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Determinants of Zinc Status of 2-3-Year-Old Children in Laguna, Philippines

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ABSTRACT

Introduction: Zinc deficiency has been considered a micronutrient problem of high magnitude in the Philippines. The effect of zinc deficiency on physical growth manifests during the first two years of life and is associated with high rates of infection and inadequate nutrition. The study aims to assess the zinc status of children and identify factors that affect zinc status. **Methods:** A multi-stage stratified random sampling was used in a cross-sectional study of 2 -3-year-old children currently residing in the province of Laguna, Philippines. Data were collected through a structured questionnaire. A 24-hour food recall data sheet was used for evaluation of food intake. The physical dimensions of children were measured using salter weighing scale and height board. A static biochemical test of nutrients in the blood was carried out to assess the level of zinc and presence of infection in the body. The Early Childhood Care and Development program checklist, Metro Manila Developmental Screening Test and Child Development Index were adapted to determine the level of cognitive development of children. **Results:** Correlation analysis revealed that anthropometric indices and food intake had a significant and positive linear association with zinc status (energy r=.014; P=.000; protein r=.027; P=.000; zinc r=.044; P=.000; iron r=.070; P=.000). The presence of infection was found to have a negative but significant relationship with zinc status. Zinc status was significantly associated with cognitive development. **Conclusion:** The study showed that determinants of zinc status are nutrient intake (such as energy and zinc), infection, height-for-age index and cognitive development.

Key words: Associated factors, cognitive development, height-for-age, infection, zinc status

INTRODUCTION

Zinc deficiency has been associated with stunting and poor cognitive function among children. Scientific investigations associated with linear growth, which is intimately connected to nutrition, has given primary focus on studies related to zinc. As a manifestation of chronic undernutrition, stunting has been linked to multiple adverse health outcomes that extend beyond childhood into adult life. Recent evidence also suggests that zinc deficiency may be related to shortfalls in attention, activity and motor development that generally occur in nutritionally deficient children (Souganidis, 2012) as

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zinc contributes to the development of brain structure and function (Black, 1998).

Zinc deficiency has been recognised in the Philippines as one of the causes of stunting. The Philippines is ranked 48th out of 136 countries in terms of prevalence of stunting (World Bank, 2012), and 32% of Filipinos are vulnerable to health-related risks from insufficient zinc intake (FNRI-DOST, 2011). The results of the 2008 National Nutrition Survey suggest that the level of zinc deficiency among children and other age groups may as well be of public health significance. Generally, zinc status has been known to be of high magnitude (>20%) among infants and preschool children, female adolescents, older persons and pregnant women (FNRI-DOST, 2008). In addition, 70% of the staple food consumed by Filipinos are of plant origin like rice and corn which contain high levels of phytate. Phytate is likely to prevent zinc absorption. Meanwhile, the cognitive development of 0 to 6-year-old Filipino children was found to be affected by being stunted and underweight: 30% of children with delayed cognitive abilities are stunted (Barba *et al.,* 2004). The study aims to assess the zinc status of children and identify factors that affect zinc status.

METHODS

The study was conducted in the province of Laguna, Philippines among 2- to 3-year-old children with no present illness. A multi-stage stratified random sampling was used in a cross-sectional study.The province was stratified according to districts and 6 barangays were randomly selected from each stratum. Barangays from each stratum were identified using random selection of select cases from a statistical program. A simple random selection of respondents represented by 2- to 3-year-old children was done to compute a sample size of 149 children.

Weight and height of children were measured using salter weighing scale and height board, respectively. The anthropometric measures and age in months of children were applied to yield three indices of nutritional status: weight-for-age, height-for-age and weight-for-height. Z-scores were determined using the suggested WHO Child Growth Standards cut-off points. A 24-hour food recall data sheet was used for evaluation of a non-consecutive 2-day food intake obtained from mothers of 2 - 3-year-old children.

The proportion of children with adequate energy intake was evaluated by computing the number of children with percent adequacy equal to or greater than 100%. With regard to protein intake, no definitive EAR value was available for protein; hence, 80% of the RENI was set as the cut-off value in the study. For zinc and iron intakes, EAR cut-off point method was used to determine the proportion of children with adequate zinc and iron intakes. A static biochemical test of nutrient in the blood was carried out through finger prick to assess levels of zinc and presence of infection in the body by medical technologists from the Food and Nutrition Research Institute of the Department of Science and Technology. Plasma/serum zinc was analysed using flame atomic absorption spectrometry (Butrimovitz & Purdy, 1977).

Zinc deficiency prevalence was evaluated using the suggested IZiNCG lower cut-off points and guidelines for public health concern. CRP was analysed using latex agglutination method. The Early Childhood Care and Development program checklist, Metro Manila Developmental Screening Test and Child Development Index were adapted to determine the level of cognitive development of children. Cognitive development was analysed using scaled score equivalent of raw score table of the ECCD checklist. All statistical analyses were assessed by using SPSS 19. A *p*-value <0.05 was deemed as statistically significant for all analyses.

Survey weights were used in the analysis taking into consideration the research design. Bivariate analyses using Chi-square test of independence and Correlation Coefficients were applied to assess for potential confounders. Cramer's V and ETA values were used to test the strength of associations. Potential risk factors associated with zinc deficiency in children were identified using relative odds ratios (ORs) and 95% confidence intervals (CIs). Logistic regression models were used to calculate the prevalence of ORs. Using a multiple logistic regression model, the outcome variable was dichotomised as zinc deficient or zinc sufficient.

The study was reviewed and approved by the University of the Philippines Manila Research Ethics Board (UPMREB).

RESULTS

In the study, 81.2% of the children had normal weight-for-age, although 18.8% suffered from underweight, of which 3.4% were severely underweight. On the other hand, no overweight children were identified. Disaggregating by gender, females (14.1%) were more at-risk to be underweight than males (10%). In general, 33.5% of children were stunted and of these, 10.7% were severely stunted. On the other hand, 66.4% of children had normal height-for-age, with none identified as tall relative to age. Contrary to underweight, the distribution of stunting by gender indicated that males had a higher prevalence at 19.5% than females. Among the children, 3.4% was wasted. The majority (95.3%) had normal weight-for-height, and 1.3% was overweight-for-height. Considering the weight-for-height distribution by gender, the current nutritional status of children revealed that 45.6% and 49.7% of males and females, respectively, had normal weight-for-height. Wasting or thinness is a public health problem at 2% for males and 1.4% for females. Overweight-for-height was about 1% in both males and females.

Generally, males (2%) were more at-risk to wasting than females (1.4%). The mean serum zinc level was 123.13 μg/dL, which is twice of the suggested serum zinc in children. Both genders had the same mean serum zinc, but female children were found at risk of zinc deficiency (3.9%). The overall zinc deficiency prevalence among children was 2%, which is considered of low public health significance. Moreover, only 12.1% of children tested positive for infection, wherein both male and female were equally at risk. In general, 26.2% of the children were advanced in their overall development, of which 1.3% were significantly advanced; meanwhile 27.5% were delayed in overall development, of which 12.1% were considered to be significantly delayed. Generally, low serum zinc was found in children with normal nutritional status. However, about 1% of stunted children were observed to be zinc-deficient. No risk of low serum zinc was identified in underweight and wasted children. Among children with low serum zinc concentration, about 1.5% were inadequate in terms of energy and zinc intake. No nutrient inadequacies were found in protein intake of children with low serum zinc level. On the other hand, 1.3% of children with low serum zinc were energy adequate, 2% were protein adequate and 1.3% were zinc sufficient. Meanwhile, the occurrence of infection was observed in about 1% of zinc-deficient children. In addition, zinc deficiency was seen in about 1% of children with delayed cognitive development and in 1.3% with average cognitive development. No children with advanced development were zinc deficient (Table 1). Overall, the majority of children had an energy intake of 100% or more (61.7%) and protein intake of 80% or more (89.9%). Based on this, 80.5% of the children were able to meet the EAR for iron and 79.2% for zinc. Thus, no elevated risk of zinc deficiency was found among children based on zinc intake (Table 2).

Table 1. Percentage distribution, median z-scores, prevalence and association between nutritional status and zinc status

Nutritional status	*All*	*Gender*		*Zinc status*		
		Male	*Female*	*Deficient*	*Normal*	*Value*
Weight-for-age						.018**
Severely underweight	3.4	1.3	2.0	0.0	3.4	
Underweight	15.4	8.7	12.1	0.0	15.4	
Normal	81.2	38.3	37.6	2.0	79.2	
Overweight	0.0	0.0	0.0	0.0	0.0	
Median z-score	-1.37	-1.52	-1.13	-	-	
Height-for-age						.110**
Severely stunting	10.7	5.4	5.4	0.0	10.7	
Stunting	22.8	14.1	8.7	0.7	22.1	
Normal	66.4	28.9	37.6	1.3	65.1	
Tall	0.0	0.0	0.0	0.0	0.0	
Median z-score	-1.54	-1.71	-1.33	-	-	
Weight-for-height						.076**
Severely wasted	0.7	0.0	0.7	0.0	0.7	
Wasted	2.7	2.0	0.7	0.0	2.7	
Normal	95.3	45.6	49.7	2.0	93.3	
Overweight-for-height	1.3	0.7	0.7	0.0	1.3	
Median z-score	-0.64	-0.71	-0.50	-	-	
Prevalence of zinc deficiency	2.0	0.0	3.9	-	-	
Anemia prevalence	12.1	11.1	13.0	-	-	
Infection						-.093**
Yes	12.1	-	-	0.7	11.4	
No	87.9	-	-	1.3	86.6	
Cognitive development						.075**
Delay	27.5	-	-	0.7	26.8	
Normal	46.3	-	-	1.3	45.0	
Advanced	26.2	-	-	0.0	26.2	

**Correlation is significant at the 0.01 level (2-tailed).

The regression model showed the contributory factors that may affect zinc deficiency. Children with adequate intake of energy, zinc and iron were less likely to become zinc deficient by 0.4%, 378.4% and 5%, respectively. Zinc deficiency was less likely to occur among children with normal height for their age by 13.7%. Likewise, it was less likely to occur in children who have an average cognitive development of 60.2%. Conversely, the odds of becoming zinc deficient were higher in children with infection of 80.1% (Table 3).

DISCUSSION

Though of low prevalence, the data show that zinc deprivation can impair

Table 2. Mean two-day food intake, standard deviation, confidence interval, proportion of children that met the Recommended Energy and Nutrient Intake and Estimated Average Requirement, prevalence and association between food intake and zinc status

Food Intake	*Mean + SD (95% CI)*	*Proportion of children that meet RENI/EAR*	*Deficient*	*Zinc status Normal*	*Value*
Energy (kcal)a	1226.2 (+388.8) 1222.86 – 1229.61				.014**
>100		61.7	1.3	60.4	
<100		38.3	0.7	37.6	
Protein (g)b	44.9 (+20.8) 44.71 – 45.07				.027**
>80		89.9	2.0	87.9	
<80		10.1	0.0	10.1	
Iron (mg)c	10.0 (+ 18.3) 9.94 – 10.03				.070**
>EAR		80.5	2.0	78.5	
<EAR		19.5	0.0	19.5	
Zinc (mg)d	3.8 (+2.5) 3.82 – 3.87				.044**
>EAR		79.2	1.3	77.9	
<EAR		20.8	0.7	20.1	

[a] computed based on 100% RENI; [b] computed based on 80% RENI; ccomputed based on FAO/WHO value; dcomputed based on IZiNCG

**Correlation is significant at the 0.01 level (2-tailed).

Table 3. Multiple logistic regression analysis for contributory factors of zinc deficiency Independent variables

				95% Wald confidence limits		
	B	*Se*	*Odds ratio*	*Lower*	*Upper*	*P-value*
Energy (kcal)	-0.004	0.000	1.004	1.003	1.004	.000
Zinc (mg)	-1.565	0.100	4.784	3.934	5.819	.000
Iron (mg)	-0.051	0.008	0.950	0.935	0.965	.000
Height-for-age	-0.148	0.054	0.863	0.776	0.959	.006
Cognitive development	-0.922	0.034	0.398	0.372	0.426	.000
Infection	1.612	0.088	0.199	0.168	0.237	.000
Constant	-4.641	0.182	0.010			.000

height-for-age index in children. Zinc is abundant within the body and is essential for protein synthesis, cellular growth and cellular differentiation. Deficiency in zinc may result from inadequate intake and, to some extent, increased losses. The data support studies in experimental animals and human intervention trials that zinc deficiency is growth limiting. Meta-analysis of 33 randomised controlled zinc intervention studies to improve children's growth showed that zinc supplements produced highly significant improvements in linear growth (Brown *et al*., 2002). Similarly, children with low height-for-age are likely to be zinc deficient (Hotz & Brown, 2004).

The study showed that the quality of food intake, indicative of high consumption in meat and meat products among children, affects zinc absorption, aside from the quantity of food intakes. It is illustrated in the amount and sources of protein intake of children that may have an influence on zinc absorption. Nonetheless, the present data suggested that a calcium-rich diet for children had no significant inhibitory effect on zinc absorption, provided intake of zinc was adequate. As discussed in literature, more zinc is absorbed from a diet high in animal proteins such as beef, eggs and cheese that from a diet high in plant proteins such as soy and legume. Therefore, as protein and heme-iron from animal source food increase, a greater percentage is absorbed. On the other hand, protein sources such as casein found in milk protein have an inhibitory effect on zinc absorption. Similarly, phytate found in whole grain cereals, legumes, and nuts and seeds influence zinc bioavailability because it cannot be digested or absorbed. Although high-fibre containing food is likely to be phytate-rich, fibre itself may not affect zinc absorption (Lonnerdal, 2000). In addition, phytate may also alter the effect of calcium on zinc due to formation of insoluble complexes, thereby reducing zinc absorption. Our findings, are similar to the meta-analysis of 24 estimates in 18 randomised controlled trials which found a significant effect of zinc intake and serum/plasma zinc concentration in children; for every 2-fold increase in zinc intake, the difference in zinc serum/plasma concentration was 9% (Moran *et al*., 2012).

Data indicate that the acute phase response can affect the status of micronutrients in the body such as zinc, where the effect of an infection on zinc metabolism manifests in a decline in serum zinc. Zinc deficiency impairs the overall immune function and resistance to infection as it adversely affects the integrity of the immune system. Thus, impairment of the immune system may increase the prevalence of childhood infections. The data support the findings of intervention studies that zinc supplementation reduces the incidence, duration and severity of acute and chronic diarrheal disease, as well as the incidence and rates of acute lower respiratory tract infections and malaria among children (Larson *et al*., 2008; Lukacik, Thomas & Arranda, 2007; Baqui *et al*., 2006). Similarly, low zinc status in children is also associated with an increased risk of severe infectious diseases (Black, 2003) and zinc concentration is suppressed during infection (Wieringa *et al*., 2002). Moreover, serum CRP is related to serum zinc suggesting that CRP is a suitable marker for the depression of serum zinc in apparently healthy children (Kongsbak *et al*., 2006).

Cognitive performance of children may be explained by synaptic pruning, which may happen during this period. Slightly used synapses are slowly eliminated to attain the quantity needed for the brain to function efficiently. The retention of synapses is characterised by early stimulating experiences that may trigger certain neural synapses, activate growth processes, and consequently fuse the connections. Synapses that are not stimulated gradually decline over time. This principle demonstrates that the structure of the developing brain becomes adapted to the needs of everyday stimulation and experience, which can be observed in a child's early years (Blakemore & Choudhury, 2006). This indicates that poor growth and development due to zinc deficiency can be attributed to its depression on appetite. Besides growth, zinc supplementation also improves neuro behavioural functions in children. This denotes that zinc deficiency in early childhood influences cognitive development. The results of the study suggests that zinc status is associated with attention, memory and language of children and can be attributed to its structure and function in the brain including cerebellar function, behavioural and emotional responses (Hambidge, 2000; Black, 1998) and as a cofactor of synaptic vesicles of specific contingent neurons (Frederickson *et al.*, 2000). Evidence also suggests that zinc is an essential mineral for neuropsychologic functioning during childhood (Penland *et al.*, 1997). The data agree with findings that when zinc deficiency and cognitive development are depressed, zinc supplementation in children results in increased activity and/or responsiveness and improved neuropsychologic function, (Sazawal *et al.*, 1996; Sandstead *et al.*, 1998; Penland *et al.*, 1999; Bhatnagar & Taneja, 2001; Bentley *et al.*, 1997).

CONCLUSION

Correlation analysis found significant associations between zinc status and infection, nutritional status and cognitive development. Using the regression model, the study showed that the contributory factors of zinc status include energy intake, iron intake, zinc intake, height-for-age, cognitive development and infection.

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Conflict of interest

The authors declare that they have no conflict of interest. The opinions expressed in this paper are those of the authors and do not represent the official position of Sight and Life.

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