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Dietary factors influencing iron and zinc status of female adolescents in the Philippines

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ABSTRACT

Introduction: Adolescence demands good nutrition, in particular iron and zinc, which are vital for cognitive development, immunity, and reproductive health. In the Philippines, female adolescents often face iron and zinc deficiencies due to poor diet and limited nutrient-rich foods. They are often neglected in public health and perpetuate the malnutrition cycle. **Methods:** This study analysed 2013 Philippine National Nutrition Survey of 1,669 non-pregnant, non-lactating female adolescents aged 10-19 years. Haemoglobin and serum zinc concentrations indicated iron and zinc status, respectively. Independent variables were dietary intakes of meat, total fat, zinc, thiamine, and riboflavin, and sociodemographic factors such as age, residence, household wealth quintile, and smoking status. Descriptive statistics, chi-square tests, independent *t*-tests, Pearson's correlations, and multiple linear regression analyses were used. **Results:** Mean haemoglobin (13.2 g/dL) and serum zinc (78.9 µg/dL) levels exceeded deficiency thresholds; however, 96.1% of adolescents did not meet the dietary iron recommendations. Serum zinc levels were significantly associated with meat (β=0.020, p=0.001), total fat (β=0.136, p<0.001), dietary zinc (β=0.678, p=0.002), thiamine (β=5.442, p=0.003), and riboflavin (β=6.838, p<0.001) intakes. Haemoglobin was weakly correlated with serum zinc levels (r=0.089, p<0.001), but not with dietary variables. **Conclusion:** Animal-sourced foods were associated with serum zinc, not haemoglobin, indicating that iron status is influenced by broader physiological and environmental factors. These findings emphasise nutrition programmes to promote dietary diversity and improve micronutrient bioavailability in Filipino adolescents.

Keywords: adolescents, haemoglobin, micronutrient deficiencies, Philippines, serum zinc

INTRODUCTION

Adolescence is marked by rapid physiological, cognitive, and reproductive changes that increase nutritional needs (WHO, 2005). Iron and zinc are vital for oxygen transport, immune functions, and cellular metabolism (Gibson, Heath & Ferguson, 2002). Globally, deficiencies in these micronutrients among adolescents lead to impaired cognitive performance, reduced physical capacity, and adverse

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pregnancy outcomes, thereby impacting individual and population health (Hess & King, 2009).

In the Philippines, iron and zinc deficiencies remain significant public health concerns. National data show that 9.6% of female adolescents are anaemic and 22.0% experience zinc deficiency. These deficiencies stem from suboptimal dietary patterns, including a high reliance on refined cereals and inadequate intake of nutrient-dense foods (DOST-FNRI, 2015; DOST-FNRI, 2022).

Female adolescents face increased physiological demands due to menstruation and reproductive maturity, which increases the risk of iron and zinc inadequacy (Roohani *et al.,* 2013). However, existing literature and nutrition programmes have focused on children under five, leaving female adolescents underrepresented in nutrition surveillance (Viner *et al.,* 2012). Structural barriers include weak intersectoral coordination, lack of culturally responsive approaches, and limited evaluative data, particularly in marginalised populations (DOH, 2013; NNC, 2017). Without targeted interventions, adolescent undernutrition perpetuates intergenerational cycles of malnutrition, affecting physical development and increasing the likelihood of low birth weight and stunting in future offspring (Black *et al.,* 2013).

The Philippine Plan of Action for Nutrition (PPAN) 2017-2022 laid the foundation for adolescent nutrition by integrating life-course principles. The updated PPAN 2023-2028 has expanded this focus by targeting adolescents through comprehensive strategies (NNC, 2023). Complementing this is the Department of Health's Administrative Order No. 2013-0013, which outlines a framework to promote adolescent health and development, emphasising the inclusion of underserved and marginalised groups (DOH, 2013).

This study analysed data from the 2013 Philippine National Nutrition Survey (NNS) to investigate the dietary determinants of iron and zinc status among female adolescents aged 10-19 years, examining associations between dietary intake patterns and biochemical markers.

METHODOLOGY

Study design and sampling

This study analysed data from the 2013 NNS of the Department of Science and Technology, Food and Nutrition Research Institute (DOST-FNRI). The 2013 NNS was chosen for its national representativeness and detailed biochemical data, including serum zinc concentration, which is a key biomarker of zinc deficiency. The inclusion of serum zinc measurements, absent in subsequent surveys, highlights the value of the 2013 dataset for evaluating micronutrient status among Filipino adolescents (DOST-FNRI, 2015).

The survey used the 2003 Master Sample of the Philippine Statistics Authority, which utilised a stratified, multi-stage probability sampling design for national and regional representativeness (Barcenas, 2004). The sampling framework collected comprehensive data on dietary intake, anthropometry, clinical and biochemical indicators, as well as sociodemographic characteristics. The detailed methodological documentation has been published elsewhere (Patalen *et al.*, 2020).

The study sample was restricted to non-pregnant, non-lactating female adolescents aged 10–19 years with complete dietary, biochemical, clinical, and sociodemographic data. The exclusion of pregnant and lactating adolescents reduced the physiological variability associated with gestation and lactation, which may confound micronutrient biomarkers. The final analytical sample comprised 1,669

female adolescents, stratified into early adolescence (10–14 years) and late adolescence (15–19 years) (Figure 1). This classification reflects established distinctions in nutritional needs, hormonal development, and growth trajectories across adolescence (Black *et al.*, 2013).

Outcome and explanatory variables

The primary outcomes of interest in this study were biochemical indicators of nutritional status, including haemoglobin and serum zinc concentrations. Haemoglobin concentration was used to assess anaemia status using World Health Organization (WHO) thresholds, with values below 12 g/dL indicating anaemia among non-pregnant adolescent females (WHO, 2005). Serum zinc level was evaluated using a cut-off of <70 µg/dL, based on the International Zinc Nutrition Consultative Group (IZiNCG) guidelines, to identify zinc deficiency risk (Gibson, King & Lowe, 2016). Laboratory procedures for both biomarkers were conducted by the DOST-FNRI as previously described (DOST-FNRI, 2015).

The explanatory variables included dietary intake indicators for energy and nutrient consumption, derived from 24-hour dietary recalls. They were analysed using the Philippine Food Composition Table (FCT), which contains 1,121 food items and nutrient profiles for 12 micronutrients. Due to limited zinc values in the local FCT, the dataset included values from the International Master List (IML) FCT and the FAO/International Network of Food Data Systems (INFOODS) database to enhance completeness.

Usual nutrient intakes were estimated using PC-SIDE software version 1.0 (Iowa State University), adjusted for intra-individual variability to produce reliable estimates of intake distributions. To address misreporting biases, methodological corrections were applied following López-Olmedo *et al.* (2016). Nutrient inadequacy was

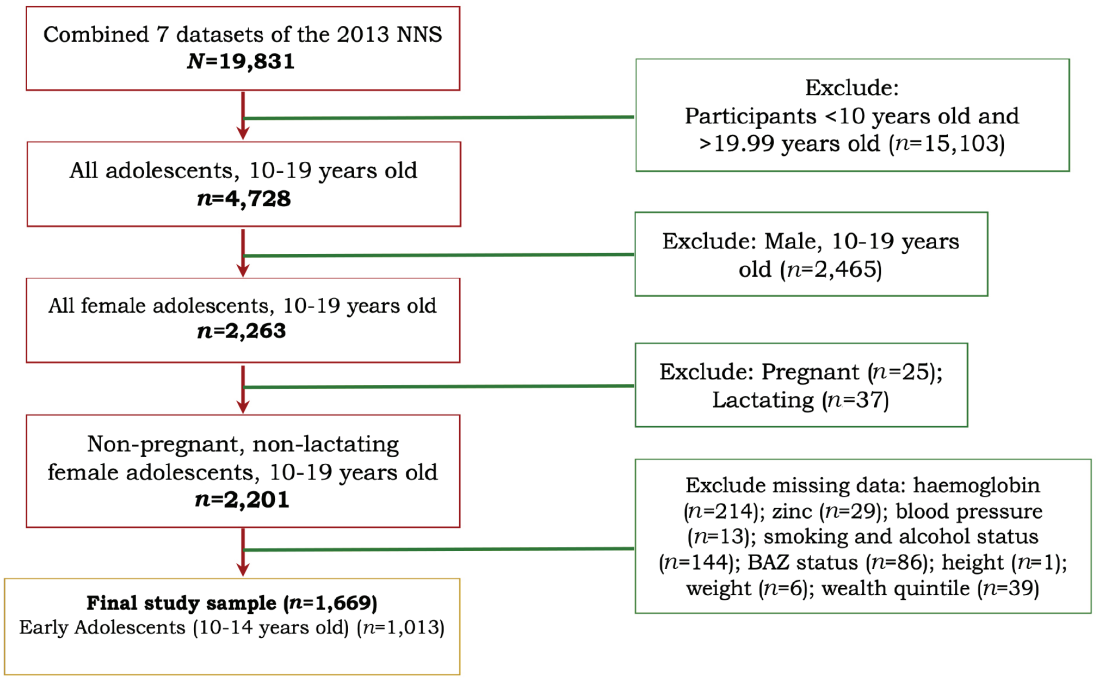

Figure 1. Flow diagram on the selection of study participants

assessed by comparing intakes to the Estimated Average Requirements (EARs) for each nutrient (Carriquiry, 1999).

Covariates included age (in years), residential classification (urban vs. rural), and ethnicity (non-indigenous people vs indigenous people). Additional covariates comprised household wealth quintiles derived through principal component analysis and physiological and lifestyle factors, including blood pressure status (normal [systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg] vs. hypertension [systolic blood pressure ≥140 mm Hg and Diastolic BP ≥90 mm Hg]), smoking status (non-smoker, former smoker, or current smoker), and alcohol use (non-drinker, former drinker, or current drinker).

Statistical analyses of independent and dependent variables

A structured analytical framework was used to examine the relationships between dietary intake, sociodemographic characteristics, and biochemical indicators of iron and zinc status among Filipino female adolescents. Descriptive statistics summarised key demographic variables (e.g., age group, residence, household wealth quintile), clinical variables (e.g., blood pressure), lifestyle variables (e.g., smoking, alcohol use), dietary variables, and biochemical variables (haemoglobin and serum zinc concentrations) to develop a population profile.

Pearson's correlation coefficients were used to assess the strength and direction of linear associations between continuous variables. Chi-square tests examined associations between categorical variables, particularly demographic and lifestyle characteristics between early and late adolescent groups. Independent sample *t*-tests were used to evaluate mean differences in dietary and biochemical indicators between age groups to identify variations in nutrient intake and biomarker levels. Multiple linear regression analyses assessed associations between dietary components, sociodemographic covariates, and two primary biochemical outcomes, namely haemoglobin and serum zinc concentrations. Survey sampling weights account for complex sampling design and selection probabilities, ensuring national representativeness. Diagnostic tests across the six model specifications assessed regression assumptions, including linearity, absence of multicollinearity, homoscedasticity, and normal distribution of residuals. Variance inflation factors (VIF) were calculated to assess potential multicollinearity among independent variables. All VIF values were <10, indicating no substantial collinearity. Standardised residual plots and normal probability plots evaluated distributional properties and detected potential outliers. A comparative evaluation demonstrated consistency of the estimated coefficients, supporting the internal validity of the regression models.

Statistical analyses were conducted using STATA version 15 (StataCorp, 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). Statistical significance was set at a two-sided *p*-value of <0.05. Ethical exemption for secondary data analysis was granted by the University of the Philippines Los Baños Research Ethics Board (UPLB REB), Los Baños, Laguna, Philippines (Protocol Code: UPLB REB-2023-0037).

RESULTS

Sociodemographic, clinical, and lifestyle characteristics of Filipino female adolescents

Table 1 presents the demographic, clinical, and lifestyle characteristics of 1,669 non-pregnant, non-lactating Filipino female adolescents aged 10–19 years, stratified by developmental stage: early (10–14 years) and late adolescence (15–19 years). Early adolescents

Table 1. Sociodemographic, clinical, and lifestyle characteristics of Filipino female adolescents by age group (*N*=1,699)

Characteristics	*All adolescents*		*Early adolescents*		*Late adolescents*	
	n	*%*	*n*	*%*	*n*	*%*
Age	1669	100.0	1013	59.0	656	41.0
Ethnicity						
Non-indigenous people	1524	93.0	922	92.9	602	93.3
Indigenous people	145	7.0	91	7.1	54	6.7
Place of residence						
Urban	982	51.2	612	53.2	370	48.4
Rural	687	48.8	401	46.8	286	54.6
Wealth quintile						
Poorest	441	23.4	296	26.4	145	19.0
Poor	396	22.5	249	23.5	147	21.1
Middle	347	20.7	205	20.5	142	21.1
Rich	262	16.4	143	14.9	119	18.5
Richest	223	17.0	120	14.7	103	20.2
Blood pressure						
Normal Systolic BP <140 mm Hg and Diastolic BP <90 mm Hg	1657	99.3	1010	99.7	647	98.8
Hypertension, Systolic ≥140 mm Hg and Diastolic BP ≥90 mm Hg	12	0.7	3	0.3	9	1.2
Smoking status						
Non-smoker	1607	95.8	995	98.1	612	92.5
Current smoker	14	0.9	4	0.4	10	1.7
Former smoker	48	3.3	14	1.5	34	5.8
Alcohol status						
Non-alcohol drinker	1448	85.1	957	94.1	491	72.1
Current alcohol drinker	160	11.0	36	3.7	124	21.4
Former alcohol drinker	61	3.9	20	2.2	41	6.5

comprised 59.0% of the sample, compared to late adolescents (41.0%).

Regarding ethnicity, 7.0% were identified as indigenous people, with no substantial differences across age groups. Half of the sample resided in urban areas (51.2%), with early adolescents being more urban-based (53.2%) than their older counterparts (48.4%). Socioeconomic distribution showed that early adolescents were concentrated in the poorest quintile (26.4%) compared to late adolescents (19.0%), while the latter had a higher representation in the richest quintile (20.2% vs. 14.7%), suggesting that socioeconomic differences may intersect with age-related transitions.

Nearly all participants had normal blood pressure, with elevated readings in 0.7% of the sample. Hypertension was more prevalent among late adolescents (1.2%) than early adolescents (0.3%), reflecting age-related increases in cardiovascular risk indicators (Bloetzer *et al.,* 2015).

Lifestyle behaviours differed by age. While most adolescents were non-smokers (95.8%), late adolescents reported more current (1.7%) or former (5.8%) smokers than early adolescents (0.4% and 1.5%, respectively). Late

adolescents also reported higher rates of alcohol use, with 21.4% currently drinking and 6.5% reporting past use, versus only 3.7% and 2.2%, respectively, among early adolescents. These patterns align with global trends of increasing risk behaviours during later adolescence (Johnston *et al.*, 2020; WHO, 2005), which may cause nutritional vulnerabilities.

Disaggregation by age group underscores the heterogeneity of adolescent experiences in the Philippines and highlights the factors that may influence nutritional outcomes.

Food group contributions to daily intake among Filipino female adolescents

Total daily food consumption averaged 607.0 grams, with variation across food groups. Cereal and cereal products were predominant, accounting for 51.4% of the total food consumed and 73.8% of total energy intake. This reliance on refined cereals showed the dominance of staple grains in the Filipino diet, reflecting a high energy density but limited micronutrient diversity. Such dietary profiles meet caloric needs but fail to fulfil the elevated micronutrient demands of adolescence, contributing to "hidden hunger".

Animal-sourced foods, including meat and meat products (10.3%) and fish and shellfish (6.8%), contributed moderately to food weight. These groups contain bioavailable haem iron, zinc, and high-quality protein, yet only half of the population consumed them. Dairy products contributed less than 1.0% to energy and quantity, highlighting low dairy consumption.

Fruits and vegetables intake was low, averaging 20.6 g and 36.3 g per day, contributing 1.4% and 1.0%, respectively, to energy intake – far below the WHO-recommended 400 g per day (WHO, 2020). This affected dietary fibre, vitamin C, folate, and provitamin A carotenoid contents.

Non-alcoholic beverages (12.3% of food weight; 3.3% of energy) and sugars/confectioneries (2.3% of food weight; 1.5% of energy) indicated a high intake of low-nutrient items. Fats and oils contributed 0.9% of food weight but 2.5% of total energy, reflecting their energy density.

Food group distribution showed a carbohydrate-heavy diet with inadequate fruit, vegetable, and animal-sourced food intakes, contributing to multiple micronutrient inadequacies and reflecting food environment constraints in low- and middle-income settings.

Age-stratified differences in food group intake among Filipino female adolescents

Significant differences were observed in two food groups. Vegetable consumption was higher among late adolescents (mean: 71.2 g/day) than early adolescents (59.4 g/day; p=0.009). Although both groups remained below the WHO-recommended intake of 400 g per day, the higher intake in older adolescents may indicate enhanced food autonomy, dietary awareness, or household food provisioning aligned with nutritional needs.

Early adolescents consumed more sugar, syrup, and confectionery products (32.1 g/day) than late adolescents (22.7 g/day; p=0.046). This difference may be attributed to the preference for sweetened snacks among younger adolescents, coupled with exposure to school-based processed food environments and reduced dietary regulation.

A marginally significant difference was observed for meat products, with late adolescents consuming more (125.1 g/day) than early adolescents (110.6 g/day; p=0.085). Although not meeting conventional significance thresholds, this suggests a trend associated with increased nutritional requirements and greater decision-making capacity over food choices.

No significant differences were found for other food groups, including cereals, fish and shellfish, fruits, eggs, dairy, fats and oils, fish, legumes, non-alcoholic beverages, and starchy roots. Cereals remained the most consumed food group across both age strata, contributing over 300 g/day, showing reliance on refined grains as a dietary staple.

These findings reflect age-related shifts in dietary quality, notably increased intake of vegetables and meats, among late adolescents. Despite these differences, inadequacies in key food groups remained evident across both age groups, indicating a limited dietary diversity. Higher consumption of sugar-rich foods observed among early adolescents may indicate distinct preferences during this developmental stage. This pattern is notable, given its association with long-term cardiometabolic outcomes, as documented in previous studies (Bloetzer *et al.,* 2015).

Energy and nutrient intakes and inadequacy among female adolescents

Table 2 presents the mean nutrient intake and prevalence of inadequate energy and selected nutrients among Filipino female adolescents by age group. The average energy intake was 1,551 kcal/day, which was substantially below the recommended levels. Energy inadequacy affected 85.5% of the participants, with similar rates among early (86.6%) and late (86.4%) adolescents (p=0.301), indicating uniform caloric shortfalls across ages.

Macronutrient distribution showed near-universal adequacy for protein and carbohydrates, with only 0.2% and 0.7% inadequacy,

Table 2. Usual energy and nutrient intakes and prevalence of inadequacy among female adolescents by age group

Nutrients	*All adolescents*		*Early adolescents*		*Late adolescents*		*p-value*
	Mean±SE	*Prevalence of inadequacy (%)*	*Mean±SE*	*Prevalence of inadequacy (%)*	*Mean±SE*	*Prevalence of Inadequacy (%)*	
Energy (kcal)	1551±14	85.5	1542±21	86.6	1576±26	86.4	0.301
Carbohydrates (g)	276.5±2.6	0.7	276.5±3.9	2.8	278.3±4.9	5.8	0.779
Protein (g)	46.9±0.4	0.2	45.8±0.6	0.1	49.1±0.8	0.3	0.001*
Fat (g)	28.1±0.3	48.0	27.8±0.7	49.7	29.1±0.8	50.8	0.249
Iron (mg)	8.2±0.1	96.1	8.2±0.1	98.1	8.3±0.2	95.9	0.653
Zinc (mg)	5.4±0.1	45.1	5.3±0.1	54.9	5.5±0.1	51.5	0.219
Calcium (mg)	288.9±2.5	92.9	288.8±5.9	95.1	286.4±6.3	95.3	0.787
Niacin (mg)	14.5±0.1	23.1	14.2±0.2	32.5	15.3±0.3	27.0	0.005*
Riboflavin (mg)	0.59±0.01	88.2	0.6±0.01	86.5	0.6±0.01	88.4	0.648
Thiamine (mg)	0.72±0.01	70.9	0.7±0.01	74.3	0.7±0.01	74.4	0.484
Vitamin A (mcg RE)	449.1±17.8	68.0	438.9±27.8	75.1	465.3±41.9	76.7	0.585
Vitamin C (mg)	19.8±0.2	98.7	20.3±0.9	92.1	19.0±1.0	92.8	0.353

SE: Standard Error
*Correlation is significant at p<0.05

Table 3a. Nutrient contributions of major food groups to energy, macronutrient, and micronutrient intakes among female adolescents by age group

Food groups	*% Energy*		*% Protein*		*% Carbohydrates*		*% Total Fat*		*% Fibre*		*% Total Sugar*		*% Sodium*		*% Calcium*	
	Early	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*
Cereals and products	71.4	70.7	50.3	47.5	85.9	86.1	26.8	25.4	65.1	66.2	26.3	27.3	43.7	45.3	34.2	36.6
Combination foods/ mixed dishes	0.3	0.2	0.2	0.2	0.3	0.3	0.1	0.1	0.3	0.6	0.7	0.6	0.2	0.3	0.4	0.4
Condiments and spices	0.3	0.3	0.3	0.3	0.3	0.4	0.1	0.1	0.5	0.6	1.7	2.4	7.5	8.3	1.8	1.5
Eggs and products	1.0	1.0	2.8	2.7	0.1	0.1	3.5	3.5	0.0	0.0	0.1	0.2	1.5	1.7	1.3	1.3
Fats and oils	2.7	2.8	0.1	0.1	0.0	0.0	15.5	16.2	0.3	0.3	0.0	0.0	0.3	0.2	0.1	0.1
Finfish, shellfish, and other aquatic animals and products	3.0	3.0	17.1	16.5	0.1	0.1	4.5	4.6	0.1	0.2	0.1	0.1	16.0	15.1	21.0	21.3
Fruits and products	1.8	1.3	0.6	0.4	2.2	1.6	1.2	0.7	6.8	5.0	14.0	9.9	0.3	0.2	4.7	2.6
Meat and other animals and products	10.1	11.0	21.7	26.2	0.9	0.8	39.9	41.7	2.3	1.4	6.0	5.6	24.8	23.0	7.5	10.6
Milk and products	1.1	0.8	1.6	1.1	0.5	0.3	2.9	2.2	0.2	0.1	4.4	3.2	1.7	1.6	8.7	6.3
Miscellaneous	0.2	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.5	0.2	0.5	0.7	0.1	0.7	0.9	0.5
Non-alcoholic beverages	3.4	4.5	0.8	0.9	4.4	6.0	1.1	1.2	2.3	1.7	21.6	29.2	1.7	1.8	6.4	5.3
Nuts, dried beans, seeds and products	1.0	1.0	2.2	1.9	0.6	0.7	1.6	1.8	6.5	7.6	0.8	1.0	0.6	0.4	2.4	1.4
Starchy roots, tubers and products	1.3	1.0	0.4	0.3	1.4	1.1	1.7	1.1	4.4	3.3	2.3	1.0	0.9	0.7	2.0	1.5
Sugar, syrup and confectionery	1.6	1.1	0.2	0.2	2.1	1.4	0.6	0.8	0.3	0.4	18.1	13.2	0.2	0.3	2.0	1.9
Vegetables and products	0.9	1.1	1.6	1.7	0.8	1.1	0.4	0.5	10.3	12.4	3.3	4.8	0.6	0.6	6.4	8.7

Table 3b. Nutrient contributions of major food groups to energy, macronutrient, and micronutrient intakes among Filipino female adolescents by age group

Food groups	*% Phosphorus*		*% Iron*		*% Thiamine*		*% Riboflavin*		*% Niacin*		*% Vitamin C*		*% Vitamin A*		*% Zinc*	
	Early	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*	*Early*	*Late*
Cereals and products	59.4	58.3	52.3	53.3	56.7	55.5	34.8	36.0	54.5	51.7	1.6	3.7	7.7	6.6	47.7	46.2
Combination foods/ mixed dishes	0.2	0.2	0.2	0.2	0.2	0.1	0.4	0.4	0.1	0.1	0.0	0.0	0.1	0.3	0.2	0.7
Condiments and spices	0.4	0.3	1.3	1.3	0.1	0.1	0.3	0.4	0.2	0.2	0.8	0.7	0.3	0.3	0.4	0.4
Eggs and products	2.4	2.4	2.3	2.3	1.2	1.1	6.8	6.6	0.1	0.1	0.0	0.0	4.6	4.1	2.7	2.6
Fats and oils	0.2	0.2	0.3	0.3	0.4	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.2
Finfish, shellfish, and other aquatic animals and products	12.4	12.7	7.0	7.1	4.1	3.9	9.0	8.7	18.9	17.1	0.0	0.1	11.0	11.1	8.5	7.7
Fruits and products	0.9	0.6	3.0	2.0	1.5	1.1	1.8	1.2	1.0	0.7	27.4	22.7	1.9	1.0	0.5	0.3
Meat and other animals and products	13.4	15.4	18.3	20.4	19.0	23.4	23.7	27.8	17.6	22.0	3.5	5.0	43.5	50.5	29.8	34.2
Milk and products	2.8	2.1	0.4	0.3	1.2	0.8	7.1	4.6	0.4	0.2	1.4	0.7	3.3	2.2	1.4	1.0
Miscellaneous	0.0	0.1	1.9	0.8	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2
Non-alcoholic beverages	2.7	2.7	5.3	3.5	7.6	4.5	8.1	5.9	3.8	4.0	34.0	31.2	5.8	3.1	4.1	3.2
Nuts, dried beans, seeds and products	1.8	1.7	2.2	1.9	2.5	2.9	1.1	1.2	0.8	1.2	0.9	1.2	0.1	0.1	1.7	1.0
Starchy roots, tubers and products	0.8	0.6	1.4	1.3	1.4	1.2	0.6	0.6	0.7	0.7	9.9	8.5	0.5	0.2	0.7	0.5
Sugar, syrup and confectionery	0.3	0.3	0.6	0.4	0.1	0.1	0.6	0.6	0.1	0.1	0.0	0.0	0.2	0,2	0.5	0.4
Vegetables and products	2.0	2.3	3.6	4.8	3.9	4.8	5.4	6.0	1.9	2.1	20.5	26.2	20.8	20.4	1.0	1.2

respectively. Protein intake was higher among late adolescents (49.1±0.8 g) compared to early adolescents (45.8±0.6 g; p=0.001), aligning with physiological demands. Fat intake averaged 28.1±0.3 g/day, with 48.0% below adequacy thresholds, showing no age-based differences (p=0.249).

Micronutrient insufficiencies were widespread. Iron intake averaged 8.2±0.1 mg/day with 96.1% inadequacy. Early (98.1%) and late (95.9%) adolescents showed similar inadequacy rates (p=0.653). Zinc inadequacy affected 45.1% of participants, with higher rates in early adolescents (54.9%) than late adolescents (51.5%), although the difference was not significant (p=0.219). Calcium inadequacy was pervasive (92.9%) across the age groups.

Among B vitamins, niacin showed age-based difference (p=0.005), with higher intake and lower inadequacy in late adolescents (15.3±0.3 mg; 27.0%) than early adolescents (14.2±0.2 mg; 32.5%). Thiamine and riboflavin inadequacies exceeded 70.0% and 88.0%, respectively, with no age-based differences. Vitamin A and vitamin C inadequacies were high (68.0% and 98.7%, respectively), with no significant age-based differences (p=0.585 and p=0.353, respectively).

The findings showed widespread micronutrient inadequacy, particularly for iron, calcium, riboflavin, thiamine, and vitamins A and C, across age groups. Significant differences in protein and niacin intakes between early and late adolescents reflected growth-related changes, whereas most nutrient inadequacies remained consistent across developmental stages.

Nutrient contributions of major food groups among female adolescents

Table 3 shows the percentage contributions of major food groups to energy, macronutrient, and selected micronutrient intakes among early and late adolescent females. Cereals and cereal products were the predominant dietary contributors of nutrients. They accounted for over 70.0% of total energy intake in both age groups (71.4% early; 70.7% late) and were the leading sources of carbohydrates (85.9-86.1%), protein (47.5-50.3%), iron (52.3-53.3%), and thiamine (55.5-56.7%). However, their contributions to vitamin A (6.6-7.7%) and vitamin C (1.6-3.7%) were minimal, reinforcing their role as energy-dense but micronutrient-poor staples.

Meat and other animal products contributed significantly to protein (21.7% early; 26.2% late), total fat (39.9-41.7%), and zinc (29.8-34.2%) intakes. Their contributions were higher among late adolescents across micronutrients, including iron (20.4%), riboflavin (27.8%), vitamin A (50.5%), and phosphorus (15.4%), suggesting improved dietary quality with age. Finfish and shellfish were important protein and micronutrient sources, contributing 16.5-17.1% protein and 7.0-7.1% iron intakes, along with modest amounts of vitamin A and zinc. Fruits and vegetables provided limited energy (1.1-1.8%) but contributed substantially to dietary fibre (10.3-12.4%), vitamin C (22.7-27.4%), and vitamin A (20.4-20.8%), especially among early adolescents. The contribution of vegetables to micronutrients, notably iron (3.6-4.8%) and thiamine (3.9-4.8%), was more prominent than fruits. Fats and oils, while marginal in energy (2.7-2.8%) and protein contributions (0.1%), were major sources of total fat (15.5-16.2%). Eggs and milk products, despite low consumption levels, provided critical amounts of riboflavin (6.6-7.1%), calcium (6.3-8.7%), and phosphorus (2.1-2.8%).

Non-alcoholic beverages contributed more to sugar intake among late adolescents (29.2%) than early adolescents (21.6%) and accounted for significant amounts of vitamin C (31.2-34.0%), likely due to fortification. Sugar, syrup, and confectionery items contributed over 13.0% to total sugar

intake and minimal energy (1.1-1.6%). Their low nutrient density raises concerns regarding excessive sugar intake, particularly among younger adolescents.

Nutrient contributions across the food groups reflected known food composition profiles. The data highlighted the high reliance on cereals and animal-sourced foods for both macro- and micronutrient intakes, whereas nutrient-dense groups, such as fruits, vegetables, dairy, and legumes, contributed marginally, suggesting limited dietary diversity and concerns regarding essential vitamin and mineral adequacy.

Biochemical indicators of iron and zinc status among female adolescents

Mean haemoglobin concentration was 13.2 g/dL, exceeding the WHO threshold of <12.0 g/dL for anaemia in non-pregnant adolescents (WHO, 2005). Early and late adolescents had similar mean haemoglobin values (13.2 g/dL and 13.2 g/dL, respectively), with overlapping 95% confidence intervals, indicating no statistical differences between groups. The prevalence of anaemia was higher among late adolescents (11.2%) than early adolescents (9.1%), possibly reflecting increased menstrual loss.

Mean serum zinc concentration was 78.9 µg/dL, exceeding the IZiNCG deficiency threshold (<70 µg/dL) for this age group (Gibson *et al.,* 2016). Subgroup means were above the deficiency cut-off: 78.9 µg/dL for early adolescents and 79.0 µg/dL for late adolescents. Zinc deficiency affected 21.1% of the cohort, with a similar prevalence across age groups (20.6% in early and 21.8% in late adolescents).

Of note, 2.0% of the sample (*n*=39) was concurrently deficient in iron and zinc, based on subnormal haemoglobin and serum zinc concentrations. This subgroup highlighted the potential for overlapping micronutrient deficiencies that may intensify adverse outcomes, such as impaired linear growth, cognitive delays, and increased vulnerability to infection (Bailey, West & Black, 2015).

These findings reaffirmed the importance of maintaining an adequate zinc level during adolescence for its roles in immune function, cellular growth, and potential influence on haemopoietic processes. Although the cross-sectional data precludes causal inference, the observed positive association between serum zinc and haemoglobin supports the evidence that zinc status may modulate iron metabolism and erythropoiesis (Jeng & Chen, 2022). This interaction has implications for understanding the multifactorial aetiology of anaemia in adolescents, where zinc and iron status may act synergistically.

Bivariate associations between dietary intake and biochemical indicators of iron and zinc status

Table 4 presents Pearson's correlation coefficients assessing the linear associations between dietary nutrient intake and biochemical indicators of iron and zinc status (haemoglobin and serum zinc) among Filipino female adolescents. The coefficients suggested weak to moderate associations, with variations across the age subgroups.

In the full sample, haemoglobin concentration was weakly correlated with serum zinc levels (r=0.0882), suggesting a modest association between zinc status and haemopoiesis. Haemoglobin levels showed no correlation with dietary iron intake (r=-0.0071) or other nutrients, indicating that non-dietary factors influence haemoglobin concentrations.

Serum zinc levels were correlated with dietary intake variables, particularly dietary zinc (r=0.0861), total fat (r=0.0916), thiamine (r=0.0760) and riboflavin (r=0.0842). These associations suggested that zinc bioavailability is enhanced by fat-soluble components and B vitamins, which co-occur in

Table 4. Pearson's correlation coefficients between dietary nutrient intake and biochemical indicators of iron and zinc status among female adolescents

	Haemoglobin	*Serum Zinc*	*Dietary zinc*	*Iron*	*Energy*	*Total Fat*	*Fibre*	*Niacin*	*Phosphorus*	*Protein*	*Sodium*	*Sugar*	*Thiamine*	*Vitamin A*	*Vitamin C*	*Riboflavin*
All Adolescents																
Haemoglobin	1															
Serum Zinc	0.0882	1														
Dietary zinc	0.0537	0.0861	1													
Iron	-0.0071	0.0513	0.7516	1												
Energy	0.0292	0.0448	0.7846	0.7758	1											
Total Fat	0.0002	0.0916	0.7401	0.6162	0.6476	1										
Fibre	0.0213	-0.0125	0.336	0.4787	0.5346	0.1664	1									
Niacin	0.0268	0.0531	0.7512	0.6878	0.8024	0.561	0.2804	1								
Phosphorus	0.0311	0.0451	0.7727	0.7451	0.8966	0.558	0.4304	0.8745	1							
Protein	0.017	0.0608	0.835	0.7571	0.8563	0.6933	0.3689	0.8966	0.9051	1						
Sodium	-0.0197	0.0201	0.4695	0.5631	0.5031	0.6182	0.2128	0.3943	0.3949	0.5121	1					
Sugar	-0.0241	0.0397	0.3879	0.5584	0.5085	0.4482	0.3723	0.3011	0.3642	0.3553	0.452	1				
Thiamin	0.0466	0.076	0.7993	0.7129	0.7444	0.6625	0.474	0.699	0.6969	0.707	0.4951	0.4558	1			
Vitamin A RE	-0.0217	0.0259	0.3972	0.46	0.261	0.2324	0.2986	0.2804	0.3016	0.3123	0.161	0.2316	0.3596	1		
Vitamin C	-0.025	0.0282	0.1847	0.3118	0.2222	0.1282	0.478	0.1443	0.1843	0.1268	0.0925	0.3999	0.2855	0.377	1	
Riboflavin	0.0186	0.0842	0.7374	0.7373	0.6493	0.6573	0.3362	0.6631	0.6756	0.7165	0.4706	0.4914	0.7462	0.5851	0.3434	1

to be continued...

Table 4. Pearson's correlation coefficients between dietary nutrient intake and biochemical indicators of iron and zinc status among female adolescents (continued)

	Haemoglobin	*Serum Zinc*	*Dietary zinc*	*Iron*	*Energy*	*Total Fat*	*Fibre*	*Niacin*	*Phosphorus*	*Protein*	*Sodium*	*Sugar*	*Thiamine*	*Vitamin A*	*Vitamin C*	*Riboflavin*
Early Adolescents																
Haemoglobin																
Serum Zinc	0.109	1														
Dietary zinc	0.0342	0.1077	1													
Iron	-0.0159	0.0542	0.7527	1												
Energy	0.0201	0.0654	0.7947	0.7837	1											
Total Fat	-0.0081	0.1226	0.7362	0.6281	0.6682	1										
Fibre	0.0234	-0.0339	0.3642	0.4873	0.5309	0.186	1									
Niacin	0.0268	0.0475	0.7652	0.709	0.8177	0.5771	0.2993	1								
Phosphorus	0.0217	0.0486	0.7845	0.7669	0.9051	0.5827	0.4456	0.891	1							
Protein	0.0087	0.0655	0.8353	0.7656	0.8715	0.7114	0.3867	0.8948	0.9087	1						
Sodium	-0.033	0.04	0.4668	0.5718	0.4998	0.6217	0.2099	0.4091	0.4117	0.5272	1					
Sugar	-0.0514	0.0751	0.4234	0.5769	0.5093	0.4674	0.3342	0.3396	0.3975	0.3847	0.4392	1				
Thiamin	0.0377	0.1058	0.7981	0.7175	0.74	0.6543	0.4758	0.709	0.7109	0.7072	0.4815	0.4798	1			
Vitamin A	-0.0244	0.0292	0.3905	0.4423	0.2726	0.2448	0.3028	0.3007	0.3184	0.3006	0.1787	0.2311	0.3758	1		
Vitamin C	-0.0259	0.0201	0.189	0.3163	0.2203	0.1117	0.4881	0.154	0.2024	0.1194	0.0983	0.3723	0.2863	0.3866	1	
Riboflavin	0.0172	0.0956	0.7298	0.7318	0.648	0.6714	0.3191	0.6743	0.6774	0.7087	0.4884	0.5102	0.7462	0.5617	0.3189	1

to be continued...

Table 4. Pearson's correlation coefficients between dietary nutrient intake and biochemical indicators of iron and zinc status among female adolescents (continued)

	Haemoglobin	*Serum Zinc*	*Dietary zinc*	*Iron*	*Energy*	*Total Fat*	*Fibre*	*Niacin*	*Phosphorus*	*Protein*	*Sodium*	*Sugar*	*Thiamine*	*Vitamin A*	*Vitamin C*	*Riboflavin*
Late Adolescents																
Haemoglobin	1															
Serum Zinc	0.0622	1														
Dietary zinc	0.087	0.052	1													
Iron	0.0068	0.0466	0.751	1												
Energy	0.0471	0.0111	0.7686	0.7634	1											
Total Fat	0.0166	0.0423	0.746	0.5968	0.613	1										
Fibre	0.015	0.0218	0.2948	0.4653	0.5433	0.1367	1									
Niacin	0.0383	0.056	0.7314	0.661	0.7818	0.5362	0.2596	1								
Phosphorus	0.053	0.0363	0.7539	0.712	0.8834	0.5169	0.4115	0.8492	1							
Protein	0.0392	0.0494	0.8357	0.75	0.8358	0.6667	0.3499	0.8975	0.8998	1						
Sodium	-0.001	-0.0103	0.4764	0.5487	0.5103	0.6143	0.2169	0.3783	0.3709	0.4961	1					
Sugar	0.0073	-0.008	0.342	0.5333	0.5152	0.4255	0.43	0.262	0.325	0.3287	0.4733	1				
Thiamin	0.0632	0.0277	0.8025	0.7054	0.7519	0.6763	0.4728	0.6879	0.6747	0.7109	0.5195	0.4229	1			
Vitamin A RE	-0.0185	0.0215	0.4081	0.4881	0.2452	0.2152	0.2931	0.2555	0.2795	0.3318	0.1349	0.2331	0.337	1		
Vitamin C	-0.0273	0.0431	0.1806	0.3047	0.228	0.1585	0.4604	0.1361	0.1584	0.1452	0.0814	0.4446	0.2856	0.3647	1	
Riboflavin	0.0216	0.0659	0.7525	0.7472	0.6523	0.634	0.3663	0.6524	0.6754	0.7364	0.4398	0.465	0.7464	0.6255	0.3882	1

Legend: No correlation (0) — *Strong correlation (1)*

Table 5. Multiple linear regression models predicting haemoglobin and serum zinc concentrations based on dietary and sociodemographic variables

Model	*Independent variables*	*Coefficient*	*95% confidence interval*		*p-value*
Haemoglobin					
1	Age (years)	-0.005	-0.038	0.028	0.705
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-0.21	-1.324	0.901	0.625
	Former smoker	0.18	-0.254	0.605	0.319
	Serum zinc (mcg)	0.007	0.004	0.0104	<0.001***
Serum Zinc					
1	Age (years)	0.21	-0.149	0.568	0.251
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-7.61	-17.730	2.507	0.410
	Former smoker	-0.29	4.658	4.074	0.896
	Meat (g)	0.020	0.004	0.036	0.001**
2	Age (years)	0.23	-0.135	0.591	0.219
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-3.85	-15.271	7.560	0.508
	Former smoker	0.93	-4.872	0.212	0.754
	Total fat (g)	0.136	0.061	0.212	<0.001***
3	Age (years)	0.14	-0.392	0.671	0.507
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-2.76	-17.768	12.246	0.636
	Former smoker	0.88	-6.431	8.193	0.755
	Dietary zinc (mg)	0.678	0.251	1.105	0.002**
4	Age (years)	0.22	-0.126	0.575	0.210
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-2.82	-11.311	5.679	0.516
	Former smoker	1.18	-4.398	6.768	0.677
	Riboflavin (mcg)	6.838	3.444	10.232	<0.001***
5	Age (years)	0.19	-0.161	0.541	0.289
	Smoking status				
	Nonsmoker	Reference			
	Current smoker	-2.43	-9.892	5.025	0.522
	Former smoker	0.94	-4.577	6.464	0.738
	Thiamine (mcg)	5.442	1.816	9.067	0.003**

**p<0.01; ***p<0.001

animal-sourced foods (Agte *et al.*, 2004; Krebs, 2000). Stronger correlations were observed between dietary nutrients. Dietary zinc was strongly associated with dietary protein (r=0.835), phosphorus (r=0.773), thiamine (r=0.799), and riboflavin (r=0.737), indicating that nutrient-dense foods contribute to the intake of multiple micronutrients.

Subgroup analyses revealed stronger associations among early adolescents than late adolescents. Serum zinc was more strongly correlated with dietary zinc (r=0.1077) and total fat (r=0.1226) in early adolescents, suggesting greater sensitivity to dietary inputs at this life stage. Among late adolescents, correlations between serum zinc and dietary nutrients were weaker. These patterns confirmed the differential responsiveness of biochemical indicators to dietary factors. While serum zinc levels appear sensitive to nutrient intake, particularly from animal-sourced foods, haemoglobin concentrations exhibit complex, multifactorial regulation. These findings underscore the importance of distinguishing between nutrient intake and biochemical status when assessing micronutrient adequacy in adolescents.

Dietary predictors of haemoglobin and serum zinc concentrations

Table 5 presents the linear regression models predicting haemoglobin and serum zinc concentrations based on dietary and sociodemographic variables. A significant positive association was observed between serum zinc and haemoglobin concentrations (β=0.007, 95% CI:0.004-0.0104, p<0.001). This finding suggests that for every 1 µg/dL increase in serum zinc, haemoglobin increases by 0.007 µg/dL, with other variables held constant. The effect size implies a physiologically relevant link between zinc status and haemopoiesis in this population.

Serum zinc concentrations were significantly associated with dietary variables. Meat intake was positively associated with serum zinc levels. A 1 g/day increase in meat consumption predicted a 0.020 µg/dL increase in serum zinc (p=0.001), indicating the role of animal-sourced foods in zinc nutrition. Fat intake was a strong predictor, with a 1 g/day increment associated with a 0.136 µg/dL increase in serum zinc concentration (p<0.001). This aligns with the literature highlighting the effect of dietary lipids on zinc solubility and absorption (Krebs, 2000; Gibson *et al.,* 2002).

Dietary zinc intake predicted serum zinc levels. A 1 mg/day increase in dietary zinc intake was associated with a 0.678 µg/dL increase in serum zinc levels (p=0.002). B vitamins co-ingested with zinc in animal-sourced foods showed strong associations. Riboflavin intake predicted serum zinc concentration, with a 6.838 µg/dL increase per 1 µg/day increment (p<0.001). Thiamine showed a significant effect, with a 1 µg/day increase associated with a 5.442 µg/dL rise in serum zinc (p=0.001). These findings suggest the synergistic effects of nutrient-dense dietary patterns on zinc status.

The models did not identify age or smoking status as significant predictors of haemoglobin or serum zinc levels, suggesting that nutritional biomarker variability is more attributable to dietary factors than to demographic characteristics. These results confirmed that serum zinc concentrations respond to zinc-rich and micronutrient-dense foods, particularly from animal sources. Riboflavin, thiamine, dietary fat, and meat intakes were key dietary determinants of zinc status. The association between serum zinc and haemoglobin suggest an interaction between zinc and iron status. However, no dietary variable directly predicted haemoglobin concentration, highlighting the multifactorial determinants of iron status, including menstrual loss, inflammation, infection,

and micronutrient interactions, which were not captured here (Thurnham *et al.,* 2010; WHO, 2011).

DISCUSSION

This study identified the dietary determinants of iron and zinc status among Filipino female adolescents using the 2013 NNS. Multivariate regression analyses revealed that higher intakes of animal-sourced foods and micronutrients, including meat, dietary fat, zinc, thiamine, and riboflavin, were associated with increased serum zinc concentrations, highlighting the role of nutrient-dense animal products in zinc bioavailability. Dietary iron intake was not a significant predictor of haemoglobin concentration. Although a modest correlation existed between serum zinc and haemoglobin levels, no direct association was found between haemoglobin and dietary components. These findings suggest that serum zinc status is more responsive to dietary intake, whereas haemoglobin concentration appears to be influenced by broader physiological and environmental factors.

Despite high dietary iron inadequacy (96.1%), mean haemoglobin concentrations exceeded the WHO anaemia cut-off, suggesting enhanced intestinal iron absorption (WHO, 2005). The correlation between serum zinc and haemoglobin may reflect the concurrent adequacy of micronutrients essential for erythropoiesis. However, haemoglobin lacks sensitivity and specificity to distinguish nutritional from non-nutritional causes of anaemia (WHO, 2011). Menstrual blood loss, infection, inflammation, and micronutrient interactions may confound the interpretation of haemoglobin status (Killilea & Siekmann, 2022; Jeng & Chen, 2022).

Adolescence is a critical life stage for physical, cognitive, and reproductive development, with increased iron and zinc requirements (WHO, 2005). Analyses have shown inadequacies in energy, iron, calcium, riboflavin, thiamine, vitamin A, and vitamin C intakes, which are essential for immune function, haemopoiesis, tissue repair, and growth (Jacob & Nair, 2011). Adolescent girls are vulnerable to menstruation-related iron loss and early pregnancy risks, which can exacerbate nutrient demands (Black *et al.,* 2013).

Disaggregated analyses indicated that late adolescents had higher energy, protein, and fat intakes, consistent with increased physiological demands (DOST-FNRI, 2018). Early adolescents reported higher calcium and vitamin C intakes, which are important for bone growth during puberty (Mesías, Seiquer & Navarro, 2011). However, the overall consumption of fruits, vegetables, and animal-sourced products remains low. Although protein adequacy was achieved through staple foods, micronutrient intake was compromised by dietary patterns that were dominated by refined grains. Strong intercorrelations between energy, protein, and micronutrient intakes reflect nutrient clustering in shared sources, particularly cereals and animal products.

Animal-sourced foods, such as pork, chicken, fish, and eggs, are major contributors to dietary iron and zinc, supplying haem iron, bioavailable zinc, and B-complex vitamins that aid zinc absorption and metabolism (Agte *et al.*, 2004). This study confirmed that animal-sourced foods enhanced zinc bioavailability (Gibson *et al.,* 2002; Krebs, 2000). While zinc deficiency based on serum concentrations was low (21.1%), dietary inadequacy was high, posing a public health concern owing to increased adolescent requirements (Roohani *et al.*, 2013).

These findings support the importance of dietary interventions to improve zinc status through more animal-sourced foods and other nutrient-rich dietary

sources. However, improving the iron status of female adolescents requires a comprehensive strategy to address dietary bioavailability, infection control, inflammation, reproductive health, and supplementation. Despite national efforts, including school-based feeding and iron supplementation programmes, adolescent girls in the Philippines remain at risk of micronutrient deficiencies. The modest decline in anaemia prevalence from 2013 to 2021 (DOST-FNRI, 2022) highlights persistent challenges, including low dietary diversity, poor access to micronutrient-rich foods, and socioeconomic constraints.

This study has limitations inherent to the 2013 NNS. Firstly, the cross-sectional design limited the establishment of temporal or causal relationships between dietary intake and micronutrient status. Secondly, biomarkers, such as serum zinc, were only available in the 2013 NNS and not in the 2018-2021 Expanded NNS, limiting longitudinal comparisons. The absence of inflammation-adjusted indicators, including C-reactive protein (CRP), alpha-1-acid glycoprotein (AGP), serum ferritin, and soluble transferrin receptor (sTfR), limits the characterisation of iron deficiency and anaemia (Skikne, 2008; Thurnham *et al.,* 2010). Thirdly, supplement use was not considered, potentially underestimating actual micronutrient intake. Moreover, reliance on self-reported dietary intake introduces recall bias and may not capture usual intake or seasonal variation. The Philippine FCT was supplemented with international datasets that may not accurately reflect the nutrient content of local or homemade dishes, complicating dietary assessments (López-Olmedo *et al.*, 2016). Finally, excluding pregnant and lactating adolescents limits the generalisability of the findings to the broader adolescent population.

CONCLUSION

This study investigated the dietary determinants of iron and zinc status among Filipino female adolescents using nationally representative data from the 2013 NNS. Serum zinc concentrations were significantly associated with meat, total fat, zinc, thiamine, and riboflavin intakes, highlighting the influence of animal- and micronutrient-dense foods on zinc status. In contrast, haemoglobin levels were not significantly predicted by dietary intakes, suggesting that iron status is shaped by factors other than dietary iron alone.

Despite mean haemoglobin and serum zinc values being within normal ranges, dietary inadequacies for iron, calcium, riboflavin, thiamine, and vitamin A remained high. These patterns indicate a risk of subclinical micronutrient deficiencies not captured by biomarker averages alone. The correlation between haemoglobin and serum zinc also points to potential micronutrient interdependencies during adolescence, particularly in relation to growth and haemopoiesis.

This study underscores the importance of dietary quality, diversity, and nutrient bioavailability in adolescent nutrition. Future studies should use longitudinal designs and inflammation-adjusted biomarkers to better capture the determinants of nutritional status and micronutrient deficiencies. These improvements will inform more evidence-based strategies to address adolescent undernutrition and its consequences in the Philippines, as well as in other low- and middle-income countries.

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Authors' contributions

Naupal-Forcadilla RT, principal investigator, conceptualised and designed the study, acquired data, data analysis and interpretation, prepared the draft of the manuscript, and reviewed the manuscript; Barba CVC, advised on the design of the study, reviewed the manuscript; Bouis HE, advised on the design of the study, data analysis and interpretation, and reviewed the manuscript; Africa LS, advised on the design of the study, assisted in drafting the manuscript, and reviewed the manuscript; Atienza LM, advised on the design of the study, assisted in drafting the manuscript, reviewed the manuscript; Elauria MM, advised on the design of the study, assisted in data analysis and interpretation; Angeles-Agdeppa I, approved the data remote access, reviewed and approved the version of the manuscript; Ferrer EB, assisted in the data remote access, reviewed and approved the version of the manuscript.

Conflict of interest

The authors declare no conflicts of interest.

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