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Research Article

Serum Zinc and Copper Levels among Pregnant Women of African Descent Attending Antenatal Clinic in Sokoto North Western Nigeria

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Abstract

Pregnancy is the fertilization and development of one or more offspring, known as an embryo or foetus in a woman's uterus. It is a critical stage of development during which maternal nutrition can strongly influence obstetric and neonatal outcomes. The aim of this study was to determine the effect of pregnancy on serum zinc and copper levels among pregnant women in Sokoto, North Western Nigeria. This case- control study included 74 pregnant women as the subjects and 22 non-pregnant women as controls. The zinc and copper levels were determined using each reagent produced by Diagnostic Reagents Ltd (UK). There was no statistically significant difference in the serum zinc and copper levels between the pregnant subjects and non-pregnant controls (19.1 ± 1.47 and 41.5 ± 1.53) versus (16.8 ± 1.95 and 38.1 ± 3.84 (t=-0.954 and -0.954; p= 0.434 and 0.342) respectively. The serum zinc and copper level were compared based on trimester. There was no statistically significant difference in the serum zinc and copper levels based on trimester (21.7 ± 2.47, 18.0 ± 2.76, 17.4 ± 2.40 and 39.2 ± 2.31, 42.3 ± 3.65, 43.1 ± 1.69) (F=0.848 and 0.644; p=0.471 and 0.589) respectively. This study was unable to demonstrate any significant variation in the level of serum zinc and copper levels among pregnant subjects and the non-pregnant controls. Trimester appears to have no significant effect on the serum copper and zinc levels among pregnant women of African descent in Sokoto, North Western Nigeria.

Keywords: Zinc; Copper; Pregnancy; Antenatal; Sokoto; Nigeria

Introduction

Pregnancy is a critical stage of development during which maternal nutrition can strongly influence obstetric and neonatal outcomes [1, 2]. Optimal nutrition is necessary to maintain the health of the mother, to help ensure a normal, healthy delivery, and also to reduce the risk of birth defects, sub-optimal foetal development and chronic health problems in childhood [3]. Poor nutritional status and sub-optimal pre- and antenatal care are common in developing countries, often resulting in pregnancy complications and poor obstetric outcomes [4]. Pregnant women in Sub-Saharan Africa (SSA) face huge nutritional risk as a result of poverty, food insecurity, political and economic instabilities, frequent infections and pregnancies [5]. The main nutritional issues impacting these women include maternal under- and over-nutrition and deficiencies of key pregnancy micronutrients, such as iron, folate, calcium, vitamin D and vitamin A. Consequently, poor obstetric outcomes, such as anaemia, neural tube defects (NTDs), rickets and low birth weight (LBW) and maternal and neonatal mortality, are common in SSA. SSA is a region of intensive migration prompted by adverse economic, political and ecological conditions. Consequently, SSA immigrants represent a sizeable and growing immigrant population in many Western countries. Several studies have reported that pregnant women of African origin are one of the immigrant groups at highest risk of pregnancy complications, such as hypertension and diabetes [6], and adverse birth outcomes, including preterm delivery, low birth weight infants, caesarean delivery and perinatal mortality [7,8]. Although the exact causes of such outcomes have not yet been clearly identified, it is possible that poor pre-migration health and nutritional status, high parity, closely-spaced pregnancies, pre-existing diseases and lower socioeconomic status in the host countries are contributing factors [7].

Pregnancy is a period of increased metabolic demands, with changes in the woman's physiology and the requirements of a growing foetus [9]. During this time, inadequate stores or intake of vitamins or minerals, referred to collectively as micronutrients, can have adverse effects on the mother, such as anaemia, hypertension, complications of labor and even death [10]. Furthermore, the foetus can be affected, resulting in stillbirth, pre-term delivery, intrauterine growth retardation, congenital malformations, reduced immunocompetence and abnormal organ development. Occurrence of multiple micronutrient deficiencies in pregnant women in developing countries has numerous confounding factors [10].

Zinc is one of the trace elements important in human nutrition and metabolism, participating in all major biochemical pathways and playing multiple roles in the perpetuation of genetic materials [11]. Zinc is widely recognized as an essential micronutrient with a catalytic role in over one hundred specific metabolic enzymes in human metabolism. Zinc supports the function of numerous proteins in the body, such as the metalloenzymes, which are involved in variety of metabolic processes, including the regulation of gene expression [12].

In addition, zinc stabilizes cell membranes, helping to strengthen their defence against free –radical attack [13]. It assists in immune function, growth and development. Zinc is found in a variety of foods, but the bioavailability of zinc from foods of animal sources is higher than those from plant sources [14]. The highest concentration occurs particularly in beef, pork, poultry and fish and in lesser amounts in eggs and dairy products. Legumes and whole grain product are good sources of zinc of consumed in large quantities. Dietary factors can influence zinc absorption for example; phytates binds zinc, thus limiting its bioavailability [15]. Generally, the causes of zinc deficiency include inadequate intake, increased requirements malabsorption, increased losses and impaired utilization. Inadequate dietary absorption of zinc is the primary cause of zinc deficiency in most situations. This may result from a combination of low dietary intake, heavy reliance on foods with low zinc content and/or with zinc that is poorly absorbable. Several studies show that inadequate dietary intake is common in many parts of the world [16]. About 45% of the world population lives in countries with a high risk of zinc deficiency [17]. The prevalence of zinc deficiency in Sub-Saharan Africa including Nigeria is 50% [18] (Caulfield *et al*., 2006). The national prevalence of zinc deficiency among under-five was reported to be 21% [19]. In addition, studies among school children aged between 5-13 years from Lagos and Nasarawa states put the prevalence of zinc deficiency at 21% and 43% respectively [20, 21].

Copper (Cu) is an essential trace element for humans and animals that serves as a constituent of several enzymes. In the body, copper shifts between the cuprous (Cu^{1+}) and cupric (Cu^{2+}) forms, though the majority of the body's copper is in the Cu^{2+} form. The ability of copper to easily accept and donate electrons explains its important role in oxidation-reduction (redox) reactions and in scavenging free radicals [22].

Copper is a critical functional component of several essential enzymes known as cuproenzymes [23]. The copper-dependent enzyme, cytochrome *c* oxidase, plays a critical role in cellular energy production. Copper also play a significant role in iron metabolism. Four copper-containing enzymes, known as multi-copper oxidases (MCO) or ferroxidases have the capacity to oxidize ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}), the form of iron that can be loaded onto the protein transferrin for transport to the site of red blood cell formation. A number of reactions essential to normal function of the brain and nervous system are catalyzed by cuproenzymes. Free copper and iron ions are powerful catalysts of free-radical damage. By binding copper, ceruloplasmin prevents free copper ions from catalyzing oxidative damage. The ferroxidase activity of ceruloplasmin (oxidation of ferrous iron) facilitates iron loading onto its transport protein, transferrin, and may prevent free ferrous ions (Fe^{2+}) from participating in harmful free-radical-generating reactions [24]. Copper is known to play an important role in the development and maintenance of immune system function, but the exact mechanism of its action is not yet known. Micronutrients have important influences on the health of pregnant women and the growing foetus. Zinc deficiency has been associated with complications of pregnancy and delivery, as well as with growth retardation, congenital abnormalities and retarded neurobehavioral and immunological development in the foetus. Deficiency of other minerals such copper and zinc has also been associated with complications of pregnancy, childbirth or foetal development. There is paucity of data on the copper and zinc levels among pregnant women in Sokoto, North Western Nigeria. There is a need to investigate the copper and zinc levels among pregnant women in the area to generate data that can help optimize the care offered pregnant women in the area. The aim of the study is to investigate the copper and zinc levels among pregnant women subjects in Sokoto, North-Western Nigeria.

Materials and Methods

Study Area

This study will be conducted at the Specialist Hospital Sokoto (SHS), North-West Nigeria. The hospital is a secondary health institution located in Sokoto metropolis committed to the provision of quality healthcare services to people in Sokoto State and its environs. The state is located between longitudes 11° 30̍ to 13° 50̍ East and latitude 4° to 6° North. It has a land area of about 28,232.37sq kilometer and stands at an altitude of 272 m above sea level near to the confluence of the Sokoto River and the Rima River. Sokoto state is at the extreme Northwest of Nigeria forming a border with Niger Republic. The state is in the dry Sahel surrounded by sandy terrain and isolated hills with an average annual temperature of 28.3°C (82.9°F). The weather is characterized by two seasons the wet and dry seasons. Rainfall (wet season) starts late around June and ends in September sometimes extending into October. The average annual rainfall is 550 mm with peak rainfall usually recorded in the month of August. The highest temperatures of 45°C during the hot season are experienced in the months of March and April. Harmattan, a dry cold and dusty condition is experienced between the months of November and February. Sokoto state had a population of 4.2million as at the 2006 census [25]. The metropolis is estimated to have a population of 427,760 people 19 made up of Hausa and Fulani majority and a minority of Zabarmawa and Tuareg and other non- indigenous settlers. The two major languages in the state is Hausa and Fulfulde is spoken among the Fulani ethnic group. The main occupation of the people is grain production and animal husbandry. Majority of the indigenous people practice agriculture. Crops produced include commercial crops like millet, sorghum, beans, rice and maize. Other occupations commonly practiced are dying, blacksmithing, weaving, carving, trad-

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ing, and cobbling. Sokoto ranks second in livestock production in Nigeria. Modern Sokoto city is a major commercial center in leather crafts and agricultural products. Occupation of city inhabitants also include trading, commerce, with a reasonable proportion of the population working in private and public sectors.

Study Design

Out of a total of 196 pregnant women and 58 non-pregnant controls, 74 pregnant women and 22 non-pregnant women were selected to participate in the study. The study population were recruited from among patients attending the antenatal clinic at Specialist Hospital Sokoto (SHS).

Sampling Techniques

Inclusion Criteria

All consenting legal adult (>18years) pregnant woman who are attending antenatal clinic without any history of hypertension and diabetes mellitus were consecutively recruited into the study.

Exclusion Criteria

Non-consenting and non-legal adults (<18years) pregnant woman and those with history of hypertension and diabetes mellitus attending antenatal clinic will be excluded from participating in the study.

Sample Size Estimation

Using the formula $n=Z^2pq/d^2$

Where n= minimum required sample size in a population >10,000

Z= standard normal deviation

P= proportion of success or prevalence

q = proportion of failure (1-p)

d= precision, tolerable margin of error, expected difference

Documented prevalence of 15% from the previous study was used [26]. Consecutive recruitment of all consenting pregnant women was done to prevent bias. A structured questionnaire will be used to collect socio-demographics and obstetric-related data from subjects.

$n = Z^2pq/d^2$

Z = 95% (1.96)

P = 15% (0.15)

Q = 1-0.15 = 0.85

D = 5% (0.05)

Therefore n = (1.96)2 x 0.15 x 0.85 / (0.05)2

= 195.9

Sample size = 196

Study Instrument

Study Participation Consent Form

Written informed consent will be obtained from all participants in the study according to the Declaration of Helsinki. Example of the informed consent form for use in this study is included below.

Sample Collection and Processing

About 5mL of blood will be collected from each participant; 3mL of whole blood will be dispensed into plain bottles for the determination of zinc and copper levels.

Estimation of Serum Copper

Serum copper will be estimated colorimetrically with Dibrom-PAESA. Serum copper was determined by colorimetric method using SPECTUM kit according to the manufacturer's instructions. Serum zinc will be estimated colorimetrically with 5- Brom- PAPS. Serum zinc was determined by colorimetric method using SPECTRUM Kit according to the manufacturer's instructions.

Statistical Analysis

The data obtained will be analysed using SPSS version 20 (SPSS Inc., Chicago, IL., USA, 2011). The sample size was calculated for the comparison of the results between the groups. The result will be expressed as percentage and Mean + SD. Comparison will be made using analysis of variance (ANOVA), paired comparison will be carried out using the student t- test and a p-value of equal to or less than 0.05 ($p<0.05$) will be considered as significant.

Results

This case-control study investigated copper and zinc levels among 74 consecutively -recruited pregnant women aged 18 to 44 years and mean age and Mean Income of 28.00 ± 8.295 years and 2760.42± 7975.178 naira respectively. Twenty-two non-pregnant age-matched women were monitored as controls. Table 1 shows the mean values of some socio-demographic variables among the subjects and controls. Table 2 shows the distribution of the subjects based on obstetric (trimester, parity) and socio-demographic variables (ethnicity, educational status and age). Table 3 shows the mean values of zinc and copper among the pregnant subjects and non-pregnant controls. There was no statistically significant difference in the serum zinc and copper levels between the pregnant subjects and the non-pregnant controls ($p>0.05$). Table 4 shows the mean values of Zinc and Copper among pregnant subjects based on Trimester. There were no statistically significant differences in the mean zinc and copper levels based on trimester ($p>0.05$).

Table 1: Mean Values of Socio-Demographic Data of Subjects

Parameter	Mean
Age (Years)	28.00±8.295
Income (Naira)	2760.42± 7975.178

Table 2. Distribution of Subjects and Controls Based On Socio-Demographic and Obstetrics Indices

Parameter	Frequency	%
Trimester		
First	25	26.0
Second	25	26.0
Third	46	48.0
Parity		
Prima	39	40.6
Para	14	14.6
Multi Para	43	44.8
Ethnicity		
Hausa	59	61.5
Fulani	11	11.3
Igbo	3	3.1
Yoruba	9	9.4
Others	14	14.6
Non – Formal		
Primary	36	37.5
Secondary	12	12.5
Tertiary	38	39.6
Tertiary	10	10.4
Age (Years)		
<24	43	44.79
25 – 34	44	45.83
35 – 44	9	9.38

Table 3. Mean Values of Zinc and Copper among Pregnant Subjects and Non-Pregnant Controls

Parameter	Mean Values of Subjects	Mean Values of Controls	t-value	p-value
Zinc (μmol/L)	19.1 ± 1.47	16.8 ± 1.95	-0.954	0.434
Copper (μmol/L)	41.5 ± 1.53	38.1 ± 3.84	-0.954	0.342

Table 4. Mean Values of Zinc and Copper among Pregnant Subjects Based on Trimester

Parameter	1st Trimester	2nd Trimester	3rd Trimester	F-value	p-value
Zinc (μmol/L)	21.7 ± 2.47	18.0 ± 2.76	17.4 ± 2.40	0.848	0.471
Copper (μmol/L)	39.2 ± 2.31	42.3 ± 3.65	43.1 ± 1.69	0.644	0.589

Discussion, Conclusion and Recommendations

Pregnancy is associated with increased nutritional needs due to the physiologic changes of the woman and the metabolic demands of the embryo/foetus. Proper maternal nutrition during pregnancy is thus imperative for the health of both the woman and the offspring. Maternal malnutrition during pregnancy has been associated with adverse outcomes, including increased risk of maternal and infant mortality, as well as low birth weight Newborns (<2,500 grams) — a measure that accounts for preterm birth and intrauterine growth restriction of the foetus [2].

Our finding shows that there was no significant difference in the copper level among pregnant women and non-pregnant controls. Our finding is consistent with a study which indicated that there were few anaemic as well as non-anaemic pregnant subjects have copper deficiency [27]. Copper is essential micronutrient and has an important role in the human body. The serum copper increases during pregnancy and is doubled at full term. Lower levels of serum copper in pregnancy are connected with some pathological conditions [28]. Copper is essential micronutrient and is required for the formation of many enzymes, with important role in the human body. It has an important role in pregnancy for the formation of a wide variety of enzymatic and other processes within the developing foetus. During pregnancy, many changes occur in copper levels and transport in both mother and foetus. The serum copper increases in early pregnancy and continues to rise to reaching levels at full term approximately twice those found in non-pregnant women. A constant trend of increase of mean serum copper values during normal pregnancy is detected compared to mean serum copper values in healthy non-pregnant women. Serum copper levels are influenced by numerous humoral factors [29-31]. Our finding is also at variance with various reports that compared serum copper levels between healthy pregnant women with their non-pregnant counterparts and reported significantly higher mean serum copper levels among pregnant women compared to non-pregnant controls [32-35].

We observed that there was no significant difference in the serum zinc level among pregnant women and non-pregnant controls. Our finding is at variance with a previous report which indicated that the mean plasma zinc concentrations declined as pregnancy progressed until ≈22 week of gestation [36]. Zinc during pregnancy is crucial for the health and optimal outcomes of mother and foetus [37, 38]. A previous report indicated that an estimated 82% of all pregnant women in the world suffer from zinc deficiency [39]. Low Zn levels during pregnancy has been associated with growth retardation; low birth weight, congenital abnormalities; abnormalities in gene replication, activation and repression, transcription and translation of DNA and protein synthesis [40]. Similarly, a previous cross sectional-analytical study carried out among pregnant women referred to Naghavi Polyclinic, Kashan, Iran indicated that serum Zn deficiency (<66 μg/dl) were present in 9 (7%) of women [41]. Previous report indicated that the nutritional status in our study appeared to be an important factor responsible for low plasma Zn levels during pregnancy [42].

Conditions that may alter maternal plasma zinc concentrations and the transport of zinc to the foetus include smoking, alcohol abuse, and an acute stress response to infection or trauma [9] The mechanisms responsible for a decline in serum zinc concentrations during pregnancy has not been well documented. It is thought to occur as a result of normal physiologic adjustment in pregnancy, response to hormonal changes, haemodilution or a combination of these factors and is not necessarily indicative of inadequate zinc nurture [9, 43]. Zinc deficiency has been associated with complications of pregnancy and delivery, as well as with growth retardation and congenital abnormalities in the foetus [37]. A

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previous report among 349 pregnant women in Abakaliki, South Eastern, Nigeria, 45.8% and 58.2% respectively were deficient in zinc and copper with mean plasma concentrations of 2.65 ± 1.16mol/l for zinc and 3.26 ± 1.80 mol/l for copper while 23.8% were deficient for both copper and zinc [44]. It is also higher than 36% reported in pregnant Malawian women at 24 weeks gestation [45], but however lower than 49% and 73.5% observed among pregnant women in Iran [46] and in rural area of Hayarna State of India [35] respectively. Although studies have consistently demonstrated that plasma copper increases with gestational age [47].

Our finding shows that trimester has no statistically significant effect on the serum copper and zinc levels among pregnant women. Our finding is at variance with a previous report which showed that there was significant difference in zinc and copper levels during three trimesters of pregnancy [48]. Similarly, a comparison between the mean serum zinc during the three trimesters among pregnant women in China [49] showed that the mean serum zinc levels kept decreasing during pregnancy from first trimester to third trimester. Similar results were shown in other studies in Turkey [50]. The decline may be explained by a disproportionate increase in plasma volume, as well as the maternal–foetal transfer. The other reasons possibly be decrease in zinc binding [51], or low dietary bioavailability [52] or very high amounts of copper or iron in the diet that compete with zinc at absorption sites [53]. Our finding is at variance with a previous report among pregnant women in Spain which indicated that serum Cu levels in the second and third trimesters of pregnancy were significantly higher ($p < 0.05$) than those determined during the first trimester [54]. During the three trimesters of pregnancy, the serum levels of zinc and copper significantly decreased and increased, respectively [55]. During pregnancy, the serum copper levels escalate from 80 to 155 μg/dl to about 118 to 302 μg/dl in third trimester of gestation [56]. A previous report in Enugu, Nigeria indicates that the mean copper level increased ($p = 0.018$) as pregnancy advanced. It is recommended that the Nigerian government implement a policy on food diversification, biofortification, copper and zinc supplementation as ways of improving child and maternal health in this population.

Conclusions

This study was unable to demonstrate any significant variation in the level of serum zinc and copper levels among pregnant subjects and the non-pregnant controls. Trimester appears to have no significant effect on the serum copper and zinc levels among pregnant women of African descent in Sokoto, North Western Nigeria. We recommend that authorities involved should do more in the area of improving the health condition of the pregnant women by a massive campaign on the administration of multiple micronutrients supplementation. We advocated for the fortification of food and beverages with various micronutrients to improve the wellbeing of pregnant women in the state. There is need for public enlightenment program to educate pregnant women on the need to maintain a balanced diet containing sufficient amounts of micronutrients and vitamins containing food. It is recommended that facilities for the routine monitoring of micronutrients among pregnant women in the area be provided.

References

1. Godfrey K, Robinson S, Barker DJP, et al. (1996) Maternal nutrition in early and late pregnancy in relation to placental and fetal growth. BMJ 312: 410-414. [Crossref]
2. Kramer MS (2003) The epidemiology of adverse pregnancy outcomes: an overview. J. Nutr 133: 1592S-1596S. [Crossref]
3. American Dietetic Association (ADA) (2008) Position of the American Dietetic Association: nutrition and lifestyle for a healthy pregnancy outcome. Am J Diet 108: 553-561. [Crossref]
4. Hampshire R, Aguayo V, Harouna H, et al. (2004) Delivery of nutrition services in health systems in sub-Saharan Africa: opportunities in Burkina Faso, Mozambique and Niger Pub Health Nutr 7: 1047-1053. [Crossref]
5. Lartey A (2008) Maternal and child nutrition in Sub-Saharan Africa: challenges and interventions. Proc Nutr Soc 67: 105-108. [Crossref]
6. Salvador S, Bertozzi S, Londero AP, et al. (2010) Outcome of pregnancy for immigrant women: a retrospective study. Minerva Ginecol 62: 277-285. [Crossref]
7. Carolan M (2010) Pregnancy health status of sub-Saharan refugee women who have resettled in developed countries: a review of the literature. Midwifery 26: 407-414. [Crossref]
8. Urquia ML, Glazier RH, Blondel B, et al. (2010) International migration and adverse birth outcomes: role of ethnicity, region of origin and destination. J Epidemiol Community Health 64: 243-251. [Crossref]
9. King JC (2000) Physiology of pregnancy and nutrient metabolism. Am J Clin Nutr 71: 1218-1225. [Crossref]
10. Ramakrishnan U, Manjrekar R, Rivera J, et al. (1999) Micronutrients and pregnancy outcome: a review of the literature. Nutr. Res 19: 103-159. [Crossref]
11. Ayman Abu Mostafa, Adnan A Alwahaidi, Ayman Abu Mostafa (2020) Zinc Deficiency among Malnourished Children under 5 Years in Gaza City. EC Paediatrics 9: 106-118. [Crossref]
12. Abah R, Okolo S, John C, et al. (2015) Prevalence of Zinc Deficiency among School Children in a Rural Setting in North-Central Nigeria. Int J Public Health Res 3: 214-217. [Crossref]
13. Maret W. (2017) Zinc in Cellular Regulation: The Nature and Significance of Zinc Signals. Int J Mol Sci 18: 2285. [Crossref]
14. Kurutas EB (2016) The importance of antioxidants which play the role in cellular response against oxidative/nitrosative stress: current state. Nutr J 15: 71. [Crossref]

Citation: Iwueke IP, Erhabor O, Digban K. (2020) Serum Zinc and Copper Levels among Pregnant Women of African Descent Attending Antenatal Clinic in Sokoto North Western Nigeria. OSP J Case Rep 2. JCR-2-117

15. Roohani N, Hurrell R, Kelishadi R, et al. (2013) Zinc and its importance for human health: An integrative review. J Res Med Sci 18: 144-157. [Crossref]

16. Hotz C (2009) The potential to improve zinc status through biofortification of staple food crops with zinc. Food Nutr Bull 30: S172-178. [Crossref]

17. Caulfield LE, Zavaleta N, Shankar AH, et al. (1998) Potential contribution of maternal zinc supplementation during pregnancy to maternal and child survival. Am J Clin Nutr 68: 499-508. [Crossref]

18. Wessells KR, Brown KH (2012) Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting. PLoS One 7: e50568. [Crossref]

19. Aaron GJ, Kariger P, Aliyu R, et al. (2011) A multi-micronutrient beverage enhances the vitamin A and zinc status of Nigerian primary schoolchildren. J Nutr 141: 1565-1572. [Crossref]

20. Akeredolu IA, Oguntona BE, Okafor C, et al. (2011) Iron, zinc and copper malnutrition among primary school children in Lagos, Nigeria. Food Nutr Sci 2: 1063-1070. [Crossref]

21. Lobo V, Patil A, Phatak A, et al. (2010) Free radicals, antioxidants and functional foods: Impact on human health. Pharmacogn Rev 4: 118-126. [Crossref]

22. Festa RA, Thiele DJ (2011) Copper: an essential metal in biology. Curr Biol 8: R877-883. [Crossref]

23. Texel SJ, Zhang J, Camandola S, et al. (2011) Ceruloplasmin deficiency reduces levels of iron and BDNF in the cortex and striatum of young mice and increases their vulnerability to stroke. PLoS One 6: e25077. [Crossref]

24. National Population Commission (NPC) (2006) National and State population and Housing Table. [Crossref]

25. Gibson RS (1990) Principles of Nutritional Assessment. New York, NY: Oxford University Press Inc. [Crossref]

26. Ma AG, Chen XC, Xu RX, et al. (2004) Comparison of serum levels of iron, zinc and copper in anaemic and non-anaemic pregnant women in China. Asia Pac J Clin Nutr 13: 348-352. [Crossref]

27. Vukelić J, Kapamadzija A, Petrović D, et al. (2012) Variations of serum copper values in pregnancy. Srp Arh Celok Lek 140: 42-46. [Crossref]

28. Alebic Juretic A, Frković A (2005) Plasma copper concentrations in pathological pregnancies. J Trace Elem Med Bio 19: 191-194. [Crossref]

29. Maia A, Figueiredo C, Anastacio S, et al. (2007) Zinc and copper metabolism in pregnancy and lactation of adolescent women. Nutr 23: 248-253. [Crossref]

30. Knutson MD (2007) Steap proteins: implications for iron and copper metabolism. Nutr Rev 65: 335-40. [Crossref]

31. Anetor JI, Adelaja O, Adekunle AO (2003) Serum micronutrient levels, nucleic acid metabolism and antioxidant defences in pregnant Nigerians: implications for fetal and maternal health. Am J Clin Nutr 32: 257-262. [Crossref]

32. Meran I, Bozkurt A I, Ahi S, et al. (2003) Plasma copper and zinc levels in pregnant women in Gaziantep, Turkey. Saudi Med J 24: 1121-1125. [Crossref]

33. Pathak P, Kapoor S K, Kapil U, et al. (2002) Copper nurture amongst pregnant women in a rural area of India. Eastern J Med 8: 15-17. [Crossref]

34. Pathak P, Kapil U, Kapoor S K, et al. (2004) Prevalence of multiple micronutrient deficiencies among pregnant women in rural area of Haryana: Micronutrient deficient disorders. Indian J Pediatr 71: 1007-1014. [Crossref]

35. Tsunenobu Tamura, Robert L Goldenberg, Kelley E Johnston, et al. (2000) Maternal plasma zinc concentrations and pregnancy outcome. Am J Clin Nutr 71: 109-113. [Crossref]

36. Black RE (2001) Review Micronutrients in pregnancy. Br J Nutr 85: S193-197. [Crossref]

37. Brown K, Wuehler S, Peerson J (2001) The importance of zinc in human nutrition and estimation of the global prevalence of zinc deficiency. Food Nutr Bull 22:113-125. [Crossref]

38. Caulfield LE, Zavaleta N, Shankar AH, et al. (1998) Potential contribution of maternal zinc supplementation during pregnancy to maternal and child survival. Am J Clin Nutr 68: 499S-508S. [Crossref]

39. Pathak P, Kapil U, Dwivedi SN, et al. (2008) Serum zinc levels amongst pregnant women in a rural block of Haryana state, India. Asia Pac J Clin Nutr 17: 276-279. [Crossref].

40. Samimi M, Asemi Z, Taghizadeh M, et al. (2012) Concentrations of Serum Zinc, Hemoglobin and Ferritin among Pregnant Women and their Effects on Birth Outcomes in Kashan, Iran. Oman Med J 27: 40-45. [Crossref]

41. Aydemir F, Çavdar AO, Soylemez F, et al. (2003) Plasma zinc levels during pregnancy and its relationship to maternal and neonatal characteristics. Biol Trace Elem Res 91: 193. [Crossref]

42. Gernand AD, Schulze KJ, Stewart CP, et al. (2016) Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. Nat Rev Endocrinol 12: 274-289. [Crossref]

43. Ugwuja E, Akubugwo E, Ibiam U, et al. (2009) Plasma Copper and Zinc among Pregnant Women in Abakaliki, Southeastern Nigeria. Internet J Nutr Wellnes 10: 1-8. [Crossref]

44. Gibson RS, Huddle JM (1998) 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 67: 701-709. [Crossref]

45. Salimi S, Yaghmaei M, Joshaghani HR, et al. (2004) Study of zinc deficiency in pregnant women. Iran J Public Health 33: 15-18. [Crossref]

46. Upadhyaya C, Mishra S, Ajmera P et al. (2004) Serum iron,

copper and zinc status in maternal and cord blood. Indian J Clin Biochem 19: 48-52. [Crossref]

47. Tabrizi FM, Pakdel FG. (2013) Serum Level of Some Minerals during Three Trimesters of Pregnancy in Iranian Women and Their Newborns: A Longitudinal Study. Indian J Clin Biochem 29: 174-180. [Crossref]
48. Liu J, Yang H, Shi H, et al. (2010) Blood copper, zinc, calcium, and magnesium levels during different duration of pregnancy in Chinese. Biol Trace Elem Res 135: 31-37. [Crossref]
49. Ilhan N, Simsek M (2002) The changes of trace elements, malondialdehyde levels and superoxide dismutase activities in pregnancy with or without preeclampsia. Clin Biochem 35: 393-397. [Crossref]
50. Tamura T, Goldenberg RL, Johnston KE, et al. (2000) Maternal plasma zinc concentrations and pregnancy outcome. Am J Clin Nutr 71: 109-113. [Crossref]
51. Schuchardt JP, Hahn A. (2017) Intestinal Absorption and Factors Influencing Bioavailability of Magnesium-An Update. Curr Nutr Food Sci 13: 260-278. [Crossref]
52. Freddy J Troost, Robert Jan M Brummer, Jack R Dainty, et al. (2003) Iron supplements inhibit zinc but not copper absorption in vivo in ileostomy subjects. Am J Clin Nutr 78: 1018-1023. [Crossref]
53. Martín Lagos F, Navarro Alarcón M, Terrés Martos C, et al. (1998) Zinc and copper concentrations in serum from Spanish women during pregnancy. Biol Trace Elem Res 61: 61. [Crossref]
54. Awadallah SM, Abu Elteen KH, Elkarmi AZ, et al. (2004) Maternal and Cord Blood Serum Levels of Zinc, Copper, and Iron in Healthy Pregnant Jordanian Women. J Trace Elem Exp Med 17: 1-8. [Crossref]
55. Izquierdo AS, Castanon SG, Ruata ML, et al. (2007) Updating of normal levels of copper, zinc and selenium in serum of pregnant women. J Trace Elem Exp Med Biol 21: 49-52. [Crossref]
56. Nwagha UI, Ogbodo SO, Nwogu Ikojo EE, et al. (2011) Copper and selenium status of healthy pregnant women in Enugu, Southeastern Nigeria. Niger J Clin Pract 14: 408-412. [Crossref]