Philippine Journal of Science
148 (2): 225-236, June 2019
ISSN 0031 - 7683
Date Received: 29 Oct 2018

Risk Factors Associated with Zinc Status of Filipino Preschool and School-aged Children

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In the 2008 National Nutrition Survey, zinc deficiency among preschool and school-aged children was reported as a significant public health problem. This study aimed to identify the risk factors correlated to zinc deficiency in preschool (6 mo – 5 yr old) and school-aged (6 – 12 yr old) Filipino children. Statistical analyses were done to measure the association of zinc status of children with demographic, anthropometric, biochemical, dietary, environmental, and socioeconomic data of the 2008 National Nutrition Survey using test on means, chi-square test and test on distributions and logistic regression analysis. Older preschool and school children were more at-risk to zinc deficiency. Stunting, anemia, vitamin A deficiency, and iodine deficiency disorder were more prevalent in zinc-deficient children. Lower average intakes of most nutrients; consumption of lesser amounts of fish, meats, and poultry; and higher intake of corn and corn products and green leafy vegetables were also noted among zinc-deficient children. Children belonging to households with lower wealth quintile and with household head working as agricultural farmer or fisherman are also more at-risk. Being male, residence in rural areas and educational attainment of household head below high school also lower zinc status in school-aged children. Older age, high prevalence of stunting, anemia, and vitamin A deficiency, and inadequate and poor quality diets are significantly associated to zinc deficiency among preschool and school-aged children. Poor households and household head working as agricultural farmer or fisherman are likewise significant risk factors among these children. Being male, residence in rural areas and educational attainment of household head below high school also significantly correlates to low zinc status of school children.

Key words: Filipino preschool and school children, micronutrient deficiencies, nutrient and food intakes, socio-economic status, stunting, zinc deficiency

INTRODUCTION

Global recognition of the importance of zinc nutrition in human health has dramatically expanded in recent years. Research conducted during the past 10–15 years suggests that zinc deficiency is widespread and affects the health and well-being of populations worldwide (Caulfield & Black 2004). It increases the risk and severity of infections, restricts physical growth and development, and impairs health and specific outcomes of pregnancy. Zinc deficiency ranks fifth among the 10 leading causes of illness and disease in developing countries (WHO 2002) and was estimated to contribute to over half a million deaths/year in infants and children under 5 years of age (Krebs *et al.* 2014).

Similar to other nutrient deficiencies, infants and children appear to be among the most commonly affected by low zinc status. Inadequate intake of absorbable zinc is likely the primary cause of zinc deficiency in most situations.

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This may be a result from combination of low total dietary intake and heavy reliance on foods with low zinc content and/or with zinc that is poorly absorbable (Hotz & Brown 2004). Increased demands of zinc due to rapid growth and decreased intake of zinc due to inadequate feeding practices predispose preschool children at elevated risk of zinc deficiency (Dhingra *et al.* 2009). Environmental enteropathy (or exposure to contaminated food and water), which is prevalent in low-resource settings, may substantially impair zinc absorption and/or increase endogenous losses – leading to relatively high zinc requirements (Krebs *et al.* 2014). The physiologic and pathologic conditions associated with elevated zinc requirements place individuals at increased risk to zinc deficiency (Hotz & Brown 2004). Multiple factors may be responsible for zinc deficiency among preschool and school-aged children. Establishment of these factors is a major way of enhancing, planning, and implementing intervention to curb the menace of these problems (Krebs *et al.* 2014). In the 2008 National Nutrition Survey (NNS), zinc deficiency in the Philippines based on serum zinc levels was reported generally of high magnitude (≥20%) both at the national level (30.0%) and at different population groups – with 21.6 and 30.8% of preschool and school-aged children, respectively found zinc-deficient (Marcos *et al.* 2015).

This study aimed to identify the risk factors associated with zinc deficiency among Filipino preschool and school-aged children. Results of the study will be relevant inputs for program planners and policy makers in designing or formulating new and effective intervention strategies to alleviate zinc status of Filipino children.

METHODOLOGY

The data of this study were extracted from the Biochemical Component of the 2008 NNS conducted by the Department of Science and Technology's Food and Nutrition Research Institute (DOST-FNRI) during May–Dec 2008. This component of the 2008 NNS was designed to provide national level estimates of malnutrition using biochemical variables. The 2008 NNS covered all 17 regions of the country, including 79 provinces except Batanes.

The sampling design of the 2008 NNS is a stratified multi-stage sampling design, named 2003 master sample, developed by the Philippine Statistics Authority (formerly named Philippine National Statistics Office). The primary sampling unit is a group of households (HHs) with at least 500 HHs was the 1st stage of sample, followed by enumeration areas or barangay/village with 150–200 HHs, while the final unit of sample was the HHs. All members of each sampled HH were considered eligible participants for the 2008 NNS.

Participants were requested to sign an informed consent form after a thorough briefing on the protocol of the 2008 NNS. The consent form also contains no-disclosure of information, in which the information obtained from the respondent(s) and participant(s) with corresponding identity will not be disclosed to any person or agency. Age was computed as of last birthday. Data on infections for the past 30 days and supplement intakes for the past three months were collected through face-to-face interview of mother/caregiver using the Biochemical Component questionnaire. Those members with illness during the survey were excluded in the blood extraction.

The survey team's registered medical technologist provided appropriate emergency measures or first aid whenever the subject/participant experienced untoward incident or negative side effects during the collection of biological samples using sterile disposable syringes and needle. Arrangements were also made with the Department of Health for the use of facilities in government hospitals in emergencies during data collection (DOST-FNRI 2010).

The protocol for the conduct of the 7th NNS project specifically for each survey component was submitted to the FNRI Institutional Ethics Review Committee (FNRI-IERC) for clearance. However, according to FNRI-IERC, the 7th NNS does not require ethical clearance since it is a legal mandate of the Food and Nutrition Research Institute. It is also an activity of a health program that defines the nutritional status of the Philippine population for public health or welfare and serves as a reliable guide for health planning and intervention. The NNS is within the ambit of Executive Order 128, which mandates the FNRI to define the nutritional status of the Filipino citizenry. Ethical principles such as protection of life, health, privacy, and dignity of human subjects/participants – along with scientific integrity – were largely considered in the implementation of the NNS.

In this present in-depth study, all preschool (6 mo – 5yr) and school-aged children (6 – 12 yr) of the Biochemical Component of the 2008 NNS with serum zinc values were included in the data analyses. Based on their zinc status, both preschool and school-aged children were categorized as normal and zinc-deficient using the lowest cut-off for serum zinc recommended by International Zinc Nutrition Consultative Group (IZiNCG) (Hotz & Brown 2004). Serum zinc levels less than these suggested lowest cut-off points were considered zinc-deficient, while children with serum zinc level equal and above these cut-off points were considered with normal zinc status.

A calibrated 160 kg capacity Detecto platform balance was used to measure the weight. Standing height of children two years and up was measured using a microtoise, and the recumbent length for those less than two years was taken using an infantometer or wooden length board (DOST-FNRI 2010). Anthropometric indices were based on World Health Organization Child Growth Standards for 0–5 yr old children (WHO-MGRS 2006) and WHO Growth Reference 2007 for 5.08–12 yr old children (De Onis *et al.* 2007). WHO Anthro version 3.2.2 (2011) and WHO AnthroPlus version 1.0.3 (2009) were used in generating the anthropometric indices.

Serum zinc levels was assessed by atomic absorption spectrometer (Smith *et al.* 1979), hemoglobin (Hb) by cyanmethemoglobin (ICSH 1978), serum retinol (SR) by high performance liquid chromatography (Furr *et al.* 1992), and urinary iodine excretion (UIE) by acid digestion method (Dunn *et al.* 1993). Serum zinc levels <65 µg/dL for children <10 yr and <70 and <66 µg/dL for boys and girls ≥ 10 yr, respectively were considered zinc-deficient (Hotz & Brown 2004). Vitamin A deficiency (VAD) was defined as SR < 20 µg/dL based on Guidelines for the Interpretation of Plasma Vitamin A level (WHO/UNICEF/HKI/IVACG 1982), while anemia based on Hb was defined as Hb <11.0 and 12.0 g/dL among children ≤ 6 y and > 6y, respectively (WHO 1972). Iodine deficiency disorder (IDD) was median UIE < 100 µg/L based on epidemiological criteria for assessing severity of IDD (WHO/UNICEF/ICCIDD 2001), determined only among school-aged children.

Food and nutrient intakes were based on average of two-day, non-consecutive 24-hour food recall. The Individual Dietary Evaluation System (IDES) of DOST-FNRI was used in generating the energy and nutrient intakes. Environmental and other socioeconomic data were also included in the study.

The sampling design of the data was incorporated in data analysis using the survey module of Stata 12.1 and survey package of R 3.5.0. All variables were used for descriptive statistics and confounders were controlled in logistic regression. Five percent (5%) level of significance was used all through-out the statistical analysis.

Chi-square test, test on means, design-based ranks test (Lumley & Scott 2013), and logistic regression analysis were used to measure the association of different variables to zinc status of the children.

RESULTS

Table 1 presents the selected demographic, anthropometric, and biochemical profile of Filipino preschool and school-aged children. A total of 2301 preschool children and 3760 school-aged children were included in this study. Mean age (standard error) in months was 39.8 (4) and 115 (0.38) for preschool and school-aged children, respectively. The proportion of male was slightly higher than female for preschool and school-aged children. Mean weight and height for preschool children were 12.7 (0.07) kg and 90.7 (0.3) cm, respectively, while 25.1(0.14) kg and 126.0 (0.2) cm for school-aged children. Prevalence of underweight was 21.8% among preschool children, while the underweight prevalence of school-aged children was not presented since only 0–120 mo children had weight-for-age index. Prevalence of stunting was 31.1% for preschool children and 36.2% for school-aged children, while the proportion of wasting among preschool children was 6.0% and 12.3% for school children. Preschool children had higher mean serum zinc with 94.8 (1.2) µg/dL than school children with 79.9 (0.8) µg/dL. On the other hand, prevalence of zinc deficiency was lower among preschool children (21.4%) compared to 30.8% among school-aged children. Mean Hb in preschool children was 11.7 (0.03) g/dL and 12.8 (0.02) g/dL in school children, while prevalence of anemia was higher at 23.8% in preschoolers than 19.9% in school children. Mean SR was almost the same among preschool and school-aged children at 31.6 (0.4) µg/dL and 32.5 (0.3) µg/dL,

Table 1. Selected demographic, anthropometric and biochemical profile of Filipino preschool and school-aged children.

Indicators	Preschool Children	School-aged Children
	(n = 2301)	(n = 3760)
Age (mo)	39.8 (0.4)	115 (0.38)
Sex		
% Male	53.0 (1.1)	52.6 (0.9)
% Female	47.0 (1.1)	47.4 (0.9)
Anthropometric status		
Height (kg)	90.7 (0.3)	126.0 (0.2)
Weight (cm)	12.7 (0.07)	25.1 (0.14)
% Underweight	21.8 (1.0)	–
% Stunted	31.1 (1.1)	36.2 (1.0)
% Wasted	6.0 (0.6)	12.3 (0.6)
Biochemical status		
Serum Zinc (µg/dL)	94.8 (1.2)	79.9 (0.80)
% Zinc Deficiency	21.4 (1.3)	30.8 (1.2)
Hemoglobin (µg/dL)	11.7 (0.03)	12.8 (0.02)
% Anemia	23.8 (1.0)	19.9 (0.9)
Serum Retinol (µg/dL)	31.6 (0.4)	32.5 (0.3)
% Vitamin A Deficiency	14.6 (0.9)	11.0 (0.7)

Notes:
[a]Mean (SE)
[b]Weight-for-age is measured among 0–10 yr. No comparison was done in school aged children since some children are older than 10 years.

respectively. The proportion of preschool and school-aged children with VAD was 14.6% and 11.0%, respectively.

Table 2 presents the demographic, anthropometric, and biochemical profile of preschool and school-aged children with normal and deficient zinc status. Data of 2301 preschool and 3760 school-aged children from the 2008 NNS were used. Among the preschoolers, 1800 had normal and 501 with deficient zinc status. Among the school-aged children, 2607 presented normal zinc level,

Table 2. Demographic, anthropometric and biochemical profile of normal and zinc deficient Filipino preschool and school-aged children.

Indicators/Predictors	Preschool Children			School-aged Children		
	Zinc status			Zinc status		
	Normal	Deficient	***p*-value**	Normal	Deficient	***p*-value**
	(n = 1800)	(n = 501)		(n = 2607)	(n =1153)	
Age, mo	39.5 (0.5)[a]	40.8 (0.8)	0.149	108.4(0.5)	110.5 (0.7)	0.014
Sex						
% Male	53.1	54.5	0.972	51.3	55.9	0.017
% Female	46.9	45.5		48.7	44.1	
Anthropometric Status						
Weight, kg	12.7 (0.1)	12.7 (0.1)	0.881	25.2 (0.2)	24.9(0.2)	0.389
Height, cm	90.7 (0.3)	90.8 (0.5)	0.875	126.0 (0.3)	125.8 (0.04)	0.737
% Underweight[b]	21.4	23.7	0.302	–	–	–
% Stunted	30.0	36.3	0.030	34.3	40.4	0.002
% Wasted	6.1	6.1	0.231	12.7	11.1	0.237
Biochemical Status						
Serum Zinc, µg/dL	108.9 (1.1)	43.4 (1.0)	<0.001	93.5(0.6)	49.4 (0.7)	<0.001
Hemoglobin, g/dL	11.7 (0.03)	11.6 (0.06)	0.148	12.8 (0.03)	12.6 (0.04)	<0.001
% Anemic	23.2	25.5	0.385	18.3	23.6	0.003
Serum Retinol, µg/dL	31.8 (0.4)	30.8 (0.8)	0.252	33.1 (0.3)	30.9 (0.5)	<0.001
% Vitamin A Deficiency	14.4	14.7	0.900	10.1	13.3	0.027
Median UIE, µg/L[c]	–	–	–	133	109	<0.001
% UIE, <100 µg/L	–	–	–	39.7	46.2	0.002
With Infections						
Fever	23.4	26.4	0.275	13.4	14.3	0.515
Diarrhea	7.5	6.9	0.704	3.6	3.9	0.702
URTI	44.5	42.4	0.496	29.6	26.5	0.093
No Infection	55.1	54.4	0.842	62.0	64.5	0.216
Supplement						
Vitamin A	22.1	18.8	0.174	11.6	9.6	0.162
Iron	21.8	15.7	0.143	4.0	3.9	0.842
Vitamin C	22.8	18.3	0.042	18.4	12.9	0.001
B-vitamins	22.2	18.6	0.148	12.9	10.0	0.081
Zinc	21.5	20.3	0.825	3.0	4.0	0.145
Iodine	1.8	1.5	0.565	2.9	1.4	0.261

Notes:
[a]Mean (SE)
[b]Weight-for-age is measured among 0–10 yrs. No comparison was done in school- aged children since some children are older than 10 years.
[c]Measured among school-aged children only

while 1153 had deficient level. Mean age (standard error) in months was 39.5 (0.5) and 40.8 (0.8) for normal and deficient preschool children, respectively and 108.4 (0.5) and 110.5 (0.7) for normal and zinc deficient children, respectively. While no significant difference was noted between age of normal and deficient preschool children, zinc-deficient school-aged children were significantly older by 2 mo than those with normal zinc status. School-aged boys were more at-risk to zinc deficiency than girls. Both zinc deficient preschool (p = 0.030) and school-aged children (p = 0.002) presented significantly higher prevalence of stunting. Mean serum zinc of preschool children and children with normal and deficient zinc status were 108.9 (1.1) and 43.4 (1.0) µg/dL, respectively and 93.5 (0.6) and 49.4 (0.7) µg/dL in school-aged children with normal and deficient zinc status, respectively. Lower mean Hb (p < 0.001), mean SR (p < 0.001), and median UIE (p < 0.001) with higher prevalence of anemia (p = 0.003), VAD (p = 0.027), and IDD (p = 0.002) were likewise observed among zinc-deficient school-aged children. Use of supplements was generally higher in children with normal zinc status, but only use of vitamin C showed significant difference. No significant difference was noted on the prevalence of infection in the past month among normal and zinc-deficient children.

Table 3 presents nutrient and food intake profile of normal and zinc-deficient preschool and school children. Intakes of energy, protein, iron, calcium, riboflavin, thiamin, fats, and niacin intakes were significantly higher among preschool and school children with normal zinc status compared to zinc-deficient children. Preschool children with normal zinc levels showed significantly higher carbohydrate intakes. Consumption of fish, meat and poultry, meat and products, and other cereal products were likewise significantly higher among children with normal zinc status. Zinc-deficient children exhibited significantly higher intake of corn and products as well as green leafy and yellow vegetables. Fruit and other fruit product intakes were also found significantly higher among zinc-deficient school children.

Table 4 presents socioeconomic characteristics of preschool and school-aged children by zinc status. Zinc deficiency was higher among children belonging to poorer wealth quintiles, and those whose household heads were agricultural farmers and fishermen. Zinc deficiency was more prevalent among children in rural areas; however, it was only found significant in school children. Educational attainment of household head below high school also significantly correlated to zinc deficiency among school children.

Logistic regression among preschool children showed that corn intake, age, and energy intake were significantly correlated with zinc deficiency (Table 5). Higher corn intake and older age increases the risk of zinc deficiency, while higher energy intake lowers the risk of zinc deficiency among preschool children.

Among school children, higher corn intake, being male and older age, residence in rural areas, belonging to lower wealth quintile, and educational level of household head below high school were significant factors related to zinc deficiency in school children (Table 6).

DISCUSSION

This study documents the risk factors associated with zinc deficiency among Filipino preschool and school-aged children utilizing a national data. Results show that preschool and school-aged children who are older are more at-risk to zinc deficiency. Stunting, anemia, and vitamin A deficiency are more prevalent in zinc-deficient children. Lower average intakes of most nutrients; consumption of lesser amounts of fish, meats, and poultry; and higher intake of corn and corn products and green leafy vegetables are likewise noted among these children. Children belonging to poor households and with household head working as agricultural farmer or fisherman are also more at-risk. Being male, residence in rural areas and educational attainment of household head below high school also lower zinc status in school-aged children.

Age and sex are two well-established major confounding variables affecting serum zinc concentrations (Hotz & Brown 2004). Consistent to other reports, preschool and school-aged children who are older had greater risk of zinc deficiency in this present study. Children aged 25–60 mo had the highest prevalence (25.0%) of zinc deficiency, while children aged of 0–6 mo had the least deficiency (15.0%) (Steve-Edemba 2014). Ferraz *et al.* (2007) likewise observed that children >40 and <60 mo tended to have lower serum zinc levels. Higher plasma zinc levels of infants 6–11 mo old as compared to children in the higher age groups was attributed to appropriate breastfeeding practices among younger age group, leading to better zinc status (Dhingra *et al.* 2009). Breastmilk is clearly an important source of zinc for exclusively breastfed young infants, and it remains a potentially important source of zinc for older infants and young children who continue breastfeeding beyond early infancy (Brown *et al.* 2009). Older children, on the other hand, are dependent on diets of low diversity, marginal caloric adequacy, and food sources – including primarily of starchy staples and infrequent consumption of cellular protein (Krebs *et al.* 2014). Vulnerability of males to zinc deficiency has been well-documented. This may be partly due to higher requirement for zinc for higher growth rate and greater

Table 3. Nutrient and food intake profile of normal and zinc deficient Filipino preschool and school-aged children.

Indicators/Predictors	Preschool Children			School-aged Children		
	Zinc Status			Zinc Status		
	Normal	Deficient	***p*-value**	Normal	Deficient	***p*-value**
	(n =1729)	n = 481		(n = 2499)	(n =1105)	
Nutrient Intake						
Energy, kcal	877.9 (13.2)[a]	795.9 (22.6)	0.001	1415.0 (15.2)	1352.0 (23.3)	0.014
Protein, g	27.1 (0.5)	24.4 (0.8)	0.003	42.9 (0.5)	40.1 (0.7)	0.001
Iron, mg	5.3 (0.1)	4.7 (0.2)	0.008	7.1 (0.1)	6.6 (0.1)	0.002
Vitamin C, mg	23.6 (1.0)	21.6 (1.7)	0.319	29.3 (1.1)	30.5 (1.5)	0.994
Riboflavin, mg	0.59 (0.02)	0.52 (0.03)	0.032	0.6 (0.01)	0.5 (0.01)	0.003
Thiamin, mg	0.51 (0.01)	0.46 (0.02)	0.029	0.7 (0.01)	0.6 (0.02)	0.005
Carbohydrates, g	146.1 (2.1)	137.1 (3.6)	0.025	251.3 (2.6)	248.1 (4.2)	0.480
Fats, g	20.7 (0.6)	16.9 (0.9)	<0.001	26.6 (0.6)	22.2 (0.9)	<0.001
Niacin, mg	7.9 (0.1)	7.2 (0.3)	0.018	15.5 (0.2)	14.5 (0.3)	0.001
Vitamin A, µg	160 [64,323] [b]	150 [58,305]	0.113	171 [92, 298]	143 [78, 251]	<0.001
Calcium, g	205 [126,377]	185 [112,311]	0.021	235 [172, 320]	221 [159,304]	0.011
Food Intake (g)						
Cereal & Products	151.7 (2.9)	150.3 (5.0)	0.806	276.7 (3.2)	279.2 (5.3)	0.656
Rice & Products	123.2 (2.9)	120.8 (5.3)	0.682	237.4 (3.3)	236.7 (5.9)	0.904
Corn &Products	6.4 (1.0)	11.3 (1.9)	0.015	11.0 (1.0)	20.1 (2.8)	0.002
Other Cereal Prods.	22.0 (0.8)	18.1 (1.1)	0.005	28.2 (0.8)	22.5 (1.1)	<0.001
Starchy Roots/Tubers	7.9 (1.1)	8.7 (1.5)	0.656	12.9 (1.4)	10.3 (1.3)	0.155
Sugars & Syrups	11.2 (0.6)	9.3 (0.8)	0.063	15.7 (0.8)	13.5 (0.9)	0.053
Dried Beans, Nuts/Seeds	2.7 (0.3)	1.6 (0.5)	0.044	3.4 (0.3)	3.4 (0.4)	0.917
Vegetables	15.5 (0.8)	21.1 (1.9)	0.006	39.9 (1.8)	44.0 (2.3)	0.113
Green Leafy/Yellow	6.2 (0.5)	9.7 (1.4)	0.013	15.6 (1.0)	18.5 (1.3)	0.027
Other Vegetables	9.3 (0.6)	11.4 (1.3)	0.148	24.3 (1.3)	25.5 (1.7)	0.545
Fruits	24.9 (2.1)	21.8 (4.8)	0.520	40.9 (2.5)	52.9 (5.5)	0.032
Vit. C-rich Foods	3.4 (0.6)	3.7 (1.9)	0.906	9.2 (1.2)	2.0 (2.8)	0.346
Other Fruits	21.5 (1.9)	18.2 (3.6)	0.366	31.7 (2.0)	40.9 (4.2)	0.033
Fish, Meat & Poultry	71.2 (2.2)	62.8 (3.5)	0.039	143.6 (3.3)	129.0 (4.3)	0.002
Fish & Products	37.4 (1.5)	36.5 (2.4)	0.755	75.0 (2.6)	77.9 (3.8)	0.462
Meat & Products	23.2 (1.3)	17.9 (2.0)	0.027	47.6 (2.0)	36.2 (2.5)	<0.001
Poultry & Products	10.6 (1.0)	8.3 (1.3)	0.147	21.0 (1.4)	14.9 (1.6)	0.002
Eggs	7.6 (0.4)	6.8 (0.8)	0.393	10.6 (0.5)	8.6 (0.7)	0.012
Milk & Milk Prods.	180.9 (10.9)	135.7 (16.5)	0.020	32.4 (3.2)	26.9 (4.4)	0.293
Whole Milk	165.1 (10.1)	123.6 (15.1)	0.020	15.3 (1.1)	12.5 (2.0)	0.204
Milk Products	15.8 (3.0)	12.1 (3.4)	0.379	17.1 (3.0)	14.4 (3.8)	0.551
Fats & Oils	4.2 (0.4)	4.28 (1.0)	0.965	7.8 (0.5)	6.7 (0.8)	0.249

Notes:
[a]Mean (SE)
[b]Median [25th, 75th percentile]
Missing number for preschool children (n=91) and school-aged children (n=156)

Table 4. Socioeconomic characteristics of Filipino preschool and school-aged children by zinc status.

Indicators	Preschool Children (n =2301) Zn deficiency		School Children (n = 3760) Zn deficiency	
	% (SE)	***p*-value**	% (SE)	***p*-value**
Environmental				
Urban	19.1 (1.9)	0.089	23.7 (1.7)	<0.001
Rural (Baseline)	23.4 (1.7)		36.6 (1.9)	
Wealth Quintile				
Poorest	27.4 (2.4)	<0.001**	39.3 (2.1)	<0.001
Poor	21.1 (2.3)	0.382	34.5 (2.1)	0.003
Middle	20.9 (2.2)	0.415	23.8 (2.1)	0.698
Rich	14.9 (2.3)	0.525	23.8 (2.4)	0.688
Richest (Baseline)	17.5 (3.6)	–	22.2 (3.3)	–
Household (HH) Head's Occupation				
Officials	14.7 (3.7)	0.368	22.1 (3.6)	0.214
Professionals, Tellers, Associate	28.7 (7.1)	0.133	25.6 (5.5)	0.703
Service Workers	14.0 (4.2)	0.343	32.6 (4.7)	0.383
Agricultural, Farmers, Fishermen	25.9 (2.0)	0.045	35.7 (1.9)	0.026
Skillled Workers	19.6 (2.4)	0.882	27.1 (2.0)	0.807
Unskilled Workers	19.8 (2.7)	0.855	32.7 (2.3)	0.177
Special Occupation	42.9 (14.7)	0.063	29.7 (12.8)	0.893
No Occupation (Baseline)	19.1 (2.8)	–	27.9 (2.9)	–
HH Head's Educational Background				
Below High School	23.1 (1.7)	0.148	37.1 (1.7)	<0.001
At Least High School (Baseline)	20.0 (1.6)		25.2 (1.4)	
Family Size				
<6 Members	21.7 (1.9)	0.879	29.3 (1.7)	0.260
≥ 6 Members (Baseline)	21.3 (1.5)		31.5 (1.4)	

Notes:
p-values were based on comparison to baseline groups.
Missing for pre-school children (n = 3) and school-aged children (n = 7) for household head occupation

Table 5. Logistic regression of zinc deficiency among Filipino preschool children.

Variables	Odds Ratio	SE	t	***p***	[95% Confidence Interval]	
Age (in mo)	1.008	0.003	2.84	0.005	1.003	1.014
Energy Intake (kcal)	0.999	0.0002	–3.17	0.002	0.999	0.999
Corn Intake (log)	1.154	0.057	2.51	0.013	1.031	1.291
Constant	0.395	0.171	–5.45	<0.001	0.282	0.552

Note: n = 2210

Table 6. Logistic regression of zinc deficiency among Filipino schoolchildren.

Variables	Odds Ratio	SE	t	*p*	[95% Confidence Interval]	
Sex (Male = 1)	1.217	0.093	2.57	0.010	1.047	1.415
Urbanity (Urban = 1)	0.687	0.085	–3.03	0.003	0.539	0.877
Middle-upper Quintile (= 1)	0.679	0.078	–3.38	0.001	0.542	0.850
Intake of Corn & Products (in g)	1.002	0.001	2.36	0.019	1.0004	1.0043
Age (in mo)	1.001	0.0002	2.69	0.007	1.0001	1.0009
HH Head is At Least High School	0.735	0.080	–2.84	0.005	0.594	0.909
Constant	0.392	0.074	–4.93	<0.001	0.269	0.569

Note: n = 3597

proportion of muscle per kilogram body weight as muscle contains a higher content of zinc than fat (Hotz & Brown 2004). Similar to our finding, being male was one of the significant risk factors for zinc deficiency reported among school children in North East Thailand (Thurlow *et al.* 2006, Gibson *et al.* 2007).

Zinc-deficient children in this study had significantly higher prevalence of stunting. Impaired linear growth is a prominent feature of zinc deficiency among children in both developed and developing countries. There is abundant evidence that stunted children are likely to be zinc-deficient (Hotz & Brown 2004). Stunted school children had significantly higher prevalence of zinc deficiency than non-stunted children in East Iran (Fesharakinia *et al.* 2009), in North East Thailand (Gibson *et al.* 2007), and among African American and Hispanic children in Atlanta (Cole *et al.* 2010) among others. Plasma zinc concentration and stunting prevalence provided strong evidence that zinc deficiency is prevalent among 12–59 mo children, even in the presence of apparently adequate total dietary zinc (Engle-Stone *et al.* 2014).

Similar to other reports, lower iron (based on Hb) and vitamin A status were likewise observed among zinc-deficient school children in this study. Several data sets have demonstrated a positive correlation between anemia and indicators of the risk of zinc deficiency (Hettiarachchi *et al.* 2006, Paknahad *et al.* 2007, Cole *et al.* 2010). This relationship is likely due to the common dietary sources and nutritional factors of zinc and iron or the role of zinc in erythropoiesis (Hotz & Brown 2004, Paknahad *et al.* 2007, Cole *et al.* 2010). Zinc is an integral component and an important cofactor in the function of vitamin A nuclear receptors. It helps vitamin A absorption in the small intestine and is required for the synthesis of retinol-binding protein (RBP) that transports retinol in plasma and is involved in the exchange of retinol through circulation, among target tissues, and for liver storage (Rahman *et al.* 2002). Thai school children with SR <1.05 mmol/L had a nearly two-fold greater risk of being zinc-deficient than those with adequate vitamin A status (Thurlow *et al.* 2006). Likewise, 66.7% of Nigerian preschool children with VAD exhibited severe zinc deficiency (Bilbis *et al.* 2003). A moderate correlation has been recently reported between urinary iodine concentration and zinc levels ($r = 0.305$, $p < 0.001$) among primary Turkish school children (Çelik *et al.* 2014). Zinc-deficient school-aged children in this study likewise exhibited lower median UIE. In contrast, no association was found between suboptimal UIE and low serum zinc among school children in North East Thailand (Thurlow *et al.* 2006)

Proteins and fat, especially of animal origin, are the most important sources of absorbable zinc (Micheletti *et al.* 2001) – thus having explained and supported our findings that children with normal zinc level had significantly higher protein and fat intake than zinc-deficient children. Animal protein (*e.g.*, beef, eggs, cheese) has been demonstrated to counteract the inhibitory effect of phytate on zinc absorption from single meals (Sandström & Cederblad 1980), which may be due to amino acids released from the protein that keep the zinc in solution rather than a unique effect of animal protein as such. A low-fat diet could compromise health and performance because essential fatty acids and zinc may be too low, and zinc is an important determinant of the intestinal absorption of lipid-soluble vitamins (Micheletti *et al.* 2001). Lower energy intake was found to be a significant factor that increased the risk of low zinc status among deficient preschool children in this study. Diets low in energy with poor bioavailability of dietary zinc is likely to be the primary cause of the high prevalence of zinc deficiency reported among Indian women (Herbst *et al.* 2014). Consistent with our findings, dietary intakes of riboflavin and thiamin were also found to be influencing factors in zinc deficiency among apparently healthy Indian population (Agte *et al.* 2005).

In developing countries, poor dietary quality is often a major determinant of low zinc status. Diets of poor quality are predominantly plant-based and often contain very small amounts of expensive animal source foods.

In this study, intake of meat, fish, poultry, and meat products were found to be significantly lower among the zinc-deficient children, while corn, other cereal products as well as green leafy and yellow vegetables were significantly higher. These findings translate to poor dietary quality of our zinc-deficient children. The mean per capita daily intake of meat and fish products of the typical Filipino diet, which are the best sources of bioavailable zinc, reported in the same survey was only 9.6% and 12.8%, respectively (DOST-FNRI 2010). Consumption of >15 g/day meat has been reported to be positively associated with serum zinc level (Schneider *et al.* 2007). Generally, a great proportion of the Filipino diet was from plant origin (70%) – of which rice and corn are main staples. Phytate is a mineral chelator present in staple foods like cereals, corn, and rice, and has a strong negative effect on zinc absorption (Hotz & Brown 2004). The risk of zinc deficiency was reported to be 1.65 (95% CI: 1.02–2.67) times higher among women from maize staple diet category compared to enset (*Enset ventricosum*) staple diet category (Gebremedhin *et al.* 2011). Fruits and vegetables have low zinc content. Phytate or other dietary inhibitors in vegetables typically decrease zinc absorption (Hotz & Brown 2004). Populations that habitually consume vegetarian diets have low zinc intakes and status (Foster *et al.* 2013). Availability of zinc may also be compromised by the high content of phytates present in vegetables (Lönnerdal 2000).

It has been recognized that zinc deficiency may be attributable to underlying social and economic problems present in low-income populations, such as poverty, poor quality of food supply, lack of nutrition education, and elevated exposure to pathogens because of poor environmental sanitation and/or personal hygiene (Hotz & Brown 2004). Zinc deficiency was significantly more prevalent in children residing in rural areas and belonging to the poorest groups of population (Laillou *et al.* 2012, Engle-Stone *et al.* 2014). Populations relying on agriculture as their main means of subsistence constitute a large proportion of the poor in low income countries. And because poor populations often depend heavily on monotonous plant-based diets low in animal products and high in phytate, poverty is bound to be associated with poor zinc status (Hotz & Brown 2004). These reports are in agreement with our findings that children in the rural areas, in the poorer households, with household head working as farmer and fisherman, and educational level below high school had higher risk of low zinc status.

The lack of data on zinc content of local foods is one of the limitations of this study. Instead, data on other nutrients and selected food items were used to extract possible factors that may contribute to zinc deficiency. Data on infection were only based on interview as no sensitive biomarker for infection was done in the 2008 NNS. Likewise, exclusion of children afflicted with any illness during the time of data collection in the same survey, although only few, may have in a way introduce some bias and affected the deficiency rates.

To our knowledge, this is the first study that identified risk factors of zinc deficiency among Filipino preschool and school-aged children using national level data. Results of the study urgently suggest the development of an effective sustainable intervention strategy to reduce and/or eliminate zinc deficiency among these children. Supplementation, fortification, and dietary diversification/modification are three major categories of nutrition-focused zinc intervention strategies (Hotz & Brown 2004). Efforts have also been done towards these intervention strategies and current evidences indicate a beneficial impact to eliminate or reduce the risk of zinc deficiency (Brown *et al.* 2009), yet no policy have been put in place. Supplementation is an essential component of successful strategies to address the problem; however, zinc supplement is only incorporated in the management of diarrhea, both globally (WHO/UNICEF 2004) and locally (DOH 2007). Simple household/community-based strategies that will improve zinc status of Filipino children are encouraged like promotion and support of appropriate breastfeeding practices, as well as preparation and serving of more absorbable zinc foods like meat and fish and proportionally less phytate-containing foods. Conduct of nutrition education among mothers and caregivers may also serve as an important nutrition tool to improve low zinc status of children.

CONCLUSION

In conclusion, this study provides systematic information on the risk factors of zinc deficiency among preschool and school-aged children. Older age, high prevalence of stunting, anemia and vitamin A deficiency, and inadequate and poor-quality diets are significantly associated to zinc deficiency among preschool and school-aged children. Poor households and household head working as agricultural farmer or fisherman are likewise significant risk factors among these children. Being male, residence in rural areas, and educational attainment of household head below high school also significantly correlates to low zinc status of school children. These results are in accordance/similar with those from other countries.

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