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Association of Life Style and Sociodemographic Parameters with Plasma Heavy Metals in Apparently Healthy Adult in Ebonyi State, South East Nigeria

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ABSTRACT

Introduction: Lifestyle and sociodemographic parameters have been recognised to play important roles in human exposure to heavy metals and metal toxicity in both environmental and occupational setting.

Aim: To determine the association of life style factors and sociodemographic parameters with plasma heavy metals; arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), selenium (Se) and zinc (Zn) in apparently healthy individuals.

Materials and Methods: Randomly selected subjects (n=301) from 130 political wards in the 13 Local Government Area of the State, were studied. Structured questionnaires were used to collect sociodemographic data while anthropometric parameters were collected using standard techniques. Metal concentrations were determined in blood plasma using atomic absorption spectrophotometer. One-way Analysis of Variance (One-way ANOVA) was use to analyse the data and $p \leq 0.05$ was considered significant.

Results: The observed mean levels of heavy metals were: As (0.21±0.02), Cd (0.37±0.04), Cu (156.49±2.16), Fe (132.66±2.14), Pb (1.13±0.12), Ni (0.06±001), Se (0.14±0.01) and Zn (94.32±1.10) µg/dL. Plasma levels of heavy metals were affected by body mass index (BMI), age, educational level and occupation. However, there was no significant ($p>0.05$) difference in the levels of heavy metals between males and females, smokers and non-smokers and alcohol consumers and non-consumers. Plasma As and Cd were significantly negatively associated with age and BMI.

Conclusion: It is concluded that indicators of socioeconomic status have effect plasma levels of heavy metals with levels of toxic metals raised while the levels of essential trace elements were low. Dietary diversification in addition to prevention of exposure is advocated.

Keywords: Bioaccumulation, Dietary diversification, Mineral elements, Oxidative stress

INTRODUCTION

Heavy metals are elements that occur naturally on the earth's crust and possess high atomic weight and densities above that of water [1]. They are classified as either essential (Cu, Zn, CO, Cr, Mn, Se, and Fe), non-essential (Ba, Al, Li and Zr), less toxic (Sn and Al) or highly toxic (Hg, Cd and Pb) based on their roles in human or animal health [2]. Heavy metals are collectively referred to as trace element due to their presence in minute quantities in the environment. They are widely dispersed in the environment due to their wide applications in various human endeavours, including agriculture and industries thereby raising concerns over their potential health consequences in human and the environment [1,3]. While some heavy metals (zinc, copper, selenium, iron, chromium, cobalt and manganese) are essential for important physiological and biochemical functions; where they act as co-factors and can only be toxic at higher concentration [4], others (arsenic, cadmium, lead) have no known function and can be toxic even at lower concentration [1,5].

The toxicity of heavy metals depend on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals [1]. The mechanisms by which heavy metals manifest their toxicity include interactions with macromolecules (DNA, nuclear proteins and some enzymes) involvement in cellular processes such as metabolism, detoxification, and repair of cellular damage [6] as well as the generation of reactive species and perturbation of antioxidant defense systems [7-9].

Ebonyi State, in south-east Nigeria, is endowed with rich deposits of mineral elements; including Pb and Zn. Mining these metals with little or no containment facilitate their discharge into the environment (soil, water and air) where they find their way into the food chain [10] via bioaccumulation in plants. Since, consumption of contaminated water and foods are important routes of exposure to heavy metals, it is hypothesised that residents of the State may have higher levels of heavy metals in their plasma. This was based on the fact that higher concentrations of some heavy metals (Cd, Cu, Fe, Pb, Ni, and Zn) have been previously reported in stable foods and water in the State [11-16].

The aim of the present study was to determine the association of life style factors and sociodemographic parameters with plasma levels of some heavy metals (As, Cd, Cu, Fe, Pb, Ni, Se and Zn) among apparently healthy Individuals in the State.

MATERIALS AND METHODS

Study area: The location of Ebonyi State is on longitude 8°E and latitude 6°N. The state has a moderate relief of 125-245 m above sea level with vegetation typical of the tropical rain forest. It has an average annual rainfall of 1,600 mm and atmospheric temperature of about 30°C. The State has 3 Senatorial Districts (Ebonyi South, Central and North), 13 Local Government Areas (LGAs) and 215 political Wards [17] and has large deposits of mineral resources. The major occupation of the residents is farming; mainly peasant in nature with rice, yam and cassava as the major crops with little animal husbandry.

This prospective cross-sectional study was part of a state-wide study that investigated the correlation of the levels of some toxic metals in foods and water with their levels in blood of residents and associated biochemical consequences. One hundred and thirty (130) Political Wards randomly selected from 13 LGAs formed the study area. Details of participants' selection have been previously described [18].

In brief, participants were selected if they fulfilled the following inclusion criteria: being aged 18 years and above, having no history of trace element supplementation in the last six months and being apparently healthy. Individuals with history of chronic diseases, including liver and renal diseases, diabetes, malignancy, sickle cell anaemia, or seropositive to Human Immunodeficiency Virus (HIV) were excluded from the study.

At the onset of the study, members of the research team paid advocacy visits to the selected wards. During the visits, the objectives of the study were made known to the leaders of the different faiths and trade unions in their native indigenous dialects by members of the research team. Village Heads and Ward Councillors were also involved in the public enlightenment process. To facilitate coverage, central locations (study centres) were mapped out where eligible participant were encouraged to assemble for sample collection on appointed date.

At each study centre, participants were given health talk on environmental pollution with specific reference to heavy metals pollution by the team Physicians. The study rationale and objectives were explained to the subjects and after that, their consent were sought. Only 301 volunteers who gave written consent to participate in the study were enrolled at no cost.

Socio-demographic characteristics of volunteers were collected using structured questionnaire administered by one of the study team members in the native language of the participants. Measurement of height was done using a standard calibrated meter rule that was fixed to a perpendicular wall on a smooth surface floor. Digital weighing scale (Seca, Harmburg, Germany) was used to determine the body weights of participants with the subjects wearing light clothes without putting on shoes or caps or head ties. BMI was calculated by dividing the weight of the participant (Kg) with the square of height (meter^2). The subjects were grouped into five BMI categories in accordance with Abrams B and Selvin S as follows: Underweight (BMI ≤19.9 Kg/m^2); Normal weight (BMI=20-24.9 Kg/m^2); Overweight (BMI=25-29.9 Kg/m^2) and obese (BMI ≥30 Kg/m^2) [19].

Venous blood (6.0 mL) was collected between 8.00-10.00 hours from each subject at recruitment and dispensed into trace element-free lithium heparin bottle for the determination of plasma heavy metals. The samples were transported in ice packs to the laboratory, where plasma was separated and frozen until analysis was done. Plasma heavy metals were determined using atomic absorption spectrophotometer (Bulk Scientific, Model AVG 210). Certified reference solutions of heavy metal (obtained from Sigma-Aldrich Co. LLC, USA) for atomic spectrometry were used as controls. Each sample analysis was performed in duplicate, and the mean of both measurements was used for this analyses. In order to control contaminations, all glassware were washed and soaked in three successive dilute nitric acid bathes and thoroughly rinsed in ultra-pure double distilled deionised water.

Ethical consideration: The Ethics and Research Committee of Federal Teaching Hospital, Abakaliki, Ebonyi State approved the protocol for the study (Grant No.: EBSU/TETFUND Grant APPL/012/2012). The anonymity of the patients were maintained and the Helsinki guidelines were followed [20].

STATISTICAL ANALYSIS

IBMS Statistical Package for Social Sciences (SPSS®) for Windows ® version 20 (SPSS Inc., Chicago, IL, USA) was used to analyse data generated. Values were expressed as Mean±Standard Errors of Means (SEM). One-way Analysis of Variance (One-way ANOVA) was used for multiple comparisons while relationships among the parameters were determined using Pearson correlation analysis. Values of p≤ 0.05 were considered statistically significant.

RESULTS

General Characteristics of the Subjects

Total 117 male and 184 female subjects were investigated. Significantly (p<0.05) higher number of males consumed alcohol and smoked tobacco, in comparison to the females. Similarly, both systolic and diastolic blood pressures were significantly (p<0.05) higher among males, in comparison to their female counterparts. Although the males were significantly (p<0.05) older than the females, there was no significant (p>0.05) difference in the plasma levels of heavy metals between males and females [Table/Fig-1].

Parameters	Male (n=117)	Female (n=184)	p-values
BMI (Kg/m^2)	23.3±0.3	24.7±0.4	0.105
Smokers (n)	40	8	0.001*
Non-smokers (n)	77	176	0.001*
Alcohol consumers (n)	89	36	0.001*
Non-consumer of alcohol (n)	28	147	0.001*
SBP (mmHg)	125.7±1.7	119.1±1.5	0.005*
DBP (mmHg)	77.6±1.0	72.5±0.9	0.001*
Age (yrs)	47.5±1.3	40.8±0.9	0.001*
Arsenic (μg/dl)	0.20±0.02	0.21±0.02	0.887
Cadmium (μg/dL)	0.29±0.06	0.42±0.06	0.139
Copper (μg/dL)	156.6±3.5	156.4±2.8	0.959
Iron (μg/dL)	131.4±3.5	133.5±2.7	00.635
Lead (μg/dL)	1.11±0.1	1.13±0.18	0.929
Nickel (μg/dL)	0.06±0.01	0.06±0.01	0.940
Selenium (μg/dL)	0.13±0.01	0.14±0.01	0.784
Zinc (μg/dL)	93.4±1.7	94.9±1.5	0.516

[Table/Fig-1]: General characteristics of the study population.
SBP: Systolic blood pressure; DBP: Diastolic blood pressure; BMI: Body mass index; Values are expressed as Mean±Standard Error of Mean (SEM). Values of p ≤ 0.05 are considered statistically significant

Effect of Age Groups on Plasma Levels of Heavy Metals

[Table/Fig-2] Significantly (p<0.05) higher levels of As were observed in age groups ≤30 years, 31-40 years and 41-50 years in comparison with age group >50 years. However, while significantly (p<0.05) higher plasma levels of Pb were recorded in older age groups (41-50 & > 50 years, respectively) in comparison with the younger counterparts, plasma levels of Cd, Cu, Fe, Se and Zn were comparable among the age groups.

Effects of Occupation on Plasma Levels of Heavy Metals

Comparison of plasma levels of heavy metals among the occupational groups [Table/Fig-3] shows that, although plasma levels of Cu, Fe and Zn were significantly (p<0.05) higher among the House Wives/Retirees (HW/RT) and civil servants in comparison with individuals whose occupations were artisan and farming, respectively; other heavy metals (As, Cd, Pb, Ni, and Se) were comparable among the occupational groups.

Effects of Educational Level on the Plasma Levels of Heavy Metals

Although comparable (p>0.05) levels of plasma As, Cd, Cu, Fe, Pb, Se and Zn were observed among different educational levels,

Heavy metals (μg/dL)	Age groups (years)			
	≤30 (n=54)	31-40 (n=85)	41-50 (n=69)	>50 (n=93)
Arsenic	0.27±0.04[a]	0.22±0.04[a]	0.19±0.03[a]	0.17±0.02[b]
Cadmium	0.28±0.08	0.37±0.07	0.47±0.11	0.36±0.08
Copper	158.6±5.2	155.3±3	159.1±4.8	154.4±3.9
Iron	134.9±4.9	133.6±3.8	135.3±4.9	127.9±3.8
Lead	0.98±0.14[a]	1.07±0.11[a]	1.46±0.47[b]	1.01±0.11[a]
Nickel	0.04±0.01[a]	0.06±0.01[a]	0.09±0.03[b]	0.06±0.01[a]
Selenium	0.14±0.02	0.13±0.01	0.13±0.01	0.15±0.01
Zinc	95.0±2.5	94.4±1.9	95.1±2.4	93.3±2.1

[Table/Fig-2]: Comparison of plasma levels of heavy metals among age groups.
Values are expressed as Mean±SEM. Values with different superscripts across column are statistically different (p≤0.05).

Heavy metals (μg/dL)	Occupational groups (n)			
	HW/RT* (n=9)	C/S (n=66)	Artisan (n-67)	Farming (159)
Arsenic	0.11±0.04	0.25±0.03	0.18±0.03	0.20±0.03
Cadmium	0.14±0.03	0.35±0.07	0.33±0.09	0.41±0.06
Copper	169.9±2.7[a]	167.2±4.0[a]	153.6±5.0[b]	152.5±2.7[b]
Iron	148.7±2.7[a]	145. 0±4.1[a]	129.3±4.9[b]	128.0±2.6[b]
Lead	0.89±0.55	0.97±0.13	1.10±0.13	1.21±0.21
Nickel	0.06±0.02	0.05±0.01	0.08±0.03	0.06±0.01
Selenium	0.12±0.01	0.16±0.03	0.14±0.02	0.13±0.01
Zinc	102.3±13.5[a]	100.1±2.0[a]	92.8±2.4[b]	92.1±1.4[b]

[Table/Fig-3]: Comparison of plasma levels of heavy metals among occupational groups.
*HW/RT: House wives/Retirees (pooled because of small number); C/S: Civil servants; Values are expressed as Mean±Standard Error of Mean (SEM). Values with different superscripts across column are considered statistically significant

plasma Ni was significantly (p<0.05) higher in individuals with primary education in comparison with other educational levels [Table/Fig-4].

Heavy metals (μg/dL)	Educational level (n)			
	Illiterate (n=67)	Primary (n=112)	Secondary (n=86)	Tertiary (n=36)
Arsenic	0.18±0.03	0.24±0.03	0.20±0.03	0.19±0.02
Cadmium	0.48±0.12	0.39±0.06	0.32±0.06	0.26±0.0
Copper	155.1±5.2	153.8±3.2	163.3±4.2	151.1±5.6
Iron	131.7±5.0	129.4±3.2	139.0±4.2	129.5±5.5
Lead	1.30±0.5	1.13±0.10	1.0±0.12	0.90±0.18
Nickel	0.04±0.01[a]	0.09±0.02[b]	0.05±0.01[a]	0.05±0.01[a]
Selenium	0.14±0.02	0.13±0.01	0.14±0.02	0.14±0.02
Zinc	94.3±2.9	92.8±1.5	97.0±2.1	92.6±2.7

[Table/Fig-4]: Comparison of plasma levels of heavy metals among educational levels of participants.
Values are expressed as Mean±Standard Error of Mean (SEM). Values with different superscripts across column are considered statistically significant

Effects of BMI on the Plasma Levels of Heavy Metals

Individuals that were underweight had significantly (p<0.05) higher plasma Cd levels (1.02±0.41 μg/dL) when compared to individuals that have normal weight (0.37±0.05 41 μg/dL); while significantly higher plasma level of Cd was observed in the latter in comparison with individuals that were either overweight or obese (0.28±0.07 and 0.28±0.09 μg/dL, respectively). Also, plasma Se was significantly (p<0.05) lower in normal, overweight and obese individuals than in individuals that were underweight. However, the plasma levels of other heavy metals were not significantly (p>0.05) different among the BMI groups [Table/Fig-5].

Effect of Life Style on the Plasma Levels of Heavy Metals

Neither alcohol nor tobacco consumption had effect on plasma levels of heavy metals [Table/Fig-6].

Heavy metals (μg/dL)	BMI groups (n)			
	Underweight (n=15)	Normal weight (184)	Overweight (n=75)	Obese (n=27)
Arsenic	0.19±0.03	0.23±0.02	0.19±0.03	0.20±0.03
Cadmium	1.02±0.41[a]	0.37±0.05[b]	0.28±0.07[c]	0.28±0.09[c]
Copper	150.5±6.1	154.1±2.8	160.6±3.9	164.9±9.1
Iron	129.3±6.1	130.1±2.8	135.4±3.	144.4±9.2
Lead	0.63±0.18	1.1±0.1	1.15±0.14	0.95±0.21
Nickel	0.03±0.01	0.07±0.01	0.05±0.01	0.06±0.01
Selenium	0.22±0.08[a]	0.13±0.01[b]	0.14±0.01[b]	0.12±0.01[b]
Zinc	92.6±3.1	93.4±1.5	95.1±1.9	99.4±4.5

[Table/Fig-5]: Comparison of plasma levels of heavy metals among the BMI groups.
BMI: Body mass index; Values are expressed as Mean±Standard Error of Mean (SEM). Values with different superscripts across column are considered statistically significant

Heavy metals (μg/dL)	Non-smokers (n=253)	Smokers (n=48)	Non alcohol consumer (n=175)	Alcohol consumer (126)
Arsenic	0.21±0.02	0.20±0.03	0.21±0.02	0.20±0.02
Cadmium	0.36±0.04	0.43±0.15	0.36±0.05	0.39±0.07
Copper	156.3±2.9	157.4±5.1	159.6±3.1	151.7±2.9
Iron	132.6±2.4	133.2±3.2	135.9±3.0	127.6±2.8
Lead	1.16±0.14	0.96±0.14	1.01±0.08	1.29±0.26
Nickel	0.07±0.01	0.04±0.01	0.06±0.01	0.06±0.01
Selenium	0.13±0.01	0.15±0.03	0.14±0.01	0.13±0.01
Zinc	94.6±1.2	92.9±2.5	96.5±1.6	91.0±1.4

[Table/Fig-6]: Comparison of plasma levels of heavy metals between smokers and non-smokers and between alcohol consumers and non-alcohol consumers.
Values are expressed as Mean±Standard Error of Mean (SEM)

Relationships of Sociodemographic Parameters with Plasma Heavy Metals and among Heavy Metals

[Table/Fig-7] shows the correlation between parameters (a) and (b). Arsenic significantly (p<0.05) negatively correlated with age, while BMI negatively correlated (p<0.05) with both arsenic and cadmium. However, while Cd significantly negatively correlated with copper, As, Cu and Fe significantly (p<0.05) positively correlated with Ni, Se and Zn, respectively.

Parameters (a)	Parameters (b)	r	p-value
Arsenic	Age	-0.123	0.033
Arsenic	BMI	-0.118	0.041
Arsenic	Nickel	0.398	0.001
Cadmium	BMI	-0.137	0.018
Copper	Cadmium	-0.116	0.045
Copper	Iron	0.896	0.001
Copper	Selenium	0.131	0.024
Copper	Zinc	0.836	0.001
Iron	Selenium	0.144	0.013
Iron	Zinc	0.838	0.001

[Table/Fig-7]: Correlation analyses among the parameter.
Values of p≤0.05 are considered statistically significant

DISCUSSION

From the present study, indicators of socioeconomic status were found to have significant effect on plasma levels of heavy metals with levels of toxic metals raised while that of essential trace elements was low. While plasma levels of heavy metals were not affected by gender, alcohol consumption and tobacco smoking, there was significant positive association of plasma As, Cu and Fe with Ni, Se and Zn, respectively.

High plasma levels of heavy metals observed among this population is in corroboration with earlier studies [21,22]. The higher plasma levels of these elements among the adult population observed in the present study might in part be attributed to consumption of contaminated foods and water as high levels of Cd, Cu, Fe, Pb and Zn have been previously reported in water, leafy vegetables and tubers [11-16] in the same environment. This speculation is borne out of reports [23,24] that have implicated consumption of polluted water and foods as well as inhalation of contaminated dust as the major sources of exposure to heavy metals.

The observed lack of significant difference in the plasma levels of heavy metals between the male and female in the present study is in contrast with the findings of several studies [25-29]. For instance, a Korean study reported that the geometric mean concentrations of Pb, Cd, and Hg were influenced by gender [25]. In the same vein, a biomonitoring survey of metalloids in the general population of northern France, reported significantly higher mean blood levels of Pb and Zn in men than in women while mean blood levels of Mn, Co and Cr were higher in women than in men [29]. However, the lack of gender difference in the blood levels of Cd and Zn observed in that study is in agreement with the present findings. Although the reason for the disparity in the studies is obscure, it may be related to other factors, such as nutrition, age educational levels and other sociodemographic characteristics [25]. Although the objectives of the present study did not include determination of the cause of gender differences in metal metabolism, studies have documented that the gender differences in blood Cd concentrations may be due in part to iron deficiency-associated increases in blood cadmium concentration in pre-menopausal women [30]. Women generally have higher Cd body burden than men partly due to increased prevalence of low iron stores, especially in premenopausal women [31-33]. It has been shown that gastrointestinal absorption of Cd appears to involve the main iron transporters (DMT1 and basolateral ferroportin 1), both of which are known to be upregulated when iron stores are low. However, no association between iron deficiency and elevated cadmium levels had been documented either in menopausal women [34,35] or in men [36].

Significantly higher plasma as observed in younger than among the older age groups and significantly higher plasma Pb observed in older than in younger age groups in the present study is in contrast with another study [28], where younger age groups (17-30 years) had higher blood levels of Mn, Pb, Cu and Zn) while age group 46-60 years had higher blood Cd than other age groups. Several other studies have reported that levels of trace elements are affected by age [25,27,37] while others reported lack of significant influence on blood levels of trace elements by age [26,38]. Although the reason(s) for the disparity in the findings is/are not clear at present, it may be partly attributed to differences in subjects. However, it has been documented that some of these trace elements are cumulative toxicants that accumulate in the body over time. For instance Pb has been shown to accumulate in bone and other tissues [2]. It is therefore logical to infer that the blood levels of Pb will be higher in older age groups than among the younger counterparts, which is in corroboration with the present finding.

In addition to age and gender, it has been observed that blood levels of trace elements are affected by occupation. Higher plasma Cu, Fe and Zn observed in house wives/retirees and civil servants than in other occupational groups in the present study is in agreement with earlier study by the authors among pregnant women [39]. In that study, higher plasma levels of Cu, Fe and Zn were found in economically-advantaged groups; for example, in women whose living accommodation were flats, those with secondary/tertiary education, and among those whose occupations were civil servants and artisans, respectively. A study [39] also reported decreased prevalence of lower plasma Fe and Zn with increased maternal education. Additionally, a study by Son JY et al., among Korean population reported that levels of heavy metals were influenced by educational level of participants [25]. However, the present finding is in contrast with the lack of statistical difference in Se status among educational levels reported by Chen CJ et al., in Taiwanese adults [38]. The reason for higher plasma levels of heavy metals in individual in the higher socio-economical strata; for example, in civil servants, is not obvious but it might be speculated that educated individuals are more likely to dwell in urban areas than their less educated counterparts. For example, Liou SH et al., had reported an association of blood Pb level with residential location among Taiwanese adults [40]. Increase in population, industrialisation and urbanisation have been associated with contamination/pollution as a result of increased human and animal activities [3,41]. This is even worrisome in the face of indiscriminate disposal of industrial, domestic and agricultural waste water without compliance to standard safety and disposal regulation [42]. Bocca B et al., had however reported lack of significant effect of place of living on plasma level of some heavy metals [26].

Significantly higher Cd was observed in individuals that were underweight or normal weight than in overweight and obese individuals. Similarly, significantly lower plasma Se was observed in overweight and obese subjects than in underweight subjects in the present study. This shows the inverse association between plasma Cd and Se with BMI. This is in agreement with previous study by the authors, where plasma As was significantly ($p<0.05$) lower in obese subjects in comparison with individuals having normal BMI, with plasma Se levels significantly lower in obese, normal weight and overweight subjects in comparison with underweight subjects [18]. Arnud J et al., had also reported an association between obesity and decreased serum Se, which is also in corroboration with the present finding [43]. However, the positive association between serum Se and BMI and total cholesterol reported by Li N et al., is in contrast with the present study [44]. According to Savini I et al., increased oxidative stress associated with obesity may partly be responsible for the lower plasma Se observed in overweight and obese individuals in the present study [45]. This is because Se is an important antioxidant nutrient and may have been used to form antioxidant enzymes [46], such as glutathione peroxidase (GPx) used in the defense against oxidative stress. On the other hand, the lower plasma Se observed in overweight and obese individuals in comparison to individuals with normal weight may be related to the eating habits of the subjects; though the authors did not take record of eating habits of the participants. However, in a recent study by Wang S and Shi X, high dietary intake of Se was suggested to be beneficial to body composition [47]. Although we did not encounter study that related plasma Cd and BMI, the inverse correlation between BMI and plasma Cd observed in the present study need to be further investigated.

Life styles such as tobacco smoking and alcohol consumption have also been found to affect plasma levels of heavy metals [48]. This is in contrast with the present findings where plasma levels of heavy metals were not affected by either alcohol consumption or tobacco smoking. Several studies have reported that smoking and alcohol consumption affect plasma levels of heavy metals [25,28,29,38,40] while study elsewhere [26] had also reported lack of effect of smoking and alcohol consumption on plasma levels of heavy metals. Although we could not establish the mechanism by which alcohol and/or tobacco affect plasma levels of heavy metals, it may not be connected with increased intestinal absorption and increased oxidative stress earlier suggested by Ugwuja EI et al., [18].

The significant positive association of plasma As, Cu and Fe with plasma Ni, Se and Zn, respectively in the present study is quite intriguing. The reasons for these positive relationships are not clear but it might in part be attributed to the widespread contamination of the environment by heavy metals. Indeed, an increase in one element brings about a corresponding increase in the other, which in effect may have deleterious effect on the population, especially if the elements are expected to be antagonistic in nature. For instance, an inverse association have been reported between metals; for example, between As and Se [49] and between Cd and zinc [50] with clinical consequences. For instance, Xu Z et al., showed that Se protects liver cells against As-induced oxidative damage [49] as well as As-triggered atherosclerosis [51]. Also, metallothionine (a zinc metalloprotein), was reported to protect against Cd-induced tissue damage while pretreatment with Zn has been found to be protective against Cd toxicity [47]. Therefore, in the event of a positive association between two elements that otherwise would have been an inverse relationship and beneficial, as observed in the present study, such beneficial effect may be nullified and toxicity might manifest with its attendant health implications.

Limitation(s)

The interpretations of the present study should be done with caution as it was a cross-sectional study. Additionally most of the residents were illiterates and their responses may not be completely reliable.

CONCLUSION(S)

Healthy individuals in Ebonyi state have elevated plasma levels of toxic heavy metals and low levels of essential trace elements, which are affected by some indicators of socio-economical status. Therefore, to avoid the risk of toxicity, dietary diversification is advocated in addition to prevention of exposure to heavy metals.

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