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Assessment of zinc status of women resident in the National Capital District, Papua New Guinea

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SUMMARY

This cross-sectional study assessed the zinc status of non-pregnant and pregnant women resident in the National Capital District (NCD), Papua New Guinea (PNG). Non-fasting morning blood samples were collected by venipuncture from consented women. Flame atomic absorption spectrometry was used to measure the serum zinc concentration in 27 non-pregnant and 100 pregnant women. C-reactive protein (CRP) in serum was measured by enzyme immunoassay and used to interpret the serum Zn data. For all the non-pregnant women, the median serum zinc concentration was 42.7 µg/dl with an interquartile range (IQR) of 27.6 to 91.2 µg/dl. Zinc deficiency was prevalent among 59% in this group of women. For those with normal CRP the median and IQR serum zinc concentrations were 48.9 µg/dl and 30.2 to 98.7 µg/dl, respectively. The median and IQR for all the pregnant women were 63.8 µg/dl and 40.9 to 93.2 µg/dl, respectively. Prevalence of zinc deficiency was 42% using the cut-off point of 56.0 µg/dl. Of the 100 pregnant women, 16 (16%) were in the first trimester, 51 (51%) in the second trimester and 33 (33%) in the third trimester. The median serum zinc concentrations of pregnant women in the first, second and third trimesters were 87.0 µg/dl, 61.6 µg/dl and 60.8 µg/dl, respectively. Using gestational period-specific cut-off points, zinc deficiency was prevalent among 31%, 39% and 36% of the pregnant women in the first, second and third trimesters, respectively. Our results clearly indicate suboptimal zinc status among non-pregnant and pregnant women in the NCD. According to the International Zinc Nutrition Consultative Group (IZiNCG) criteria, this should be considered as a public health problem among these groups of women in the NCD. To effectively address the issue, social mobilization, intensive education and awareness campaigns, with all relevant target groups and policy makers, are urgently required.

Introduction

Zinc (Zn) is one of the essential trace elements in human nutrition. It is a component of over 200 metallo-proteins with a wide range of biochemical functions (1,2). Zn is required for normal cellular growth and differentiation, and for the expression of multiple genes regulating mitosis; it plays a crucial role in the development and maintenance of the immune system; it is also required for the regulation of a family of transcriptional regulators with Zn-finger motif involved in sequence-specific DNA (deoxyribonucleic acid) recognition and gene expression (1-4). Zinc is also required for the absorption, transport, metabolism, hepatic release and tissue utilization of vitamin A as well as for regulation of blood sugar, acid-base balance, calcium metabolism, and normal functions of the gonads, thyroid and adrenal glands (1-6). Zn is an antioxidant that helps to stabilize and maintain the integrity of cellular membranes (5,6). The consequences of Zn deficiency are manifold (1-12).

Inadequate dietary intake of Zn by women of

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childbearing age can compromise major body functions, including impairment of physical growth, immune competence and reproduction (1,2,12,13). Some scientific reports have indicated that women are at increased risk of Zn deficiency during pregnancy, because of the high fetal requirement for Zn (1,2,13-15). Mild to moderate (subclinical) Zn deficiency has been associated with prolonged gestation, intrauterine growth restriction, pregnancy-induced hypertension, preterm delivery, complications of labour and delivery of neonates with low birthweights (1-3,11-20).

According to the International Zinc Nutrition Consultative Group (IZiNCG), World Health Organization (WHO) and United Nations Children's Fund (UNICEF), serum or plasma Zn concentration is the best available biomarker of the risk of Zn deficiency in target populations, because it is the only biochemical indicator for which some acceptable reference data are available (1,7,21-24).

Flame atomic absorption spectrometry (FAAS) is one of the recommended analytical methods for the assay of Zn in serum. It is a robust technique with high sensitivity, reproducibility, specificity and precision; however, to avoid contamination by ambient sources of Zn, appropriate precautions must be taken during collection, processing and analysis of the serum samples (1,22,24).

Several criteria have been proposed for data interpretation, because serum Zn concentration is affected by recent meals, time of day of sample collection, age, gender, systemic infections, inflammation or trauma (1,22,25,26).

Serum Zn concentration below 66.0 µg/dl (10.1 µmol/l) is the recommended cut-off point that indicates Zn deficiency for non-fasting, non-pregnant women (1,22,25,26).

During the various stages of pregnancy, blood volume expansion and hormonal changes cause variations in the Zn concentration in blood (1,22,25,26). Thus various cut-off points have been used to indicate Zn deficiency in pregnant women (17-19,27,28). However, according to the IZiNCG and others, trimester-specific cut-off points should be used for assessing the Zn status of pregnant women (21,22,25, 26). In the first trimester, serum Zn concentration below 56.0 µg/dl (8.6 µmol/l) indicates Zn deficiency while in the second and third trimesters of pregnancy, serum Zn concentration below 50.0 µg/dl (7.6 µmol/l) indicates Zn deficiency (2,22,26). To control for infection, inflammation or trauma, the concentration of C-reactive protein (CRP) should be measured in each serum sample (1,2,7) and the results used for appropriate interpretation of the Zn status of the target population (1,2,7,22,26). Zn deficiency in a target population is considered to be of public health significance when the prevalence of Zn deficiency is greater than 20% (1,2,22,26).

Published data on the Zn status of Papua New Guinea (PNG) populations have been focused mainly on children (10,29), with no available data on pregnant women. There are published scientific data indicating a high prevalence of subclinical Zn deficiency status among pregnant women in some resource-limited countries (17,27,28,30,31). These reports are important because of the negative impact of Zn deficiency on maternal and fetal outcomes. Thus the need for continuous monitoring of the Zn status of pregnant women in resource-limited countries like PNG cannot be overemphasized.

Currently there are no published data on the prevalence of zinc deficiency among non-pregnant and pregnant women in PNG. The major objective of this study was to assess the Zn status of non-pregnant and pregnant women resident in the National Capital District (NCD), PNG.

Subjects and Methods

Study site

The primary site was the antenatal clinic in the Obstetrics and Gynaecology (O&G) Department in Port Moresby General Hospital (PMGH), which is the major, general, specialist and referral hospital in the National Capital District and PNG. PMGH is also the Teaching Hospital for the School of Medicine and Health Sciences (SMHS), University of Papua New Guinea (UPNG).

Sample size

Calculation of sample size was based on a design effect of one, relative precision of 10% and confidence level of 95%. As there were no available data on the likely prevalence rate of zinc deficiency among women in NCD, a prevalence rate of 25% was assumed. The

sample size of about 160 was obtained for a predicted non-response rate of 20% (32).

Study design and sampling

This was partly a hospital outpatient-based cross-sectional study, because it is difficult to get pregnant women outside the hospital to donate blood samples for research. All pregnant women who attended the antenatal clinic in PMGH between May and July 2013 were eligible for enrolment in the study. The pregnant women were selected by simple random sampling after their routine examination by the O&G consultants. Non-pregnant, non-lactating women of childbearing age residing in NCD were selected randomly from staff and students in PMGH and SMHS.

Collection of blood samples and questionnaire data

The major aim of the study was explained to each of the women and their accompanying relative before requesting their signed informed consent. A non-fasting morning blood sample was obtained by venipuncture from each consented woman. The blood was transferred into a labelled sterile micronutrient-free polypropylene tube, placed into a cool-box kept at 4-8ºC and transported to the Micronutrient Research Laboratory (MRL) in the SMHS, UPNG. The blood samples were centrifuged at 3500 rpm at 4ºC for 30 minutes, after which aliquots of each serum were separated into two labelled sterile micronutrient-free Eppendorf vials and kept frozen at −70ºC until required for analysis. Special precautions were taken to avoid contamination of the serum by ambient sources of Zn (1,2,22,24). A self-designed pretested questionnaire was used to collect specific information, including time of last meal, type of meal, time of sample collection, age, gestational age and residential location of each participant.

Exclusion criteria

Women with significant illness, those to be admitted in the wards, and women not resident within the NCD were excluded from the study.

Analysis of serum samples

The quantitative assay of Zn in serum was carried out in the PNG National Agricultural Research Institute (NARI) Chemistry Laboratory, using the Varian AA 240 flame atomic absorption spectrometer. The recommended procedures and precautions for assay of serum Zn were implemented, including the use of four levels of standard serum samples for internal quality control (22,24). The FAAS parameters used were: wavelength 213.9 nm, slit width 1.0 nm, lamp current 4.0 mA, burner height 10.0 mm, acetylene flow 2.0 l/min, air flow 13.5 l/min and aspiration time 5 seconds (33). The assay of C-reactive protein in serum was carried out in the MRL in the SMHS, UPNG. A commercial enzyme immunoassay (EIA) kit for the in vitro diagnostic quantitative determination of CRP in serum was used (34). The controls provided by the manufacturer were used to determine the inter- and intra-assay coefficients of variation (CV), which were 3.0% and 2.4% respectively.

Data analysis and interpretation

The statistical package for social sciences (SPSS) version 20 for Windows and Excel MS data pack software were used for statistical analysis of data. Data distribution was determined by the Shapiro-Wilk test. The Chi-squared test, Fisher's Exact test, Mann-Whitney U test, Wilcoxon rank sum test and one-way analysis of variance (ANOVA) were used as appropriate.

In the present study, the results were interpreted using the recommended criteria proposed by the IZiNCG expert committee (1,22,25,26). Serum Zn concentration below 66.0 µg/dl (10.1 µmol/l) indicates Zn deficiency among non-pregnant women. Two cut-off points were used for the pregnant women, serum Zn concentration below 56.0 µg/dl (8.6 µmol/l) and below 66.0 µg/dl.

The trimester-specific cut-off points indicating Zn deficiency were used as follows: serum Zn below 56.0 µg/dl for pregnant women in the first trimester; serum Zn below 50.0 µg/dl (7.6 µmol/l) for pregnant women in the second and third trimesters. Other cut-off points were used for the purpose of comparing our results with published data in other countries. Risk of a public health problem is indicated when the prevalence of Zn deficiency is between 10 and 20% of the target population; a prevalence of above 20% indicates a public health problem (1,22,26). A serum CRP level below 8.0 µg/ml indicates a

normal CRP level (34).

Ethical clearance

Approval for this study was obtained from the Ethical and Research Grant Committee in the SMHS, UPNG, and the Medical Research Advisory Committee (MRAC), PNG National Department of Health (NDoH). Permission was obtained from the Chief Executive Officer and Director of Medical Services of PMGH. In addition, signed informed consent was obtained from each subject before collecting the blood sample.

Results

The total number of women recruited was 160, but informed consent was obtained from 127 women (response rate 79%). Of the 127 women who participated in the study, 27 (21%) were non-pregnant and 100 (79%) were pregnant. All the women indicated that they had consumed their regular meal before coming to the clinic in the morning. The various foodstuffs they had consumed included bread, rice, sago, sweet potato (kaukau), taro, yam, tapioca, breadfruit, green vegetables, betelnuts, peanuts, coconut, coconut milk, fruits, pork, tinned fish and other seafood.

The mean age of the non-pregnant women was 23.4 ± 2.7 years (mean ± standard deviation) and the age range was 19 to 33 years. The Shapiro-Wilk test ($p = 0.03$; $df = 27$) indicated that the serum Zn concentration for the non-pregnant women was not normally distributed. The box-plot of the serum Zn concentration (Figure 1) also indicates that the values were not normally distributed. The median serum Zn concentration for the non-pregnant women was 42.7 µg/dl and the interquartile range (IQR) was 27.6 to 91.2 µg/dl. Zn deficiency was prevalent among 59% of the non-pregnant women (Table 1).

In order to assess the effect of acute infection on serum Zn concentration, the non-pregnant women were separated according to their serum CRP levels.

The serum CRP level was within the normal range in 24 (89%) of the 27 non-pregnant women; their serum Zn data obtained is presented in Table 1. The median and IQR serum Zn concentrations were 48.9 µg/dl and 30.2 to 98.7 µg/dl respectively. A very weak inverse correlation (Spearman's rho = −0.13, $p = 0.35$) was obtained between the serum Zn concentrations and serum CRP levels for the non-pregnant women.

Using the Mann-Whitney U and Wilcoxon W tests, no significant difference ($p = 0.392$, 2-tailed) was obtained between the serum Zn concentrations for all the non-pregnant women and the non-pregnant women with normal

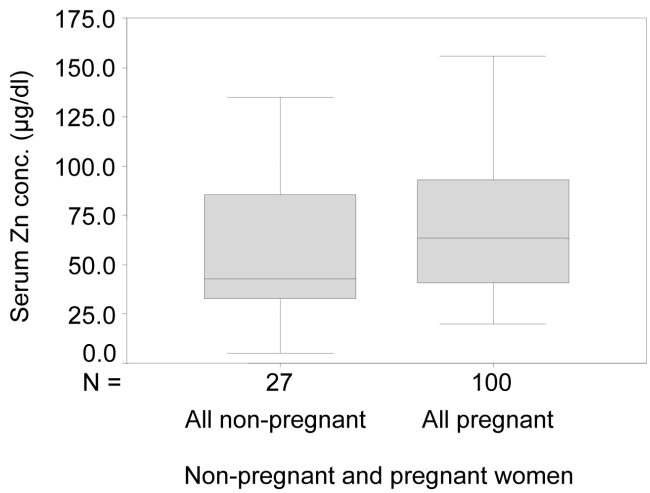

Figure 1. Box-plots of serum Zn concentrations (µg/dl) for all the non-pregnant and all the pregnant women.

TABLE 1

SERUM ZINC CONCENTRATION FOR ALL THE NON-PREGNANT WOMEN AND FOR THOSE WITH NORMAL SERUM CRP AND PERCENT BELOW THE CUT-OFF POINT THAT INDICATES ZINC DEFICIENCY

	Non-pregnant women (n = 27)	Non-pregnant women with normal CRP (n = 24)
Median serum Zn (µg/dl)	42.7	48.9
Interquartile range	27.6-91.2	30.2-98.7
Mean serum Zn (µg/dl)	58.3	61.4
Standard deviation	37.5	38.6
95% CI (µg/dl)	43.5-73.1	45.1-77.7
Percent (number) with serum Zn below 66.0 µg/dl	59.3% (16)	54.2% (13)

NB: divide µg/dl by 6.54 to convert to µmol/l
CRP = C-reactive protein
Zn = zinc
CI = confidence interval

serum CRP level. ANOVA also indicated no difference between the two groups ($F = 0.085$, $p = 0.77$). Zn deficiency was prevalent in 54% of the non-pregnant women with normal serum CRP level.

The mean age for the pregnant women was 26.0 ± 5.3 years and the age range was 16 to 42 years. The box-plot for the serum Zn concentrations for all the pregnant women is also presented in Figure 1, which shows that the data were slightly skewed. The Shapiro-Wilk test ($p = 0.001$, $df = 100$) further confirmed that the data were not normally distributed. Table 2 shows the serum Zn data obtained for all the pregnant women and for the pregnant women with normal serum CRP level. A very weak inverse correlation ($rho = -0.108$, $p = 0.55$) was obtained between the serum Zn concentrations and serum CRP levels for all the pregnant women. No significant difference ($p = 0.095$, 2-tailed) was obtained between the serum Zn concentrations for all the pregnant women and pregnant women with normal serum CRP level. A similar result was obtained using ANOVA ($F = 3.304$, $p = 0.071$).

Using the serum Zn cut-off point of 56.0 µg/dl, Zn deficiency was prevalent in 42% of all the pregnant women, compared to 51% of the pregnant women with normal CRP. Analysis of the data for the 30 (30%) pregnant women with elevated serum CRP levels indicated that only 6 (20%) of them had a serum Zn concentration below the cut-off point indicating Zn deficiency.

Of the 100 pregnant women, 16 (16%) were in the first trimester, 51 (51%) in the second trimester and 33 (33%) in the third trimester of pregnancy. The mean ages of the pregnant women in the first, second and third trimesters were 26.1 ± 6.2 years, 26.0 ± 5.0 years and 26.0 ± 5.6 years, respectively. The corresponding age ranges were 23 to 42 years, 16 to 39 years and 17 to 36 years.

The distribution of the serum Zn concentrations for the pregnant women in their first, second and third trimesters are presented in the box-plots in Figure 2. The 3 box-plots are slightly skewed, thus indicating that the data were not normally distributed. The serum Zn data obtained for the pregnant women in the three trimesters of pregnancy are presented in Table 3. The median serum Zn concentrations of the pregnant women in the first, second and third trimesters were 87.0 µg/dl, 61.6 µg/dl and 60.8 µg/dl, respectively.

TABLE 2

SERUM ZINC CONCENTRATION FOR ALL THE PREGNANT WOMEN AND FOR THOSE WITH NORMAL SERUM CRP AND PERCENT BELOW THE TWO CUT-OFF POINTS THAT INDICATE ZINC DEFICIENCY

	All pregnant women (n = 100)	Pregnant women with normal CRP (n = 70)
Median serum Zn (µg/dl)	63.8	55.1
Interquartile range	40.9-93.2	40.3-68.6
Mean serum Zn (µg/dl)	68.0	58.9
Standard deviation	34.3	28.7
95% CI (µg/dl)	61.2-74.8	52.1-65.7
Percent (number) with serum Zn below 66.0 µg/dl	56.0% (56)	70.0% (49)
Percent (number) with serum Zn below 56.0 µg/dl	42.0% (42)	51.4% (36)

CRP = C-reactive protein
Zn = zinc
CI = confidence interval

No significant differences ($p > 0.05$) were obtained when the serum Zn concentrations in the various trimesters were compared. Table 3 also shows the Zn status of the pregnant women in the three trimesters according to the various cut-off points indicating Zn deficiency. Using the cut-off point of 56.0 µg/dl, zinc deficiency was prevalent in 31% of the pregnant women in the first trimester. Zn deficiency was prevalent in 39% and 36% of pregnant women in the second and third trimesters, respectively, using the cut-off point of 50.0 µg/dl.

The serum CRP level was within the normal range in 56%, 73% and 73% of the pregnant women in the first, second and third trimesters of pregnancy, respectively. The serum Zn data obtained for the three groups of pregnant women with normal serum CRP levels are also presented in Table 3. There were no significant differences ($p > 0.05$, 2-tailed) obtained when their serum Zn concentrations were compared. Using the appropriate cut-off points, Zn deficiency was prevalent in 33% of the pregnant women in the first trimester (cut-off point 56.0 µg/dl). The prevalence was 46% and 46% of the pregnant women in the second and third trimesters, respectively (cut-off point 50.0 µg/dl).

Discussion

The mean serum Zn concentration (58.3 µg/dl) obtained for the non-pregnant women in the present study was higher than the 53.0 µg/dl reported for rural Malawian women (17), but lower than the values reported for women in Enugu, Nigeria (27), Uruguay, Brazil and Mexico (18). The prevalence (59%) of Zn deficiency was higher than that reported for non-pregnant women in these countries (17,18,23). In the present study, the prevalence (54%) of Zn deficiency among the non-pregnant women with normal CRP was higher than the 36% reported for a similar group of non-pregnant women in rural Malawi (17).

The high prevalence of Zn deficiency among the non-pregnant women in the present study should be of concern to program planners, because it may indicate a prolonged status of Zn depletion in the population. This is because, during short-term Zn depletion, the homeostatic mechanisms in the metabolic

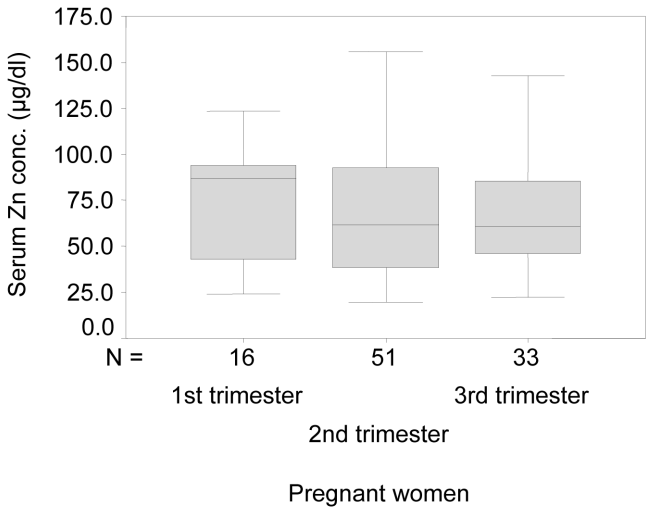

Figure 2. Box-plots of serum Zn concentrations (µg/dl) for the pregnant women in the first, second and third trimesters of pregnancy.

system can fairly well maintain serum Zn concentration within a normal range (1,26).

Suboptimal Zn status in non-pregnant women can be one of the major causes of Zn deficiency during pregnancy (1,19,26). Among the pregnant women in the present study, the prevalence of Zn deficiency was 42%. This was lower than the 55.5% in the urban slums of Delhi (35) and the 53% and 76% reported for pregnant women in Southern Ethiopia (9,13,36). In some developing countries (18,19,27,35,37), the cut-off point of 66.0 µg/dl was used to indicate Zn deficiency among pregnant women. Using the same cut-off point, the prevalence among the pregnant women in the present study was 56%. This was higher than the 7 to 14% reported for pregnant women in Uruguay and Argentina (18), the 41% in India, the 54% in Sindh Province Pakistan (19) and the 50% in Pakistan (35,37), but lower than the over 64% prevalence reported for pregnant women in the rural areas in Haryana India and Bangladesh (19).

According to the IZiNCG, since blood volume expansion is not consistent across the three trimesters of pregnancy, changes in serum Zn concentrations are highly variable (1,22). Failure therefore to use trimester-specific cut-off points to indicate serum Zn deficiency may lead to erroneous interpretation of the data obtained for pregnant women.

In the present study, the prevalence of Zn deficiency of 31% among pregnant women in the first trimester, 39% in the second trimester and 36% in the third trimester was lower than the respective prevalence (46.8%, 48.5% and 58.0%) reported for their counterparts in Southern Ethiopia (13). The 36% prevalence of Zn deficiency among the third trimester pregnant women in our study was lower than the over 70% reported for third trimester pregnant women in the rural areas of Ethiopia (9,36,37), but higher than the 22% reported for India (35).

Our results clearly indicate suboptimal Zn status among the non-pregnant and pregnant women in the NCD. According to the IZiNCG criteria (2,22,26), the extent of Zn deficiency should be considered as a public health problem among non-pregnant and pregnant women in the NCD. This should be of concern, because of the association between Zn deficiency and the potential risk to the fetus and neonate (1,9,12,20,30).

Suboptimal intake of dietary Zn, leading to high prevalence of Zn deficiency in a population group, may be due to several causes, including inadequate dietary intake of absorbable Zn, low bioavailability of Zn caused by anti-nutritional factors in ready-to-

TABLE 3

Serum zinc concentration for all the pregnant women in the first, second and third trimesters of pregnancy and for those with normal serum CRP and percent below the various cut-off points that indicate zinc deficiency

	Pregnant women					
	All first trimester (n = 16)	**First trimester with normal CRP (n = 9)**	**All second trimester (n = 51)**	**Second trimester with normal CRP (n = 37)**	**All third trimester (n = 33)**	**Third trimester with normal CRP (n = 24)**
Median serum Zn (µg/dl)	87.0	73.5	61.6	55.1	60.8	53.3
Interquartile range	42.2-94.0	43.0-110.4	37.4-93.0	35.4-67.8	43.6-87.0	40.6-63.6
Mean serum Zn (µg/dl)	79.1	83.5	65.8	55.7	66.0	54.6
Standard deviation	41.0	47.8	34.3	24.8	30.6	21.1
95% CI (µg/dl)	57.3-100.9	46.7-120.3	56.2-75.4	47.4-64.0	55.2-76.8	45.7-63.5
Percent (number) with serum Zn below 66.0 µg/dl	37.5% (6)	44.4% (4)	58.8% (30)	70.3% (26)	60.6% (20)	79.2% (19)
Percent (number) with serum Zn below 56.0 µg/dl	31.3% (5)	33.3% (3)	43.1% (22)	51.4% (19)	45.5% (15)	58.3% (14)
Percent (number) with serum Zn below 50.0 µg/dl			39.2% (20)	45.9% (17)	36.4% (12)	45.8% (11)

CRP = C-reactive protein
Zn = zinc
CI = confidence interval

eat foods, poor food choices and improper food preparation practices. It can also be caused by inadequate knowledge of dietary requirements, poor socioeconomic status, recurrent infections, or religious or cultural practices (1-4,13).

In the present study, the data obtained from the questionnaires indicated popular consumption of foodstuffs such as tubers, root crops, legumes, cereals and leafy vegetables, but lacking in micronutrient-rich foodstuffs like fish, meat, poultry, eggs, dairy products and a variety of fruits. Some of the roots, tubers, nuts and vegetables that are regularly consumed by the non-pregnant and pregnant women contain anti-nutritional factors, such as phytate, oxalate, tannins, saponins and dietary fibre, that chelate Zn, forming complexes that cannot be absorbed in the gastrointestinal tract (1-4,10,29,36-41). Thus the low availability of absorbable Zn may be one of the major contributing factors for the high prevalence of Zn deficiency among the non-pregnant and pregnant women in this study. In addition, haemodilution may potentiate Zn deficiency in pregnant women (1,26). Similar findings have been reported by others in some countries (17,19,27,28,35-37).

In order to achieve optimal Zn status among non-pregnant and pregnant women, an increase in the intake of dietary absorbable Zn is required. Some of the recommended long- and medium-term strategies include supplementation, fortification, dietary diversity (food-based strategies) and nutrition education (41-44). These strategies are usually complementary and not mutually exclusive. In the short term, women should be advised to consume a variety of foodstuffs with high absorbable Zn – foodstuffs such as fresh fruits, meat, poultry, eggs and dairy products – and also to use multivitamins that contain appropriate amounts of Zn and other micronutrients.

Our data also indicated a high prevalence of infection among the pregnant women, with 30% having an elevated serum CRP level. This implies that effective public health and community health policies should be included in all food-based sustainable intervention strategies, because poor sanitation, inadequate disease control measures and high prevalence of infection are often correlated with Zn deficiency (1,22,26). Thus to effectively reduce the current status of Zn deficiency in the NCD, social mobilization, intensive education and awareness campaigns, including communication with all relevant target groups and the relevant policy makers, are urgently required.

Conclusions

Our results clearly indicate suboptimal Zn status among non-pregnant and pregnant women in the NCD. To achieve optimal Zn status among these women, an increase in the intake of dietary absorbable Zn is required. One of the short-term practical methods is to encourage consumption of foodstuffs with high bioavailability of zinc. In addition, basic nutrition education and aggressive advocacy of appropriate and adequate use of micronutrient-dense foodstuffs for optimal health should be carried out at the antenatal and well-baby clinics in PMGH and at all levels in the various communities in NCD.

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REFERENCES

1 **International Zinc Nutrition Consultative Group (IZiNCG), Brown KH, Rivera JA, Bhutta ZA, Gibson RS, King JC, Lönnerdal B, Ruel MT, Sandström B, Wasantwisut E, Hotz C.** International Zinc Nutrition Consultative Group (IZiNCG) Technical Document # 1. Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr Bull* 2004;25(1 Suppl 2):S99-S203.

2 **Brown KH, Hess SY, eds.** International Zinc Nutrition Consultative Group Technical Document No 2. Systematic reviews of zinc intervention strategies. *Food Nutr Bull* 2009;30(1 Suppl):S1-S186.

3 **Gibson RS.** A historical review of progress in the assessment of dietary zinc intake as an indicator of population zinc status. *Adv Nutr* 2012;3:772-782.

4 **Temple VJ, Masta A.** Zinc in human health. *PNG Med J* 2004;47:146-158.

5 **Konukoglu D, Turhan MS, Ercan M, Serin O.** Relationship between plasma leptin and zinc levels and the effect of insulin and oxidative stress on leptin levels in obese diabetic patients. *J Nutr Biochem* 2004;15:757-760.

6 **Ennes Dourado Ferro F, de Sousa Lima VB, Mello Soares NR, Franciscato Cozzolino SM, do Nascimento Marreiro D.** Biomarkers of metabolic syndrome and its relationship with the zinc nutritional status in obese women. *Nutr Hosp* 2011;26:650-654.

7 **de Benoist B, Darnton-Hill I, Davidsson L, Fontaine O, Hotz C.** Conclusions of the Joint WHO/UNICEF/IAEA/IZiNCG Interagency Meeting on Zinc Status Indicators. *Food Nutr Bull* 2007;28(3 Suppl):S480-S484.

8 **King JC.** Determinants of maternal zinc status during pregnancy. *Am J Clin Nutr* 2000;71(5 Suppl):1334S-1343S.

9 **Stoecker BJ, Abebe Y, Hubbs-Tait L, Kennedy TS, Gibson RS, Arbide I, Teshome A, Westcott J, Krebs NF, Hambidge KM.** Zinc status and cognitive function of pregnant women in Southern Ethiopia. *Eur J Clin Nutr* 2009;63:916-918.

10 **Gibson RS, Heywood A, Yaman C, Sohlström A, Thompson LU, Heywood P.** Growth in children from the Wosera subdistrict, Papua New Guinea, in relation to energy and protein intakes and zinc status. *Am J Clin Nutr* 1991;53:782-789.

11 **Gibson RS, Hess SY, Hotz C, Brown KH.** Indicators of zinc status at the population level: a review of the evidence. *Br J Nutr* 2008;99(Suppl 3):S14-S23.

12 **Shankar AH, Prasad AS.** Zinc and immune function: the biological basis of altered resistance to infection. *Am J Clin Nutr* 1998;68(2 Suppl):447S-463S.

13 **Gebremedhin S, Enquselassie F, Umeta M.** Prevalence of prenatal zinc deficiency and its association with socio-demographic, dietary and health care related factors in rural Sidama, Southern Ethiopia: a cross-sectional study. *BMC Public Health* 2011;11:898-908.

14 **Caulfield LE, Zavaleta N, Shankar AH, Merialdi M.** Potential contribution of maternal zinc supplementation during pregnancy to maternal and child survival. *Am J Clin Nutr* 1998;68(2 Suppl):499S-508S.

15 **Tamura T, Goldenberg RL.** Zinc nutriture and pregnancy outcome. *Nutr Res* 1996;16:139-181.

16 **Goldenberg RL, Tamura T, Neggers Y, Copper RL, Johnston KE, DuBard MB, Hauth JC.** The effect of zinc supplementation on pregnancy outcome. *JAMA* 1995;274:463-468.

17 **Gibson RS, Huddle JM.** Suboptimal zinc status in pregnant Malawian women: its association with low intakes of poorly available zinc, frequent reproductive cycling, and malaria. *Am J Clin Nutr* 1998;67:702-709.

18 **Severi C, Hambidge M, Krebs N, Alonso R, Atalah E.** Zinc in plasma and breast milk in adolescents and adults in pregnancy and postpartum; a cohort study in Uruguay. *Nutr Hosp* 2013;28:223-228.

19 **Pathak P, Kapil U, Dwivedi SN, Singh R.** Serum zinc levels amongst pregnant women in a rural block of Haryana State, India. *Asia Pac J Clin Nutr* 2008;17:276-279.

20 **Chaffee BW, Kinga JC.** Effect of zinc supplementation on pregnancy and infant outcomes: a systematic review. *Paediatr Perinat Epidemiol* 2012;26(Suppl 1):118-137.

21 **de Benoist B, Darnton-Hill I, Davidsson L, Fontaine O, Hotz C.** Recommendations for indicators of population zinc status. Report of WHO/UNICEF/IAEA/IZiNCG Interagency Meeting on Zinc Status Indicators. *Food Nutr Bull* 2007;28(3 Suppl):S399-S400.

22 **International Zinc Nutrition Consultative Group.** Assessing population zinc status with serum zinc concentration. Technical Brief No 2, 2012, 2nd edition. Davis, California: IZiNCG, 2012:1-4. www.izincg.org

23 **Gibson RS.** Determining the risk of zinc deficiency: assessment of dietary zinc intake. Technical Brief No 3, 2007. Davis, California: International Zinc Nutrition Consultative Group (IZiNCG), 2007:1-4. www.izincg.com

24 **International Zinc Nutrition Consultative Group.** Practical tips: Collecting blood in the field for assessment of plasma zinc concentration. Davis, California: IZiNCG, 2012. www.izincg.org/publications/practical-tips

25 **Brown KH.** Effect of infections on plasma zinc concentration and implications for zinc status assessment in low-income countries. *Am J Clin Nutr* 1998;68(2 Suppl):425S-429S.

26 **Hotz C, Peerson JM, Brown KH.** Suggested lower cutoffs of serum zinc concentrations for assessing zinc status: reanalysis of the second National Health and Nutrition Examination Survey data (1976-1980). *Am J Clin Nutr* 2003;78:756-764.

27 **Ejezie FE, Nwagha UI.** Zinc concentration during pregnancy and lactation in Enugu, South-East Nigeria. *Ann Med Health Sci Res* 2011;1:69-76.

28 **Akhtar S.** Zinc status in South Asian population: an update. *J Health Popul Nutr* 2013;31:139-149.

29 **Ross J, Gibson RS, Sabry JH.** A study of seasonal trace element intakes and hair trace element concentrations in selected households from the Wosera, Papua New Guinea. *Trop Geogr Med* l986;38:246-254.

30 **Wessells KR, Brown KH.** Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting. *PLoS One* 2012;7:e50568.

31 **Torheim LE, Ferguson EL, Penrose K, Arimond M.** Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients. *J Nutr* 2010;140:2051S-2058S.

32 **Bartlett JE, Kotrlik JW, Higgins CC.** Organizational research: determining appropriate sample size in survey research. *Inform Tech Learn Perform J* 2001;19:43-50.

33 **Jian-Xin Q.** Determination of Cu, Zn, Fe, Ca, Mg, Na and K in serum by flame atomic absorption spectroscopy. Varian AA Instruments at Work, No AA-93, 1990:1-2. www.ccsservices.ru/lab/res/aa093_3.pdf

34 **IBL International GmbH.** CRP (C-reactive protein) ELISA: enzyme immunoassay for the in-vitro-diagnostic quantitative determination of C-reactive protein in human serum and plasma. Hamburg, Germany: IBL International GmbH, 2013. www.IBL-International.com

35 **Kapil U, Pathak P, Singh P, Singh C.** Zinc and magnesium nutriture amongst pregnant mothers of urban slum communities in Delhi: a pilot study. *Indian Pediatr* 2002;39:365-368.

36 **Abebe Y, Bogale A, Hambidge KM, Stoecker BJ, Arbide I, Teshome A, Krebs NF, Westcott JE, Bailey KB, Gibson RS.** Inadequate intakes of dietary zinc among pregnant women from subsistence households in Sidama, Southern Ethiopia. *Public Health Nutr* 2008;11:379-386.

37 **Hambidge M, Abebe Y, Gibson R, Westcott JE,**

Miller LV, Lei S, Stoecker BJ, Arbide I, Teshome A, Bailey KB, Krebs NF. Zinc absorption during late pregnancy in rural Southern Ethiopia. *Am J Clin Nutr* 2006;84:1102-1106.

38 **Saweri W.** Papua New Guinea nutrition overview. Report of Technical Advisor Nutrition, Family Health Unit, National Department of Health. Port Moresby: Papua New Guinea Department of Health, 2002:1-3.

39 **Food and Agricultural Organization of the United Nations.** Nutrition country profiles: Papua New Guinea. Rome: Food and Agricultural Organization of the United Nations, 2003:6-33. ftp://ftp.fao.org/es/esn/nutrition/ncp/png.pdf

40 **Papua New Guinea Department of Health, United Nations Children's Fund Papua New Guinea, University of Papua New Guinea, Centers for Disease Control and Prevention.** Papua New Guinea National Nutrition Survey, 2005. *Pac J Med Sci* 2011;8:75-80.

41 **Temple VJ.** Ending hidden hunger: is there a weak link? *AJFAND* 2012;12(7):1-11.

42 **World Health Organization, Food and Agricultural Organization of the United Nations.** The role of food fortification in the control of micronutrient malnutrition. In: Allen L, de Benoist B, Dary O, Hurrell R, eds. Guidelines on Food Fortification with Micronutrients. Geneva: World Health Organization and Food and Agricultural Organization of the United Nations, 2006:3-37.

43 **Gibson RS.** Preventing zinc deficiency through diet diversification and modification. Technical Brief No 5, 2007. Davis, California: International Zinc Nutrition Consultative Group (IZiNCG), 2007:1-4. www.izincg.org

44 **Thurnham DI.** Multiple micronutrient nutrition: evidence from history to science to effective programs. Workshop Proceedings: Second World Congress of Public Health Nutrition, Porto, Portugal, 23-25 Sep 2010. *Sight and Life* 2012;26:28-42.