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Research Article
Incidence of Zinc Deficiency Among Under-five Children of Kanam Local Government Area, North-central Nigeria

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Abstract

Background: A survey of rural population of Kanam Local Government Area (LGA) North-central Nigeria for zinc deficiency was undertaken following the outcome of a pilot survey which suggested a prevalence of morphological and other clinical indicators of zinc deficiency among under-five years children. **Objective:** The objective of this study was to carry out a formal systematic investigation of zinc status of the under-five children of Kanam, North-central Nigeria. **Materials and Methods:** Incidence of zinc deficiency in the study area was determined by measuring plasma zinc, a biomarker of zinc status, in the most vulnerable group of the population, the under-5-year children and carrying out a household food consumption survey. Sixty six blood samples were collected from under-5-year children of randomly selected households across the LGA and analysed for zinc content by inductively coupled plasma-mass spectrophotometry (ICP-MS). The households of the under-5 children were surveyed for the pattern and frequency of consumption of selected zinc-rich foods and for incidence of zinc deficiency related illnesses among the under-5 subjects by means of questionnaire. The resultant plasma zinc data were analysed statistically by the student's t-test on SPSS version 17.0, the relationship between plasma zinc data of the under-5 subjects and their zinc-rich food consumption patterns was analysed by Pearson's correlation analysis. **Results:** Mean plasma zinc concentration, 57.59±30.40 μg dL^{-1}, was significantly below the normal. Thirty nine or 59.09% of the 66 under-5 subjects had plasma zinc content below the 61 μg dL^{-1} cut-off point for zinc deficiency. Incidence of zinc deficiency, as determined by plasma zinc was higher among male than female subjects. **Conclusion:** The results indicate a high incidence of zinc deficiency in the studied population. The population is therefore, at risk of zinc deficiency. There is a significant negative (r = -0.65) correlation between pattern of consumption of zinc-rich diet and zinc status, suggesting that prevalence of zinc deficiency may be due to zinc deficient staple diet. The risk of zinc deficiency is high enough and calls for a national intervention programme through public health nutrition interventions to improve the zinc status.

Key words: Zinc, plasma, under-five, deficiency, Kanam, status, infections, signs, symptoms

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Adequate zinc nutrition is essential for human health because of zinc's critical structural and functional roles in many enzyme systems that are involved in gene expression, cell division and growth and immunologic and reproductive functions[1,2]. On account of its very important roles in strategic biologic functions in the body, inadequate dietary intake of zinc has serious health consequences. In the past decade, results of meta-analyses identified Zn deficiency as a major factor in the aetiology of diarrhoea, acute lower respiratory infections and impaired linear growth in low income countries[3]. In children, it causes an increase in infection and diarrhoea, contributing to the death of about 800,000 children worldwide per year[4]. Infants and children under 5 years are the most vulnerable group to zinc deficiency in human population[4]. Hence, they present with the critical diagnostic clinical manifestations of zinc deficiency such as diarrhoea, malaria and pneumonia[5], impaired taste sensation, poor night vision, skin rashes and lesions around the body orifices and at extremities and characteristic behaviourial disturbance[1,6]. Under-5 years children are therefore the logical target group for population surveys for incidence of zinc deficiency.

It is now clear that nutritional deficiency of zinc is widely prevalent[7] and its morbidities are severe[8]. About two billion people in the developing world are reported to have zinc deficiency[8]. In developing countries, zinc deficiency is a significant factor in the mortality and disease burden of about 58% of children[9] with countries in Sub-Saharan Africa and South and Southeast Asia having the greatest risk of deficiency[7]. The adverse clinical conditions associated with zinc deficiency, such as stunted growth, severe and repeated infections are closely linked with the general standard of living of the human population as determined by the population's ability to meet its basic needs for adequate nutrition, clean and safe water, good housing, acceptable levels of environmental sanitation and hygiene and ready and easy access to standard healthcare[10].

Previous study[11] has reported that Nigeria is a country with a high risk of zinc deficiency, based on the prevalence of stunting among children less than 5 years and the amount of absorbable zinc in the national food supply. According to Nigeria Demographic and Health Survey (NDHS) 2013, 37% of children under age 5 are stunted, 18% are wasted and 29% are underweight[12]. Stunting in children is considered as an indirect indicator of zinc nutritional status[11]. These findings suggest that the food supply may contain insufficient absorbable zinc to satisfy the population's zinc requirements[7]. However, nationally representative data on the distribution of plasma zinc concentrations and dietary zinc intake have not been reported. Therefore, the true risk of zinc deficiency remains uncertain.

Data collected previously from a survey by Maziya-Dixon *et al.*[10] covered only 12 of the 36 states of Nigeria following pilot surveys in six other states. Plateau state was neither covered in the pilot survey nor in the main survey although, it is an area where the prevalence of other micronutrients deficiencies, notably Iodine Deficiency Disorders (IDD) has been reported[13,14]. In particular, the dietary, behavioural and socioeconomic conditions known to predispose to zinc deficiency and zinc deficiency-related clinical manifestations are also prevalent in many areas of Plateau state; hence, the current interest in extending the survey to the state. One such area of Plateau state is Kanam Local Government Area (LGA), North-central Nigeria.

A pilot survey on under-5 years children in this area had revealed prevalence of low plasma zinc concentration along with more of the morphological and behavioural presentations associated with zinc deficiency[15], all suggesting a probable existence of zinc deficiency and hence, the need for a formal systematic investigation of zinc status of the population, which is the interest of the present study. This study aims to provide evidence from a survey of zinc status biomarker, plasma zinc, of under-5 children to confirm the prevalence of zinc deficiency among the rural population of Kanam LGA of North-central Nigeria.

MATERIALS AND METHODS

Subjects: The subjects are under-5 children randomly selected from collaborating households in Kanam LGA. They were selected statistically using the method adopted in the Nigeria Food Consumption and Nutrition Survey[10] 2001-2003. The method entails carrying out the survey in a third of the constituent communities, randomly selected and representative households in the selected communities. Consequently, 18 communities/settlements, representing a third of the settlements in the LGA were randomly selected for the study and from each of them, three households were selected by simple random sampling method, making a total of 54 households. Probability sampling so adopted and applied in determining the sample size for the study is the recommended method for obtaining a representative sample with minimum bias[16]. It was the under-5 years children in the 54 households that were sampled for zinc status and dietary zinc consumption pattern. A total of 66 under-5 years

children consisting of 30 males and females with mean age of 3.33±1.30 years (range 1.25-4.75 years) living in the 54 households were recruited for the study.

Ethical clearance and consent: Ethical clearance and approval for the study was obtained from the Plateau state ministry of health. Prior permission and clearance were obtained from village heads who facilitated the sensitization and mobilization of the communities in support of the survey. Finally, informed consents of heads of focal households were cultivated and obtained prior to commencement of the survey.

Human sample collection and preparation: Human sample collection operations involving invasive technique were done by qualified health professionals. Samples were collected and processed using zinc-free equipment (mostly plastics, stainless steels and ceramics). All laboratory devices used in the test were sterilized to prevent contamination and plasticproducts were soaked in a 0.4% EDTA solution. Glass products were placed in a 10% hydrochloric acid (EMD Chemicals, NJ, USA) solution for 24 h before being washed with deionised water [obtained from a Milli-Q water purification system (Millipore, Belford, MA, USA)] three or more times and then dried in a drier.

Blood samples for zinc content determination: Blood samples were collected according to the protocol described by the International Zinc Nutrition and Consultative Group (IZiNCG)[17]. The blood sample was then centrifuged at about 3000×g for 10 min to remove all blood cells. The plasma was then transferred to a screw-up vial and stored frozen until analysis. The concentration of zinc in the blood plasma samples was determined by the inductively coupled plasma-mass spectrophotometry (ICP-MS) method of Rodushkin *et al.*[18].

Household food consumption survey: The survey was done by means of a questionnaire administered on household heads. The questionnaire, a dietary and health history recall instrument was designed to elicit and capture information on the following:

- Frequency of daily dietary intake over previous 1 month of two categories of zinc-rich foods, namely:
  - Foods of animal origin devoid of zinc antinutritional factor (liver, fish, milk and eggs)
  - Food of vegetable origin including those known to contain a zinc antinutritional factor (cereals and beans) and a local mineral source of zinc (clay)
- Frequency of affliction of under-5 children by four infectious disease conditions associated with zinc deficiency (viz., malaria, pneumonia, diarrhoea, others) over the previous 6 months
- Incidence of under-5 years household members living with certain physiological and behavioural abnormalities relevant to zinc deficiency (i.e., loss of taste sensation, poor night vision, delayed wound healing, behavioural disturbances at school)

Statistical analyses: Statistical analyses were performed using the computer software, SPSS version 17.0 (SPSS Inc., Chicago). The statistical programme was SPSS Statistics Data Editor. Plasma zinc concentration data were analysed using tailed student's t-test. The acceptable level of statistical significance was $p<0.05$. Results were presented as arithmetic Means±Standard Deviation (SD).

Data from survey instrument were analysed by calculating the percentages:

- Prevalence (in the case of disease frequencies and/or sign and symptoms predisposing to zinc deficiency)
- Intake (in the case of frequency of consumption of foods)

A bivariate Pearson's correlation was used to determine the relationship between food intake and plasma zinc concentration of the under-5 children. A $p<0.05$ value was considered statistically significant.

RESULTS

Plasma zinc of under-five children: The result of the analysis of plasma zinc is as shown in Table 1. A total of 66 plasma samples from under-5 children were analysed for their zinc content. Of the plasma samples, 36 (or 54.55%) were from females while 30 (or 45.46%) were from males. The plasma zinc levels vary widely (17.20±0.05 to 119.60±0.19 μg dL^{-1}) with an overall mean value of 57.59±30.40 μg dL^{-1}. Thirty nine out of the 66 plasma samples (or 59.09%) showed zinc content (≤60.97±0.25) that were significantly below the lower limit of the normal range of 65-117 μg dL^{-1} for children under-5 years and the WHO/UNICEF/IAEA/IZiNCG cut-off for zinc deficiency[19]. This suggests a relatively high incidence of zinc deficiency of 59.09% as determined by plasma Zn level. Twenty (or 51.28%) of the 39 plasma samples containing lower than normal zinc levels were females, while 19 (or 48.72%) were males.

Table 1: Zinc concentration of plasma samples of under-5 children of Kanam LGA

Sample	Gender	Zinc concentration (μg dL^{-1})	Sample	Gender	Zinc concentration (μg dL^{-1})
S1	M	90.53±0.12	S34	F	90.57±0.07
S2	F	43.33±0.09	S35	M	59.67±0.23
S3	F	39.00±0.09	S36	M	38.33±0.04
S4	F	62.40±0.52	S37	F	53.70±0.07
S5	M	104.70±0.21	S38	F	28.33±0.09
S6	F	92.40±0.13	S39	M	47.93±0.20
S7	F	46.17±0.25	S40	F	77.23±0.12
S8	F	58.33±0.10	S41	F	23.70±0.09
S9	M	42.70±0.22	S42	M	40.93±0.01
S10	M	46.67±0.10	S43	M	27.37±0.13
S11	F	119.60±0.19	S44	F	57.20±0.28
S12	F	52.13±0.12	S45	F	43.00±0.11
S13	M	32.67±0.02	S46	M	17.20±0.05
S14	M	105.33±0.29	S47	F	43.33±0.11
S15	F	71.67±0.04	S48	F	58.53±0.56
S16	M	75.53±0.30	S49	M	81.87±0.54
S17	M	112.40±0.14	S50	M	29.33±0.03
S18	F	61.30±0.12	S51	F	29.67±0.08
S19	F	74.67±0.21	S52	M	20.57±0.02
S20	F	33.37±0.01	S53	M	65.47±0.36
S21	M	36.00±0.05	S54	F	32.60±0.07
S22	M	59.93±0.22	S55	F	25.73±0.13
S23	F	46.43±0.08	S56	F	23.67±0.03
S24	F	33.20±0.03	S57	F	31.97±0.10
S25	F	108.97±0.08	S58	F	71.00±0.18
S26	F	64.67±0.60	S59	M	29.70±0.16
S27	F	80.03±0.33	S60	F	81.60±0.30
S28	M	83.33±0.09	S61	M	39.47±0.19
S29	M	42.93±0.19	S62	M	70.30±0.27
S30	F	88.60±0.37	S63	F	75.17±0.09
S31	M	59.97±0.27	S64	M	68.90±0.11
S32	F	60.97±0.25	S65	M	68.73±0.04
S33	M	66.33±0.23	S66	M	49.50±0.28

Overall mean: 57.59±30.40, range: 17.20±0.05 to 119.60±0.19, tabulated data are Means±SD of three determinations per sample

Table 2: Comparison of plasma zinc of male and female under-5 children subjects of Kanam LGA*

Parameters	Male	Female
No. (%) of under-5 plasma samples (n = 66)	30 (45.46%)	36 (54.55%)
Range of plasma zinc values (μg dL^{-1})	17.20±0.05 to 112.40±0.14	23.67±0.03 to 119.60±0.19
Mean plasma zinc (μg dL^{-1})	57.20±30.53	59.92±30.40
No. (%) of under-5 with plasma zinc below WHO/UNICEF** cut-off	19 (63.33%)	20 (55.56%)

*Tabulated values are Means±SD of 3 determinations, p = 0.05, **WHO/UNICEF normal range: 65-117 μg dL^{-1}

Table 3: Summary of observed pattern of intake of zinc-rich food by under-5 children households

	No. (%) of under-5 children in category	
Level of dietary Zn intake	Foods of animal origin	Food of vegetable origin
Very adequate	6 (10.33)	26 (44.83)
Adequate	3 (5.17)	19 (32.76)
Moderate	12 (20.69)	10 (17.24)
Marginal	6 (10.35)	3 (5.17)
Poor/inadequate	31 (53.45)	0 (0.00)

Values in parentheses are percentage of total number of subjects, n = 58 under-5 children

Among the genders, 20 (or 55.56%) of the 36 female samples and 19 (or 63.33%) of the 30 male samples showed deficient plasma zinc level (Table 2), suggesting a higher incidence of zinc deficiency, as determined by plasma zinc, among the males than females.

So also, the gender sub-population plasma zinc means for males (57.20±30.53 μg dL^{-1}) and females (59.92±30.40 μg dL^{-1}). Although, the means were lower in male under 5 years than in females, the difference was statistically not significant (p>0.05).

Intake pattern of zinc-rich foods by the under-5 children: Table 3 summarizes the pattern of consumption of zinc sources of plant and animal origins. In the Table 3, there is a

Table 4: Summary of observed incidence of affliction of under-5 children by three infectious diseases over the previous 6 months

Level of disease affliction incidence	No. of under-5 children in category (%)
Very high	2 (3.45)
High	12 (20.69)
Moderate	16 (27.59)
Low	28 (48.28)

Values in parentheses are percentage of the sample population (n = 58)

Table 5: Summary of incidence of Zn deficiency signs and symptoms among the under-5 children

Probability of frank zinc deficiency	No. of under-5 children in category (%)
Strong	17 (29.3)
Moderate	13 (22.4)
Nil	28 (48.3)

Values in parentheses are percentage of the sample population (n = 58)

high (77.59%) rate of consumption of plant foods. About 17.24% of the studied population consumed plant-based foods at moderate amounts, while marginal consumption is at 5.17%.

Data from questionnaire showed that, overall, cereal foods were the most frequently consumed (Table 3) with 91.38% of the studied population consuming it every day to several times a day. Only 8.62% of the population consumed cereal foods less than once a day but at least once a week. Consumption of leguminous foods was less frequent among the respondents with 17.24% consuming it less than once a day but at least once a week; 56.90% consuming it less than once a week but at least once a month; 24.14% consuming it less than once a month, while 1.72% did not have access to leguminous foods in a month.

A bivariate Pearson's correlation analysis revealed a strong negative ($r = -0.65$), significant ($p<0.05$) correlation between consumption of zinc-rich foods and the zinc status of the studied population.

Incidence of affliction of under-5 children by zinc-deficiency predisposing infectious diseases: The incidence of affliction of the under-5 children by zinc-deficiency predisposing diseases are as presented on Table 4. From the Table 4, there is a 3.45% very high incidence and a 20.69% high incidence of zinc-related diseases [malaria, pneumonia and diarrhoea] among the under-5 children surveyed. In the Table 4, 27.59% of the population showed moderate incidence of zinc-deficiency predisposing diseases, while 48.28% presented low incidence of malaria, pneumonia and/or diarrhoea.

Incidence of under-5 children presenting with physiologic and behavioural signs and symptoms of zinc deficiency: The results of the survey on the incidence of presentation with three signs and symptoms of zinc-deficiency among under-5 children are summarized in Table 5. It can be deduced from the table that 30 under-5 children presented with one or the other of known symptoms of Zn deficiency but only 17 manifested two or more symptoms and hence a strong probability of frank zinc deficiency. The 17 subjects with strong probability of frank zinc deficiency out of 58 subjects surveyed translated to a zinc deficiency prevalence of 29.31%.

Seven of the 58 under-5 children subjects reportedly manifest poor night vision, a well-known sign and symptom of vitamin A deficiency; of the seven, 5 subjects also manifested symptoms associated with zinc deficiency (ZnD) suggesting co-existence of VAD (vitamin A deficiency) and ZnD.

DISCUSSION

A large part of Nigeria was not covered in any aspect of the Nigeria Food Consumption and Nutrition Survey (NFCNS), 2001-2003 which established the prevalence of zinc deficiency in the country. Hence, the foundation/rationale for the present study of the zinc status for the most vulnerable group (the under-5 children) of the human population of Kanam LGA, a rural population where the socio-economic and dietary behavioural conditions which are generally known to predispose to zinc deficiency (ZnD) were known to exist and where a pilot survey discovered a significant incidence of clinical anthropometric signs and symptoms of ZnD and infectious illnesses associated with ZnD. However, the present study was more intensive than the national survey, NFCNS 2001-2003, which was not primarily for zinc alone. Evidence from the results of the measurements of direct and indirect indices of Zn status, critically analysed and discussed hereunder, would appear to support the working hypothesis of ZnD prevalence among the under-5 children of Kanam LGA.

Abnormally low plasma zinc level is an important, sensitive diagnostic biochemical index of ZnD[17,20]. Of the 66 children surveyed, have plasma zinc concentration significantly below the cut-off of 61 μg dL^{-1} for children less than 5 years. The result has a wide range of values from 17.20 ± 0.05 to 375. About 119.60 ± 0.19 μg dL^{-1} and an overall mean of 57.59 ± 30.40 μg dL^{-1}, which is also significantly below the cut-off. This suggests a relatively high incidence of zinc deficiency of 59.09% as determined by plasma zinc level. The prevalence of zinc deficiency is expressed as the percentage of the population with plasma zinc concentration below the specific lower cut-offs in relation to reference data for age[21], sex, time of day and fasting status[22] of the individuals examined.

Information on expected prevalence of low serum zinc concentration in at-risk populations is somewhat limited. A recent National Nutrition Survey in Mexico indicated that 25% of preschool and school-aged children and 30% of women had low serum zinc concentrations, defined as <65 μg dL^{-1} in that survey[23]. In rural areas, these prevalence reached 40% among children and 34% among women. Some community-based zinc supplementation trials from various populations have reported prevalence of low serum zinc. Examples include a study of 6–24 month old vietnamese infants (n = 163) where the prevalence of low serum zinc (defined as <70 μg dL^{-1}) was ~34% at baseline and dropped to <10% after 3 months of supplementation with a concurrent increase in height-for-age Z-score among initially stunted children[24]. A group of Indian children 6–35 months of age (n = 609) had a prevalence of ~36% low plasma zinc (defined as <60 μg dL^{-1}) concentration at baseline[25]. In the group receiving zinc supplements for four months, the prevalence was reduced to 11.6% with a concurrent reduction in the incidence of acute lower respiratory infection. In Africa, Engle-Stone *et al.*[26] studied the plasma concentrations and dietary zinc intakes of women and young children in Cameroon and reported that 83% of the children (n = 1002) had low plasma zinc concentrations (defined as <65 μg dL^{-1}) with 92% of the total occurring in the northern part the country nearing Nigeria. However, only 8% of the children had inadequate zinc intake[26]. Similarly, in Ethiopia, Kumera *et al.*[27] reported a 57.4% prevalence of zinc deficiency among pregnant women. These results were in agreement to these recent findings.

Among the gender sub-population, Cavan *et al.*[28] studied a group of peri-urban 6-8 years old Guatemalan school children (n = 155) reported a prevalence of low plasma zinc concentration (defined as <70 μg dL^{-1}) of 12.3% among boys and 1.5% among girls. Following 3 months of supplementation, plasma zinc concentrations increased and the children demonstrated some body composition changes, without improvements in growth or other functional tests of zinc deficiency[29]. Similarly, Beinner *et al.*[30] found no significant difference between genders regarding plasma zinc and so was Favaro and Vannuchi[31].

Although, the above studies are not entirely comparable because of different sampling techniques and use of different cut-off points, they can be used to set tentative guidelines for taking action based on prevalence of low serum zinc concentrations. In populations with a prevalence of low serum zinc concentrations less than 10%, zinc deficiency would not be considered a public health concern warranting national level programmes. However, a prevalence of between 10 and 20% for low serum zinc values warrants further assessment of results, as the slightly elevated prevalence suggests that some segments of the population may be at high risk of zinc deficiency. Programmes targeted to high-risk groups may be necessary. Where the prevalence of low plasma zinc values exceeds 20%, as it is in this study, national level programmes may be considered following further assessment to identify groups at elevated risk[11]. The result of this study corroborates two earlier studies[26,27] that in Sub-Saharan Africa, over 55% of children less than 5 years are zinc deficient.

In terms of dietary intake, 54% of the study population do not have access to zinc-rich foods such as fish, eggs, milk and meat. The risk for zinc deficiency is further compounded by the high consumption of cereal-based diet by 91.4% of the study population, taking it every day to several times a day. This nutritional inadequacy presents itself as a basis for high prevalence of zinc deficiency-dependent diseases among the study population (24.14% incidence of affliction). Furthermore, many more subjects that are seemingly healthy are presented with one sign and symptom of zinc deficiency or the other (51.72%), suggesting a potential increase in the prevalence of zinc deficiency-dependent diseases. Consumption of cereal-based foods over four times in a month which could indicate that the foods were consumed almost every day in a week substantially reflected foods most preferred by households or those that were available to them and affordable and of utmost importance for their food security and nutrition. The wide range of uses of maize and millet, especially as green maize and millet respectively, as major component of complementary foods in most Nigerian households and as common beverages in the area of research, accounted for the indicated frequency of consumption.

In this study, a high incidence of zinc deficiency was found among the studied population. This confirmed the high prevalence of affliction by zinc-deficiency predisposing infectious diseases among the children. The study also discovered a significant negative correlation between the consumption of foods rich in zinc and the zinc status of the children. Because the prevalence of low plasma zinc values exceeds 20%, a national level programme was recommended through public health nutrition interventions to improve the zinc status. The result of this study corroborated an earlier study by Maziya-Dixon *et al.*[10] that in Nigeria, at the national level, 26% of children less than 5 years are zinc deficient.

CONCLUSION

The percent of children with plasma zinc level below the cut-off point for positive zinc status was 59.09%. This represents a rather high level of incidence of zinc deficiency among the studied population and calls for necessary action through public health nutrition intervention programmes to improve the zinc status. This study corroborates the fact that populations that rely on plant-based diets, often lacking in diversity, tend to suffer micronutrient deficiencies, including zinc. This explains the low zinc levels observed among the children in the current study in Kanam local government area, which is resource poor and lacks diet diversity, as over 91% of the studied population consume cereal-based food every day to several times a day. For the most part of the area, sorghum, beans and corn meal were the main foods prepared by the caregiver.

SIGNIFICANCE STATEMENTS

- This study found a high prevalence of zinc deficiency among children under-five years of age in Kanam, North-central Nigeria
- The study also discovered a significant negative correlation between the consumption of foods rich in zinc and the zinc status of the children
- This study further revealed that the deficiency might be due to over-reliance on zinc-deficient staple foodstuffs
- Because the prevalence of low plasma zinc values exceeds 20%, national level programmes may be considered through public health nutrition interventions to improve the zinc status

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