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Dietary Zinc Intake and the Underlying Factors of Serum Zinc Deficiency among Preschool Children in the Philippines

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Keywords: Filipino children, stunting, zinc deficiency, zinc intake

Zinc deficiency is linked to linear growth and is considered as one of the risk factors of stunting. Stunting persists as a public health problem in the Philippines, affecting 30% of children below 5 yr old. This study assessed the adequacy of dietary zinc intake and the prevalence and associated factors of serum zinc deficiency among preschool-age children 6–71 mo old. Data from the 8th National Nutrition Survey (NNS) conducted in 2013, involving 2,892 preschool-age children, were analyzed. Zinc intake was collected using two non-consecutive 24-hr food recalls, while dietary zinc inadequacy was intake below 100% of the estimated average requirement (EAR) for zinc prescribed by the 2015 Philippine Dietary Reference Intakes (PDRI). Serum zinc level was analyzed using atomic absorption spectrophotometry. Factors associated with zinc deficiency such as micronutrient status, wealth status, food security, and dietary adequacy were identified using multivariate linear regression analysis. Almost half (47.2%) of preschool-age children had inadequate zinc intake. The national prevalence of serum zinc deficiency was 17.9%, and it is highest among children 6–23 mo old and those from rural, poorest, and food-insecure households relative to other subgroups. Poor wealth status was found to be a strong predictor of zinc deficiency (OR 4.0; 95% CI = 2.22–6.00). Stunting (OR 1.37; 95% CI = 1.06–1.76) and serum vitamin A deficiency (OR 1.80; 95% CI = 1.43–2.26) were associated with higher odds of zinc deficiency. Adequate vitamin A intake was an important protective factor against zinc deficiency. The odds of a child being zinc deficient is significantly predicted by poor wealth status, stunting, and vitamin A deficiency, while adequate nutrient intake serves as a crucial protective factor. Strengthening programs on micronutrient supplementation (including zinc), food fortification, and dietary diversification – combined with micronutrient-dense food consumption among preschool-age children – could help achieve long-term nutrition and health outcomes.

Keywords: Filipino children, stunting, zinc deficiency, zinc intake

INTRODUCTION

Zinc, an essential micronutrient, has multiple roles in numerous processes – including gene expression and cellular growth and differentiation – which have implications for brain development and immunity (Brown *et al.* 2004). Deficiency in zinc has been identified as a major risk to a child's health, which can lead to retardation of linear growth, poor appetite, and impaired immune function as may be manifested by infections such as diarrhea, pneumonia, and malaria (Roohani *et al.* 2013). Zinc deficiency is prevalent in developing countries, where 116,000 deaths among children under five years

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were reported to be associated with inadequate zinc intake (Black *et al.* 2013). Data from the 2008 NNS in the Philippines indicated that zinc deficiency was of high magnitude (≥ 20%) at the national level (30.0%), with 21.6% of preschool children identified as zinc-deficient (Marcos *et al.* 2015). Recently, stunting – a sign of chronic undernutrition in children below five years of age – was recognized as a proxy indicator of zinc deficiency. This is based on the premise that zinc deficiency among children is associated with inadequate food intake or caused by diets with limited bioavailable zinc, despite the increased zinc requirement to support rapid growth (Brown *et al.* 2001, 2004; Black 2003).

In the Philippines, high stunting prevalence persists despite economic growth and development over the past years. Filipinos are the second-shortest nationality among Southeast Asians (GHI 2018) and ranked 48th out of 136 countries in terms of stunting prevalence (World Bank 2011). The 2013 NNS conducted by the Department of Science and Technology–Food and Nutrition Research Institute (DOST-FNRI) reported that stunting prevalence was 30.0% among under-five children (DOST-FNRI 2015a). In the same survey, it was revealed that Filipino children 6 mo–5 yr old have a predominantly plant-based diet – comprising of rice, corn, and cereal products – with a limited amount of animal-source foods rich in zinc (DOST-FNRI 2015b). A strong association between the consumption of plant-based diets and zinc deficiency in developing countries has been widely reported (Gibson *et al.* 2010). Phytate, which is common in plant sources foods (*e.g.* cereals, legumes, nuts, fruits, and vegetables) is likely to reduce zinc absorption.

Aside from inadequate dietary intake and low bioavailability, high prevalence of zinc deficiency has been associated with elevated zinc requirements, poor sanitation and hygienic practices, poor socioeconomic status, inadequate evidence to monitor the inadequacy of intake, and lack of public awareness in low-income countries in Asia (Akhtar 2013). Evaluating the risk of zinc deficiency in preschool-age children requires a comprehensive analysis of biological, dietary, maternal, and socio-economic factors. Despite the widely documented lack of adequate biomarkers for measuring zinc, serum zinc has been found to be the most suitable for evaluating zinc status in young children and is recommended by both the World Health Organization (WHO) and the International Zinc Nutrition Consultative Group (IZiNCG) (Hotz and Brown 2004; Gibson *et al.* 2008).

In spite of the growing public health concern over zinc deficiency as an etiology of stunting among under-five children, in the Philippines, there is a dearth of nationally representative studies investigating dietary zinc inadequacy and serum zinc deficiency in children. Thus, this study was undertaken to assess dietary zinc intake and serum zinc status. Moreover, this study determined the association between dietary zinc intake and serum zinc concentrations, and examined the factors associated with zinc deficiency in preschool-age children 6 mo–5 yr old. This study aims to provide evidence as a basis for zinc deficiency prevention programs in the Philippine government, which would possibly contribute to addressing stunting among children below 5 yr of age, and would ultimately direct towards the achievement of the country's 2030 Sustainable Development Goals, 2025 World Health Assembly of the Global Nutrition Report, and the 2017–2022 Philippine Plan of Action for Nutrition targets of improving the health and nutrition of Filipino children.

MATERIALS AND METHODS

Study Design and Population

This study analyzed the data from the 8th NNS, a cross-sectional, population-based survey conducted by DOST-FNRI in 2013. The survey employed a stratified three-stage sampling design to select representatives from the 17 regions and 80 provinces in the Philippines. Of the 4,370 eligible subjects belonging to the 6–71-mo-old age group drawn from sample households, 3,129 children had records on biochemical analysis. However, only 2,892 (92.4%) children had complete food consumption data and, were, thus included in data analysis. Children were disaggregated by short age group interval (6–11, 12–23, 23–35, 36–47, 48–59, and 60–71 mo) in order to capture the shifts in the dietary patterns among the pre-school-age children. Further details on the survey and sampling design are published elsewhere (DOST-FNRI 2015c).

Assessment

Food and nutrient intakes. Two non-consecutive 24-hr food recalls were administered by registered nutritionist-dietitians using pre-tested questionnaires conducted through face-to-face interviews with the child's mother or caregiver. Foods and beverages consumed during the previous 24-hr period were collected using standard common household measurements, such as cups and tablespoons. The weight of food consumed by the child was further converted to weight as purchased using conversion factors. The corresponding energy and nutrient content was estimated using the Individual Dietary Evaluation System (IDES), a computer software containing updated data of the Philippine food composition table that was built on previous NNS data. Food items excluded from the IDES were sourced out from the following references: 1) the United States Department of Agriculture national nutrient database, 2) the food composition database of the Association of Southeast Asian Nations, and 3) information from food labels. For breastfed children 6–24 mo of age, average breastmilk intake was assumed with estimated energy, protein, fat, carbohydrate, and nutrient intakes based on child's age (PAHO 2003). For children 6–23 mo with complementary feeding and those aged 23–36 mo, the amount of breast milk intake was assumed to be 650 ml based on the 2015 PDRI (DOST-FNRI 2015d).

The percentage of inadequate intake of zinc was evaluated by determining the number of children with adequacy below 100% of the EAR for zinc. The 2015 PDRI defined zinc inadequacy using EAR for children aged 6–11 mo (boys: < 2.8; girls: < 2.5 mg), 1–2 yr (boys: < 2.8; girls: < 2.6 mg), and 3–5 yr (boys: < 3.3; girls: < 3.2 mg) (DOST-FNRI 2015d). Similarly, the proportion of children with inadequate intakes of energy and protein were those with intake below 100% of the recommended energy intake and EAR for protein. Likewise, the proportion of children with inadequate daily intakes of iron, vitamin A, and vitamin C refers to all children with intakes below the respective EAR (DOST-FNRI 2015d). The mean percent contribution of zinc from animal and plant sources was computed by adding the corresponding amount of zinc from each animal- and plant-source consumed by all children and dividing the result by the total zinc intake of all children.

Biomarkers. Blood extraction was conducted in a centralized location, *e.g.* "barangay" (village/ward) health center or barangay hall. Blood was drawn through the finger-prick method using sterile contact activated blood lancets and collected in trace-element-free microtainer tubes. The entire blood sample was centrifuged at 3,000 rpm for 10 min within 2 hr of collection using an electric centrifuge (Beckman Allegra model) at the field data collection center. Serum was aliquoted into a trace-element-free blue top tube (BD tube #369737) using a disposable pipette. Microtainer tubes were stored in a freezer. In the field, serum was kept frozen in freezers or ice chests with dry ice. Blood samples were transported frozen to the biochemical laboratory of DOST-FNRI and kept in –80 °C freezers until laboratory analysis was conducted.

Serum zinc was analyzed using a flame atomic absorption spectrometer (Agilent 240 FS AA). Accuracy was assessed using two standard reference materials, *i.e.* the NIST SRM 1598a and Seronorm trace elements serum. Hemoglobin (Hb) level was assessed by cyanmethemoglobin (ICSH 1995) and serum retinol by high-performance liquid chromatography.

There is no single, specific, and sensitive biomarker of zinc status at the individual level. However, it is suggested that serum zinc can be useful in identifying groups at risk of developing zinc deficiency. In this study, zinc deficiency was defined using the cut-off suggested by IZiNCG, *i.e.* serum zinc concentration < 65 μg/dL (< 9.9 μmol/L) for children under 10 yr and for morning blood samples. Vitamin A deficiency was defined as serum retinol < 20 μg/dL based on the Guidelines for the Interpretation of Plasma Vitamin A Level (WHO 2011), while anemia was based on Hb <11.0 g/dL among children less than 6 yr of age (WHO 2001).

Physical growth. The nutritional status of study participants was assessed based on weight, recumbent length (for children under 2 yr of age), and standing height (for children 2–5 yr old). The WHO Child Growth Standard and 2007 growth reference were used to define the nutritional status of children 6–60 mo old and 61–71 mo old, respectively. Underweight was defined as weight-for-age Z score (WAZ) below –2SD from the median distribution and normal weight-for-age was defined as WAZ –2SD to +2SD (WHO 2006). Stunting was defined as height-for-age Z score (HAZ) below –2SD from the median distribution and not stunted as having HAZ –2SD to +2SD.

Household characteristics. Data on socioeconomic status (SES), place of residence (urban/rural), household sanitation, and household food insecurity were analyzed. SES was assessed by constructing the household wealth index through principal component analysis, taking into consideration the type of housing materials used on the floor, roof, and wall, household water access and toilet facility, household ownership of selected assets such as appliances (TV, radio, refrigerator, *etc.*), vehicles (car, bicycle, *etc.*), and electricity connection (DOST-FNRI 2015c). The household wealth index was categorized into five quintiles (poorest, poor, middle, rich, and richest).

Household food insecurity was assessed using the Household Food Insecurity Access Scale (HFIAS), which was modified, translated, and pre-tested for its applicability in the Philippine setting during the pilot study of the 2013 NNS. Based on nine questions regarding difficulties experienced in securing food needs in the past month from the date of the interview, households were categorized into four levels: food secure, mildly, moderately, and severely food insecure.

Household source of drinking water was categorized as improved sources (protected well or spring, communal faucet system or stand post or waterworks system, and bottled water) or not improved sources (unprotected dug well or spring, tanker truck/cart with drum, and surface water). Household type of toilet facility was classified as no facility (bush/field, wrap and throw), water-sealed (pour/flush to septic tank), or not water-sealed (without septic tank, pit latrine). Place of residence was grouped into two – urban residents were those living in urban areas and rural residents were those living in rural areas – as specified by the national census of the Philippine Statistics Authority.

Statistical Analysis

Statistical analysis was performed using the statistical software package STATA version 15 (Corp LLC, Texas, USA). Proportion estimates were calculated with a 95% confidence interval, while mean estimates were calculated with standard deviations. T-test of means and analysis of variance (ANOVA) were used to compare means of two and more than two categories, respectively. Pearson's chi-squared (χ^2) test was used to compare proportions. Sampling weights were applied to each individual so that the distribution of the sample corresponds more closely to the actual distribution of the whole population. Thus, statistical analyses such as means, proportions, and odds ratio (OR) in the regression analysis were computed based on weighted data. All relevant socio-economic, demographic, anthropometric, biomarker, and dietary predictor variables that were logically presumed to have an association with zinc deficiency were entered in the bivariate logistic regression analysis. If there was a significant association at $p < 0.05$, the variable was included in the multivariate logistic regression analysis.

Backward stepwise multivariate logistic regression analysis was performed to identify the potential factors contributing to serum zinc deficiency. The independent variables that were presumed to have an association with serum zinc deficiency were entered in the initial regression model. If the regression coefficient (β) of the interacting predictor was significant, it was retained and entered into the final regression model. Independent variables with multicollinearity were excluded from the analysis. The reliability of estimates for the OR was set at a 95% confidence interval.

Ethics Approval

The 8th NNS 2013 was approved by the DOST-FNRI Institutional Ethics Review Committee (FIERC) on 19 Feb 2013 with Protocol Code FIERC-2012-001. All surveyed households provided informed consent prior to participation.

RESULTS

Nearly half (47.2%) of preschool-age children had inadequate zinc intake at the national level (Table 1). Infants in the 6–11-mo-old age group had significantly the highest prevalence of inadequate zinc intake at 68.4% as compared with the other age groups. The prevalence of zinc intake inadequacy decreased as children became older, with prevalence lowest (39.0%) among the oldest children 60–71-mo-old. The prevalence rate remained similar level between sex (boys: 45.7%; girls: 48.7%). Children in rural (55.8%), poorest (62.9%), and severely food insecure households (60.2%) were more likely at risk of developing dietary zinc deficiency than those in the urban, richest, and food secure households. Inadequate zinc intake was significantly more prevalent among underweight (57.2%) and stunted (55.1%) children than children who were not underweight and not stunted. Among children with dietary zinc inadequacy, a significantly higher proportion failed to meet the daily requirements for energy (68.5%), protein (93.0%), vitamin A (62.1%), iron (66.5%), and vitamin C (61.7%) than their peers who met the adequacy requirements for energy and nutrients. Average dietary zinc consumption per day in preschool-age children was 4.0 mg, with children residing in urban areas consuming higher amounts than those from rural areas (4.3 mg *vs.* 3.6 mg; $p < 0.001$). Mean dietary zinc consumption was observed to significantly increase with age – from 2.6 mg among children 6–11 mo to 4.6 mg among children 60–71 mo old. A significant pattern was also observed in the mean dietary zinc intake by place of residence, wealth quintile, and household food security. Preschool children from urban (4.3 mg), richest (6.1 mg), and food secure households (5.2 mg) had significantly higher mean dietary zinc intake than those coming from the rural, poorest, and food-insecure households. No significant difference in the mean dietary zinc and prevalence of zinc inadequacy was observed by sex.

Zinc intake from animal food source was 2.1 mg among preschool-age children, contributing 42.1% of total dietary zinc intake. This was significantly lower than the 52.4% contribution of plant sources of zinc (42.1%; $p < 0.001$) (Table 2). The higher contribution of plant-source relative to animal-sources of zinc to total dietary zinc was significantly evident among older children in the 36–47 mo (58.0% *vs.* 39.9%; $p < 0.001$), 48–59 mo (59.5% *vs.* 39.8%; $p < 0.001$), and 60–71 mo (59.6% *vs.* 39.8%; $p < 0.001$); those in rural (56.3% vs.38.1%; $p < 0.001$), poorest income (62.3% *vs.* 31.8%; $p < 0.001$), and severely food insecure households (60.4% *vs.* 34.2%; $p < 0.001$); and those who were underweight (59.6% *vs.* 36.0%; $p < 0.001$) and stunted (60.1% *vs.* 36.6%; $p < 0.001$). Similarly, a significantly higher mean intake of animal-source zinc was noted in children aged 12–23 mo (2.3 mg) and residing in urban areas (2.3 mg) relative to their counterpart subgroups. Increasing food insecurity and poverty levels were associated with decreasing intake of animal-sources of zinc, as shown in Table 2. Intake of animal-source of zinc was significantly higher among children who were not underweight (2.2 mg) and not

Table 1. Mean dietary zinc intake and proportion of preschool-age children not meeting zinc adequacy (Philippines; 2013).

Characteristics	Zinc intake (mg/d)				Proportion of not meeting zinc requirement (%)		
	Number of subjects (n)	Mean	SD	*p*-value*	Prevalence (%)	95% CI	*p*-value**
National	**2,892**	**4.0**	**3.5**		**47.2**	**44.9- 49.5**	
Demographic and socioeconomic status							
Age (mo)							
6–11	237	2.6	2.6	***< 0.001***	68.4	61.1–74.9	***< 0.001***
12–23	497	3.6	3.7		52.7	47.7–57.7	
24–35	494	3.9	3.7		40.3	35.5–45.2	
36–47	531	4.2	3.3		47.8	42.5–53.0	
48–59	560	4.3	3.1		45.4	41.3–49.7	
60–71	573	4.6	3.8		39.0	34.6–43.6	
Sex							
Boys	1465	4.2	3.4	0.117	45.7	42.7–48.7	0.586
Girls	1427	3.8	3.6		48.7	45.6– 51.9	
Residence							
Rural	1609	3.6	4.3	***< 0.001***	55.8	52.7–59.0	***< 0.001***
Urban	1283	4.3	2.8		39.4	36.0–42.8	
Wealth quintile							
Poorest	822	3.2	4.4	***< 0.001***	62.9	58.9–66.8	***< 0.001***
Poor	634	3.4	2.6		55.0	50.1–59.7	
Middle	627	3.8	2.6		49.4	44.5–54.2	
Rich	488	4.6	2.9		33.0	28.5–37.9	
Richest	321	6.1	3.9		21.6	16.6–27.7	
Food security* **							
Severely food insecure	781	3.3	3.8	***< 0.001***	60.2	55.5–64.8	***< 0.001***
Moderately food insecure	1184	3.7	2.7		49.1	45.3–52.9	
Mildly food insecure	389	4.5	3.9		38.6	34.0–43.5	
Food secure	538	5.2	3.78		31.0	26.3–36.1	
Anthropometric status							
Weight-for-age							
Underweight	625	3.5	3.6	***< 0.001***	57.2	53.5–60.9	***< 0.001***
Not underweight	2267	4.2	3.4		44.5	42.0–47.1	
Height-for-age							
Stunted	850	3.5	3.9	***< 0.001***	55.1	51.3–58.9	***< 0.001***
Not stunted	2042	4.2	3.3		44.1	41.4–46.8	
Dietary adequacy							
Energy (%)							
Not meeting	1884	2.8	2.8	***< 0.001***	68.5	65.5–71.3	***< 0.001***
Meeting	1008	6.1	3.4		11.1	9.1–13.4	
Protein (%)							
Not meeting	646	1.5	1.1	***< 0.001***	93.0	90.5–94.9	***< 0.001***
Meeting	2246	4.7	3.6		34.9	32.6–37.2	
Vitamin A (%)							
Not meeting	1363	3.2	3.2	***< 0.001***	62.1	58.8–65.3	***< 0.001***
Meeting	1529	4.7	3.6		34.1	31.3–37.1	

Characteristics	**Zinc intake (mg/d)**				**Proportion of not meeting zinc requirement (%)**		
	Number of subjects (n)	Mean	SD	*p*-value*	Prevalence (%)	95% CI	*p*-value**
Iron (%)							
Not meeting	1996	2.7	2.7	< ***0.001***	66.5	64.0–69.0	***< 0.001***
Meeting	896	6.6	3.5		7.5	5.8–9.6	
Vitamin C (%)							
Not meeting	1671	3.1	2.4	***< 0.001***	61.7	58.7–64.6	***< 0.001***
Meeting	1221	5.2	4.2		27.9	25.1–30.9	

*Significantly different across categorical variables at $p < 0.05$ using t-test or ANOVA (test of means)
**Significantly different across categorical variables at $p < 0.05$ using Pearson's chi-squared test (test of proportion)
***Assessed using HFIAS

Table 2. Intake of animal-source zinc and percent contribution of animal- and plant-source zinc to total dietary zinc intake of preschool-age children 6–71 mo old, by child and household characteristics (Philippines; 2013).

Characteristics	**n**	**Intake of zinc from animal sources (mg/d)**			**% animal-source zinc to total zinc intake**	**% plant-source zinc to total zinc intake**	***p*-value****
		Mean	SD	*p*-value*	%	%	
National	2,892	2.1	3.1		42.1	52.4	***< 0.001***
Age (mo)							
6–11	237	1.6	2.5	0.063	34.0	33.4	0.8404
12–23	497	2.3	3.6		48.2	41.5	***0.0003***
24–35	494	2.2	3.4		47.2	52.3	***0.0026***
36–47	531	2.0	2.6		39.9	58.0	***< 0.001***
48–59	560	2.0	2.5		39.8	59.5	***< 0.001***
60–71	573	2.2	3.4		39.8	59.6	***< 0.001***
Sex							
Boys	1465	2.2	3.0	0.897	41.9	53.1	***< 0.001***
Girls	1427	2.1	3.2		42.3	51.8	***< 0.001***
Residence							
Rural	1609	1.8	3.9	***< 0.001***	38.1	56.3	***< 0.001***
Urban	1283	2.3	2.3		45.7	49.0	***0.0008***
Wealth quintile							
Poorest	822	1.4	4.1	***< 0.001***	31.8	62.3	***< 0.001***
Poor	634	1.5	1.9		37.0	57.3	***< 0.001***
Middle	627	1.9	2.1		41.7	53.2	***< 0.001***
Rich	488	2.7	2.4		51.3	43.8	***< 0.001***
Richest	321	4.0	3.7		57.2	37.2	***< 0.001***
Food security***							
Severely food insecure	781	1.5	3.5	***< 0.001***	34.2	60.4	***< 0.001***
Moderately food insecure	1184	1.8	2.2		41.0	53.7	0.1898
Mildly food insecure	389	2.5	3.4		45.9	48.5	***< 0.001***
Food secure	538	3.2	3.5		52.8	41.6	***< 0.001***

Characteristics	n	Intake of zinc from animal sources (mg/d)			% animal-source zinc to total zinc intake	% plant-source zinc to total zinc intake	*p*-value**
		Mean	SD	*p*-value*	%	%	
Weight-for-age							
Underweight	625	1.6	3.2	***< 0.001***	36.0	59.6	***< 0.001***
Not underweight	2267	2.2	3.0		43.7	50.6	***< 0.001***
Height-for-age							
Stunted	850	1.6	3.6	***< 0.001***	36.6	60.1	***< 0.001***
Not stunted	2042	2.3	2.9		44.3	49.4	***< 0.001***

*Significantly different across categorical variables at $p < 0.05$ using ANOVA/t-test (test of means).
**Significantly different between the two sources of zinc at $p < 0.05$ using t-test (test of means)
***Assessed using HFIAS

stunted (2.3 mg) as compared with underweight (1.6 mg; $p < 0.001$) and stunted (1.3 mg; $p < 0.001$).

Intake of phytate remained at similar levels irrespective of place of residence, household wealth, and food security status (Table 3). Nonetheless, phytate intake significantly increased with age, with the intake being highest among children 60–71 mo at 122.1 mg. The overall mean intake of phytate among preschool-age children was 94.3 mg.

The prevalence of zinc deficiency based on low serum zinc (< 65 µg/dL) was 17.9% (Table 4). A prevalence of this magnitude is considered to be of moderately high public health concern. Zinc deficiency prevalence was

Table 3. Intake of phytate among preschool-age children 6–71 mo old, by age, place of residence, wealth status, and food security status (Philippines; 2013).

Characteristics	n	One-day intake of phytate (mg/d)		*p*-value*
		Mean	SD	
National	2892	94.3	138.3	
Age (mo)				
6–11	237	32.7	54.9	***< 0.001***
12–23	497	57.6	54.1	
24–35	494	87.3	122.6	
36–47	531	112.1	199.7	
48–59	560	120.5	170.6	
60–71	573	122.1	92.9	
Residence				
Rural	1609	95.0	198.1	0.383
Urban	1283	94.0	72.5	
Wealth quintile				
Poorest	822	93.6	133.7	0.157
Poor	634	102.9	245.0	
Middle	627	86.1	66.7	
Rich	488	94.2	73.1	
Richest	321	96.5	91.8	
Food security **				
Severely food insecure	781	87.7	85.1	0.341
Moderately food insecure	1184	98.2	145.4	
Mildly food insecure	389	99.1	241.2	
Food secure	538	92.1	83.3	

*Significantly different across categorical variables at $p < 0.05$ using ANOVA (test of means)
**Assessed using HFIAS

significantly highest among children 12–23 mo of age (21.0%) and those from rural areas (21.1%), poorest households (27.9%), and food-insecure households (25.3%). Zinc deficiency was significantly more prevalent among underweight (21.0%) and stunted children (24.5%) compared to those with normal nutritional status. With regard to micronutrient status, the prevalence of zinc deficiency was significantly higher among anemic than non-anemic children (22.7% and 17.1%, respectively; $p < 0.05$) and among vitamin A deficient than non-vitamin A-deficient children (27.6% and 15.5%, respectively; $p < 0.001$), as shown in Table 4.

Results also showed that a significantly higher prevalence of serum zinc deficiency was noted in children who failed to meet the age-specific daily requirements for energy (19.9%), protein (24.3%), vitamin A (20.8%), iron (20.3%), and vitamin C (19.5%) than those whose diets were within the required energy and micronutrient adequacy (Table 4). Moreover, a significant association was noted between dietary zinc inadequacy and serum zinc deficiency, noting that the prevalence of serum zinc deficiency was higher among children with inadequate zinc intake than their children counterparts (21.3% and 14.8%; $p < 0.05$) as shown in Table 4.

Table 4. Prevalence of serum zinc deficiency among preschool-age children 6–71 mo old at the national level and by child and household characteristics (Philippines; 2013).

Characteristics	Number of subjects (n)	Prevalence (%)	95% confidence interval	*p*-value*
National	**2,892**	**17.9**	**16.1–19.7**	
Demographic and socioeconomic status				
Age (mo)				
6–11	237	20.5	14.3–26.7	***0.029***
12–23	497	21.0	17.0–24.9	
24–35	494	17.9	13.6–22.3	
36–47	531	13.1	10.0–16.2	
48–59	560	18.2	14.9–21.4	
60–71	573	18.1	14.8–21.5	
Sex				
Male	1465	17.2	15.0–19.5	0.875
Female	1427	18.6	16.2– 20.9	
Residence				
Rural	1609	21.1	18.4– 23.7	***0.001***
Urban	1283	15.0	12.6–17.4	
Wealth quintile				
Poorest	822	27.9	23.5–32.3	***< 0.001***
Poor	634	21.3	17.0–25.6	
Middle	627	14.3	11.0–17.6	
Rich	488	12.5	9.2–15.7	
Richest	321	7.3	4.8–9.9	
Food security**				
Severely food insecure	781	25.3	21.3–29.3	***< 0.001***
Moderately food insecure	1184	17.6	14.8–20.4	
Mildly food insecure	389	12.0	8.6–15.4	
Food secure	538	12.2	9.2–15.2	

Characteristics	Number of subjects (n)	Prevalence (%)	95% confidence interval	*p*-value*
Anthropometric status				
Weight-for-age				
Underweight	625	21.0	17.0–25.1	***0.010***
Not underweight	2267	17.0	15.2–18.9	
Height-for-age				
Stunted	850	24.5	20.5–28.4	***< 0.001***
Not stunted	2042	15.3	13.4–17.2	
Micronutrient status				
Anemia				
Anemic	2493	22.7	18.3–27.7	***0.0077***
Not anemic	399	17.1	15.5–18.9	
Serum vitamin A				
Vitamin A deficient	581	27.6	23.5–32.1	***< 0.001***
Not deficient	2276	15.5	13.7–17.3	
Dietary adequacy				
Energy				
Not meeting	1884	19.9	17.6–22.2	***< 0.001***
Meeting	1008	14.5	12.0–17.0	
Protein				
Not meeting	646	24.3	20.2–28.5	***< 0.001***
Meeting	2246	16.1	14.2–18.0	
Vitamin A				
Not meeting	1363	20.8	18.3–23.2	***< 0.001***
Meeting	1529	15.4	13.2–17.5	
Iron				
Not meeting	1996	20.3	18.0–22.6	***< 0.001***
Meeting	896	12.8	10.5–15.2	
Zinc				
Not meeting	1420	21.3	18.5–24.3	***0.003***
Meeting	1472	14.8	12.8–17.1	
Vitamin C				
Not meeting	1671	19.5	17.2–21.8	***0.024***
Meeting	1221	15.7	13.3–18.1	

**Significantly different across categorical variables at $p < 0.05$ using Pearson's chi-squared test (test of proportion)
*Assessed using HFIAS

The logistic regression analysis included 25 potential contributory factors ranging from household socio-demographic and economic factors, child anthropometric status, micronutrient status, and dietary intakes; however, only those with significant associations were presented in Table 5. Results showed that stunted children were 1.37 more likely to have zinc deficiency (95% CI = 1.06–1.76) than children who were not stunted. Likewise, children who suffered from serum vitamin A deficiency were more likely to be zinc deficient (OR 1.8; 95% CI = 1.43–2.26) than children who had normal serum retinol concentrations. Zinc deficiency was less likely to occur among children with adequate dietary vitamin A intake (OR 0.74; 95% CI = 0.60–0.92) than among children

Table 5. Multivariate logistic regression determining contributory factors for zinc deficiency in preschool-age children 6–71 mo (Philippines; 2013).

Characteristics	Adjusted odds ratio	*p*-value*	95% CI	
			LL	UL
Height-for-age Z-score				
Not stunted	Reference			
Stunted	1.3686	***0.0150***	1.0632	1.7618
Dietary vitamin A adequacy				
Not meeting	Reference			
Meeting	0.7418	***0.0040***	0.6044	0.9251
Serum vitamin A status				
Not vitamin A deficient	Reference			
Vitamin A deficient	1.8016	***0.0000***	1.4338	2.2638
Wealth quintile				
Poorest	4.0196	***0.0000***	2.2229	5.9998
Poor	3.0545	***0.0000***	1.7274	4.8616
Middle	2.0463	***0.0030***	1.1607	3.2544
Rich	1.7588	***0.0230***	1.0527	2.9275
Richest	Reference			
Constant	0.0798	0.0000	0.0530	0.1202

*Significant at $p < 0.05$

whose intakes were below the recommended amount. Children in the poorest and poor households were four and three times more likely to become zinc deficient than children in the richest households. In general, there was an increased likelihood of developing zinc deficiency as the household becomes poorer.

There is limited literature that uses national-level data to establish the extent of dietary zinc intake in Asia. In the Philippines, this study represents national estimates of dietary zinc inadequacy and serum zinc deficiency among pre-school children. The results revealed that dietary mean zinc intake was 4.0 mg/d, with a 47.2% prevalence of inadequate zinc intake, among preschool-age children. This finding was consistent with the national estimate in Bangladesh for mean zinc intake (3.1 mg/d) and zinc intake inadequacy prevalence (32.6%) among preschool-age children (Rahman *et al.* 2016). A recent epidemiological study in India reported inadequate zinc intake among 66.2% and 57.7% among 1–3- and 4–5-yr-old children, respectively (Bains *et al.* 2015). Moreover, half of the preschool children in Sri Lanka had dietary zinc inadequacy mainly due to inadequate consumption of animal-source zinc (Hettiarachchi and Liyanage 2012). Consistently, Filipino preschool-age children with adequate intake of energy, protein, vitamin A, iron, and vitamin C were found to have significantly higher serum zinc levels relative to their peers with an inadequate intake of energy and key micronutrients. The present study confirmed that inadequate zinc intake was associated with serum zinc deficiency in Filipino children, which may have detrimental effects on the physical and mental development of the children. This finding underscores the importance of adequate zinc intake and also the overall quality of food intake. It is crucial to consume adequate macro- and micronutrients to enhance zinc absorption.

Age is one important covariate affecting dietary zinc in preschool-age children in the Philippines. Children in the 6–11- and 12–23-mo age groups had the lowest mean intake of dietary zinc (2.6 mg and 3.6 mg, respectively) whereas children in the 60–71-mo age group had the highest (4.6 mg). Consequently, the proportion of children who had dietary zinc inadequacy decreased with increasing age, with the highest proportion among 6–11- and 12–23-mo-old children (68.4% and 52.7%, respectively) and the lowest among children 60–71-mo old (39.0%; $p < 0.001$). Furthermore, the lower consumption of dietary zinc among children under two years than that of their older peers 24–71 mo old could account for the higher prevalence of zinc deficiency (cut off serum zinc < 65 µg/dL). The quality of complementary foods consumed by children, which is grossly inadequate in micronutrients, could underlie this phenomenon. Information derived from the 24-hr food recall of the 2013 NNS showed that only 15.5% of children 6–23 mo old had a diverse diet and only 6.4% met the minimum acceptable diet, reflecting poor complementary feeding practices among young children. This result highlights an important finding in relation to nutrition interventions promoting nutrient-dense foods, which include zinc as an important nutrient, among Filipino children, particularly during the complementary feeding period from 6–23 mo of age. Study results suggest that increasing zinc intake to about twice the amount (2.6 mg/d to 4.6 mg/d) might be associated with a significant reduction in the prevalence of dietary zinc inadequacy (from 68.4% to 39.0%). This finding is consistent with a recent meta-analysis of all eligible randomized controlled trials that found a significant effect of zinc intake and serum/plasma zinc concentration in children, which indicated that a 9.0% difference in zinc serum/plasma concentration resulted from each two-fold increase in zinc intake (Moran *et al.* 2012).

This study also examined the factors associated with zinc deficiency based on cut-off serum zinc of < 65 µg/dL in preschool-age children 6 mo–5 yr old.

Stunting and Zinc Deficiency

The prevalence of zinc deficiency among vulnerable population groups are primarily determined using two indicators: stunting and inadequacy of zinc intake (Brown *et al.* 2004). In the Philippines, a high stunting prevalence (30.3%) was reported in preschool-age children below 5 yr old, confirming a high dietary zinc inadequacy (47.2%) among this age group. Logistic regression analysis showed that stunted children were 1.3 times (OR: 1.37; 95% CI: 1.04–1.73) more likely to become zinc deficient than non-stunted children. Similarly, stunted children were found to have lower mean serum zinc levels and higher zinc deficiency prevalence compared to non-stunted children. This is attributed to the central role of zinc in protein synthesis, cellular differentiation, and cellular growth, including DNA replication (Brown *et al.* 2004), especially in young children. The result corroborates studies in experimental human intervention trials, indicating that zinc deficiency is growth limiting. Children with low height-for-age were found to be likely zinc deficient (Hotz and Brown 2004). Furthermore, a meta-analysis performed by Imdad and Bhutta (2011) reported that zinc supplementation has a significant effect on linear growth. A study involving preschool children 2–3 yr old in Laguna, Philippines found a negative association between zinc status and stunting, indicating that zinc deficiency was less likely to occur among children with normal height for their age (Naupal-Forcadilla *et al.* 2017).

Serum Retinol, Dietary Vitamin A, and Zinc Deficiency

Logistic regression analysis showed that children with vitamin A deficiency (cut-off serum < 20 µg/dL) were more likely to have zinc deficiency than children with normal serum retinol levels. Likewise, children who had dietary vitamin A inadequacy had lower serum zinc concentration and, concomitantly, higher zinc deficiency prevalence based on serum zinc as opposed to children with adequate vitamin A intake. All these point to the important role of vitamin A in addressing zinc deficiency among preschool-age children, which could be attributed to the synergistic relationship between vitamin A and zinc as reported in epidemiological studies (Rahman *et al.* 2002) – particularly the common dietary sources of zinc and vitamin A – and the possible role of zinc in the synthesis of retinol-binding protein (Mann and Truswell 2000). Zinc deficiency reduces the amount of circulating retinol, causing functional vitamin A deficiency even when liver stores may be sufficient. Severely malnourished children or those with protein-energy malnutrition produce retinol-binding protein at a diminished rate and have lower serum retinol and zinc concentrations (WHO 2011).

Wealth Status and Zinc Deficiency

Poverty remains the primary underlying factor of inadequate food intake, poor dietary diversity and feeding practices, higher exposure to recurrent infection, and poor health status because of poor environmental sanitation, unhygienic practices, and lack of access to health services. Logistic regression analysis showed that zinc deficiency was strongly predicted by poor wealth status, indicating that children from the poorest and poor households were 4.0 times (OR = 4.2; 95% CI = 2.22–6.0) and 3.0 times (OR=3.05; 95% CI = 1.72–4.68) likely to be zinc deficient, respectively, than children belonging to the richest households. This could be due to the higher bioavailable zinc from animal sources, which was 2.6 times higher among children from the richest than from the poorest households, and 1.7 times higher among children in food-secure than from the poorest and severely food insecure households. Moreover, preschool-age children living in urban areas had a significantly higher intake of bioavailable zinc from animal sources than children in rural areas (2.3 *vs.* 1.8 mg/d). This could be explained in part by the assumption that rural areas usually have a greater proportion of poorer segments of the population that may be unable to afford or access a wide range of animal-source food such as meat, egg, fish, and poultry. This observation is consistent with other studies showing that zinc deficiency was more widespread in children residing in rural areas and belonging to the poorest groups of the population (Engle-Stone *et al.* 2014).

Animal and Plant Sources of Zinc

A strong association between the consumption of plant-based diets and zinc deficiency in developing countries has been widely reported (Gibson *et al.* 2010). A higher percent contribution of plant-sourced zinc (52.4%) relative to animal-source zinc (42.1%) in the diet of preschool-age children reported in this study was evident among children 3–5 yr old, those from rural, poor to poorest income, and severely food insecure households, and those who are stunted and underweight. The 2013 NNS described the dietary intake of preschool-age Filipino children to be generally cereal-based, composed of rice and corn (24.0%) as staples, with little amounts of fish (5.5%), meat (4.8%), or poultry (1.9%) (DOST-FNRI 2015a).

In addition, the 2008 NNS noted that zinc-deficient children had lower intakes of most nutrients; consumed lesser amounts of fish, meats, and poultry; and had higher intakes of corn and corn products and green leafy vegetables (Marcos *et al.* 2019). Thus, the high prevalence of zinc inadequacy among preschool-age Filipino children in this study could be attributed to low intake of animal-source zinc and low zinc bioavailability of plant-based diets. This emphasizes the importance of consuming animal-sourced foods in increasing zinc levels among children. As discussed previously, phytate – which is present in staple foods such as cereals, corn, and rice – has an inhibiting effect on zinc absorption (Lönnerdal 2000). Consequently, a plant-based diet that includes phytate intake needs further attention *vis-à-vis* dietary zinc inadequacy and serum zinc deficiency prevalence among preschool-age children in the Philippines.

STRENGTHS AND LIMITATIONS

This study adds to the limited studies that utilize nationally representative data to estimate dietary zinc intake and zinc inadequacy, including phytate intake, in children 6–71 mo old. Another strength of this study is its focus on zinc as an important micronutrient among preschool-age children, involving a wide range of underlying covariates of serum zinc deficiency such as age, SES, urban-rural residence, household food insecurity, and food intake. Since serum zinc is the most suitable biomarker to evaluate zinc status in children, blood collection at the assembly area was strictly done only in the morning – between 6:00 AM to 12:00 PM – to avoid diurnal variations in serum samples, thus ensuring the quality of blood samples analyzed in this study. Lastly, trained personnel administered the 24-hr food recall to ensure accurate collection of the actual amounts of food consumed in the previous day.

The cross-sectional design of the present study is constrained by its inability to establish causal relationships between studied independent variables or predictors and the outcome variable, which was the serum zinc deficiency. Moreover, the 24-hr food recall method is limited in terms of estimating nutrient intake of children, given that it is dependent on respondent's (*i.e.* mother's or caregiver's) recall, and the adoption of food composition tables from other countries may cause the possibility of under- or overestimating the child's intake. Lastly, since the purpose of this study is to estimate the nutrient intakes based on food and beverages only, the use of dietary supplements was not considered.

CONCLUSION AND RECOMMENDATIONS

There is a high prevalence of inadequate zinc intake and serum zinc deficiency among Filipino preschool-age children. Among the contributory factors associated with high serum zinc deficiency are stunting, serum vitamin A deficiency and dietary vitamin A inadequacy, and poor household wealth status. This study revealed a significantly higher intake of plant food, which is generally a poor source of bioavailable zinc. Strengthening programs on micronutrient supplementation (including zinc), food fortification, nutrition and health promotion and education, and dietary diversification through promotion of household and community food production – combined with micronutrient-dense food consumption among preschool-age children – could help achieve long-term nutrition and health outcomes. More research is needed to determine the effect of these interventions on the zinc status of Filipino children.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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