Assessment of the renal function status in occupationally exposed people working in metal fabricating factory in Nnewi

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Abstract
Background of Study: Heavy metal contamination and exposure in work environment is an issue of great public health implication.
Aim of the Study: this cross sectional study assessed the renal function status in occupationally exposed people working in metal fabricating factory in Nnewi South Eastern Nigeria.
Materials and Methods: A total of 15 apparently healthy individuals in metal fabricating factory aged between 19 and 56 years and 79 control subjects (comprising of 39 control subjects from Nnewi (N) and 40 control subjects from Elele (E) respectively) aged between 18 and 44 years were recruited for the study. 5ml of venous blood sample was collected from each subject for the determination of biochemical parameters (potassium, sodium, chloride, bicarbonate, urea and creatinine levels) using standard laboratory methods.
Results: The current study showed significantly elevated levels of sodium, potassium, urea and creatinine ($p<0.05$) and significantly reduced concentration of both bicarbonate and chloride ion in the persons exposed to heavy metals in the metal fabricating factory in Nnewi ($p<0.05$).
Conclusion: This study revealed the deleterious effect of heavy metal exposure at the work place on the functionality of the kidneys.

Keywords: Metal fabrication, Factory workers, Occupational exposure, Heavy metals, Kidney function, Body mass index, Length of service, Age.

Introduction
Factories and other industrial installations have caused such pollution since the dawn of the industrial age by burning fuels, carrying out chemical processes and releasing dust, fumes and other particulates.[1] Air pollutants emitted by coal-fired power plants and metal factories include; sulfur oxides, hydrogen chloride, hydrogen fluoride gases, green house gases like methane, carbon dioxide, nitrous oxide and arsenic, lead, nickel and other heavy metals.[2] Industrial emissions of heavy metals into air tend to originate from a small number of facilities, with metal processing and the burning of fuel for energy supply responsible for the greatest environmental pressures.[3] The vaporized metal produced by the heat of the welding process in metal fabrication oxidises to produce fumes containing particles of metal oxide such as aluminium, cadmium, chromium, and copper.[4] The health effects of welding fume can vary considerably as they are dependent on the exact composition of metals involved in the weld, composition of the electrode, fluxes and the cleaning agents used. Workers deal with great percentage of health injuries when they are exposed to the toxic gases and fumes.[5] The effects on health may be acute (occurring following short-term inhalation of various gas and smoke) or chronic (long-term effects).The toxic gases and fumes may not affect the workers' health in short period of time but long exposure to the toxic gases and fumes tends to cause serious health damage. Each type of fumes and the toxic gases has its own concentration to affect the workers health and give different health effect. The major toxic gases associated with welding are classified as primary pulmonary and non pulmonary.[6] Welding fume particles are comprised of a large proportion of nano-particles. In fact, most of the fumes and gases are smaller than one micrometer. At this size, the particles penetrate deep into the respiratory tract (they can reach the narrowest branches of the respiratory organs).[7] Renal toxicity may be caused by acute and subacute exposure to toxic elements. A number of toxic elements, as well as dust, fumes, and gases, are found in the working environments.[8]

The kidneys are a pair of bean-shaped organs present in all vertebrates. The kidneys play a vital role in the excretion of waste products and toxins such as urea, creatinine and uric acid, regulation of extracellular fluid volume, serum osmolality and electrolyte concentrations, as well as the production of hormones like erythropoietin and 1,25 dihydroxyvitamin D and renin.[9] They also help in regulating blood pressure among other functions.[10] Assessment of renal function is important in the management of patients with kidney disease or pathologies affecting renal function. Tests of renal function have utility in identifying the presence of renal disease, monitoring the response of kidneys to treatment, and determining the progression of renal disease.[9] Such renal function tests include; Blood urea nitrogen (BUN), Creatinine (blood and/or urine), creatinine clearance. Chronic environmental exposure of toxic elements produces substantial accumulation of Cd and Pb in a number of tissues, notably the liver, kidneys, and bone.[11]

Chronic kidney disease is progressive, and it is characterized by the loss of functional nephrons, and/or structural, molecular and functional changes in nephrons.[12]

As the disease develops, there is reduction in glomerular filtration and failure of the remaining functional nephrons to efficiently eliminate metabolic and toxic wastes from the body. Heavy metals such as Pb, Hg, Ni and As have harmful effects on the kidney, particularly on the proximal tubules, which suggests that the nephron plays an important role in the active transport of heavy metals.[13] Okpogba *et al.* showed an elevated level of Pb, As and Ni in the present study area[14] with alterations on the kidney tissues of chickens exposed to factory effluents in this area.[15] Tasneem *et al*. Observed a higher level of Pb in biological samples of metal factory workers than in the control subjects and Pb was associated with significantly reduced eGFR and increased serum creatinine[8] and this is an indication that lead alters renal function.[16-18] However, some occupational studies found that Pb exposure was associated with decreased creatinine concentration.[19,20] In the same vein, Anna *et al*. found out that the mean Pb levels were approximately 30-fold lower than occupational exposure levels.[21] Thus, this cross sectional study assessed the renal function status in occupationally exposed people working in metal fabricating factory in Nnewi South Eastern Nigeria.

Materials and Methods

Study design

This is a cross-sectional study designed to assess the renal function parameters in the blood of metal fabricating factory workers in Nnewi, Anambra State South eastern Nigeria.

A total of fifteen (15) apparently healthy individuals in the exposed group (metal fabricating factory workers) aged between 19 and 56 years were recruited for the study. The exposed group comprised workers from metal fabricating factory who were constantly being exposed to effluents from the factory. The control groups were made up of two (2) sets: The first set was made up of thirty-nine (39) staff and undergraduate students of the College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus whose residential homes were at least 5-10 km from the factory sites, while the second set was made up of forty (40) staff and undergraduate students of the Faculty of Medicine, Madonna University, Elele. They were aged between 18 and 44 years. Informed consent was obtained from all individuals after being educated on the benefit of the study and completing of a structured questionnaire. Thereafter, 5ml of venous blood sample was collected from each individual for the evaluation of biochemical parameters.

Estimation of serum creatinine level

Serum creatinine level was assayed using Jaffe-Slot Alkaline Picric Acid Method as described by Laron.[22]

Estimation of serum urea

Estimation of serum urea level was done using Berthlot Method as described by Ochei and Kolhatkar.[23]

Determination of electrolyte profile levels

Estimation of electrolyte (sodium, potassium, chloride and bicarbonate) profile levels was done using Ion Selective Electrode (ISE) Method.

Inclusion criteria

Apparently healthy individuals aged between 19 and 56 years who are exposed to cable manufacturing factory effluents and control individual (non-exposed groups) were included in this study.

Exclusion criteria

Individuals of any known kidney disease, alcoholics and smokers as well as those outside the age limits were excluded from the study.

Ethical consideration

Ethical approval for this study was sought and obtained from Ethical Committee, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria (NAUTH/CS/66/Vol.2/149).

Statistical analysis

The data were presented as mean±SEM and the mean values of the control and test group were compared by Students t-test and Pearson's bivariate correlation coefficient using Statistical package for social sciences (SPSS) (Version 16) software. A $P<0.05$ was considered as significant.

Results

The urea concentration of control N subjects (5.32±0.09) was significantly elevated ($p<0.05$) compared with control E subjects (2.17±0.04) while the creatinine level of control N subjects (75.59±1.48) was higher than control E though non- significantly ($p>0.05$). The urea/creatinine ratio (U/C ratio) of control N subjects (70.70±32) was significantly elevated ($p<0.05$) compared to control E subjects (32.57±0.86) (Table 1).

The sodium ion (Na^+) level of the metal fabricating (136.53±0.93) factory workers were significantly elevated ($p<0.05$) compared to that of control N subjects (122.87±0.78). The K^+ level of the metal fabricating (4.10±0.25) factory workers were significantly elevated ($p<0.05$) compared to control N subjects (3.28±0.04), but the Cl^- level of metal fabricating (88.11±9.33) factory workers were significantly reduced ($p<0.05$). Also, the bicarbonate ion (HCO_3^-) concentrations in the metal fabricating (22.47±2.44) factory workers were significantly reduced ($p<0.05$) compared to the control subjects (26.73±0.20) (Table 1).

The urea concentration of metal fabricating (4.84±0.30) factory workers were reduced but not significantly ($p>0.05$) when compared to control N (5.32±0.09) subjects, however, they were significantly elevated ($p<0.05$) compared with control E (2.17±0.04) subjects. Creatinine concentration was significantly elevated ($p<0.05$) in metal fabricating factory workers compared with control N (75.59±1.48). However,

there was elevated U/C ratio in metal fabricating factory workers compared with control E (32.57±0.86) subjects (Table 1).

Table 1: Kidney function status of metal fabricating factory workers

Factory	Na^+ ion (mmol/L)	K^+ ion (mmol/L)	Cl^- ion (mmol/L)	HCO_3^- ion (mmol/L)	Urea (mmol/L)	Creatinine (µmol/L)	U/C ratio
N (n=39)	122.87±0.78^a	3.28±0.04^a	99.25±0.18^b	26.73±0.20^b	5.32±0.09^c	75.59±1.48^{bc}	70.70±0.66^b
E (n=40)	N/A	N/A	N/A	N/A	2.17±0.04^a	67.71±1.23^{ab}	32.57±0.86^a
M(n=15)	136.53±0.93^c	4.10±0.25^b	88.11±9.33^a	22.47±2.44^a	4.84±0.30^c	93.11±7.99^d	57.22±6.27^b

*Values are in mean (±SEM); within the column, mean with different superscripts are statistically significant ($p<0.05$).

Key: **N**: Control subjects from Nnewi, **E**: Control subjects from Elele, **M**: Workers from metal fabricating factory, **U/C ratio**: Urea/Creatinine ratio, **N/A**: Not Analyzed

In the metal fabricating factory (Table 2), there was a significant elevation ($p<0.05$) of Na^+ in the factory workers with the highest at the 51-60 age group while K^+ was elevated in the factory workers but only significantly ($p<0.05$) at the 41-50yrs age group. There was no significant difference ($p>0.05$) between the Cl^- levels and the control group while HCO_3^- was significantly decreased significantly ($p<0.05$) in the 41-50 and 51-60yrs age groups. Urea level was significantly reduced ($p<0.05$) in all the age groups while creatinine levels generally elevated but significantly at the 18-30yrs age group while creatinine level was significantly elevated at the 18-30yrs age group. U/C ratio was reduced in all the age groups but significantly ($p<0.05$) at the 18-30 yrs age group. The regression of these parameters with age (Fig. 1) showed that except for HCO_3^- (r=-0.567; p=0.028) which correlated negatively with age significantly ($p<0.05$) and creatinine (r=-0.271; p=0.328) not significant ($p>0.05$), Na^+ (r=0.223; p=0.425), K^+ (r=0.191; p=0.494), Cl^- (r=0.039; p=0.891), urea (r=0.331; p=0.228) and U/C ratio (r=0.413; p=0.126) were positively correlated.

Table 3 presents the effect of LOS on the kidney function status of metal fabricating factory workers with the regression analyses in Fig. 2. Sodium ion was significantly elevated in all the factory age groups with the highest in the 6-10yrs LOS group while K^+ generally was elevated but significantly ($p<0.05$) in the 11-15 and 16-20yrs LOS groups. There was no significant difference ($p>0.05$) between the Cl^-, urea and creatinine levels and their controls. Bicarbonate ion concentration was significantly reduced ($p<0.05$) in the 6-10, 11-15 and 16-20yrs LOS groups while U/C ratio was reduced significantly in the 0-5yrs LOS group compared to the control subjects. While creatinine (r=-0.267; p=0.328) correlated negatively with age, other electrolytes were not significantly ($p>0.05$) correlated. On the other hand, there was no significant ($p>0.05$) correlation between all the parameters and LOS as Na^+ (r=-0.026), HCO_3^- (r=-0.478; p=0.072)and creatinine were negatively correlated while K^+ (r=0.380; p=0.162), Cl^- (r=0.066; p=0.816), urea (r=0.347; p=0.205) and U/C ratio (r=0.474; p=0.074) were positively correlated.

Table 2: Effect of age on kidney function status of metal fabricating factory workers

Age group	Na^+ (mmol/L)	K^+ (mmol/L)	Cl^- (mmol/L)	HCO_3^- (mmol/L)	Urea (mmol/L)	Creatinine (µmol/L)	U/C ratio
N (n=39)	122.87±0.78^a	3.28±0.04^a	99.25±0.18^a	26.73±0.20^{bc}	5.32±0.09^b	75.59±1.48^a	70.70±0.66^b
18-30yrs (n=5)	136.00 ±1.41^b	3.96±0.52^{ab}	77.80±12.68^a	29.80±4.71^c	4.48±0.54^a	104.31±13.8^b	45.38±7.63^a
31-40yrs (n=3)	136.33 ±2.73^b	4.17±0.93^{ab}	90.00±32.72^a	21.67±4.70^{ab}	4.48±0.58^a	82.51±12.84^{ab}	55.09±0.01^{ab}
41-50yrs (n=5)	136.20 ±1 .98^b	4.28±0.37^b	103.20±18.15^a	16.60±2.91^a	5.18±0.65^a	91.94±18.88^{ab}	67.21±16.53^b
51-60yrs (n=2)	139.00 ±1.00^b	3.90±0.20^{ab}	75.50±5.50^a	20.00±2.00^a	5.40±0.26^a	83.98±13.26^{ab}	65.41±7.37^b

Values in mean (±SEM); within column, means with different superscripts are statistically significant ($p<0.05$)

Key: **N:** Control subjects, **U/C ratio**: Urea/Creatinine ratio

Table 3: Effect of LOS on the kidney function status of metal fabricating factory workers

LOS group	Na^+ (mmol/L)	K^+ (mmol/L)	Cl^- (mmol/L)	HCO_3^- (mmol/L)	Urea (mmol/L)	Creatinine (µmol/L)	U/C ratio
N (n=39)	122.87±0.78^a	3.28±0.04^a	99.25±0.18^a	26.73±0.20^b	5.32±0.09^a	75.59±1.48^a	70.70±0.66^b
0-5yrs (n=6)	136.67±1.33^b	3.95±0.43^{ab}	90.00±16.00^a	30.00±3.84^b	4.29±0.48^a	97.24±13.30^a	46.76±6.38^a
6-10yrs (n=2)	137.50±2.50^b	3.75±0.35^a	74.00±4.00^a	17.50±4.50^a	4.90±0.25^a	92.82±22.10^a	56.61±16.16^{ab}
11-15yrs (n=3)	136.00±2.52^b	4.47±0.72^b	76.00±4.51^a	16.00±2.00^a	5.87±0.49^a	109.03±21.25^a	56.00±5.69^{ab}
16-20yrs (n=4)	136.14±1.62^b	4.23±0.56^b	102.50±27.02^a	18.50±3.18^a	4.84±064^a	75.14±13.74^a	74.31±19.31^b

Values are in mean (±SEM); within column, means with different superscripts are statistically significant ($p<0.05$)

Key: N: Control subjects, **LOS**: Length of service, **U/C ratio**: Urea/Creatinine ratio

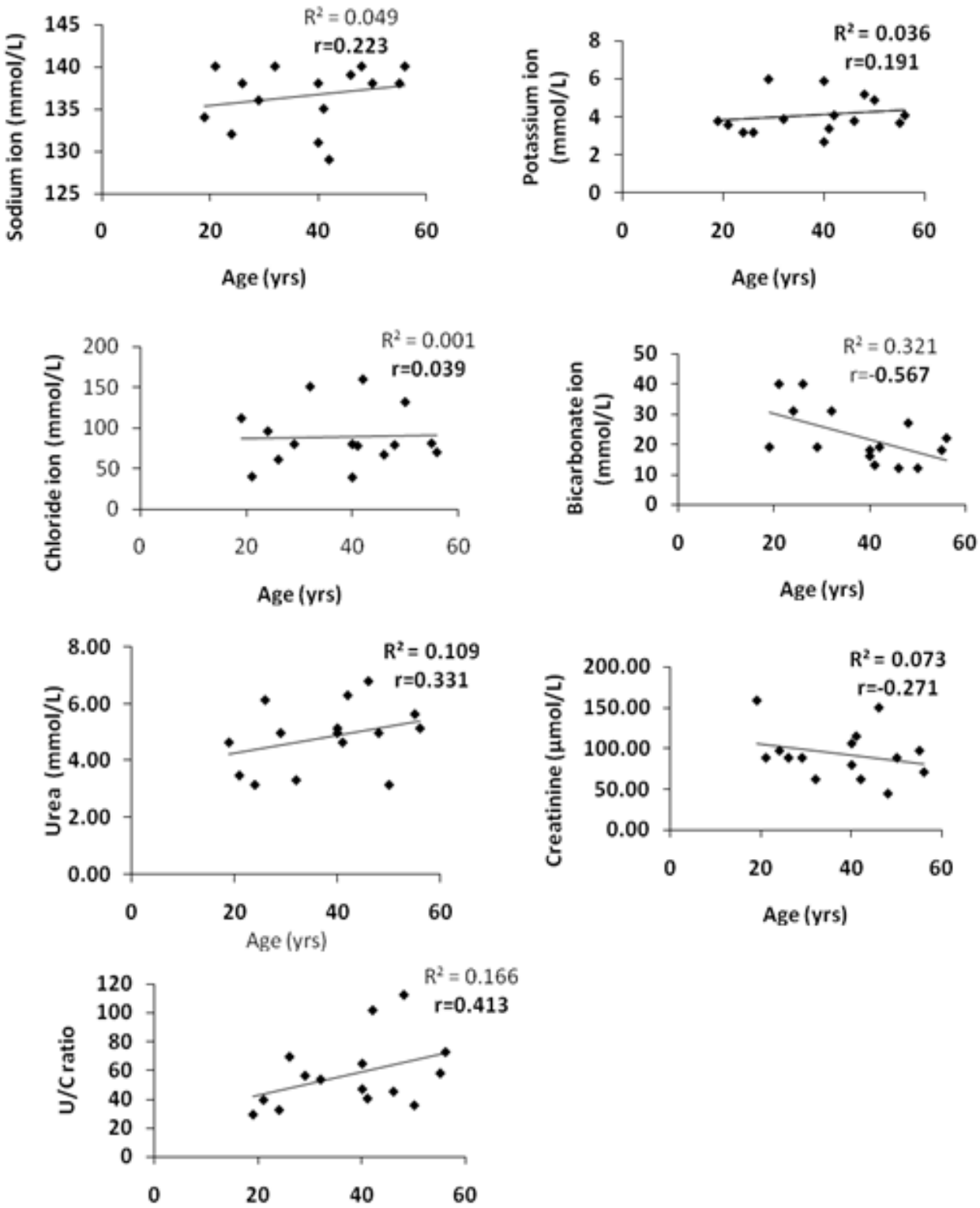

Fig. 1: Regresion of kidney function status of metal fabricating factory workers with age

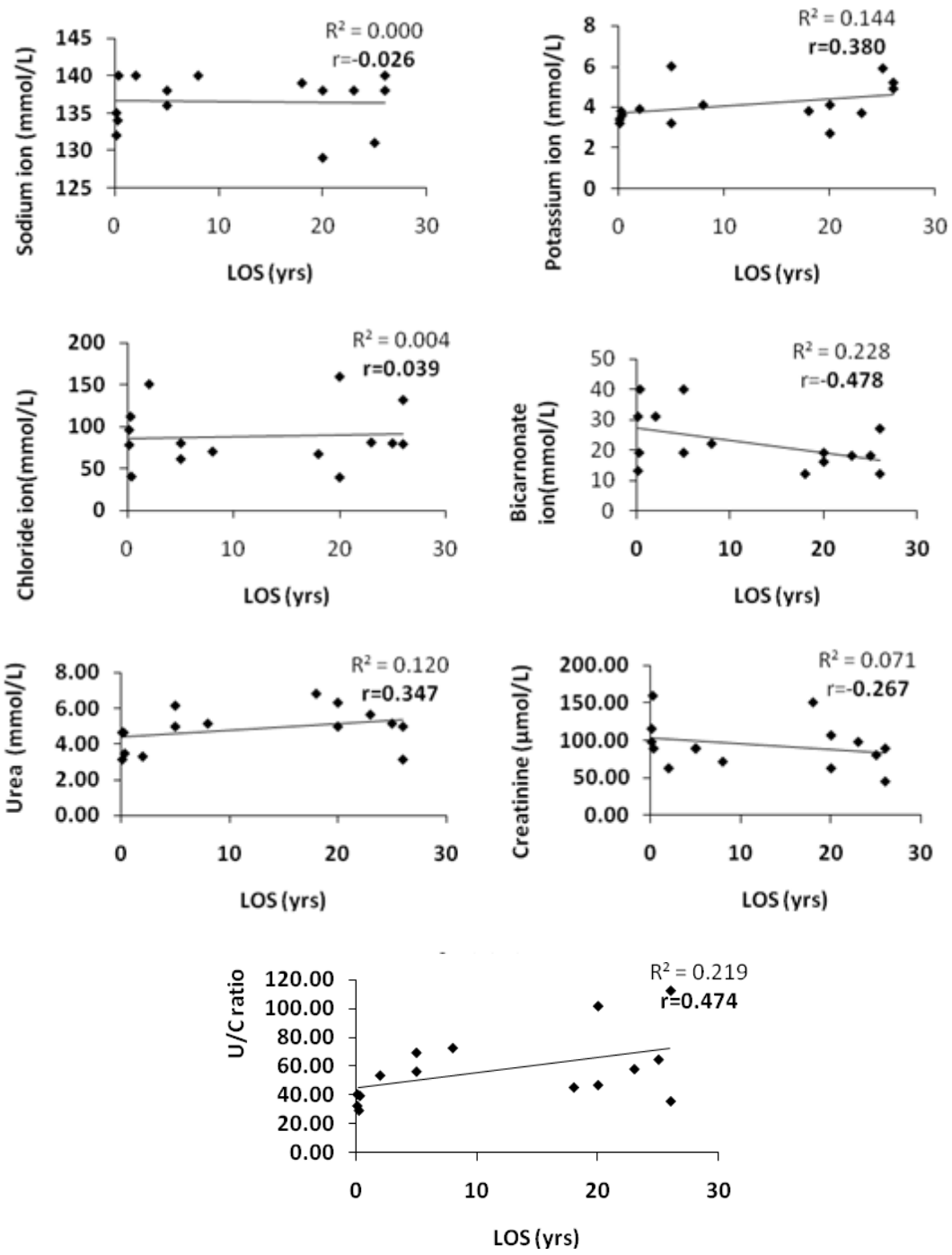

Fig. 2: Regression of kidney function status of metal fabricating factory with LOS 3.1.6.4

Discussion

Heavy metal contamination and exposure in work environment is an issue of great public health implication. Heavy metals with adverse health effects in human metabolism such as lead, cadmium, and mercury present obvious concerns due to their persistence in the environment.[24-26] Acute heavy metal intoxications may damage central nervous function, the cardiovascular and gastrointestinal systems, lungs, kidneys, liver, endocrine glands, and bones.[27] Chronic heavy metal exposure has been implicated in several degenerative diseases of these same systems and may increase the risk of some cancers.[28] The current study investigated the renal function status in occupationally exposed people working in metal fabricating factory in Nnewi South Eastern Nigeria.

In this study, the sodium (Na^+) and potassium (K^+) ion level of the metal fabricating factory workers were significantly elevated ($p<0.05$) compared to that of control

subjects respectively whereas the Cl^- and bicarbonate ion (HCO_3^-) concentrations in the metal fabricating factory workers were significantly reduced ($p<0.05$) compared to the control subjects respectively.

This is in line with the work of Onuegbu *et al.* on the renal indices of people occupationally exposed to lead.[29] It, however, disagrees with the work of Babalola and Babajide,[30] although they reported a significant increase in lead in a group of industrial workers in Ewekoro, Abeokuta granite industry, there was no difference in the sodium and potassium ions of the workers. The elevated sodium ion concentration observed in the serum of the factory workers obtained in this study may have arisen from water loss which is due to inappropriate regulation of osmolarity occasionally due to renal or hepatic disease or prolonged sweating without access to water. As for increased potassium ions observed in the metal fabricating factory workers, it may have been due to the inability of the kidneys to excrete ingested potassium probably due to dehydration.[31] On the other hand, the decrease in bicarbonate level may be indicative of a metabolic condition termed metabolic acidosis; a condition which occurs as a result of an increased production of hydrogen ions by the body or due to the inability of the body to form bicarbonate in the kidney. Metabolic acidosis may result from diabetic ketoacidosis, lactic acidosis, kidney disease, or ingestion of toxins such as methanol, ethanol, ethylene glycol etc.[32] This present finding agrees with the work of Okpogba *et al.* on the assessment of kidney function status in chickens (*Gallus gallus domestica*) in rural (Elele) and urban (Nnewi) areas in which they documented a decreased bicarbonate and chloride levels in factory chicken compared to control birds.[33]

The urea concentration of metal fabricating (4.84±0.30) factory workers were reduced but not significantly ($p>0.05$) when compared to control N (5.32±0.09) subjects, however, they were significantly elevated ($p<0.05$) compared with control E (2.17±0.04) subjects. Creatinine concentration was significantly elevated ($p<0.05$) in metal fabricating factory workers compared with control N. Higher than normal levels of urea and creatinine are indications of renal dysfunction.[34] The increased concentration of both urea and creatinine in the metal fabricating factory workers is an indication of a dysfunctional or compromised kidney function which may progress overtime to chronic kidney disease. This is not in keeping with the previous study of Okpogba *et al*.[33] but it agrees with the work of Amah *et al.* on the nephrotoxic effect of lead exposure among automobile repairers which revealed similar findings.[35]

Furthermore, In the metal fabricating factory, there was a significant elevation ($p<0.05$) of Na^+ in the factory workers with the highest at the 51-60 age group while K^+ was elevated in the factory workers but only significantly ($p<0.05$) at the 41-50yrs age group. Also, there was no significant difference ($p>0.05$) between the Cl^- levels and the control group while HCO_3^- was significantly decreased significantly ($p<0.05$) in the 41-50 and 51-60yrs age groups. Urea level was significantly reduced ($p<0.05$) in all the age groups while creatinine levels generally elevated but significantly at the 18-30yrs age group. This implies that age affects these parameters and hence consideration of the age of individuals should be made while interpreting results for clinical purposes.

However, sodium ion was significantly elevated in all the factory age groups with the highest in the 6-10yrs LOS group while K^+ generally was elevated but significantly ($p<0.05$) in the 11-15 and 16-20yrs LOS groups. There was no significant difference ($p>0.05$) between the Cl^-, urea and creatinine levels and their controls. Bicarbonate ion concentration was significantly reduced ($p<0.05$) in the 6-10, 11-15 and 16-20yrs LOS groups while U/C ratio was reduced significantly in the 0-5yrs LOS group compared to the control subjects. This goes to show that the duration of exposure to heavy metal contamination in work place is important in assessing the degree of potential damage caused by heavy metal exposure. Finally, no significant correlations were observed in parameters studied.

Conclusion

The current study showed significantly elevated levels of sodium, potassium, urea and creatinine and significantly reduced concentration of both bicarbonate and chloride ion in the persons exposed to heavy metals in the metal fabricating factory in Nnewi. Thus, revealing the deleterious effect of heavy metal exposure at the work place on the functionality of the kidneys.

Source of Funding

None.

Conflict of Interest

None.

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