insights into adolescent malnutrition in a geographically and ethnically under-represented region of Vietnam. Using the WHO growth standards and standardised anthropometric measurements has enhanced the reliability of nutritional assessments. Including a large sample size with high participation rate (N=460) also strengthened the representativeness of findings within the study setting. Moreover, integration of the study's socioeconomic, behavioural, and demographic variables allowed for a comprehensive analysis of potential risk factors. By focusing on secondary school students, an age group often overlooked in national surveys, this study filled a critical gap in the literature. It can inform future public health and education policy interventions in similar contexts.

A key limitation of this study is the reliance on univariate logistic regression, which does not account for potential confounding variables. Multivariate analysis was considered but not performed due to sample size constraints and potential multicollinearity among variables such as household economic status, maternal education, and ethnicity. Future studies with more extensive and diverse samples should explore multivariable models to isolate independent effects better. Additionally, physical activity and sleep duration data were self-reported, which may introduce recall and social desirability biases, potentially affecting the accuracy of these findings. Adolescents may have over-reported physical activity or sleep to align with perceived norms (e.g., WHO guidelines of ≥60 minutes/day MVPA or ≥8 hours/day sleep). In addition, no specific measures, such as validated questionnaires (e.g., the International Physical Activity Questionnaire) or recall aids (e.g., diaries), were employed to mitigate these biases. Similarly, self-reported socioeconomic data, including household condition and maternal education, may be subjected to underreporting biases, particularly in this rural, ethnic minority context where stigma around illiteracy or incentives

to access aid (e.g., reporting as "poor/near poor") could influence responses. While parental input was sought for socioeconomic data to enhance accuracy, the lack of formal reliability checks or triangulation with external records limits confidence in these reports. Future studies should employ validated tools and cross-verification methods to improve the reliability of self-reported data. Lastly, as this study was conducted in a single secondary school in Yen Bai Province, the findings may not be generalisable to all regions or ethnic populations in northern Vietnam.

CONCLUSION

This study underscored the complex determinants of malnutrition among secondary school students in northern mountainous Vietnam. Governments should fund and establish school-based screening programmes while fostering multi-sectoral collaboration across health, education, and agriculture sectors to address systemic barriers. Local schools should implement regular anthropometric screenings to identify at-risk students early and integrate tailored nutrition education into curricula, addressing cultural dietary practices and gender-specific risks, such as higher overweight prevalence in males. Healthcare providers should expand community-based nutrition counselling for ethnic minority groups and collaborate with schools to follow-up on screening results, ensuring targeted interventions for both undernutrition and overnutrition. Community stakeholders and non-governmental organisations (NGOs) should support culturally sensitive maternal education programmes to break intergenerational cycles of poor nutrition. These efforts require a holistic approach integrating healthcare, education, community engagement, and targeted socioeconomic policies to improve adolescent nutrition outcomes.

Future research should include longitudinal studies to track nutritional trends over time and intervention-based studies to evaluate the effectiveness of these strategies, providing a stronger evidence base for addressing malnutrition in similar settings. By implementing culturally sensitive, context-specific interventions, nutritional outcomes can be improved, health inequities reduced, and the cycle of poverty and malnutrition disrupted in these vulnerable communities. The findings contribute to a growing body of evidence advocating for global targeted and comprehensive strategies to address malnutrition.

Acknowledgement

We sincerely thank all the students, parents, and staff of Bao Ai Secondary School, Yen Binh District, Yen Bai Province, who participated and supported the data collection process. This study would not have been possible without their valuable contributions. No external funding was received for this research.

Authors' contributions

Anh TH, conceptualised and designed the study, performed data analysis, and wrote the manuscript; Dung TM, supervised the study, assisted in data interpretation, and reviewed the manuscript; Anh VT, Sinh PT, and Huong VM, contributed to data collection, curation, and drafting of the manuscript; Hung LX, guided the study design, coordinated the research process, provided statistical expertise, and critically reviewed and edited the manuscript.

Conflict of interest

The authors declare no conflicts of interest regarding the publication of this study.

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