

Unusual low plasma levels of zinc in non-pregnant Congolese women

Solo Kuvibidila^{1,2*} and Mbele Vuvu³

¹Department of Nutritional Sciences, Oklahoma State University, 301 Human Environmental Sciences, Stillwater, OK 74078, USA

²Department of Pediatrics, The Research Institute for Children's Hospital/Louisiana State University Health Sciences Center, New Orleans, LA, USA

³Nsundi-Lutete Hospital, Eglise du Christ au Congo B.P. 36, Luozi, Bas-Congo, Democratic Republic of Congo

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Zn is an essential trace element required throughout the life cycle. Although suboptimal Zn status is thought to be common in many sub-Saharan countries, there is a paucity of data in the Democratic Republic of Congo. The objective of the study was to determine Zn status in non-pregnant Congolese women. We measured plasma Zn and indicators of nutritional status (albumin, prealbumin, retinol-binding protein) and inflammation (C-reactive protein (CRP), ceruloplasmin, α 1-acid glycoprotein (AGP)) in seventy-seven lactating and thirty non-lactating women (mean age 28 and 31 years, respectively). Blood samples were collected in summer 1989 in rural Bas-Congo during a survey on Fe status. Mean lactation period was 8.3 months. Mean parity was higher in lactating (3.6) than in non-lactating (2.2) women ($P < 0.05$). Mean biochemical indicators of nutritional status, CRP and ceruloplasmin were within normal range and not different between groups. Mean AGP concentrations were above normal (> 1.2 g/l) and higher in lactating (1.365 g/l) than in non-lactating (1.178 g/l) women ($P < 0.05$). Mean Zn concentration (540 μ g/l) of the overall study population was below normal (700 μ g/l); and the mean was lower in lactating (455 μ g/l) than in non-lactating (759 μ g/l) women ($P < 0.05$). Multiple regression analysis suggested that parity ($P < 0.05$), but not inflammation, was the most important factor associated with low Zn levels. Despite the lack of data on dietary intake, the results suggest that suboptimal Zn status may be common in the studied population.

Zinc: Lactation: Inflammation: Democratic Republic of Congo

Zn, an essential trace element involved in the metabolism of proteins, nucleic acids, lipids and carbohydrates, is required for immunity, growth and cognitive development of children^(1–3). The requirement of Zn is high during lactation because of secretion into milk^(4–8). In humans, although in general there is a poor correlation between maternal Zn status and milk Zn content, some animal studies suggest that maternal Zn supplementation may affect milk Zn levels⁽⁹⁾. A few human studies have also suggested that Zn supplementation during pregnancy and/or lactation was associated with a slower fall in milk Zn levels during lactation^(1,4,10).

Marginal Zn deficiency is thought to be very common in many developing countries because of inadequate dietary intake and poor bioavailability^(2–3). In sub-Saharan Africa, it is estimated that 68% of the population is at risk of low Zn intake and therefore at risk of moderate Zn deficiency⁽²⁾. The diet of many Congolese individuals is composed of various vegetables, legumes such as beans and peas, and tubers and therefore is rich in phytates. Cassava, the staple food in the Democratic Republic of Congo (DR Congo), is relatively rich in Zn content (2.33–6.93 mg/100 g) compared with rice (1.60–1.73 mg/100 g), banana plantains (1.35–4.46 mg/100 g) and groundnuts (2.46–2.95 mg/100 g)⁽¹¹⁾. However, because of the high phytate content (355–530 mg/100 g), Zn bioavailability is limited⁽¹²⁾.

Meat and fish intake of individuals who live in rural areas is limited.

Although marginal Zn status is expected in the DR Congo because of its geographical location, there is a paucity of data in Congolese lactating women. Considering the type of diet and the presence of factors that interfere with Zn metabolism, we hypothesise that marginal Zn status is common in women of reproductive age. The goal of the present cross-sectional preliminary study was to determine plasma Zn levels in non-pregnant Congolese women, especially lactating women, and whether low plasma Zn, if any, is due to inflammation.

Materials and methods

Study population, blood drawing and laboratory measurements

The 107 women included in the present study (seventy-seven lactating and thirty non-lactating women) were a part of a group of 213 non-pregnant women and their young children (aged 0–5 years) who were recruited in summer 1986 and 1989 for evaluation of Fe status and inflammation in the rural Bas-Congo state in the DR Congo. Conditions under which the blood samples were drawn and measurements of

Abbreviations: AGP, α 1-acid glycoprotein; APP, acute-phase protein; CER, ceruloplasmin; CRP, C-reactive protein; DR Congo, Democratic Republic of Congo.

* **Corresponding author:** Dr Solo Kuvibidila, fax +1 405 744 1357, email solo.kuvibidila10@okstate.edu

acute-phase proteins (APP) (C-reactive protein (CRP), α 1-acid glycoprotein (AGP) and ceruloplasmin (CER)) and biochemical indicators of nutritional status (albumin, prealbumin, transferrin and retinol-binding protein) have been previously published^(13,14). Inflammation was defined by the following cut-off points: AGP >1.2 g/l, CRP >10 mg/l and CER >500 mg/l⁽¹⁵⁾. The following cut-off points were used to define abnormal biochemical indicators of nutritional status: albumin <35 g/l, prealbumin <160 mg/l, retinol-binding protein <30 mg/l and Zn <700 μ g/l⁽¹⁶⁾.

Inclusion criteria in the present study were: (1) availability of plasma for measurement of Zn (by atomic absorption spectrophotometer (model 3030B; Perkin Elmer; Norwalk, CT, USA)); (2) data on any two APP and any three biochemical indicators of nutritional status; (3) no recent major illness requiring surgery and/or hospitalisation; (4) non-pregnant woman aged 15–50 years, resident in the Nsundi-Lutete area. Weight and height were measured in seventy-eight women and BMI was calculated by the standard formula (kg/m^2). Information on parity was collected by interview in seventy-four women at the time of blood drawing. No information was collected on Zn intake, and Zn supplementation is uncommon in the DR Congo. All women lived on farming and none had education above high school, had electricity and/or running water at home. The study was approved by the Investigation Review Board of Louisiana State University Health Sciences Center (New Orleans) and the Nsundi-Lutete Hospital (DR Congo). Personal consent was obtained before enrolling the women in the study.

Statistical analysis

Descriptive statistics (mean values and standard deviations), one-way ANOVA and Student's *t* test were performed by Microstatistical program (Microsoft Inc., Indianapolis, IN, USA). Multiple regression analysis with age, parity,

biochemical indicators of nutritional status and APP as independent variables, and plasma Zn as the dependent variable, and Pearson correlation were also performed. The level of significance was set at $P < 0.05$.

Results

General information and nutritional status

The range, mean and median duration of lactation, which corresponded to the age of lactating women's infants, were 0.25–25, 8.3 and 7 months, respectively. The range, mean and median age of non-lactating women's children were 9–30, 19.38 and 22 months, respectively. Parity ranged from 1 to 10 with a median of 3 for lactating women and from 1 to 4 with a median of 2 for non-lactating women, respectively. Mean parity was higher in lactating than in non-lactating women ($P < 0.05$). There were no significant differences regarding age between lactating and non-lactating women.

Based on the concentration of plasma proteins, in general, the studied women had adequate nutritional status, and the means of the various measurements were not statistically different between both study groups (Table 1). However, 11.8, 10 and 26% of lactating women had albumin, prealbumin and retinol-binding protein below normal, respectively. The corresponding values for non-lactating women were 16, 9.7 and 22.6%. Mean BMI was significantly lower in non-lactating than in lactating women ($P < 0.05$).

Acute-phase proteins

Mean AGP concentrations were significantly higher in lactating than in non-lactating women (Table 1; $P < 0.05$) and those of CRP and CER were not different. While the mean CRP and CER concentrations were within the normal range, those of AGP were above normal (>1.2 g/l) in lactating, but not in non-lactating women. A higher percentage of lactating

Table 1. General characteristics and nutritional status of the study population (Mean values and standard deviations)

	All women (n 107)		Lactating women (n 77)		Non-lactating women (n 30)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)†	29.2	8.10	28.30	7.40	31.10	9.30
Parity‡	3.35	2.24	3.59	2.37	2.23*	0.93
Weight (kg)§	62.91	11.82	65.59	8.61	58.54	15.60
Height (cm)§	153.46	0.74	152.99	0.96	154.60	5.59
BMI (kg/m^2)§	27.65	6.86	29.12	5.94	25.12*	7.72
Albumin (g/l)	45.99	75.5	45.91	1.02	46.02	1.72
Prealbumin (mg/l)	252.4	7.24	248.79	74	261.60	79.1
Retinol-binding protein (mg/l)	35.05	1.00	34.09	10.00	37.27	11.46
Transferrin (g/l)	3.21	0.56	3.17	5.51	3.31	0.12
α -1-Acid glycoprotein (g/l)	1.31	0.49	1.37	0.44	1.18*	0.65
C-reactive protein (mg/l)	6.96	1.12	7.90	13.65	4.27	0.217
Ceruloplasmin (mg/l)	492.83	14.87	494	155	484.90	151.70

* Mean value was significantly different from that of the lactating women ($P < 0.05$).

† For age, the sample sizes were 82, 52 and 30 for the overall study population, lactating women and non-lactating women, respectively. Age could not be confirmed in twenty-five lactating women because of lack of identification.

‡ For parity, the sample sizes were 74, 61 and 13 for the overall study population, lactating women and non-lactating women, respectively.

§ For weight, height and BMI, the sample sizes were 78, 52 and 26 for the overall study population, lactating women and non-lactating women, respectively.

women than of non-lactating women had AGP levels above normal (64.9 v. 38.7%; χ^2 5.588; $P=0.01$) and CRP above normal (16.9 v. 3.3%, χ^2 3.485; $P<0.05$). CER concentration was above normal in 35% lactating and 38.7% of non-lactating women. Approximately 33% of lactating women and 13% of non-lactating women had two to three APP concentrations suggestive of inflammation.

Plasma zinc

Mean Zn levels of lactating women were significantly lower than those of non-lactating women; in general, differences between both groups persisted after taking into account inflammation (Table 2; $P<0.05$). In the group of lactating women, although those with inflammation tended to have lower mean plasma Zn levels than those without inflammation, the differences were not significant. The same trend was observed with non-lactating women without and those with inflammation. Approximately 78% of the overall study population had Zn levels below 700 µg/l. As expected, the percentage of women in the overall population with Zn levels <700 µg/l increased with the number of APP in the levels suggestive of inflammation (72% (18/25), 83% (44/53), 83% (20/24) and 100% (5/5) for no, one, two and three APP above normal, respectively).

Plasma Zn poorly correlated with indicators of nutritional status, APP and age (r 0.03 to 0.1495; $P>0.05$). However, in women in whom parity was known, albumin (r 0.312) and parity (r -0.278) were significantly correlated with plasma Zn ($P<0.05$). Multiple regression analysis suggested that parity was the most important variable that was negatively and significantly associated with low plasma Zn ($P<0.05$). Albumin ($P=0.026$) and prealbumin ($P=0.021$) also had some predictive effect on plasma Zn. In contrast to indicators of nutritional status, no single APP had a significant association with plasma Zn levels.

Discussion

Plasma Zn is the most commonly used index of Zn status at the population levels⁽¹⁷⁾. Although it represents only 0.1%

of the total body pool, and 12–22% of the overall blood pool, it is sensitive to dietary depletion⁽³⁾. Unfortunately, plasma Zn levels below 700 µg/l are not always indicative of suboptimal status since values can also decrease following infections, inflammation and trauma, in part because of body redistribution^(3,18). The mean plasma Zn levels of the overall study population and lactating women are below normal for published standards for healthy adults from Western countries^(3,17). However, they are not very different from those that have been reported in women from other African countries^(19,20). Additionally, they are similar to those reported for pregnant women⁽²¹⁾.

There are several possible causes of low plasma Zn levels in the studied population: dietary intake, Zn bioavailability, acute and/or chronic inflammation, infection, diurnal variations, use of oestrogen-containing compounds such as oral contraceptives, and hypoalbuminaemia⁽³⁾. All blood samples were drawn between 09.00 and 12.00 hours; therefore diurnal variation cannot explain the low levels in the studied population. Although information on oral contraceptive use was not collected, the practice is very uncommon because of availability and cost. Although inflammation may have some influence on low plasma Zn levels, it does not fully explain the suboptimal status (Table 2). Low plasma Zn levels were not due to hypoalbuminaemia because mean plasma Zn levels of thirteen women with albumin levels below normal (469 (SD 204) µg/l) were not lower than those of women with normal levels (524 (SD 356) µg/l). We therefore speculate that low plasma Zn levels in the studied women are due to inadequate intake and/or bioavailability due to factors such as phytates that are common in cassava and other foods usually consumed by Congolese.

The negative association between parity and plasma Zn levels suggests that the cycle of frequent pregnancies and lactation very probably contributes to the low plasma Zn levels in the studied population. Normally, Zn absorption increases during lactation; however, this adaptation alone may not be enough to maintain Zn homeostasis^(6,22). Despite the limited sample size, lack of information on dietary intake and/or other indices of Zn status, our preliminary data suggest that suboptimal Zn status may be very common in the studied population and that elevated

Table 2. Plasma zinc levels (µg/l) in women without and with inflammation (Mean values and standard deviations)

	All women			Lactating women			Non-lactating women		
	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD	<i>n</i>	Mean	SD
All women	107	540	398	77	455	203	30	759*	634
Women with Zn <700 µg/l (%)	83	77.6		65	84.4		18	60.0	
AGP ≤ 1.2 g/l	45	581	467	27	446	165	18	785*	671
AGP > 1.2 g/l	62	510	341	50	460	224	12	720*	601
CRP ≤ 10 mg/l	93	554	418	64	458	203	29	767*	640
CRP > 10 mg/l	14	447	210	13	440	217	1	533	0
CER ≤ 500 mg/l	69	566	395	49	480	223	16	797*	614
CER > 500 mg/l	38	494	406	27	413	161	14	693*	693
Number of acute-phase proteins above normal†									
None	25	613	413	15	497	174	10	788*	593
One	53	563	463	37	450	218	16	823*	726
Two to three	29	436	197	25	437	208	4	429	174

AGP, α -1-acid glycoprotein; CRP, C-reactive protein; CER, ceruloplasmin.

* Mean value was significantly different from that of the lactating women ($P<0.05$).

† As defined in Materials and methods.

plasma levels of APP and/or hypoalbuminaemia do not explain the suboptimal Zn status. Given the importance of Zn in health, specifically immunity, cognition and physical development of children, and pregnancy outcome, more studies should be conducted in this population.

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S. K. designed the study, participated in blood drawing, measured biochemical indicators of inflammation and plasma Zn, analysed data and wrote the manuscript. The senior author M. V., a physician at Nsundi-Lutete Hospital, coordinated subject recruitment.

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