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Alterations in Whole Blood Count Parameters and Some Inflammatory Biomarkers of Occupationally Exposed Metal Recyclers: A Case-Control Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Metal recycling is an integral industry contributing significantly to sustainable resource management. However, metal recyclers are exposed to various occupational hazards, such as metal fumes and dust, which may impact their health. This study investigates the alterations in full blood count parameters and some inflammatory biomarkers in metal recyclers.
Method: Fifty (50) participants were enrolled from Benin City, south-south Nigeria; consisting of thirty (30) male metal recyclers matched with twenty (20) unexposed participants (control). Full blood count parameters such as hemoglobin concentration, white blood cell count, red blood cell count, platelet count, red cell indices, hematocrit, and red cell distribution width were determined using standard methods, the neutrophil-lymphocyte ratio was calculated from the full blood count parameters and high sensitivity C-reactive protein was analyzed using enzyme-linked immunosorbent assay (ELISA).
Results: Results obtained from this study showed a significant increase in the white blood cell count of exposed participants (7.17± 1.80×10 ^{3}µl) compared with control (5.08± 1.45×10^{3}µl) ($p< 0.001$). Platelet count was significantly elevated ($p< 0.048$) in the exposed group (248.73±129.13×10^{3}µl) compared to the control group (186.85± 53.29×10^{3}µl). Lymphocyte level was significantly reduced in the exposed group (43.10± 8.59%) compared to the control group (50.87± 8.69%) ($p< 0.05$). The red cell distribution width was significantly reduced in the exposed group (41.67± 5.10µm^{3}) compared to the control group (44.66 ± 5.16µm^{3}) ($p< 0.05$). The hs – C-reactive protein was significantly increased in the exposed group (9.73± 10.35µg/ml) compared to the control group (2.46±1.16µg/ml) ($p< 0.05$).
Conclusion: This study concludes that occupational exposure to metal recycling causes a significant increase in white blood cell count, platelet count, and high-sensitivity C-reactive protein and a significant decrease in lymphocytes and red cell distribution width of metal recyclers.

Keywords: Recycling; metals; full blood count; inflammatory biomarkers.

1. INTRODUCTION

To minimize the demand for newly mined ores and protect natural resources, metal recycling is an approach that renders it easier to recycle, reuse, or remanufacture metal materials. The United Nations and the European Union (EU) have set sustainable development goals, and achieving these goals includes recycling metal from waste streams, as doing so ensures a future supply of rare earth elements and valuable metals (Bruno et al., 2021).

Processes involved in metal recycling include sorting, separating, and grinding/shredding, and depending on the concentration, chemical composition, and particle size, this process will produce several sorts of emissions that are sources of toxic metals (Leung et al., 2008; Raun et al., 2013; Lau et al., 2014; Julander et al., 2014; Ceballos et al., 2020; Simonetti et al., 2022; Sonego et al., 2022).

According to several studies (Raun et al., 2013; Sepulveda et al., 2010; Purchase et al., 2020; Al-Ghamdi, 2011) metal scrap and waste from electrical and electronic devices contain poisonous and allergenic metals that, when mechanically treated, could produce airborne emissions that could be harmful to both the environment and occupationally exposed workers.

Occupational exposure to specific hazards occurs when a condition or disease is more prevalent in a particular group of workers than in the general population (Anetor et al., 2005; Hirsch & Watkins, 2020) Researchers have developed and employed biomarkers which are quantifiable signs of a biological condition or state to improve the diagnosis of various disorders, assess their risks, and select the most effective treatment. Blood, serum, urine, or soft tissues are frequently used to measure and evaluate biomarkers (Khalid et al., 2016).

In cases of metal toxicity, hematological markers are frequently utilized to assess health status (Pepys & Hirschfield, 2003). Heavy metal toxicity to bone marrow precursors causes cell division, maturation-related enzyme inhibition, red blood cell transport impairment, and immune-mediated cell division, all of which can cause harm to the haematopoetic system (Massanyi et al., 2014).

Evidence from animal research has shown that high concentrations of lead, cadmium, and

chromium have been linked to changes in several red blood cell parameters (Nikolić et al., 2015; Kovacik et al., 2017; Han et al., 2015; Ali et al., 2021; Dyatlov & Lawrence, 2002).

According to reports, lead exposure has an impact on lymphocyte function, cellular immunity, humoral immune response, host resistance, and cytokine generation. Therefore, it was assumed that a considerable drop in lymphocytes might be caused by exposure to lead fumes at work (Mccabe & Berthiaume, 1999; Jarup & Akesson, 2009).

The heavy metal cadmium is recognized to be poisonous, and to be a powerful inflammatory trigger. According to (Olszowski et al., 2012), cadmium is a known environmental pollutant that is also a health concern for the general public. Cadmium has been shown to activate several intercellular signaling pathways in immune cells, and cause upregulation of inflammatory markers and mediators in micromolar concentrations (Kataranovski et al., 2009). Cadmium may also induce acute and/or chronic inflammatory responses in cardiac tissue, liver, lung, and the reproductive system, potentially resulting in tissue damage and even systemic inflammatory responses (Kataranovski et al., 2009; Li et al., 2017).

Hs-c reactive is a protein mostly produced in the liver by hepatocytes and released into the plasma (Volanakis & Wirtz, 1979). By interacting with the humoral and cellular inflammatory effector systems, it can start the process of eliminating the targeted cells (Clyne & Olshaker, 1999). It serves as a tool for detecting inflammation, a sign of disease activity, and an aid in diagnosis (Nguyen et al., 2021).

There have been some controversies regarding the relationship between hs crp levels, and metals as some studies have been linked to a positive relationship between them, where heavy metals were found to be associated with an increased cardiovascular risk, which ultimately led to an increase in the hs crp of the individuals (Song et al., 2021). Whereas in a study carried out by (Huang et al., 2020) on Blood lead, cadmium and mercury about homocysteine and C-reactive protein in women of reproductive age, hs crp was found to be negatively associated to the cadmium and lead levels.

The neutrophil-lymphocyte ratio (NLR) is another inflammatory biomarker that is calculated as a simple ratio between the lymphocyte and neutrophil counts measured in peripheral blood. It conjugates two phases of the immune system, the innate immune system and the adaptive immune system (Pollack et al., 2017).

Aim: This study aimed to investigate the alterations in whole blood count parameters and certain inflammatory biomarkers among metal recyclers in Benin City, Nigeria who are occupationally exposed to metals. The study sought to determine if prolonged exposure to metal dust, fumes, and other hazardous substances in the recycling environments results in significant changes in blood composition and inflammatory responses. Potentially indicating an increased risk of adverse health outcomes in this workforce. Specifically, we analyzed differences in full blood count parameters such as hemoglobin, white blood cell count, and platelet count, alongside inflammatory markers including C-reactive protein and interleukins comparing metal recyclers with a control group to such occupational hazards.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in metal recycling workshops around Oredo, Ikpoba-okah, and Ovia North-East local government Areas in the metropolitan city of Benin, Edo state, Nigeria. Edo state has an estimated population of 1,147,166 according to the 2006 general census. She is bounded to the Northeast by Kogi state, to the east by Anambra, to the southeast by delta, and to the west by Ondo state.

2.2 Research Design

This was a case-control study of occupationally exposed metal recyclers working in metal recycling industries in the Benin metropolis, and was matched with apparently healthy nonexposed participants**.**

2.3 Inclusion Criteria

Male metal recyclers between the ages of 18 and 60 years carrying out informal (primitive) metal recycling without any history of chronic ailment, who have been occupationally exposed to metal recycling.

2.4 Exclusion Criteria

Subjects with a history of any form of cancer, tobacco smoking, and alcoholism were excluded from the study, and individuals below 18 years and above 60 years of age.

2.5 Collection of Blood Samples

4.5 ml of blood was collected from all the participants in a potassium Ethylene Diamine Tetra acetic acid (K3 EDTA) plain container. The sample in the plain container was separated into serum using the centrifuge and the sample in the EDTA container was used for full blood count and metal analysis.

2.6 Determination of Full Blood Count

Full blood count was analyzed immediately after collection using the SYSMEX KX-1N hematology analyzer. Calibration and standardization of the equipment, processing, and analysis were done strictly according to the manufacturer's instructions.

2.7 High sensitivity-C- reactive Protein (hs-CRP)

HS-CRP analysis was analyzed using the Accu-bind enzyme-linked immunoassay (ELISA) microwells with product code 3125-300.

2.8 Neutrophil-lymphocyte Ratio

The neutrophil-lymphocyte ratio was calculated by dividing the absolute neutrophil by the absolute lymphocyte.

$$Neutrophil\ lymphocyte\ ratio\ (NLR) = \frac{Absolute\ neutrophil}{Absolute\ lymphocyte}$$

2.9 Statistical Analysis

This was carried out with the aid of Statistical Package for Social Sciences (SPSS) version 21. The mean, standard deviation, and correlation coefficient were determined using this package.

3. RESULTS

The study aimed to investigate the alterations in full blood count parameters and inflammatory biomarkers among metal recyclers in Benin City, Nigeria. The findings revealed significant differences between the exposed group and control group, indicating that occupational exposure to metals has a profound impact on hematological and inflammatory profiles. Specifically, the study found a marked increase in white blood cell counts and platelet levels among metal resellers, alongside a notable decrease in lymphocyte percentage. These alterations suggest an inflammatory response potentially linked to exposure to metal fumes and dust, highlighting the need for ongoing health monitoring and protective measures for individuals working in this industry.

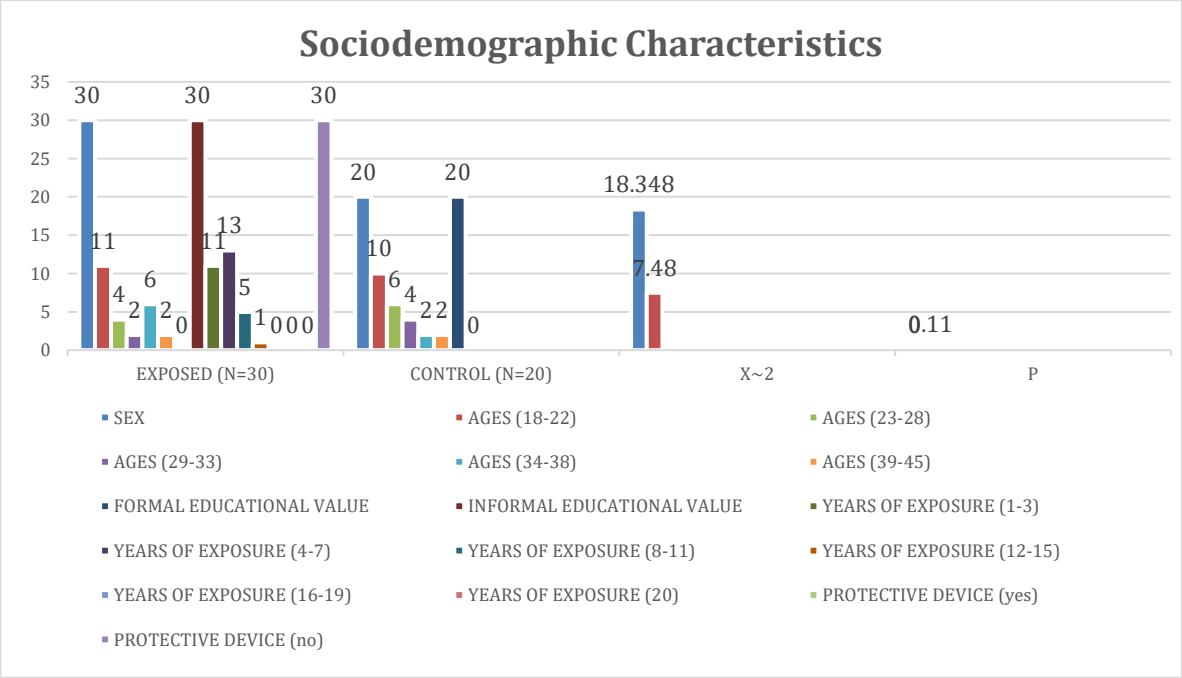

Fig. 1. Sociodemographic Characteristics

Table 1. Mean Comparison of Full Blood Count Parameters of Exposed and Control Subjects

Parameters	Metal recyclers	Control	t	P Value
WBC x 10^3µl	7.17 ±1.80	5.08 ± 1.45	4.344	0.000
Lymphocytes LYM%	43.10 ± 8.59	50.87 ±8.69	-3.119	0.003
Monocytes MON%	10.70± 7.62	7.96 ± 3.42	1.508	0.138
Eosinophil EOS%	3.68 ± 0.78	3.46 ± 0.89	0.913	0.366
Basophil BAS%	0.89 ± 0.49	0.87 ± 0.44	0.147	0.884
Neutrophil NEU%	41.15 ±11.27	45.79 ± 9.26	-1.526	0.134
Haemoglobin HGB g/dl	13.81±1.12	13.89±1.81	0.175	0.862
Red blood cell RBC × 10^6µL	4.74 ± 0.66	5.01 ± 0.81	0.147	0.884
MCH Pg.	31.25 ± 8.67	27.89 ± 2.20	1.69	0.097
MCHC g/dl	33.79 ± 2.02	34.47 ±1.01	-1.382	0.173
MCV µm^3	2.29±11.58	78.32±11.83	0.176	0.245
Haematocrit HCT %	40.68±3.33	44.66±5.16	0.350	0.728
RDWS%	41.67±5.10	44.66±5.16	2.024	0.048
Platelet PLT × 10^3µL	248.73±129.13	186.85±53.29	2.026	0.048

Values are shown in Mean ± SD, p<0.05 signifies statistical significance. MCV= Mean cell volume, MCHC= Mean cell hemoglobin concentration, MCH= Mean cell hemoglobin, RDWS= Red cell distribution width

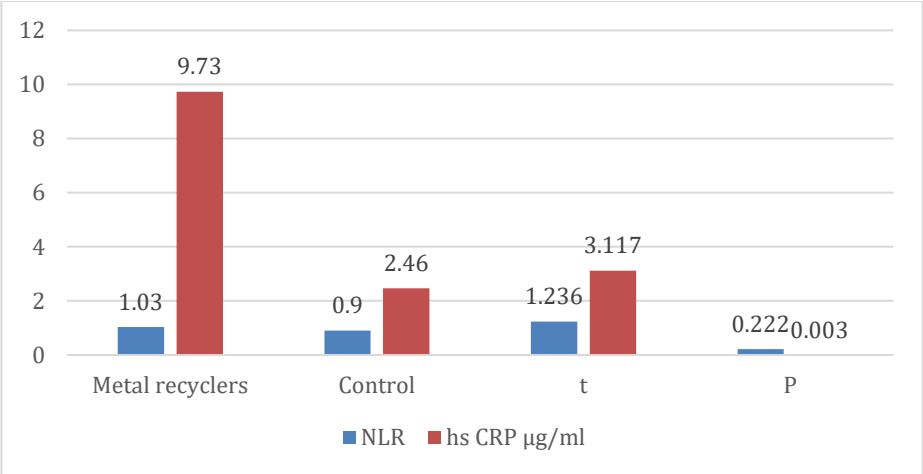

Fig. 2. Mean Comparison of Inflammatory Markers of Exposed and Control Subject

Values are shown in Mean ± SD, p<0.05 signifies statistical significance

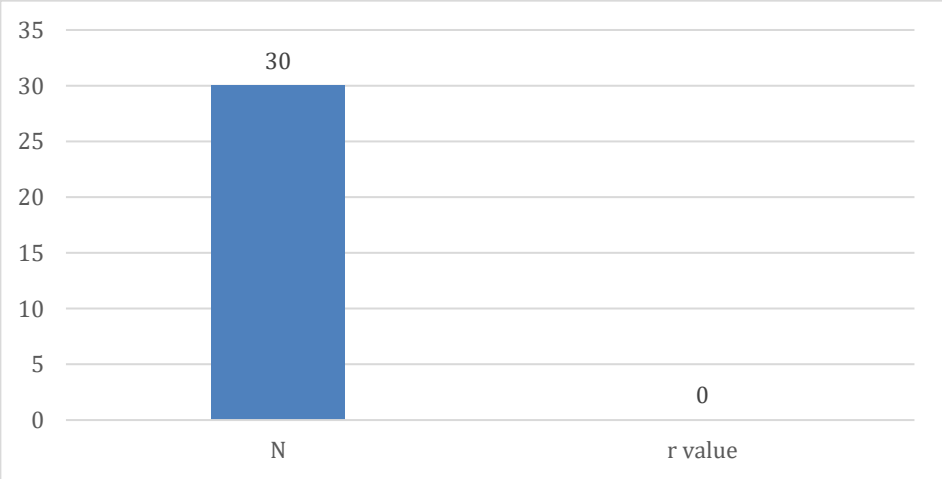

Fig. 3. Correlation Between hs-C-reactive protein and Neutrophil Lymphocyte Ratio of the exposed group

r value = coefficient of significance, n sample size

Fig. 3 shows the correlation between hs C-reactive protein and neutrophil lymphocyte ratio (r=.796). There was a positive correlation between hs-C-reactive protein and neutrophil-lymphocyte ratio.

4. DISCUSSION

Concerns regarding ambient air pollution levels have been raised by the discovery of metal recycling emissions as sources of toxic metals on a local and regional scale (Raun et al., 2013; Lau et al., 2014; Gangwar et al., 2019; Farkhondeh et al., 2014). Metal recyclers are exposed to different metals that are carcinogenic and are listed as restricted hazardous substances in waste of electronic and electrical equipment (WEEE). This present study investigates alterations in full blood count parameters and some inflammatory biomarkers of occupationally exposed metal recyclers. In this study, it was observed that metal recyclers are exposed to toxic metals particularly due to the occupational lifestyle of the primitive metal recyclers who work with near-zero safety. The result showed that the test participants who are occupationally exposed to metal recycling had an increased white blood cell count (WBC) compared to the control participants, this was in accordance with a study carried out by Gangwar et al., (2019) on the association and interactions between heavy metals with white blood cell count and eosinophil count. Additionally, Clara et al. (2022) demonstrated the utility of complete blood count (CBC) parameters as inflammatory biomarkers in patients with colorectal cancers, suggesting that similar mechanisms may be at play in occupational settings where exposure to toxic metals occurs.

The white blood cell count was seen elevated in the test group than in the control group and there was a correlation between the elevated white blood cell count and a high concentration of lead in the blood. (Thompson et al., 1988) also investigated immune reactions to different concentrations of Lead (Pb) exposure in guinea pigs, and in this study the guinea pigs inhaled 0.1m, 0.2m, and 0.4m of aerosol Lead (Pb) for 1 hour, twice a week, after which blood samples were collected and analyzed. The results showed elevated levels of total white blood cell count supporting the proinflammatory effect of Lead (Pb) poisoning (Thompson et al., 1988).

The lymphocyte level in the test participants was significantly lower than the lymphocytes in the control participants. Research has shown that lead exposure has an impact on lymphocyte function, cellular immunity, humoral immune response, host resistance, and cytokine generation. Therefore, it was assumed that a considerable drop in lymphocytes might be caused by exposure to lead fumes at work. (Mccabe & Berthiaume, 1999; Jarup & Akesson, 2009). Moreover, the reduction in lymphocyte levels observed in our study is consistent with findings from Foroutan et al. (2022), who reported alterations in blood cell parameters among diabetic patients, indicating that chronic exposure to harmful substances can compromise immune function. This is particularly concerning for metal recyclers, as a weakened immune response may increase susceptibility to infections and other health complications.

According to Peter et al. (2021), the red cell distribution width (RDW) is a quantitative measure of the consistency in the size of circulating erythrocytes, such that higher red cell distribution width (RDW) reflects greater variability in the size of red blood cells. It is interesting to note that this study had a significantly reduced red cell distribution width (RDW) ($p<0.05$) compared to our controls. This study is not in agreement with previous studies carried out by Loprinzi & Hall, (2015) on the association of cadmium and lead exposure with red cell distribution width. The red cell distribution width may be reduced as a result of the physical activities metal recyclers go through due to their demanding job compared to individuals with sedentary lifestyles. This is in accordance with the work of (Sonmez & Sonmez, 2017) where an increase in physical activity was inversely related to the red cell distribution width.

Platelet value was significantly increased in the test group compared to the control. This is in agreement with the work of (Sonmez & Sonmez, 2017) where platelets were found to have a significant role in modulating clot formation and also considerable roles in inflammation and immune response. Platelets gather at the damaged site and adhere to white blood cells. Subsequently, they release cytokines and chemokines which are chemotactic for neutrophils and monocytes. These interactions result in the formation of platelet granulocyte or platelet leucocyte aggregates which triggers further inflammation. Researchers have shown that exposure to metals and metalloids causes pathological conditions, including immunotoxicity

and inflammation-related diseases (Raun et al., 2013; Shen et al., 2000).

Serum levels of high sensitivity C reactive protein an inflammatory biomarker an inflammatory biomarker was significantly increased in metal recyclers compared with the unexposed population. This is in accordance with the work of (Metryka et al., 2018), where blood lead level was associated with an elevated hs-CRP level, which could be supported by the study of (Mrowicki et al., 2018) where elevated lead level induces oxidative stress and acted on various pathways through specific mediators such as interleukin (IL-6). Another investigation in Nigerian lead-exposed workers found a decreased immune status and significantly raised CRP ($p<0.001$) in response to elevated lead levels (Sirivarasai et al., 2013). The high-sensitivity C-reactive protein (hs-CRP) levels were significantly elevated in the exposed group, reinforcing the notion that metal exposure can lead to chronic inflammation. Lin et al. (2020) highlighted the prognostic value of CBC-based inflammatory scores in cancer patients, suggesting that similar inflammatory markers could serve as indicators of health risks in occupationally exposed populations.

In another study by Gangwar et al. (2019) blood lead levels, cadmium, and mercury were not associated with hs-crp concentrations although this study was carried out in pregnant women.

Neutrophil lymphocyte ratio which is also an inflammatory biomarker as high sensitivity C-reactive protein (hs-C-reactive protein). This may be due to C reactive protein being present in minute quantities in healthy individuals which increases quickly in inflammation within a few hours and decreases when the inflammation subsides (Khan et al., 2008) However, in this present study, a positive correlation was found between the neutrophil-lymphocyte ratio and hs C-reactive protein of the exposed metal recyclers ($r=.796^*$).

Furthermore, the implications of these findings extend to the potential for using CBC parameters as biomarkers for various health conditions. Araújo et al. (2024) explored the application of CBC in diagnosing preeclampsia, illustrating the versatility of these parameters in different clinical contexts. This suggests that the alterations in blood count parameters observed in metal recyclers could also be indicative of broader health issues that warrant further investigation.

5. CONCLUSION

The significant changes in blood count parameters such as white blood cell count, Lymphocyte count, red blood cell distribution width, platelet count and inflammatory biomarker, and high sensitivity C-reactive protein among metal recyclers highlight the urgent need for monitoring and intervention strategies to mitigate health risks associated with occupational exposure to metals. The study concludes that exposure to toxic metals such as lead and cadmium during the metal recycling process might cause an increase in white blood cell count, platelet count, serum level of high sensitivity C-reactive protein, and a decrease in red blood cell distribution width. Future research should focus on longitudinal studies to better understand the long-term health implications of such exposures and the potential for using CBC parameters as reliable biomarkers in occupational health assessments.

INFORMED CONSENT

Subjects for this study were adults who were adequately briefed on the research protocol and informed consent was obtained before sample collection. The informed consent form used for this study was clearly explained to the participants in English and their native language.

ETHICAL APPROVAL

Approval was obtained from the College of Medical Sciences Ethical Committee of the University of Benin with REC Approval No: CMS/REC/2023/372

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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