Original Research Article

ASSESSMENT OF ESSENTIAL TRACE ELEMENTS AND TOXIC METAL CONTAMINANTS OF BANKED BLOOD DESIGNATED FOR TRANSFUSION IN IGBINEDION UNIVERSITY TEACHING HOSPITAL, OKADA, NIGERIA

Abstract

Blood transfusion is a critical part of patient's intensive care and is life saving for patients with severe anemia or hemorrhage. The goal of blood banking is to provide adequate and safe blood to recipients at no risk to donors. These donors may have had a variety of exposures to substances including toxic heavy metals from environmental and occupational sources. Exposure to environmental heavy metals is common among Africans. Although many of these metals are known neurotoxicants, to date, monitoring of this exposure is limited, even in countries such as Nigeria that are undergoing rapid industrialization.Concentration of Lead, Cadmium, Zinc and copper in samples from eighty six (86) blood donors comprising of O, A, B and AB blood groups were estimated by inductively Coupled Plasma Mass Spectrometer (ICP-MS), aliquot of 20µL of blood sample was aspirated into the quartz spray chamber after instrument was standardized with standard blank and various standards (Cadmium, Lead, Zinc and Copper).Data values of Lead, Cadmium, Zinc and Copper obtained indicated that essential and toxic metal levels from donor blood were within permissible range. Data were analysed using SPSS version 20 and significance level were set at $p =\leq 0.05$. The observed blood levels of cadmium and lead in donor blood banked designated for transfusion in this study were in correlation with the permissible range of toxic metals. More so, there was an insignificant increase in the essential metals level in the blood donor group when compared with the reference range. This study therefore concludes that donor blood designated for transfusion at Igbinedion university teaching hospital Okada had metal concentrations that is within the estimated tolerable concentration.

Keyword: Blood transfusion, heavy metals.

Introduction

Blood donors are grouped into voluntary donors, replacement donors, and paid donors. The safest of these is the voluntary donor blood. Blood banking is highly regulated to ensure both donor and recipient safety. The goal of blood banking is to provide adequate and safe blood to recipients at no risk to donors (1). Baseline hemoglobin of 12 g/dl and 13 g/dl for potential female and male donors' respectively, and a donation interval of 12 weeks minimum have been stipulated in some countries to ensure donor safety (2, 3). As a way of attaining this goal, voluntary non-remunerated blood donation is encouraged and the World Health Organization (WHO) has set a target of achieving 100% voluntary non remunerated donation by 2020 (4). Nigeria as a member nation of WHO has made little progress with voluntary donor recruitments. Only about 5% of donor bloods used in Nigeria come from voluntary donors; family replacements and paid donors are still the major sources of donor blood procurement (1, 5).

However these donors may have had a variety of exposures to substances including toxic heavy metals from environmental and occupational sources (6). Exposure to environmental heavy metals is common among Africans. Although many of these metals are known neurotoxicants, to date, monitoring of this exposure is limited, even in countries such as Nigeria that are undergoing rapid industrialization. An assessment of the burden and potential causes of metal exposure is a critical first step in gauging the public health burden of metal exposure and in guiding its elimination.

The federal government has codified exposure levels acceptable to adult workers and to children exposed to environmental contaminants. These exposures occur mainly via ingestion or inhalation. Toxic heavy metals present in transfused blood are administered intravenously. Safe levels for intravenous administration of most of these toxic metals are unknown. Toxic metals such as lead in donor blood have previously been shown to be present at concentrations that pose a health risk for infants (7). Aluminum (Al), arsenic (As), beryllium (Be), cadmium (Cd), mercury (Hg), Lead (Pb), Manganese (Mn) and Nickel (Ni) have been studied extensively due to the known serious adverse health effects associated with human exposure to these metals. According to the Agency for Toxic Substance and Disease Registry's (ATSDR) priority list of hazardous substances, the latent effects from these heavy metals include carcinogenesis, neurotoxicology and developmental deficits in humans and animals (8,9,10). Toxic metals tend to stay in the body for long periods of time and may cause detrimental adverse effects on human growth and development (11,12). Therefore, it is an urgent and high priority to explore and determine the burden of exposure of toxic metals from human blood to the developing infants. It has been hypothesized that `metals, known to have especially detrimental neurotoxic health effects, could be present in banked blood designated for transfusion at potentially toxic concentrations. Thus this study aims at determining the levels of essential metals and toxic metals burden of banked blood designated for transfusion in Igbinedion University teaching hospital Okada.

Materials and methods

The study was carried out at the Analytical Laboratory of the International Institute for Tropical Agriculture (IITA), Ibadan, Oyo state and the department of Laboratory Medicine, Igbinedion University Teaching Hospital, Okada, Edo state, Nigeria.

Study design

This is a cross sectional study among individuals of different blood groups that entails voluntary donors visiting the Igbinedion University Teaching Hospital, Okada, Edo State. The individuals consented to participate after fulfilling the requirements to donate. A total of 86 individuals were recruited in this research.

Ethical consideration

Ethical Clearance and Informed Consent

Ethical approval was sought and obtained from theInstitutionalEthics Committee of the Igbinedion University Teaching Hospital, Okada, Edo State. Informed written consent after well understood verbal communication relating to the aims of the study. Each recruit was identified by means of serial numbers rather than names to ensure confidentiality

Study population

The study populations were made up of male and female individuals whose haemoglobin concentration were within the normal range as regards gender and were screened for transfusion and transmissible diseases

Data collection

Questionnaires were used to collect necessary information from the 86 voluntary donors which include socio-demographic data, frequency of blood donated, and other social vices such as smoking. The research instrument included data from laboratory investigation for transfusion and transmissible diseases

Specimen collection

Aliquots of about 4ml of whole blood were collected from the blood bag serially numbered to tag with the 86 donor individuals into plain bottles, plasma samples were obtained after centrifugation and stored at -20°C prior to analysis.

Specimen analysis

Concentration of Lead, Cadmium, Zinc and copper in the sample were estimated by inductively Coupled Plasma Mass Spectrometer (ICP-MS) (Agilent 7500, Norwalk, U.S.A) adopting the methods of Fong *et al*. (2007).

The instrument was standardized with standard blank and various standards (Cadmium, Lead, Zinc and Copper). An aliquot of 20µL of plasma was aspirated into the quartz spray chamber. The concentration of the respective metal in the sample was displayed on the screen of the instrument after the run time was completed.

Results

Table 1 shows the comparison of measured toxic metals and essential metals level in donor blood with permissible range. Data indicated that essential and toxic metal levels from donor blood were within permissible range.

Table 2 shows the comparison of measured toxic metals and essential metals level in the different blood group among the donors. Data indicate an insignificant difference ($P>0.05$) in the serum concentration of lead among group A, B, AB and O donors. Also there were no significant difference ($P>0.05$) in the serum concentration of cadmium, zinc and copper among group A, B, AB and O donors.

Table 3 shows the comparison of measured toxic metals and essential metals level in male donors and female donors. However there were no significant differences between the mean serum concentrations of lead ($P>0.05$) Cadmium ($P>0.05$), zinc ($P>0.05$) and Copper ($P>0.05$) in male donors compared with the female donors.

Table 4 shows the comparison of measured toxic metals and essential metals level in different age groups among blood donors. Data indicated an insignificant difference in the mean serum concentration of lead and cadmium ($P>0.05$) in the different age groups among blood donors. Furthermore there was no significant difference between the mean serum concentrations of Zinc and Copper ($P>0.05$) in the different age groups among blood donors

Table 1: Comparison of metals level in donor banked blood with reference ranges. (Mean ±SEM)

Measured toxic/essential metals	Donor banked blood	Reference range

Lead (µg/dl)	0.14±0.01	<10ug/dl
Cadmium (µg/dl)	0.07±0.01	0.03–0.12 µg/dl
Zinc (µg/dl)	78.46±1.09	70.46-177.53 µg/dL
Copper (µg/dl)	85.85±0.76	74.30-170.68 µg/dL

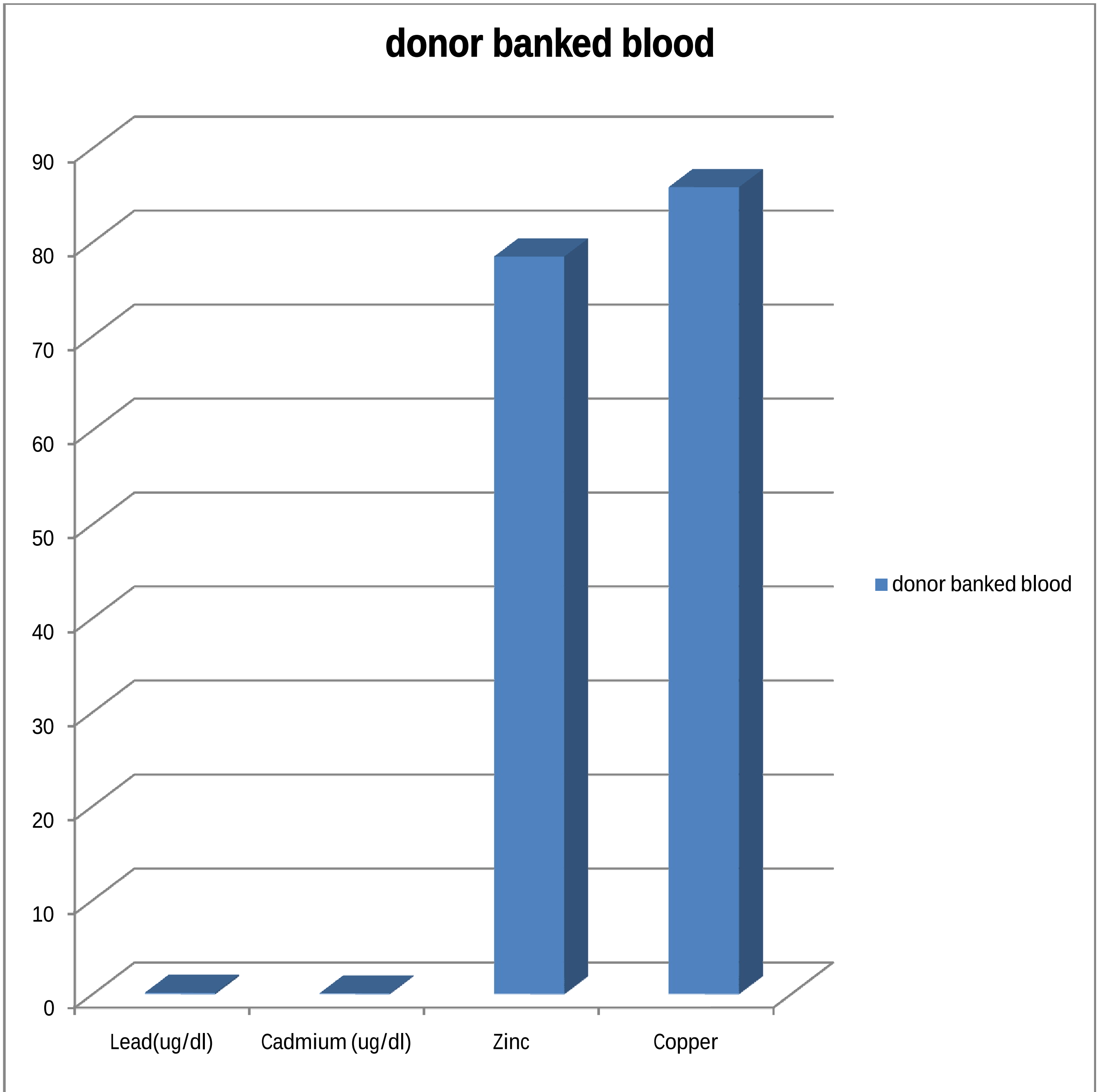

Figure 1: Comparison of metals level in donor banked blood with reference ranges. (Mean ±SEM)

Table 2: Comparison of metals level in different blood group among blood donors (Mean ±SEM)

Measured toxic and essential metals	Blood Group system				p-value
	A(n=9)	B(n=7)	AB (n=2)	O(n=68)	
Lead (µg/dl)	0.13±0.02	0.12±0.02	0.13±0.08	0.15±0.02	P>0.05
Cadmium (µg/dl)	0.07±0.01	0.06±0.02	0.09±0.01	0.06±0.01	P>0.05
Zinc (µg/dl)	79.14±2.92	84.19±3.01	86.00±0.32	88.60±1.27	P>0.05
Copper (µg/dl)	85.54±0.76	86.35±0.59	85.56±0.65	85.84±0.25	P>0.05

Note: SEM: Standard Error of Mean.

P>0.05- Not Significant

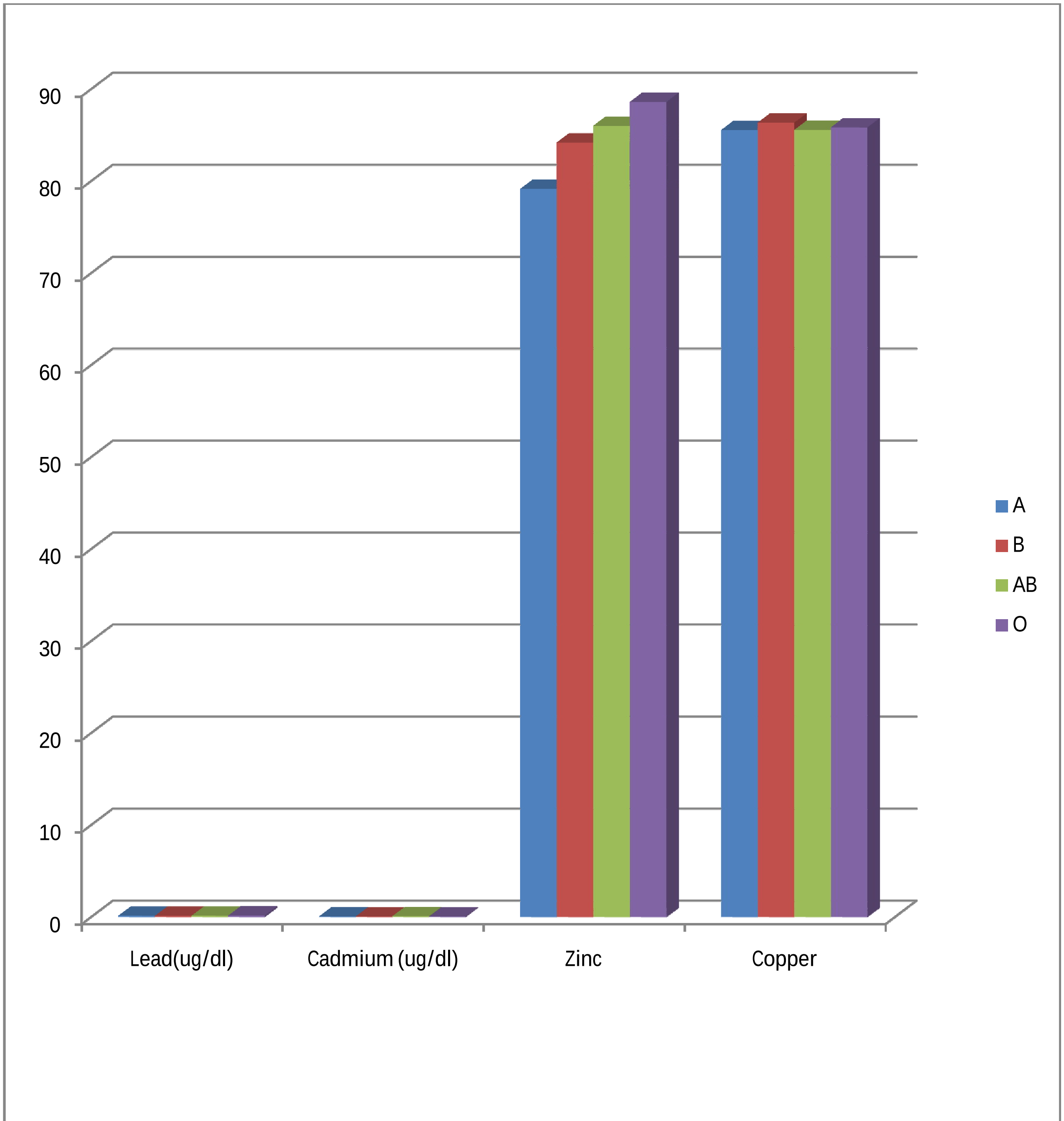

Figure 2: Comparison of metals level in different blood group among blood donors (Mean ±SEM)

Table 3: Comparison of measured toxic metals and essential metals level in male and female donors (Mean ±SEM).

Measured toxic and essential metals	Sex		p-value	Level of significance
	Male (n=76)	Female (n=10)		
Lead (µg/dl)	0.14±0.01	0.14±0.01	P>0.05	Not significant
Cadmium (µg/dl)	0.06±0.00	0.07±0.01	P>0.05	Not significant
Zinc (µg/dl)	79.46±1.09	76..90±2.66	P>0.05	Not significant
Copper (µg/dl)	85.82±0.21	85.85±0.61	P>0.05	Not significant

Note: SEM: Standard Error of Mean.

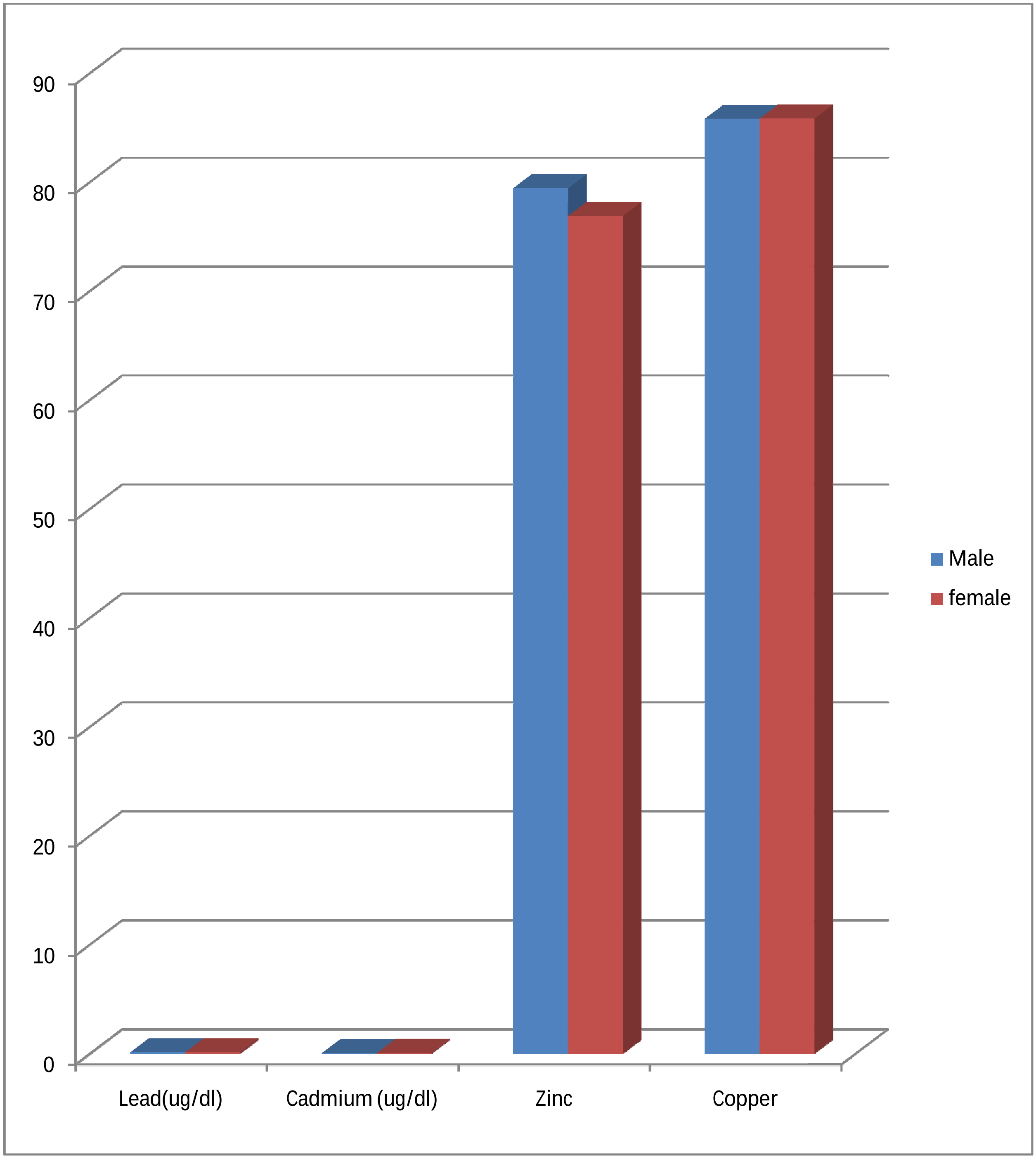

Figure 3: Comparison of measured toxic metals and essential metals level in male and female donors (Mean ±SEM).

Table 4: Comparison of measured toxic metals and essential metals level among the different age groups of blood donors (Mean ±SEM).

Measured toxic and essential metals	Age Group				p-value
	<21-25 (n=24)	26-30 (n=23)	31-35 (n=18)	36-40 (n=21)	
Lead (µg/dl)	0.12±0.01	0.16±0.03	0.12±0.01	0.17±0.03	P>0.05
Cadmium (µg/dl)	0.05±0.01	0.07±0.01	0.07±0.01	0.07±0.01	P>0.05
Zinc (µg/dl)	79.99±1.83	76.59±2.01	78.83±2.18	71.37±2.14	P>0.05
Copper (µg/dl)	85.95±0.35	85.32±0.35	85.66±046	86.39±0.20	P>0.05

Note: SEM: Standard Error of Mean.

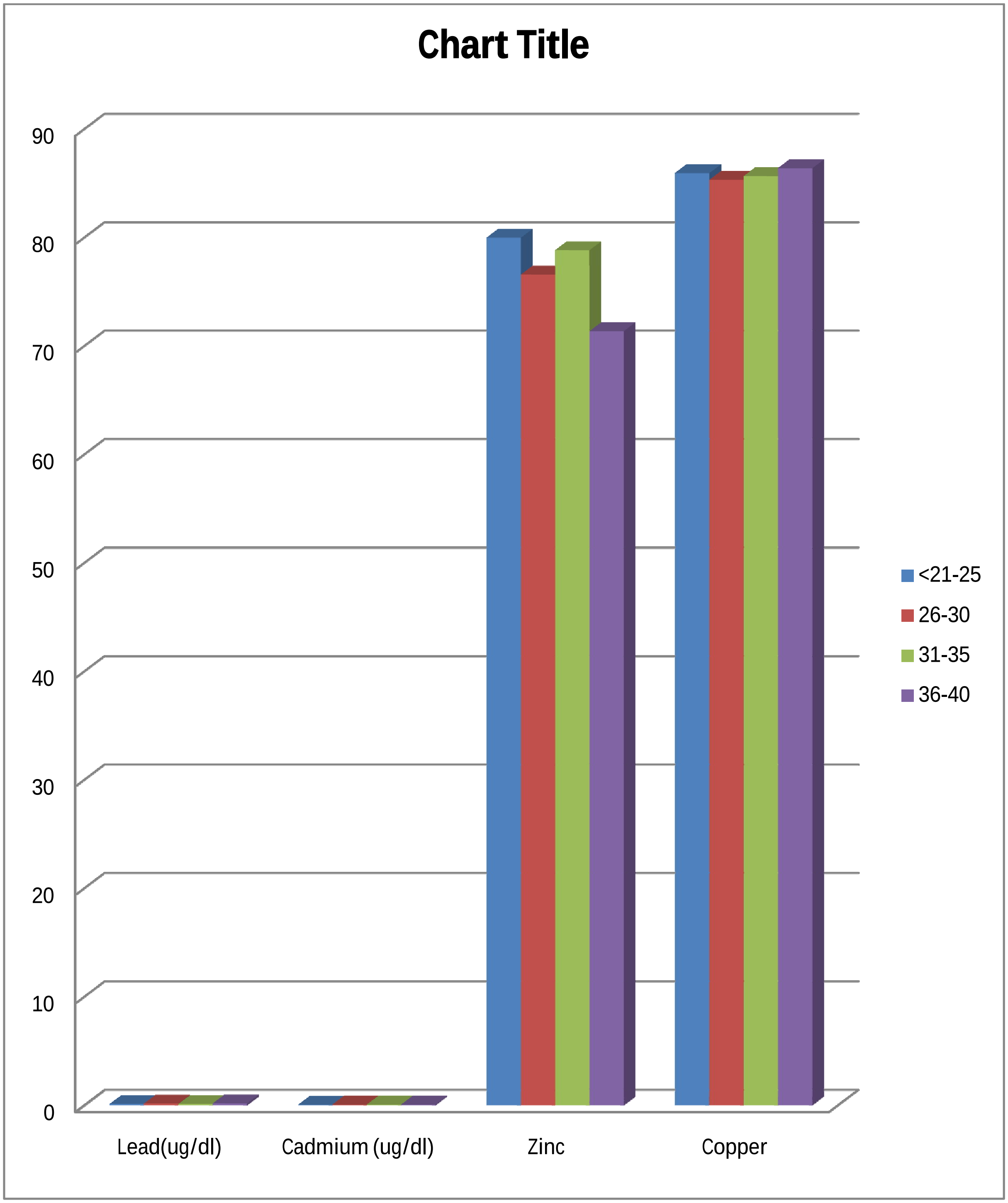

Figure 4: Comparison of measured toxic metals and essential metals level among the different age groups of blood donors

5.0 DISCUSSION

Blood transfusion is a critical part of patient's intensive care and is life saving for patients with severe anemia or hemorrhage (13). Furthermore, some heavy metals and trace elements are necessary for the continuation of human life and play an important role in various reactions in the human body (such as iron, selenium, copper, and zinc). However, the elements that are considered to be necessary for human metabolism may have a toxic effect if a certain amount is exceeded. On the other hand, some elements (such as lead, cadmium, arsenic and mercury) do not have a known role in human physiology and their accumulation in the body may pose a risk to health (14). Therefore, the concentrations of heavy metals and trace elements taken from various sources must not exceed certain limits within the human body (15).

In this present study serum concentration of toxic metals and essential metals were determined in banked blood designated for transfusion in Igbinedion university teaching hospital. Data indicated an insignificant difference (P>0.05) in the serum concentration of lead and cadmium of the blood donors when compared with the permissible range according to **WHO,** (1996) 0.03–0.12 µg/dl for cadmium (Cd) and <10ug/dl for lead (Pb). The findings of this study were consistent with previous findings of **Sundararajan et al.** (2015) who observed no significant difference in the toxic metal levels of banked blood designated for neonatal transfusion in USA when compared to mean blood concentrations from the 2013–2014 National Health and Nutrition Examination Survey (NHANES). The reason for this insignificant difference is not farfetched as blood donors within Igbinedion university teaching hospitals are mainly made up of voluntary non-remunerated blood donors who are apparently healthy non-cigarette smokers (passive smokers), living in rural dwellings with no industrial settings and are not occupationally exposed to toxic metals. More so, research by **Bearer et al.** (2018) shows that heavy metal concentrations in donor blood are variable and can be greater in some regions that are highly industrialized and regions with heavy metal contaminated soil. Toxicities of heavy metals in the blood stream of an individual can vary according to various factors such as dose, route of exposure, age, gender, genetics, and nutritional status of the individual. Okada and its environment is not an industrial hub, thus this may account for the insignificant concentration of toxic metals in the donor blood. Data also indicated an insignificant increase in the essential metals level in the blood donor group when compared with the reference range. Zinc and Copper are essential metals derived from foods such as beef, ground beef, legumes, potato and potato products, nuts and seeds poultry, ready-to-eat and hot cereals, and pork constituted the major sources of zinc. Blood donors in Okada and its environs are mainly farmers who have access to healthy and fresh agricultural products, this may contributes to the normal level of essential metals observed among this group of people. The significant different may presumably be attributed to the significantly higher red cell counts found in the male population which formed bulk of the blood donor found in Okada. This evidence has been previously documented (16). Zinc is a component of more than 200 enzymes, involved in various activities, such as metabolic functions, immunity and wound healing (17). Copper is an essential nutrient that is widely spread in food and water. It is a part of several metalloenzymes that is required for oxidative metabolism, including cytochrome oxidase, feroxidase, amino oxidase, superoxide dismutase, ascorbic acid oxidase and tyrosinase (18).

Likewise, the level of toxic metals and essential metals were compared among different blood group. Data indicate an insignificant difference ($P>0.05$) in the serum concentration of lead among group A, B, AB and O donors. Also there were no significant difference ($P>0.05$) in the serum concentration of cadmium, zinc and copper among group A, B, AB and O donors. This finding is consistence with the report of **Emokpae et al.** (2020), who observed no significant difference in the blood levels of some toxic and essential metals among rural and urban dwellers of different blood groups in Edo State, Nigeria. These insignificant differences may be attributed to a product of chance. More so to the best of our knowledge there is no available data on the comparison of toxic metals and essential metals levels of banked blood designated for transfusion.

Analysis of lead and copper in the serum of donors indicates no significant differences between the mean serum concentrations of lead ($P>0.05$) Cadmium ($P>0.05$), zinc ($P>0.05$) and Copper ($P>0.05$) in male donors compared with the female donors. These findings were also consistence with the previous report of **Emokpae et al.** (2020), who observed no significant difference in the blood levels of some toxic and essential metals among male and female rural and urban dwellers.

Data from this study also indicated an insignificant difference in the mean serum concentration of lead and cadmium ($P>0.05$) in the different age groups among blood donors. Furthermore there was no significant difference between the mean serum concentrations of Zinc and Copper ($P>0.05$) in the different age groups among blood donors. Trace elements are needed for many metabolic and physiological processes in the human body (19). Alterations in iron (Fe), zinc (Zn) and copper (Cu) levels in the sera change during inflammation and infections. These are associated with elevated levels of acute phase proteins, such as ceruloplasmin (20, 21). Zinc is a component of more than 200 enzymes, involved in various activities, such as metabolic functions, immunity and wound healing (17).

Copper is an essential nutrient that is widely spread in food and water. It is a part of several metalloenzymes that is required for oxidative metabolism, including cytochrome oxidase, feroxidase, amino oxidase, superoxide dismutase, ascorbic acid oxidase and tyrosinase and have been proven to alter these metabolic processes,pro- oxidant/anti-oxidant balance and bind freely to sulfhydryl groups resulting in inhibition of glutathione metabolism and hormonal function (18).

Consequently, zinc deficiency could disrupt the function of both signaling molecules and proteins directly involved in DNA replication and repair. Limited availability of cellular zinc due to zinc deficiency could result in a loss of activity of zinc-dependent proteins involved in the maintenance of DNA integrity and may contribute to the development of cancer.

Conclusion:

The observed blood levels of cadmium and lead in donor blood banked designated for transfusion in this study were in correlation with the permissible range of toxic metals. More so, there was an insignificant increase in the essential metals level in the blood donor group when compared with the reference range. This study therefore concludes that donor blood designated for transfusion at Igbinedion university teaching hospital Okada had metal concentrations that is within the estimated tolerable concentration.

References

1. **Benedict, N., Awodu A.O., Bazuaye .N.** Journal of Laboratory Physician Thieme 2012; 4(2)
2. **Marcela, C., Clare, P.F. & Taylor, J.A.** Clinical blood transfusion in postgraduate haematology. 5th ed. Chichester Blackwell Pub.2005; pp. 250.
3. **Djalali, M., Neyestani, T.R., Bateni, J. &Siassi, F.** The effect of repeated blood donations on the iron status of Iranian blood donors attending the Iranian blood transfusion organization. International Journal of Vitamin and Nutritional Research. 2006; 76:132–137.
4. WHO, (1996). Trace Elements in Human Nutrition and Health. World Health Organization. Switzerland: Geneva. Pp. 153.
5. **Ahmed, S.G., Umar, B.A., Ibrahim, U.A., Saidu, A.T. &Jolayemi, B.** Dynamics of blood donation and donor categories in Birnin Kudu, Nigeria. Nigerian Journal of Basic Clinical Science 2004; 1:66–70.
6. Khan S, Lin AJ, Zhang SZ, Hu QH, Zhu YG. Accumulation of polycyclic aromatic hydrocarbons and heavy metals in lettuce grown in the soils contaminated with long-term wastewater irrigation. *J Hazard Mater.* 2008;152:506–515.
7. **Akinci, I., Tutkun, E., Turksoy, V.A., Yilmaz, H., Yuksel, B., Kayaalti, Z., Soylemezoglu, T., Yılmaz, H. &Abusoglu., S.** Toxic Metal and Essential Trace Element Levels of Blood Donors. Journal of Clinical and Analytical Medicine 2016;7(6):816-819

8. **Ostrowski, S.R., Wilbur, S., Chou, C.H., Pohl, H.R., Stevens, Y.W. & Allred, P.M.** Agency for Toxic Substances and Disease Registry's 1997 priority list of hazardous substances. Latent effects-carcinogenesis, neurotoxicology, and developmental deficits in humans and animals. Toxicology and Industrial Health.1999; 15: 602-644.
9. **Agency for Toxic Substances and Disease Registry (ATSDR).** (Priority List of Hazardous Substances. Agency for Toxic Substances and Disease Registry 2007; Pp 221-230.
10. **Pugh, K.H. &Zarus, G.M.** The Burden of Environmental Disease in the United States. Journal of Environmental Health 2012; 74: 30-34.
11. **Horton, L.M., Mortensen, M.E., Iossifova, Y., Wald, M.M., Burgess, P.** What do we know of childhood exposures to metals (arsenic, cadmium, lead, and mercury) in emerging market countries?. International Journal of Pediatrics 2013; 8:72-96.
12. **Rahbar, M.H., Samms-Vaughan, M., Dickerson, A.S., Hessabi, M. & Bressler, J.** Concentration of lead, mercury, cadmium, aluminum, arsenic and manganese in umbilical cord blood of Jamaican newborns. International Journal of Environmental Research in Public Health 2015; 12: 4481-4501.
13. **Kirpalani**Kirpalani H, Whyte RK, Andersen C, et al. The Premature Infants in Need of Transfusion (PINT) study: A randomized, controlled trial of a restrictive (low) versus liberal (high) transfusion threshold for extremely low birth weight infants.JPediatr2006;149(3):301-7.
14. **Duruibe**Duruibe, J. O., Ogwuegbu, M. O. C., Egwurugwu, J. N. Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences 2007; Vol. 2 (5), pp. 112-118,
15. McCally M. Human health and heavy metals exposure. The Environment and Human Health (Chapter 4)2002
16. Nriagu JO. Toxic metal pollution in Africa. *Sci Total Environ.* 1992;121:l–37.
17. Brodkin E, Copes R, Mattman A, Kennedy J, Kling R, Yassi A. Lead and mercury exposures: Interpretation and action. *CMAJ.* 2007;176:59–63.
18. Zalups RK. Molecular interactions with mercury in the kidney. *Pharmacol Rev.* 2000;52:113–43.
19. Nabulo G, Oryem-Origa H, Diamond M. Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda. *Environ Res.* 2006;101:42–52.
20. Tudor R, Zalewski PD, Ratnaike RN. Zinc in health and chronic disease. *J Nutr Health Aging.* 2005;9(1):45–51.

21. Panemangalore M, Bebe FN. Effect of high dietary zinc of plasma ceruloplasmin and erythrocyte superoxide dismutase activities in copper-depleted and repleted rats. *Biol Trace Elem Res*. 1996;55(1–2):111–26.

22. Barber EF, Cousins RJ. Interleukin-1 stimulated induction of ceruloplasmin synthesis in normal and copper-deficient rats. *J Nutr*. 1988;118:375–381.

23. Cousins RJ. Absorption, transport, and hepatic metabolism of copper and zinc: special reference to metallothionein and ceruloplasmin. *Physiol Rev*. 1985;65:238–241.