Mal J Nutr 23(2): 299 - 308, 2017

Plasma Arsenic and Selenium in Apparently Healthy Individuals in Ebonyi State, South-Eastern Nigeria

Ugwuja EI[1,2], Uro-Chukwu HC[3] & Ikaraoha IC[4]

[1] *Department of Biochemistry, Faculty of Sciences, Ebonyi State University, P.M.B. 053 Abakaliki, Nigeria*
[2] *Clinical Nutrition and Toxicology Unit, Department of Pathology, Faculty of Medicine, Ebonyi State University, P.M.B. 053 Abakaliki, Nigeria*
[3] *Department of Social Mobilization and Disease Control, National Obstetrics Fistula Centre, P.M.B. 016 Abakaliki, Nigeria*
[4] *Department of Medical Laboratory Science, Imo State University, Owerri, Nigeria*

ABSTRACT

Introduction: Although reports are conflicting on arsenic-selenium interactions, there is paucity of data on the determinants of plasma selenium (Se) and arsenic (As) in healthy individuals in Ebonyi State, South Eastern Nigeria. Ebonyi State is richly endowed with mineral deposits which are mined without consideration of their health hazards. This study is aimed at assessing the socio-demographic determinants of plasma arsenic and selenium in apparently healthy individuals in Ebonyi State. **Methods:** Apparently healthy individuals (n=441) consisting of 117 males, 184 females and 140 pregnant females, aged ≥ 18 years (mean=38.5±0.6 yrs) were randomly selected from 130 geo-political Wards (10 Wards from each of the 13 Local Government Areas of Ebonyi state) to constitute the study population. Plasma arsenic and selenium were determined in blood samples using atomic absorption spectrophotometer. Socio-demographic data were collected using questionnaires while anthropometric measurements were determined using standard methods. **Results:** The mean plasma arsenic levels were 0.204±0.02 (males), 0.209±0.02 (females), 0.186±0.02 µg/dl (pregnant females) and plasma selenium levels were 0.134±0.01 (males), 0.138±0.01 (females), 0.147±0.01 µg/dl (pregnant females), respectively. Plasma Se levels were generally lower than the value (5.92 µg/dl) considered universally as inadequate. While plasma levels of As and Se were not significantly different between male and female, obese subjects had significantly lower plasma levels of both elements. There was a significant negative correlation between BMI and plasma As. Neither smoking nor alcohol consumption was associated with plasma levels of As and Se. **Conclusion:** Apparently healthy individuals in Ebonyi State exhibited elevated plasma levels of As and low plasma Se, which may potentially place them at risk of adverse health associated with As toxicity.

Key words: Anthropometrics, arsenic, interactions, selenium, socio-demographic features

INTRODUCTION

Arsenic (As) is a toxic metal with no known biological function, while selenium (Se) is an essential trace element which plays an important role in the maintenance of normal health in humans. Although As and Se have some chemical properties in common (Pilsner *et al.*, 2011), they possess marked

Correspondence: Emmanuel Ike Ugwuja, Email: *ikeugwuja@gmail.com, emmanuel.ugwuja@ebsu-edu.net*

differences in their biological effects. While selenium is essential and vital for many biochemical functions, including as an antioxidant, thyroid hormone metabolism and immunity, arsenic displays both acute and chronic toxicity and has been associated with adverse health effects such as cancers of the skin, lung, bladder, liver and kidneys, cardiovascular disease and neurological deficits (Tseng, 2008).

Human exposure to arsenic is mainly through drinking of As-contaminated water, unlike selenium, which is obtained mainly through dietary sources in the form of selenomethionine. Antagonism of As and Se has been well recognised (Xu *et al.,* 2013; Krohn *et al.,* 2016). The interaction between As and Se raises the questions of how the development of As-induced health outcomes or Se nutritional status may be affected. The suggested mechanism through which Se intake may reduce the body burden of As is by increasing its loss through biliary excretion (Sun *et al.,* 2014).

There are conflicting reports on the effects of Se and As interactions on As-induced health outcomes and/or selenium nutritional status. More recent studies have shown that Se protects liver cells against As oxidative damage (Xu *et al.,* 2013) and that high Se levels have the potential to protect against As-triggered atherosclerosis (Krohn *et al.,* 2016). However, there have been reports of the non-beneficial effect of Se on As metabolism and toxicity (Geng *et al.,* 2009).

In Nigeria, there is a dearth of data on plasma levels of arsenic and selenium, except for the studies of Babalola, Anetor & Adeniyi (2003), which reported lack of evidence of selenium deficiency among the adult population in South-western Nigeria and that of Kolawole & Ebuehi (2013) that reported low plasma concentration of Se among healthy adult Nigerians in five different experimental locations in Cross River and Akwa Ibom States, South-south Nigeria. The present study therefore aimed at assessing the socio-demographic determinants of plasma levels of arsenic and selenium in apparently healthy individuals in Ebonyi State, South-eastern Nigeria.

METHODS

The period of enrolment, questionnaire administration, sample collection and determination of As and Se lasted from April 2013 to June 2014. Ten geo-political Wards were randomly selected from each of the 13 Local Government Areas of Ebonyi state, which totalled to 130 Wards for this study.

Calculation of sample size

Sample size for an unknown prevalence was determined using the equation:

Minimum sample size = $(\text{Z-score})^2$ x Std Dev x (1-Std Dev) / $(\text{margin of error})^2$

Where

Z-score = 1.96

Standard deviation = 0.5

Margin of error = 0.05

Substituting in the equation, we have:

$((1.96)^2 \times .5(.5)) / (.05)^2$

= 384.16

Making 15% provision for attrition, 441 subjects were recruited for the study by random sampling.

Study population

Prospective subjects were mobilised from the 130 Wards. They consisted of 445 apparently healthy individuals (male and females). Inclusion criteria included residence in the selected Wards for ≥ 1 year, aged ≥18 years, no history of trace element supplementation within 6 months prior to the study, and being apparently healthy. Subjects excluded from the study were those with a history of chronic diseases including liver and renal diseases, diabetes, malignancy, sickle cell anaemia, or seropositive to Human Immunodeficiency Virus (HIV).

Socio-demographic and anthropometric data

The socio-demographic characteristics of participants were collected using a structured questionnaire administered by one of the study team members in English language or the native Igbo language of the participants. Height and weight measurements of each participant were done using a standard calibrated meter rule affixed to a wall perpendicular to a flat smooth surface floor, and a digital weighing scale (Seca, Harmburg, Germany), respectively. Body mass index (BMI) was calculated by dividing the weight of the participant (Kg) with the square of their height (meter^2).

Sample collection and sample analyses

Six millilitres of venous blood samples were collected from each subject between 8.00 to 10.00 in the morning. About 6.0 ml was dispensed into trace element-free lithium heparin bottles for the determination of packed cell volume (PCV), haemoglobin concentration (HBC) and plasma selenium and arsenic. Samples were transported in ice packs to the laboratory, where plasma was separated and kept frozen until it was analysed.

Packed cell volume was determined using micro-haematocrit method and haemoglobin concentration was determined by cyanmethaemoglobin method as previously described by Dacie & Lewis, (1995). Plasma selenium and arsenic concentrations were determined using atomic absorption spectrophotometer (Bulk Scientific, Model AVG 210) at the Department of Biochemistry, Kogi State University, Anyangba, Nigeria. Certified arsenic and selenium reference solutions supplied by Sigma-Aldrich (Sigma-Aldrich Co. LLC, USA) for atomic absorption spectrometry were used for quality control. Each sample analysis was performed in duplicate, and the mean of both measurements was used for the final data analyses.

Statistical analysis

Data generated were analysed using the Statistical Package for Social Sciences (SPSS®) for Windows® version 20 (SPSS Inc., Chicago, IL, USA). Values were expressed as mean ± standard deviation. Multiple comparisons were done using One-way Analysis of Variance (One-way ANOVA). Relationship between variables was determined using Pearson correlation analysis. Values were considered significant at $p < 0.05$.

Ethical consideration

The Ethics and Research Committee of the Federal Teaching Hospital, Abakaliki, Ebonyi State approved the protocol for the study (Grant No.: EBSU/TETFUND Grant APPL/012/2012). Informed written consent was obtained from individual participants to participate in the study, after the rationale and implications of the study were explained to them in English language and native Igbo dialect. The subjects' anonymity and confidentiality were ensured for purposes of this research. The study was performed in accordance with the international guidelines for human experimentation in clinical research (WMA, 2002). Prospective subjects having serious medical conditions were referred to the nearest hospital or to the Federal Teaching Hospital, Abakaliki for further assessment and management.

RESULTS

Although a total of 445 subjects were recruited, 441 finally completed the study. This comprised 117 (26.5%) males, 184 (41.7%) non-pregnant females and 140 (31.8%) pregnant females. Table 1 shows the socio-demographic characteristics of the subjects. While a majority of the women had either no formal education or were educated up-to primary and secondary schools, a few had tertiary education compared with the men. Farming was the major occupation of the subjects

Table 1. Socio-demographic characteristics of the study population

	Male (n=117)	*Female (n=184)*	*Pregnant (n=140)*
Educational level n(%)			
None	11 (9.4)	56 (30.4)	17 (12.1)
Primary	50 (42.7)	62 (33.7)	47 (33.6)
Secondary	34 (29.1)	52 (28.3)	71 (50.7)
Tertiary	22 (18.8)	14 (7.6)	5 (3.6)
Occupation n (%)			
House wife/Retired	0 (0)	9 (4.9)	27 (19.3)
Civil servant	32 (27.4)	34 (18.5)	12 (8.6)
Artisan	27 (23.0)	40 (21.7)	60 (42.9)
Farming	58 (49.6)	101 (54.9)	41 (29.3)
Water source n (%)			
Bore hole	50 (42.7)	86 (46.7)	49 (35.0)
Well	11 (9.4)	15 (8.2)	18 (12.9)
Sachet	18 (15.4)	18 (9.8)	23 (16.4)
River/Dam/Stream	12 (10.3)	19 (10.3)	4 (2.8)
Others	26 (22.2)	46 (25.0)	46 (32.9)
Alcohol consumption N (%)			
No	28 (23.9)	147 (79.9)	112 (80.0)
Yes	89 (76.1)	37 (20.1)	28 (20.0)
Tobacco consumption n (%)			
No	77 (65.8)	176 (95.7)	137 (97.9)
Yes	40 (34.2)	8 (4.3)	3 (2.1)

accounting for 49.6%, 54.9% and 29.3% in males, non-pregnant females and pregnant females, respectively. However, 27%, 19% and 9% of the males, non-pregnant females and pregnant females respectively were civil servants.

Among the subjects, borehole was the major water source for domestic activities and drinking. The percentages of males, non-pregnant females and pregnant females using this major source of water were 43%, 47% and 35%, respectively. Alcohol and tobacco consumption was found to be higher in males than in the non-pregnant/pregnant females (76.1% and 34.2% vs. 20.1%/20.0% and 4.3%/2.1%).

In general, all the subjects had Se levels below 5.92 µg/dl (0.75µmol/L) considered as an inadequate Se level (Table 2). Although the mean age of the females was significantly lower than that of their male counterparts, the pregnant females had significantly lower mean age than their non-pregnant counterparts (Table 3). However, the females (both pregnant and non-pregnant) had significantly higher body mass index (BMI) than the males. Packed cell volume and haemoglobin concentration were significantly lower in females compared to the males. Pregnant females had significantly lower packed cell volume and haemoglobin concentration compared to the non-pregnant females. There was no significant difference in plasma arsenic and selenium levels among the males, non-pregnant and pregnant females subjects (Table 2).

Comparison of plasma arsenic and selenium among the socio-demographic strata (educational level, occupational groups and age groups) revealed no significant difference among the groups (Table 3). However, comparison by BMI groups showed that plasma As was

Table 2. Comparison of general characteristics among subjects

Parameters	*Male (n=117)*	*Non-pregnant female (n=184)*	*Pregnant female (n=140)*
Age (yrs)	47.5 ± 13.9[a]	40.8 ± 12.7[b]	27.9 ± 5.6[c]
BMI (Kg/m2)	23.3 ± 8.5[a]	24.7 ± 4.8[b]	25.1 ± 3.9[b]
PCV (%)	44.0 ± 6.1[a]	39.6 ± 5.2[b]	37.3 ± 6.1[c]
HBC (g/dl)	14.6 ± 2.0[a]	13.2 ± 1.8[b]	12.4 ± 2.0[c]
Plasma Arsenic (µg/dl)	0.204 ± 0.0.02	0.209 ± 0.02	0.186 ± 0.0.02
Plasma selenium (µg/dl)	0.134 ± 0.01	0.138 ± 0.01	0.147 ± 0.01

BMI: Body mass index; PCV: Packed cell volume; HBC: haemoglobin concentration
Values are expressed as mean ± SEM. Means are compared using one-way ANOVA (values with different superscripts along the rows are significantly different; $p<0.05$).

Table 3. Comparison of plasma As and Se among subjects according to socio-demographic data[β]

Variables	*Plasma As(µg/dl)*	*Plasma Se(µg/dl)*
Occupational		
H/W/Rtd (9)	0.114 ± 0.035[†]	0.116 ± 0.011
Civil servant (67)	0.252 ± 0.027	0.161 ± 0.026
Artisan (67)	0.181 ± 0.033	0.138 ± 0.016
Farming (159)	0.204 ± 0.025	0.127 ± 0.004
Educational level		
None (67)	0.179 ± 0.029	0.139 ± 0.016
Primary (112)	0.239 ± 0.035	0.129 ± 0.005
Secondary (86)	0.196 ± 0.025	0.143 ± 0.017
Tertiary (36)	0.186 ± 0.020	0.144 ± 0.025
Age groups (yrs)		
≤30 (54)	0.266 ± 0.037	0.146 ± 0.023
31-40 (85)	0.221 ± 0.040	0.128 ± 0.005
41-50 (69)	0.190 ± 0.030	0.132 ± 0.014
>50 (93)	0.172 ± 0.023	0.146 ± 0.015
BMI groups (Kg/m^2)		
Underweight (14)	0.190 ± 0.026	0.220 ± 0.056[a]
Normal (184)	0.231 ± 0.023[a]	0.132 ± 0.009[b]
Overweight (75)	0.192 ± 0.030	0.140 ± 0.014[b]
Obese (28)	0.096 ± 0.012[b]	0.113 ± 0.014[b]

[β] Excluding pregnant females
Values are expressed as mean ± SEM. Means are compared using one-way ANOVA (values with different superscripts along the rows are significantly different; $p<0.05$).

significantly ($p<0.05$) lower in obese subjects (0.096±0.012 µg/dl) in comparison with individuals having normal BMI (0.231±0.023 µg/dl). Meanwhile, plasma Se levels were significantly lower in obese, normal weight and overweight subjects in comparison with underweight subjects (Table 3).

Again, plasma levels of As and Se were not significantly different between smokers and non-smokers (0.200±0.034 & 0.151±0.026 vs. 0.208±0.018 & 0.134±0.007 µg/dl), respectively (Table 4). Similarly, plasma As and Se were comparable between subjects who took alcohol and those who did not take alcohol (0.200±0.022

Table 4. Comparison of plasma arsenic and selenium among alcohol and tobacco consumers[f]

	Tobacco consumption			*Alcohol consumption*		
	Yes (n=48)	*No (n=253)*	*p=values*	*Yes (n=126)*	*No (175)*	*p=values*
As (μg/dl)	0.200±0.034	0.208±0.018	0.836	0.200±0.022	0.213±0.023	0.702
Se (μg/dl)	0.151±0.026	0.134±0.007	0.545	0.127±0.008	0.143±0.011	0.221

[f] Pregnant females were excluded
Values are expressed as mean ± SEM. Means were compared using Independent Sample T-test

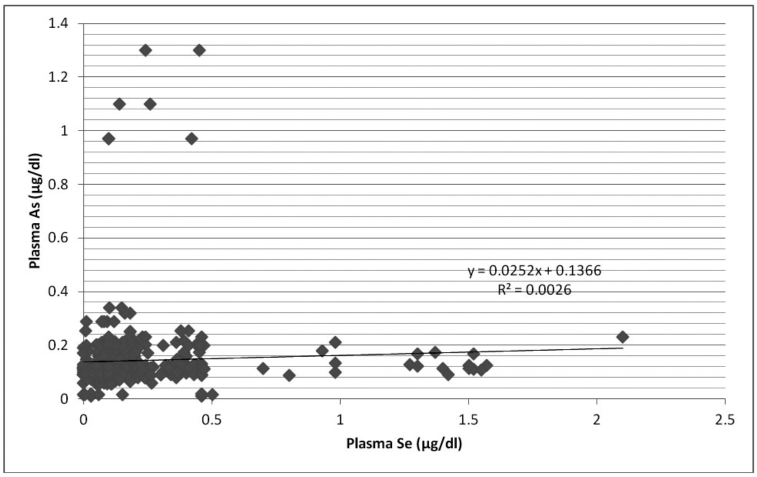

Figure 1. Scatter plots of plasma arsenic against plasma selemium

& 0.127±0.011 vs. 0.213±0.023 & 0.143±0.011 μg/dl), respectively (Table 4).

Although there was no correlation between plasma As and Se (r = 0.080; p = 0.164), plasma As was negatively correlated with BMI (r = - 0.118; p = 0.041) while there was no correlation between plasma Se and BMI (r= -0.095; p = 0.098). Figure 1 shows that there was no significant relationship between plasma arsenic and selenium in the subjects.

DISCUSSION

This study showed that mean plasma arsenic levels in apparently healthy individuals in Ebonyi State were 0.204±0.0.02 for the male, 0.209±0.02 for non-pregnant female, and 0.186±0.0.02 μg/dl for pregnant female while the plasma selenium levels were 0.134±0.0.01 for the ,male, 0.138±0.01 for non-pregnant female, and 0.147±0.01 μg/dl for pregnant female. Plasma Se levels were generally lower than the value (5.92 μg/dl or 0.75 μmol/l) considered universally as inadequate (Van Dael & Deelstra, 1993). Plasma levels of As and Se were not significantly different between male and female, although values of both elements were generally higher in the female. Excluding the pregnant female, BMI had significant effects on the plasma levels of As and Se with obese subjects having lower levels of both elements. Again, both smoking and alcohol consumption did not affect the plasma levels of As and Se. Although As was not correlated with Se, there was a significant inverse correlation between plasma As level and BMI, while there was no significant correlation between plasma Se level and BMI.

The lower plasma level of Se observed in the present study is in contrast to the findings of Babalola *et al.* (2003) in South-western Nigeria. Low plasma concentration of Se had previously been reported among healthy adult Nigerians in five different experimental locations in Cross River and Akwa Ibom States, South-south Nigeria (Kolawole & Obuehi, 2013), which corroborates the present finding. Although the cause of low plasma Se in the present population is not clear, in Nigeria, rural residency has been found to significantly increase the odds for serum Se <70µg/L (Karaye *et al.,* 2015). An epidemiological study has also shown that low Se levels in soil and in local food stuffs correlate with low Se levels in whole blood and hair samples (Wang *et al.,* 1979). Variations in plasma levels of Se may be partly related to differences in soil types. Significant difference in serum Se had previously been observed between geographical areas (Arnaud *et al.,* 2006). The distribution of Se in a geographical environment has been reported to be highly variable, reflecting the properties of different rock types. Furthermore, Se concentration in most rock types are generally low, with content in lime stones and sand stones rarely exceeding 0.05 mg/Kg, and usually associated with the clay fraction in shale than in lime stones and sand stones (Zarmai, Eneji & Ato, 2013). On the other hand, the low plasma selenium observed in the present study may partly be associated with the method used in the sample analysis. It has been reported that direct determination of plasma Se using inductively coupled plasma mass spectroscopy (ICP-MS) has an advantage over graphite furnace AAS (GF-AAS) because of its high accuracy, low detection limits and the possibility of multi-element analysis (Janasik, Trzcinka-Ochocka & Brodzka, 2011).

The comparable plasma Se among the males and females observed in the present study is in agreement with the similar level of Se earlier reported in both sexes by Murphy & Cashman (2002) in Irish adults, but is in contrast to a previous report of higher blood/serum Se in healthy males compared to females (Arnaud *et al.,* 2006). The disparity between these previous reports and the present finding may be due to difference in type of samples (plasma/serum) used. However, among children 1-16 years old, no difference was found in serum Se between genders. A previous study had reported on the relationship between sex and blood Se concentration in adults (Bates *et al.,* 2002). Also, it had been previously reported that serum Se was higher in contraceptive users than in non-users among premenopausal women (Arnaud *et al.,* 2006).

In addition to diet, geographical environment, sex, age and lifestyle habits, blood Se is also affected by alcohol and tobacco (Park *et al.,* 2011). This is in contrast to the present finding, where neither alcohol nor tobacco had an effect on plasma Se. The present finding is also in contrast to that of Arnaud *et al.* (2006) where serum Se increased with alcohol intake and decreased with tobacco smoking. Although the mechanisms by which alcohol increases and/or tobacco decreases plasma Se is not clear at the moment, it may be through increased intestinal absorption and increased oxidative stress, respectively. According to El-Boshy *et al.* (2015), Se has the potential to counteract immune suppression as well as hepatic and renal oxidative damage induced by As. It is therefore postulated that Se, in a bid to ameliorate oxidative damage induced by As, becomes consumed and this may explain in part, the lower plasma Se observed in the present study. It is, however, not known if there is increased oxidative stress in the study population as none of the oxidative stress indicators were determined.

Arnaud *et al.,* (2006) had reported that obesity (BMI ≥ 30 Kg/m^2) was associated with decreased serum Se. This is in agreement with the present findings, where BMI had a significant effect on the plasma levels of As and Se with obese subjects having lower levels of both elements. The lower serum Se observed in obese women is partly attributed to increased oxidative stress associated with obesity (Savini *et al.,* 2013) or due to differences in eating habits. Also Wang *et al.* (2016) recently suggested that a high dietary intake of Se is associated with a beneficial body composition profile. Similarly, although there is a scarcity of reports on the relationship between BMI and plasma As, the inverse correlation between BMI and plasma As observed in the present study needs to be re-evaluated, though the deleterious effects of arsenic may in part be responsible for the observed relationship. It is possible also that individuals with higher plasma As may be susceptible to weight loss with a subsequent reduction in their BMI.

The lack of a significant correlation between plasma As and Se in the present study is in contrast to an inverse association between plasma Se and both urinary and blood As concentrations reported by Pilsner *et al.,* (2011). It has been suggested that Se status may modify the health effects of As in As-exposed population (Xu *et al.,* 2013; Krohn *et al.,* 2016). Thus, the present findings have important health implications for the study population. For instance, this population may be at increased risk of As poisoning as high levels of As have been documented in the foods and water consumed in this environment (Edeogu *et al.,* 2007). It may therefore be speculated that the lack of relationship between As and Se implies that neither As nor Se may have a modifying effect on each other. The fact that As and Se, each mutually facilitate the excretion of the other in bile lends credence to the proposed modifying effects of the elements on each other. It has been proposed that the mechanisms for the facilitated excretion include: (a) formation of Se-As-glutathione conjugate (Sun *et al* 2014), although it has yet to be demonstrated in humans; (b) through direct interaction and precipitation of As and Se in renal cells and effects on cellular signalling; (c) through zinc finger protein; and (d) through methylation pathways. It has been reported that global hypomethylation of DNA, which is an early event in some cancers, occurs in response to As exposure and/or Se deficiency in both animal models and *in vitro* (Pilsner, 2011). On the other hand, the population may also be at increased risk of cancers, including cancer of the skin, urinary bladder, lung, liver and prostate. Epidemiological studies indicate that populations exposed to high levels of arsenic are susceptible to cancer of the liver, bladder, skin and lung, cardiovascular disease and impaired immune response (Anetor, Wanibuchi & Fakushima, 2007). In addition to its carcinogenic effects, As exposure has been suggested to play a role in black foot disease (a form of peripheral vascular disease) and type II diabetes mellitus (Tseng, 2005; Tseng 2008). It may therefore be inferred that the high prevalence of hypertension previously observed among the residents of the state (Ugwuja *et al.,* 2015) may in part be attributed to elevated plasma As coupled with low plasma Se. Observational studies have indicated that death from cancers, including lung, colorectal, and prostate cancers is lower among people with high blood levels of Se or high intake of Se (Kolawole & Obuehi, 2013). It may therefore be concluded that apparently healthy individuals in Ebonyi

State, South-eastern Nigeria exhibited elevated plasma levels of As and low plasma Se and may potentially be at risk of health conditions associated with elevated plasma As. Diversification of diet to include foods that contain Se may be one of the ways to prevent the deleterious effects of As exposure.

ACKNOWLEDGEMENTS

This project was funded by Ebonyi State University-Tertiary Education Trust Fund (EBSU-TEDFUND) 2012 Research Grant (Grant No.: EBSU/TETFUND Grant APPL/012/2012).

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

Anetor JI, Wanibuchi H & Fakushima S (2007). Arsenic exposure and its health effects and risk of cancer in developing countries: Micronutrients as host defence. *Asian Pac J Cancer Prev* 8: 13-23.

Arnaud J, Bertrais S, Roussel AM, Arnault N, Ruffieux D, Favier A, Berthelin S, Estaquio C, Galan P, Czernichow S & Hercberg S (2006). Serum selenium determinants in French adults: the SU.VI.M.AX study. *Br J Nutr* 95: 313-320.

Babalola OO, Anetor JI & Adeniyi FAA (2003). Assessment of selenium status of healthy adults in South-western Nigeria. *ASSET Series* 3(4): 111-120.

Bates CJ, Thane CW, Prentice A & Delves HT (2002). Selenium status and its correlates in a British national diet and nutrition survey: people ages 65 years and over. *J Trace Elem Med Biol* 16: 1-8.

Dacie JV & Lewis SM (1995). Practical Hematology(10thed), Churchill Livingstone, Edinburgh, pp 25-57.

Edeogu CO, Ekuma CE, Okaka ANC, Ezeonu FC, Uneke CJ & Elom SO (2007). Public health significance of metals concentration in soil, water and staple foods in Abakaliki, South-eastern Nigeria. *Trends Appl Sci Res.* 2(5):439-444. DOI: 10.3923/tasr.2007.439.444.

El-Boshy ME, Risha EF, Abdelhamid FM, Mubarak MS & Hadda TB (2015). Protective effects of selenium against cadmium induced haematological disturbances, immunosuppressive, oxidative stress and hepatorenal damage in rats. *J Trace Elem Med Biol* 29: 104-110.

Geng Z, Song X, Xing Z, Geng J, Zhang S, Zhang X & Wang Z (2009). Effects of selenium on the structure and function of recombinant human *S*-adenosyl-l-methionine dependent arsenic (+3 oxidation state) methyltransferase in *E coli*. *J Biol Inorg Chem* 14(4): 485–496.

Janasik B, Trzcinka-Ochocka M & Brodzka R (2011). Selenium determination in plasma/serum by inductively coupled plasma mass spectrometry (ICP-MS): comparison with graphite furnace atomic absorption spectrometry (GF-AAS)]. *Med Pr* 62(5): 489-98.

Karaye KM, Yahaya IA, Lindmark K & Henein MY (2015). Serum selenium and ceruloplasmin in Nigerians with peripartum cardiomyopathy. *Int J Mol Sci* 16: 7644-7654. DOI: 10.3390/ijms16047644.

Kolawole SE & Ebuehi HO (2013). Relationship between soil contents and plasma levels of selenium, chromium and manganese in healthy adult Nigerians. *AJB* 12(34): 5539-5546. DOI: 10.5897/AJB12.107.

Krohn RM, Lemaire M, Negro Silver LF, Lemarie C, Bolt A, Mann KK & Smits JE (2016). High selenium lentil diet protects against arsenic-induced atherosclerosis in a mouse model. *J Nutr Biochem* 27: 9-15.

Murphy J & Cashman KD (2002). Selenium status of Irish adults: evidence of insufficiency. *Ir J Med Sci* 171: 81.

Park K, Rimm E, Siscovick D, Spiegelman D, Morris JS & Mozaffarian D (2011). Demographic and lifestyle factors and selenium levels in men and women in the US. *Nutr Res Pract* 5(4): 357-364.

Pilsner JR, Hall MN, Liu X, Ahsan H, Ilievski V, Slavkovich V, Levy D, Factor-Litvak

P, Graziano JH & Gamble MV (2011). Associations of plasma selenium with arsenic and genomic methylation of leukocyte DNA in Bangladesh. *Environ Health Perspect* 119: 113–118. DOI: 10.1289/ehp.1001937.

Savini I, Valeria MC, Evangelista D, Gasperi V& Avigliano L (2013). Obesity-associated oxidative stress: strategies finalized to improve redox state. *Int J Mol Sci* 14(5): 10497–10538.

Sun HJ, Rathinasabapathi B, Wu B, Luo J, Pu LP & Ma LQ (2014). Arsenic and selenium toxicity and their interactive effects in humans. *Environmental International* 69: 148-158.

Tseng CH, Huang YK, Huang YL, Chung CJ, Yang MH, Chen CJ *et al*. (2005). Arsenic exposure, urinary arsenic speciation, and peripheral vascular disease in blackfoot disease hyperendemic villages in Taiwan. *Toxicol Appl Pharmacol* 206(3): 299–308.

Tseng CH (2008). Cardiovascular disease in arsenic-exposed subjects living in the arseniasis-hyperendemic areas in Taiwan. *Atherosclerosis* 199(1):12–18. DOI: 10.1016/j.atherosclerosis.2008.02.013.

Ugwuja E, Ezenkwa U, Nwibo A, Ogbanshi M, Idoko O & Nnabu R (2015). Prevalence and determinants of hypertension in an agrarian rural community in South-east Nigeria. *Ann Med Health Sci Res* 1(1): 45-49. DOI: 10.4103/2141-9248.149787.

Van Dael P & Deelstra H (1993). Selenium. *Int J Vit Nutr Res* 63: 312–316.

Wang GY, Zhou R, Sun S, Yin T & Ying G (1979). The difference between whole blood and hair selenium levels of inhabitants in the endemic and non-endemic areas of Keshan disease (author's translation). *Zhonghua Yu Fang Yi Xue Za Zhi* 13: 204–206.

Wang Y, Gao X, Pedran P, Shahidi M, Du J, Yi Y, Gulliver W, Zhang H & Sun G (2016). Significant beneficial association of high dietary selenium intake with reduced Body fat in the CODING study. *Nutrients* 8: 24.

World Medical Association (WMA)(2002). Declaration of Helsinki. Ethical principles for medical research involving human subjects. *J Postgrad Med* 48: 206–208.

Xu Z, Wang Z, Li JJ, Chen C, Zhang PC, Dong L, Chen JH, Chen Q, Zhang XT & Wang ZL (2013). Protective effects of selenium on oxidative damage and oxidative stress related gene expression in rat liver under chronic poisoning of arsenic. *Food Chem Toxicol* 58: 1-7.

Zarmai S, Eneji IS & Ato RS (2013). Analysis of selenium content in root and tuber plants in central Nigeria. *AJAC* 4: 739-743. DOI: 10.4236/ajac.2013.412089.