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Zinc deficiency and its correlates among infants aged 6-11 months in rural areas of Thanh Hoa province, Vietnam

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ABSTRACT

Introduction: Zinc deficiency remains prevalent among children in developing countries and is associated with stunting, which negatively impacts children's growth and development. This study describes zinc deficiency status among infants in selected communes in Thanh Hoa province, Vietnam, in April 2020. **Methods:** A descriptive cross-sectional study was conducted, with random selection of 360 children aged 6 to 11 months. General information was collected through interviews with mothers/caregivers using pre-designed questionnaire. Zinc and ferritin concentrations were analysed using laboratory quantitative tests. Multivariate logistic regression was used to identify factors associated with zinc deficiency. **Results:** Mean zinc concentration was 9.0 mmol/L, with proportion of zinc deficiency at 71.7% (95% *CI*: 66.7%–76.3%), iron deficiency 16.4% (95% *CI*: 12.5%–20.0%) and stunting 17.8% (95% *CI*: 14.0%–22.1%). Several factors were found to be significantly associated with zinc deficiency: non-exclusively breastfed children aged under 6 months (*OR*=1.88; 95% *CI*: 1.09–3.24); children with diarrhoea (*OR*=2.33; 95% *CI*: 1.01–5.35); children with acute respiratory infections (*OR*=2.35; 95% *CI*: 1.04–5.30); and mothers who did not take micronutrient supplements during pregnancy (*OR*=2.02; 95% *CI*: 1.19–3.44), ($p<0.05$). **Conclusion:** Zinc deficiency was common in infants 6–11 months old in this study. Therefore, early interventions through dietary diversification and supplementation are warranted. Collaboration with public health programmes is vital to educate caregivers on better child nutrition and care practices, and enhance the effectiveness of prevention.

Keywords: infant aged 6 to 11 months, rural area, zinc deficiency status

INTRODUCTION

Zinc is an essential micronutrient present in all organs, tissues, and body fluids, ranking second only to iron as a trace element in mediating a wide range of physiological functions (Sadeghsoltani *et al.*, 2021). It is vital in controlling and preventing infectious diseases, as it enhances the recovery of intestinal tissues, boosting local immunity to prevent the growth of harmful bacteria and eliminating them (Lassi, Moint &

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Bhutta, 2016; Tran, Nguyen & Truong, 2021). It is estimated that approximately 17% of the global population is at risk of zinc deficiency (Khan *et al.*, 2022), with the majority concentrated in low- and middle-income countries (Gupta, Brazier & Lowe, 2020). For instance, the prevalence of zinc deficiency among children under five years old was reported to be 38% in Ethiopia (Berhe, Gebrearegay & Gebremariam, 2019) and 22.9% in Nepal (Mehata *et al.*, 2021).

A survey in 2014-2015 by the Vietnam National Institute of Nutrition reported that 69.4% of children under five years old suffered from zinc deficiency, with particularly high prevalences in mountainous areas (80.8%) and rural areas (71.6%) (Vietnam NIN, 2015). The National Nutrition Survey 2019–2020 indicated that 58% of children under five years old in Vietnam suffered from zinc deficiency. While national-level urban-rural comparisons are not always available, the 2015 survey suggested that children in rural and mountainous areas were more vulnerable due to dietary limitations and lower access to fortified foods (Vietnam NIN, 2021). Several studies have shown that diarrhoeal diseases, acute lower respiratory infections, and malnutrition increase the risk of zinc deficiency in children under five years old. Zinc supplementation in this population has been found to significantly improve the condition by reducing the duration and severity of diarrhoeal episodes, as well as enhancing height and weight growth (Khan *et al.*, 2023; Abd El-Ghaffar *et al.*, 2022).

Although the World Health Organization (WHO) and the Vietnam National Institute of Nutrition have developed and provided detailed guidelines on complementary feeding, and the healthcare system has implemented various community intervention programmes to enhance zinc supplementation and other essential micronutrients through dietary planning guidance for children, the practical implementation in rural areas remains a significant challenge. The availability of zinc-rich complementary foods, such as meat, eggs, and fortified products, is often limited due to economic constraints (Gupta *et al.*, 2020; Dembedza, Chopera & Matsungo, 2024; Vietnam NIN, 2021). Additionally, the difficulty mothers face in accessing primary healthcare services exacerbates their limited knowledge and practices in child nutrition. As a result, free services, such as medical consultations, nutrition counselling, and micronutrient supplementation (e.g., folic acid), remain inaccessible to many, further worsening the risk of micronutrient deficiencies in this population (Vietnam NIN, 2021).

Located in Thanh Hoa Province, Quang Xuong is a typical rural agricultural district with 25 communes, 1 township, and a population of around 203,020—representing 5.5% of the province's population. Its poverty rate decreased from 24.8% in 2010 to 3.25% in 2018 (Thanh Hoa Provincial Government Portal, 2021). Currently, there are no data on micronutrient deficiencies, particularly zinc deficiency, among children aged 6 to 11 months in rural areas of Vietnam, including districts within Thanh Hoa province. Consequently, specific recommendations for complementary feeding practices in this age group remain inadequate. These children are at a heightened risk of zinc and other micronutrient deficiencies due to the widespread prevalence of complementary diets that are insufficient in both quantity and quality. Unlike previous studies that focused on broader age groups, this study provided targeted insights into infancy, a critical period for growth and development. These findings will contribute to evidence-based recommendations, enhance national nutrition policies, and support the development of specific interventions aimed at improving zinc status among infants in rural Vietnam.

METHODOLOGY

Study design and rationale

A cross-sectional descriptive study on zinc deficiency and its associated factors in infants aged 6 to 11 months was conducted in Quang Xuong district, Thanh Hoa province, Vietnam in April 2020.

Subjects

Children aged 6-11 months, with recorded birth dates and gender, residing in ten communes of the Quang Xuong district, Thanh Hoa province, Vietnam, whose parents/guardians voluntarily provided written consent to participate in the study were included. The exclusion criteria were children with chronic illnesses or those who have received zinc or multiple micronutrient supplements in the past three months.

Sample size determination

Sample size was calculated using the following formula for a cross-sectional study (Lwanga & Lemeshow, 1991):

$$n = \frac{Z^2_{(1-\alpha/2)}\, p\,(1-p)}{d^2}$$

Where: *n* is the required sample size (number of children to be surveyed); Z^2 $(1-\alpha/2)$ = 1.96 (for a 95% confidence interval); p is the prevalence of zinc deficiency from the 2014-2015 National Institute of Nutrition survey in children under 5, which was 69.4% (Vietnam NIN, 2015); d is the margin of error, set at 0.05 (5%). Substituting these values into the formula, the required sample size was 327 children. An additional 10% was added to account for dropouts, rounding the total sample size to 360 children.

Sampling procedure

District selection was purposefully done. For selection of study location, ten communes in the Quang Xuong district, Thanh Hoa province, were randomly selected. The communes had similarity in socio-economic conditions, had no prior micronutrient intervention programmes, and were ensured of an adequate number of children for the survey.

Regarding participant selection, a list of all children aged 6-11 months in the ten selected communes (439 children) was compiled; 360 children who met the study criteria were randomly selected.

Data collection procedures

Information collection method

Information was gathered through interviews with the mothers of the children. The collection of information was conducted by trained research staffs using a pre-designed questionnaire covering demographics, child health status, and maternal and household characteristics. Micronutrient supplementation during pregnancy and lactation was collected qualitatively as a binary (yes/no) response. Mothers were asked whether they had taken any iron/ multivitamin supplements or consumed micronutrient-fortified foods during these two periods.

The child's length was measured while lying down using a United Nations Children's Fund (UNICEF) wooden measuring board. The board was placed horizontally and the child was positioned supine on the board, ensuring the correct nine contact points. The measurement result was recorded in centimetres with one decimal point (WHO, 2006).

Blood sampling *method*

A total of 2.5 ml of venous blood was drawn from each child in the morning between 8 and 11 a.m. using a sterile syringe. The whole blood sample was placed in a test tube without anticoagulants, centrifuged at 3,000 rpm for 10 minutes, and the serum was separated into Eppendorf tubes. The samples were stored on-site at the provincial preventive health centre at -20°C and then transported via express courier to the National Institute of Nutrition laboratory after the survey. Serum samples were stored at -80°C until analysis at the institute's laboratory. During the sampling, centrifugation, serum separation, and storage processes, measures were taken to prevent zinc contamination.

Evaluation method

Serum zinc was analysed at the Micronutrient Department, National Institute of Nutrition, using flame atomic absorption spectrometry (Beckman Coulter AU480, Japan), with methods to avoid cross-contamination of metals. Serum zinc levels were compared with quality control samples and hydrochloric acid samples. A threshold of <9.9 µmol/L was used to define zinc deficiency in children for morning blood samples (IZiNCG, 2012).

Child height (lying length) was compared with reference children of the same age and gender from the WHO 2006 child growth standards (WHO, 2006). Stunting was defined as a height-for-age *z*-score (HAZ) of <-2.

For health status evaluation, diarrhoea was defined as passing loose stools ≥3 times/day within the previous two weeks. Acute viral respiratory illness (ARI) was diagnosed if two of the following five symptoms were present: runny nose, cough, fever, difficulty breathing, or rapid breathing in the past two weeks (Vietnam Ministry of Health, 2009; Bach & Pham, 2017).

Data analysis and presentation

Data were entered using EpiData version 3.1 (EpiData Association, Odense, Denmark), and analysed by descriptive statistics using IBM SPSS Statistics for Windows version 20.0 (IBM Corporation, Armonk, New York, USA). Qualitative data were presented as frequencies and percentages. Quantitative data were presented as mean ($\bar{X}$) and standard deviation (*SD*). *T*-test was used to compare means between the two study groups. *P*-values were presented with three decimal places, with statistical significance considered at $p<0.05$. Odds ratios (*OR*) and 95% confidence intervals (*CI*) were calculated to assess the strength of associations between factors and zinc deficiency. Logistic regression was used to analyse associated factors. Multivariate logistic regression was employed to control for confounding factors (variables with $p\leq0.1$ in the univariate analysis were selected). Multicollinearity among dependent variables was assessed using variance inflation factors (VIF). The VIF values for all dependent variables included in the multivariate logistic regression analysis were below 2.0.

Ethical considerations

The study was approved by the Biomedical Research Ethics Committee of the Vietnam National Institute of Nutrition (NIN), under decision number 259/VDD-QLKH, dated June 15, 2018. Parents or caregivers were informed and provided with an explanation of the study's purpose and procedures. The child's family voluntarily consented to the child's participation by signing the consent form. All instruments used for blood sampling, weighing, and measuring were guaranteed to be completely safe, posing no harm or danger to the child. Collected data and personal information were carefully maintained and kept confidential. The study results were used solely for scientific purposes, including recommending solutions to prevent and control anaemia and micronutrient deficiencies in the community.

Table 1. Zinc concentrations and anthropometric indices of participants (*N*=360)

Indices	*mean±SD*			*p*
	Overall (n=360)	*Boys (n=172)*	*Girls (n=188)*	
Length (cm)	67.4±2.5	67.9±2.6	66.7±2.4	<0.001
Height-for-age *z*-score (HAZ)	-0.9±1.2	-0.9±1.3	-0.8±1.0	0.335
Zinc concentration (nmol)	27.9±18.9	28.1±19.8	27.7±18.2	0.829

p-values from *t*-tests comparing the means between boys and girls

RESULTS

Zinc concentrations and basic anthropometric indices of 360 children participating in the study are presented in Table 1 and Table 2.

According to Table 1, the average length of the children was 67.4±2.5 cm, with a *z*-score (HAZ) of -0.9±1.17. A significant difference in height was observed between male and female children ($p<0.05$). Ferritin concentration was 27.9±18.9 µg/L and zinc concentration was 9.0±1.6 mmol/L.

Table 2. Distribution of zinc deficiency and stunting prevalences (*N*=360)

Condition	*n*	*Percentage (95% CI)*
Zinc deficiency		
No	102	28.3 (23.7 - 33.3%)
Yes	258	71.7 (66.7 - 76.3%)
Stunting		
No	296	82.2 (77.9 - 88.0%)
Yes	64	17.8 (14.0 - 22.1%)

As shown in Table 2, among the 360 children surveyed, 258 children had zinc deficiency, accounting for 71.7% (95% *CI*: 66.7%–76.3%). Stunting affected 64 children, accounting for 17.8% (95% *CI*: 14.0%–22.1%).

Factors related to zinc deficiency in children are presented in Table 3. Univariate logistic regression analysis revealed that children who were exclusively breastfed for less than six months (*OR*=1.81; 95% *CI*: 1.08–3.02), as well as those with diarrhoea (*OR*=2.11; 95% *CI*: 1.08–4.15), acute respiratory infection (ARI) (*OR*=3.11; 95% *CI*:1.42–6.80), and stunting (*OR*=2.14; 95% *CI*: 1.07–4.28), had a higher risk of zinc deficiency compared to other groups, with $p<0.05$.

In Table 4, univariate logistic regression analysis showed that children whose mothers did not supplement with micronutrients during pregnancy (*OR*=2.62; 95% *CI*: 1.63–4.20) and breastfeeding (*OR*=2.71; 95% *CI*: 1.66–4.41) had a significantly higher risk of zinc deficiency compared to other groups, with $p<0.05$.

Model predicting factors associated with zinc deficiency are shown in Table 5. Multivariate logistic regression analysis predicted several independent factors associated with zinc deficiency, showing statistically significant differences in children who were non-exclusively breastfed for less than six months (*OR*=1.88; 95% *CI*: 1.09–3.24), children with diarrhoea (*OR*=2.33; 95% *CI*: 1.01–5.35), children with ARI (*OR*=2.35; 95% *CI*: 1.04–5.30), and children whose mothers did not supplement with micronutrients during pregnancy (*OR*=2.02; 95% *CI*: 1.19–3.44), with $p<0.05$. Birth weight, stunting, and micronutrient supplementation during pregnancy or breastfeeding showed no significant associations with zinc deficiency in infants, with $p>0.05$.

DISCUSSION

Zinc deficiency is relatively common in low-income and developing countries.

Table 3. Factors related to zinc deficiency in children (*N*=360)

Characteristics	*Zinc deficiency*		*No Zinc deficiency*		*OR (95%CI)*	*p*
	n	*%*	*n*	*%*		
Gender						
Boys	122	70.9	50	29.1	1	0.767
Girls	136	72.3	52	27.7	1.07 (0.68–1.69)	
Age group						
6 months	111	72.1	43	27.9	1	0.881
7-11 months	147	71.4	59	28.6	1.03 (0.65–1.65)	
Birth weight						
≥ 2.5 kg	235	70.6	98	29.4	1	0.105
< 2.5 kg	23	85.2	4	14.8	2.40 (0.81–7.11)	
Exclusive breastfeeding for 6 months						
Yes	54	62.1	33	37.9	1	0.023*
No	204	74.7	69	25.3	1.81 (1.08–3.02)	
Diarrhoea						
No	210	69.1	94	30.9	1	0.011*
Yes	48	85.7	8	14.3	2.11 (1.08–4.15)	
Acute respiratory infection (ARI)						
No	204	68.5	94	31.5	1	0.003**
Yes	54	87.1	8	12.9	3.11 (1.42–6.80)	
Fever within 2 weeks						
No	184	71.0	75	29.0	1	0.674
Yes	74	73.3	27	26.7	1.11 (0.67–1.87)	
Stunting						0.029*
No	205	69.3	91	30.7	1	
Yes	53	82.8	11	17.2	2.14 (1.07–4.28)	

1: Reference group for univariate logistic regression analysis
*p<0.05; **p<0.01

This study revealed a relatively high prevalence of zinc deficiency, with 71.7% of children affected. This is consistent with the 2014-2015 National Institute of Nutrition survey, which reported a zinc deficiency of 71.6% among rural children aged under five years (Vietnam NIN, 2015). However, it is lower than the 75.9% reported in a study in Phu Tho province in 2013 (Huynh, 2019). On the other hand, it is higher than the 58% reported in the 2019-2020 National Nutrition Survey for children under five across the country and 51.9% reported by Pham (2014) in a study of 586 children aged 12-72 months across 19 provinces in 2010. These varying results consistently indicate that zinc deficiency remains a significant public health issue for children in Vietnam, particularly those in rural and mountainous regions.

Multivariate logistic regression analysis showed that children who were not exclusively breastfed for the first 6 months had 1.88 times higher odds of zinc deficiency (*OR*=1.88; 95% *CI*: 1.09-3.24) compared to those who were exclusively breastfed for the first six months. Breast milk is the best source of nutrition for children, supporting their comprehensive physical and cognitive developments and increasing their

Table 4. Maternal and household factors related to zinc deficiency (*N*=360)

Characteristics	*Zinc deficiency*		*No Zinc deficiency*		*OR (CI 95%)*	*p*
	n	*%*	*n*	*%*		
Maternal education						
> High school	187	72.5	71	27.5	1	0.586
≤ High school	71	69.6	31	30.4	0.87 (0.53–1.44)	
Maternal occupation						
Government employee*†	57	72.2	22	27.8	1	0.914
Other‡	201	71.5	80	28.5	0.97 (0.56–1.69)	
Micronutrient supplementation during pregnancy						
Yes	101	61.2	64	38.8	1	<0.001***
No	157	80.5	38	19.5	2.62 (1.63–4.20)	
Micronutrient supplementation during breastfeeding						
Yes	87	60.4	57	39.6	1	<0.001***
No	157	80.5	38	19.5	2.71 (1.66–4.41)	
Number of children in the family						
> 2 children	46	65.7	24	34.3	1	0.218
≤ 2 children	212	73.1	78	26.9	1.42 (0.81–2.48)	
Total household income						
> 5 million VND/month	43	75.4	14	24.6	1	0.491
≤ 5 million VND/month	215	71.0	88	29.0	0.79 (0.41–1.53)	
Household water source						
Rainwater, well water	39	78.0	11	22.0		0.284
Tap water	219	70.6	91	29.4	0.68 (0.33–1.38)	

VND: Vietnamese Dong; 1: Reference group for univariate logistic regression analysis
†Government employees and vendors; ‡Farmers, labourers, freelancers, etc.
****p*<0.001*

intelligence quotient (Brown & Jones, 2019). WHO and UNICEF have strongly recommended exclusive breastfeeding for the first six months to ensure healthy child development (Kramer & Kakuma, 2012). Introducing complementary foods too early can impair the absorption of micronutrients, as the digestive system is not yet fully developed and complementary diets often lack zinc, increasing the risk of micronutrient deficiencies, including zinc. Similar results were reported by La *et al.* (2024), who found that children who were not exclusively breastfed during the first six months had a 7.05 times higher risk of zinc deficiency than those who were exclusively breastfed (95% *CI*: 2.76 – 18.00). Moreover, micronutrient supplementation during pregnancy

Table 5. Model predicting factors associated with zinc deficiency (*N*=360)

Independent risk factors	*β*	*OR*	*95% CI*	*p*
Birth weight				
≥ 2.5 kg	-	1	-	
< 2.5 kg	0.74	2.10	0.65 – 6.74	0.213
Exclusive breastfeeding for six months				
Yes	-	1	-	
No	0.63	1.88	1.09 – 3.24	0.024*
Diarrhoea				
No	-	1	-	
Yes	0.84	2.33	1.01 – 5.35	0.047*
Acute respiratory infection (ARI)				
No	-	1	-	
Yes	0.85	2.35	1.04 – 5.30	0.040*
Stunting				
No	-	1	-	
Yes	0.38	1.47	0.70 – 3.08	0.305
Micronutrient supplementation during pregnancy				
Yes	-	1	-	
No	0.71	2.02	1.19 – 3.44	0.009**
Micronutrient supplementation during breastfeeding				
Yes	-	1	-	
No	0.58	1.79	0.99 – 3.23	0.053

1: Reference group for multivariate logistic regression analysis
*$p<0.05$; **$p<0.01$

plays a crucial role in ensuring the health of both mothers and their foetuses, reducing the risk of complications and diseases during pregnancy. For example, zinc supplementation is essential for cell growth, immune function, and DNA synthesis. Zinc deficiency during pregnancy is associated with preterm birth, low birth weight, and other developmental issues. Our study also found that children whose mothers did not supplement with micronutrients during pregnancy had 2.02 times higher odds of zinc deficiency (*OR*=2.02; 95% *CI*: 1.19-3.44). This underscores the importance of micronutrient supplementation during pregnancy to safeguard maternal health and promote child development.

Zinc plays an essential role in preventing and controlling infections. It significantly influences the immune system, enhances immunity, reduces susceptibility to infectious diseases, and speeds up recovery time. It also shortens the duration of treatment for diarrhoea and ARI (Nguyen, 2011; Lassi *et al.*, 2016; Tran *et al.*, 2021). In our study, diarrhoea and ARI were identified as significant determinants of zinc deficiency; multivariate logistic regression analysis revealed that children with diarrhoea had 2.33 times higher odds of zinc deficiency (*OR*=2.33; 95% *CI*: 1.01-5.35) and children with ARI had 2.35 times higher odds of zinc deficiency (*OR*=2.35; 95% *CI*: 1.04-5.30) compared to those who did not have these conditions. Frequent episodes of diarrhoea may contribute to zinc deficiency by increasing zinc loss through the gastrointestinal tract and impairing absorption due to inflammation and intestinal damage, while ARI may further exacerbate zinc deficiency by triggering an inflammatory response that increases zinc utilisation. Zinc deficiency may impair immune cell functions, including T lymphocytes, B lymphocytes, and macrophages, leading to reduced intestinal mucosal integrity and a higher risk of infections, making children more susceptible to diarrhoea and ARI (Moshtagh & Amiri, 2020; Khan *et al.*, 2023; Abd El-Ghaffar *et al.*, 2022).

Strengths and limitations of the study

This study addressed the assessment of zinc deficiency in children aged 6-11 months, a high-risk group for malnutrition and micronutrient deficiencies. The study design was well-structured, with a representative sample; sample collection and evaluation processes followed rigorous and standardised methodologies recommended by reputable organisations. This allowed us to analyse the key factors contributing to zinc deficiency in this age group and provide scientific evidence to guide healthcare policymakers at both national and local levels. The findings can support the development of targeted interventions in rural areas like our study site, improving maternal nutrition knowledge and practices, while preventing zinc deficiency and broader micronutrient deficiencies in infants aged 6–11 months. However, a limitation of this study was the reliance on a structured questionnaire, with most responses based on maternal recall. This is particularly relevant for qualitative questions, such as micronutrient supplementation during pregnancy and lactation, which may introduce recall bias. Additionally, we did not analyse the zinc content of dietary intake, which could have provided more specific recommendations for optimising nutritional strategies for this vulnerable age group.

CONCLUSION

The average zinc concentration among infants aged 6-11 months in this study was 9.0±1.6 mmol/L, with a prevalence of zinc deficiency at 71.7% (95% *CI*: 66.7%-76.3%). Statistically significant differences were observed in certain groups: children with non-exclusive breastfeeding (*OR*=1.88; 95% *CI*: 1.09-3.24), children with diarrhoea (*OR*=2.33; 95% *CI*: 1.01-5.35), and children with ARI (*OR*=2.35; 95% *CI*: 1.04-5.30). Additionally, mothers without micronutrient supplementation during pregnancy were significantly associated with zinc deficiency in their children (*OR*=2.02; 95% *CI*: 1.19-3.44). The high prevalence of zinc deficiency among children is a concerning public health issue, necessitating immediate interventions to enhance parental knowledge and practices regarding nutritional care. It is essential to implement dietary diversification programmes and promote appropriate zinc-rich dietary supplementation for children aged 6-11 months, with particular emphasis on the first 1,000 days of life.

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Authors' contributions

Doanh PV, manuscript writing, data analysis, interpretation of results; Nguyet TTM, Tuyet LT, data collection; Dung LTT, manuscript writing, data collection; Chuyen HV, data analysis; Nga TT, data collection and serum samples analysis.

Conflict of interest

Authors declare no conflicts of interest.

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