

# Clinical Manifestations and Biological Markers of Heavy Metal Exposure Among Automobile Technicians in Kano Metropolis, Northwestern Nigeria

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## ABSTRACT

**Background:** Automobile technicians may experience occupational exposure to multiple heavy metals through routine workshop activities, but the relationship between biological exposure and clinical manifestations remains incompletely characterised in Nigeria. **Aim:** To compare clinical manifestations and biological markers of heavy-metal exposure among automobile technicians and non-occupationally exposed controls in Kano Metropolis, Northwestern Nigeria. **Materials and Methods:** This comparative cross-sectional study included 155 automobile technicians and 155 schoolteachers as the controls. We assessed clinical manifestations using interviewer-administered questionnaires and physical examination. Venous blood samples were analysed for ten heavy metals by atomic absorption spectrophotometry. We analysed data using descriptive statistics, chi-square or Fisher's exact tests, independent-samples t-tests, and multivariate analysis. **Results:** Compared with controls, technicians had higher frequencies of general body pain (56.8% vs 12.9%), recurrent fever (69.0% vs 31.6%), catarrh (75.5% vs 51.6%), and diarrhoea (49.0% vs 30.3%) (all  $p \leq 0.001$ ). Mee's lines (18.7%) and skin hyperpigmentation (72.9%) occurred exclusively among technicians ( $p < 0.001$ ). Laboratory-confirmed heavy-metal exposure was substantially more common among technicians (81.9% vs 39.4%; OR=6.9, 95% CI: 4.1–11.6;  $p < 0.001$ ), with aluminium (69.7%), chromium (59.4%), and nickel (44.5%) most frequently elevated. However, none of the clinical manifestations remained significantly associated with occupational group after adjustment for confounders. **Conclusion:** Automobile technicians in Kano Metropolis demonstrated a substantially greater burden of clinical manifestations and biological evidence of heavy-metal exposure than the controls. The attenuation of clinical associations after adjustment highlights the multifactorial nature of these manifestations and supports the integration of biological monitoring with clinical assessment in occupational health surveillance.

**Keywords:** Automobile technicians, heavy metal exposure, clinical manifestations, biological monitoring, Nigeria

## INTRODUCTION

Occupational exposure to toxic heavy metals remains an important public health concern because of the persistence, bioaccumulative potential, and multisystem toxicity of these elements.<sup>1-4</sup> Unlike many transient workplace hazards, heavy metals can accumulate in biological tissues and cause adverse effects after repeated or prolonged exposure, affecting the neurological, respiratory, gastrointestinal, dermatological, renal, cardiovascular, and hematological systems.<sup>2-4</sup> The occupational burden is particularly relevant in informal and small-scale industries where hazardous materials are handled routinely, and engineering controls, environmental monitoring, and access to occupational health services may be limited. Automobile repair and maintenance constitute an important setting for

occupational heavy metal exposure. Automobile technicians may encounter toxic metals through diverse activities, including battery servicing, spray painting, welding, metal grinding, engine repair, electrical maintenance, and handling of contaminated oils, lubricants, and workshop surfaces.<sup>5-7</sup>

These processes may generate metal-containing fumes, dust, aerosols, and residues that facilitate exposure through inhalation, ingestion, or dermal contact. The heterogeneous nature of automobile repair work also means that technicians may be exposed simultaneously to multiple metals rather than to a single toxicant. Nigerian studies have documented elevated concentrations of heavy metals among automobile and other occupationally

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exposed workers, highlighting the need for improved workplace controls and preventive practices.<sup>8-10</sup> Evidence from other African and Asian settings similarly demonstrates substantial heavy metal exposure among informal automobile workers and associated occupational health concerns.<sup>11-16</sup>

The health effects of heavy metal exposure are complex and may vary by metal, dose, route, and duration of exposure, as well as individual susceptibility.<sup>17-19</sup> Clinically, exposed workers may present with constitutional symptoms such as fatigue and body pain, respiratory complaints, gastrointestinal disturbances, neurological symptoms, and dermatological abnormalities.<sup>17-19</sup> However, many of these manifestations are non-specific and may arise from a broad range of occupational, environmental, infectious, or lifestyle-related conditions. Consequently, their presence does not necessarily establish heavy metal toxicity. Conversely, clinically important internal exposure may occur before overt toxicity becomes apparent. Certain physical findings, including Mee's lines and pigmentation abnormalities, may provide additional clinical clues to chronic toxic-metal exposure. Still, these findings are neither sufficiently sensitive nor specific to serve as standalone indicators of exposure.<sup>20</sup> The absence of classical manifestations should therefore not be interpreted as evidence of the absence of biologically significant exposure.

This distinction is particularly important in occupational health surveillance. Conventional clinical assessment is valuable for identifying symptoms and physical abnormalities, but it may have limited capacity to detect early or subclinical exposure.<sup>20</sup> Human biological monitoring offers a complementary approach by objectively measuring chemicals or their metabolites in biological specimens and thereby providing evidence of internal exposure.<sup>21,22</sup> In occupational settings, biomonitoring can strengthen exposure assessment, identify workers or occupational groups at increased risk, and support timely risk-reduction and surveillance interventions.<sup>21,22</sup> Its value may be especially pronounced where exposure involves mixtures of metals and where clinical manifestations are non-specific.

Despite the widespread nature of automobile repair activities in Nigeria, important gaps remain in understanding how clinically observed manifestations relate to objectively measured internal heavy metal exposure among automobile technicians. Existing

Nigerian studies have largely focused on documenting concentrations of individual metals or selected biological and clinical outcomes among occupationally exposed populations.<sup>5-10,23-25</sup> However, there remains limited evidence integrating systematic clinical assessment with multi-metal biological monitoring within the same population. This distinction is important because a high prevalence of clinical symptoms among workers does not necessarily indicate that those symptoms are attributable to heavy metal exposure. In contrast, substantial biological exposure may remain clinically silent.

Kano Metropolis provides an important setting for examining this relationship. The automobile repair sector is predominantly informal, with numerous workshops operating within residential and commercial environments and relatively limited occupational health infrastructure. The workforce encompasses several specialised activities, including mechanical repair, spray painting, panel beating, battery repair, and auto-electrical work, each with potentially different exposure profiles. The substantial variation in occupational tasks and exposure duration provides useful context for examining both clinical manifestations and biological evidence of exposure. Moreover, the occupational and sociodemographic characteristics of technicians in Kano may differ from those reported in other parts of Nigeria, limiting the direct extrapolation of findings from other settings.

The present study aimed to address this gap by characterising the clinical manifestations and biological markers of heavy metal exposure among automobile technicians in Kano Metropolis, Northwestern Nigeria, and by comparing technicians with non-occupationally exposed schoolteachers from the same metropolitan environment. The study specifically aimed to assess the frequency of clinical symptoms and physical findings, determine the prevalence and pattern of laboratory-confirmed heavy metal exposure, and examine the association between clinical manifestations and objectively measured exposure after accounting for relevant confounding factors, thereby generating evidence to inform occupational health surveillance, early identification of exposed workers, and workplace exposure-control strategies in the informal automobile repair sector.

## MATERIALS AND METHODS

### Study Design, Population, and Area

This study employed a comparative cross-sectional design among 310 participants in Kano Metropolis, Northwestern Nigeria, comprising 155 automobile technicians and 155 schoolteachers as non-occupationally exposed controls. The technicians comprised mechanics (36.8%), auto electricians (24.5%), spray painters (19.4%), panel beaters (11.6%), and battery repairers (7.7%). Kano Metropolis comprises eight Local Government Areas and has a predominantly informal automobile repair sector, with approximately 625 registered workshops and an estimated 12,460 technicians. Workshops are commonly located within residential and commercial areas and operate with limited occupational health infrastructure. Schoolteachers were selected as controls because they shared the same metropolitan environment but had no known occupational exposure to heavy metals. Eligible technicians were adults aged  $\geq 18$  years who had worked continuously in their current vocation for at least six months and provided written informed consent. Controls were adults employed in Kano for at least six months, without occupational heavy metal exposure, who provided informed consent. Individuals who did not meet the eligibility criteria or declined consent were excluded.

### Sample Size Estimation and Sampling Technique

The minimum sample size was estimated using a formula for comparing two independent proportions,<sup>26</sup> based on previously reported blood lead exposure among occupationally exposed workers in Nigeria.<sup>27</sup> The calculated sample size was adjusted for the cluster sampling design<sup>28,29</sup> and anticipated non-response, resulting in 155 participants per group and a total sample of 310. Automobile technicians were selected using single-stage cluster sampling. A register of 625 automobile workshops obtained from the Kano State chapter of the National Automobile Technicians' Association served as the sampling frame, from which 12 workshops were randomly selected. Eligible technicians within the selected workshops were identified and recruited consecutively until the required sample was attained. Teachers were similarly recruited from eight randomly selected schools, with eligible participants enrolled consecutively until 155 controls were obtained. Return visits were made as needed to minimise non-response and selection bias.

### Data Collection

Data were collected using a pretested structured interviewer-administered questionnaire adapted from a

previously validated occupational health instrument.<sup>30</sup> The questionnaire captured sociodemographic characteristics, occupational information, and relevant clinical symptoms. The instrument was pretested among 16 technicians and 16 teachers, and necessary modifications were made to improve clarity and face validity. All participants underwent a standardised physical examination for skin abnormalities, Mee's lines, neurological findings, and other relevant systemic signs. Mee's lines were defined as transverse white bands across the fingernails, while skin hyperpigmentation was assessed as diffuse or patchy darkening of the hands or forearms. Neurological assessment included examination for wrist drop, tremor, and sensory deficits. Blood pressure was measured using an automated digital blood pressure monitor (OMRON M2 Basic).

### Biological Sampling and Laboratory Analysis

Five millilitres of venous blood were collected into K-EDTA tubes and transported to the Instrumentation Laboratory, Kano State School of Technology, for analysis. Ten heavy metals—lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), zinc (Zn), aluminium (Al), arsenic (As), nickel (Ni), copper (Cu), and manganese (Mn)—were quantified using graphite furnace atomic absorption spectrophotometry with Zeeman correction (ICE 3500, Thermo Fisher Scientific). Samples were diluted 1:20 with a matrix modifier, and analytical wavelengths and detection limits were determined according to the instrument manual. Laboratory-confirmed heavy metal exposure was defined as a blood concentration exceeding the specified occupational biological reference threshold for any of the assessed metals: Pb  $\geq 20$   $\mu\text{g/dL}$ , As  $\geq 7$   $\mu\text{g/dL}$ , Cd  $\geq 0.5$   $\mu\text{g/dL}$ , Cr  $\geq 0.05$   $\mu\text{g/dL}$ , Mn  $\geq 1$   $\mu\text{g/dL}$ , Hg  $\geq 1$   $\mu\text{g/dL}$ , Al  $\geq 1$   $\mu\text{g/dL}$ , Ni  $\geq 0.05$   $\mu\text{g/dL}$ , Cu  $\geq 150$   $\mu\text{g/dL}$ , or Zn  $\geq 130$   $\mu\text{g/dL}$ .<sup>31-33</sup>

### Data Analysis

Data were analysed using IBM SPSS Statistics version 25. Categorical variables were summarised using frequencies and percentages and compared using the chi-square or Fisher's exact test. Continuous variables were summarised using means and standard deviations and compared using the independent-samples *t*-test. The Shapiro-Wilk test was used to assess normality, and non-normally distributed variables were analysed using appropriate non-parametric tests. Logistic regression was used to examine associations between laboratory-confirmed heavy metal exposure and selected clinical manifestations, adjusting

for age, sex, and occupational group. Results were presented as odds ratios (ORs) and adjusted odds ratios (AORs) with 95% confidence intervals (CIs). Statistical significance was set at  $p < 0.05$ .

### Ethical Consideration

Ethical approval was obtained from the Health Research Ethics Committee of Aminu Kano Teaching Hospital. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrolment. Participants with laboratory-confirmed elevated heavy metal levels were informed and referred to the hospital's occupational health clinic for further evaluation. Confidentiality of participant information was maintained throughout the study, and data were used solely for research purposes.

## RESULTS

### Sociodemographic characteristics of study participants

A total of 310 participants were enrolled, comprising 155 automobile technicians and 155 schoolteachers. The two groups differed significantly in age, sex, marital status, educational attainment, years in current occupation, daily working hours, and working days per week (all  $p < 0.001$ ). Technicians were predominantly aged 20–29 years (45.8%), exclusively male (100.0%), and had primary education as their highest level of education (68.4%); 71.0% were married. Among technicians, mechanics constituted the largest occupational subgroup (36.8%), followed by auto electricians (24.5%), spray painters (19.4%), panel beaters (11.6%), and battery repairers (7.7%). Most technicians reported working  $\geq 8$  hours per day (89.7%), while approximately half worked seven days per week (49.1%). In comparison, schoolteachers were predominantly aged 30–39 years (40.6%), female (54.8%), married (82.6%), and had tertiary education (89.7%). [Table 1]

### Clinical manifestations and blood pressure findings among automobile technicians and school teachers

Automobile technicians reported significantly higher frequencies of several clinical manifestations than schoolteachers, including general body pain (56.8% vs 12.9%; OR 8.87, 95% CI: 5.03–15.63), recurrent fever (69.0% vs 31.6%; OR 4.82, 95% CI: 2.98–7.79), catarrh (75.5% vs 51.6%; OR 2.89, 95% CI: 1.78–4.68), and diarrhoea (49.0% vs 30.3%; OR 2.21, 95% CI: 1.39–3.52),

all  $p < 0.001$ . Mee's lines and skin hyperpigmentation were observed exclusively among technicians, occurring in 18.7% and 72.9%, respectively (both  $p < 0.001$ ). Conversely, vomiting (47.7% vs 39.4%;  $p = 0.137$ ) and abdominal pain (45.2% vs 38.1%;  $p = 0.205$ ) did not differ significantly between groups. No participant in either group had Burton's lines, wrist drop, or dermatitis. Mean systolic blood pressure ( $113.9 \pm 15.3$  vs  $115.0 \pm 15.9$  mmHg;  $p = 0.537$ ) and diastolic blood pressure ( $74.1 \pm 10.2$  vs  $73.7 \pm 10.3$  mmHg;  $p = 0.740$ ) were also comparable between technicians and schoolteachers. [Table 2].

### Clinical findings by occupational specialisation of automobile technicians

Among automobile technicians, the prevalence of Mee's lines and skin hyperpigmentation varied across occupational specialisations, but differences were not statistically significant. Mee's lines were most frequent among panel beaters (27.8%) and mechanics (26.3%), and least frequent among battery repairers (8.3%) ( $p = 0.182$ ). Skin hyperpigmentation was most prevalent among spray painters (86.7%) and least prevalent among auto electricians (63.2%) ( $p = 0.273$ ). Neither dermatitis nor wrist drop was observed in any occupational category. [Table 3]

### Clinical manifestations according to laboratory-confirmed heavy-metal exposure status

Laboratory analysis confirmed heavy-metal exposure in 188 of the 310 participants (60.6%), with a substantially higher prevalence among automobile technicians than schoolteachers (81.9% vs 39.4%; OR 6.99, 95% CI: 4.15–11.77;  $p < 0.001$ ). Among technicians, the most frequently elevated metals were aluminium (69.7%), chromium (59.4%), nickel (44.5%), and cadmium (27.7%), each significantly more frequent than among schoolteachers ( $p < 0.001$ ).

In crude analyses, laboratory-confirmed exposure was significantly associated with general body pain (OR 3.30, 95% CI: 1.94–5.61), recurrent fever (OR 2.77, 95% CI: 1.73–4.44), catarrh (OR 2.07, 95% CI: 1.29–3.32), and abdominal pain (OR 1.64, 95% CI: 1.02–2.63). However, these associations were attenuated after adjustment for age, sex, and occupational group. None of the assessed clinical manifestations remained statistically significantly associated with laboratory-confirmed exposure: general body pain (AOR 1.69, 95% CI: 0.89–3.20;  $p = 0.108$ ), recurrent fever (AOR 1.51, 95% CI: 0.88–2.60;  $p = 0.138$ ), catarrh (AOR 1.44, 95% CI: 0.85–2.47;  $p = 0.177$ ),

vomiting (AOR 0.83, 95% CI: 0.49–1.39;  $p = 0.474$ ), abdominal pain (AOR 1.70, 95% CI: 0.99–2.91;  $p = 0.055$ ), or diarrhoea (AOR 0.76, 95% CI: 0.43–1.32;  $p = 0.326$ ). Thus, although several symptoms were associated

with laboratory-confirmed exposure in crude analyses, the associations were no longer statistically significant after accounting for potential confounding by age, sex, and occupational group. [Table 4].

**Table 1: Sociodemographic and occupational characteristics of the study participants**

| Variables                         | Automobile technicians<br>n = 155<br>Frequency (%) | School teachers<br>n = 155<br>Frequency (%) | Test of significance              |
|-----------------------------------|----------------------------------------------------|---------------------------------------------|-----------------------------------|
| Age group (years)                 |                                                    |                                             |                                   |
| <20                               | 14 (9.0)                                           | 0 (0.0)                                     | *Fe; $p < 0.001^*$                |
| 20-29                             | 71 (45.8)                                          | 38 (24.5)                                   |                                   |
| 30-39                             | 43 (27.7)                                          | 63 (40.6)                                   |                                   |
| 40-49                             | 18 (11.6)                                          | 47 (30.3)                                   |                                   |
| ≥50                               | 9 (5.8)                                            | 7 (4.5)                                     |                                   |
| Sex                               |                                                    |                                             |                                   |
| Male                              | 155 (100)                                          | 70 (45.2)                                   | Fe; $p < 0.001^*$                 |
| Female                            | 0 (0.0)                                            | 85 (54.8)                                   |                                   |
| Marital status                    |                                                    |                                             |                                   |
| Single                            | 45 (29.0)                                          | 22 (14.2)                                   | *Fe; $p < 0.001^*$                |
| Married                           | 110 (71.0)                                         | 128 (82.6)                                  |                                   |
| Widowed                           | 0 (0.0)                                            | 5 (3.2)                                     |                                   |
| Highest level of education        |                                                    |                                             |                                   |
| Quranic school only               | 4 (2.6)                                            | 0 (0.0)                                     | *Fe; $p < 0.001^*$                |
| Primary                           | 106 (68.4)                                         | 0 (0.0)                                     |                                   |
| Secondary                         | 45 (29.0)                                          | 16 (10.3)                                   |                                   |
| Tertiary                          | 0 (0.0)                                            | 139 (89.7)                                  |                                   |
| Technician specialization (n=155) |                                                    |                                             |                                   |
| Mechanic                          | 57 (36.8)                                          | -                                           | NA                                |
| Spray painter                     | 30 (19.4)                                          | -                                           |                                   |
| Panel beater                      | 18 (11.6)                                          | -                                           |                                   |
| Battery repairer                  | 12 (7.7)                                           | -                                           |                                   |
| Auto electrician                  | 38 (24.5)                                          | -                                           |                                   |
| Years in current occupation       |                                                    |                                             |                                   |
| 1-5                               | 40 (25.8)                                          | 66 (42.6)                                   | $\chi^2 = 32.96$<br>$p < 0.001^*$ |
| 6-10                              | 27 (17.4)                                          | 30 (19.4)                                   |                                   |
| 11-15                             | 42 (27.1)                                          | 19 (12.3)                                   |                                   |
| 16-20                             | 24 (15.5)                                          | 8 (5.2)                                     |                                   |
| >20                               | 22 (14.2)                                          | 32 (20.6)                                   |                                   |
| Working hours per day             |                                                    |                                             |                                   |
| <8                                | 16 (10.3)                                          | 81 (52.3)                                   | $\chi^2 = 62.24$<br>$P < 0.001^*$ |
| ≥8                                | 139 (89.7)                                         | 74 (47.7)                                   |                                   |
| Working days per week             |                                                    |                                             |                                   |
| <7                                | 79 (50.9)                                          | 155 (100)                                   | Fe; $p < 0.001$<br>$p = 0.035^*$  |
| 7                                 | 76 (49.1)                                          | 0 (0.0)                                     |                                   |

$\chi^2$ : Pearson's chi square test; Fe: Fisher's exact test; \*Fe: Fisher-Freeman-Halton Exact \*Statistically significant ( $p < 0.05$ ); NA: Not available

## DISCUSSION

This study compared the clinical manifestations and biological markers of heavy-metal exposure among automobile technicians and non-occupationally exposed controls in Kano Metropolis, Northwestern Nigeria. The study demonstrates a substantial occupational burden of heavy-metal exposure among automobile technicians in Kano Metropolis, accompanied by a higher prevalence of several clinical manifestations than among

schoolteachers. Technicians were predominantly young men, had relatively low educational attainment, and reported prolonged working hours, with almost half working seven days per week. These occupational characteristics provide an important context for the observed exposure burden and are consistent with the recognised vulnerability of informal automobile workers to multiple occupational hazards.

**.Table 2: Clinical manifestations and blood pressure findings among automobile technicians and school teachers**

| Clinical manifestation               | Automobile technicians<br>n = 155<br>Frequency (%) | School teachers<br>n = 155<br>Frequency (%) | Test of significance          | OR (95%CI)          |
|--------------------------------------|----------------------------------------------------|---------------------------------------------|-------------------------------|---------------------|
| General body pain                    | 88 (56.8)                                          | 20 (12.9)                                   | $\chi^2= 65.71$ ; $p<0.001^*$ | 8.87 (5.03 – 15.63) |
| Recurrent fever                      | 107 (69.0)                                         | 49 (31.6)                                   | $\chi^2= 43.41$ ; $p<0.001^*$ | 4.82 (2.98 – 7.79)  |
| Catarrh                              | 117 (75.5)                                         | 80 (51.6)                                   | $\chi^2= 19.06$ ; $p<0.001^*$ | 2.89 (1.78 – 4.68)  |
| Vomiting                             | 74 (47.7)                                          | 61 (39.4)                                   | $\chi^2= 2.22$ ; $p = 0.137$  | 1.41 (0.90 – 2.21)  |
| Abdominal pain                       | 70 (45.2)                                          | 59 (38.1)                                   | $\chi^2= 1.61$ ; $p = 0.205$  | 1.34 (0.85 – 2.11)  |
| Diarrhoea                            | 76 (49.0)                                          | 47 (30.3)                                   | $\chi^2= 19.06$ ; $p<0.001^*$ | 2.21 (1.39 – 3.52)  |
| Mee's lines                          | 29 (18.7)                                          | 0 (0.0)                                     | Fe; $p<0.001^*$               | NA                  |
| Skin hyperpigmentation               | 113 (72.9)                                         | 0 (0.0)                                     | Fe; $p<0.001^*$               | NA                  |
| Systolic BP (mmHg),<br>Mean $\pm$ SD | 113.9 $\pm$ 15.3                                   | 115.0 $\pm$ 15.9                            | t = -0.62; $p = 0.537$        | NA                  |
| Diastolic BP (mmHg)<br>Mean $\pm$ SD | 74.1 $\pm$ 10.2                                    | 73.7 $\pm$ 10.3                             | t = 0.33; $p = 0.740$         | NA                  |

$\chi^2$ : Pearson's chi square test; Fe: Fisher's exact test; t: independent-samples t-test; OR: odds ratio; CI: confidence Interval; SD: standard deviation; BP: blood pressure; \*Statistically significant ( $p<0.05$ ); NA: Not available

Automobile technicians had significantly higher frequencies of general body pain, recurrent fever, catarrh, and diarrhoea than schoolteachers. Similar non-specific symptom patterns have been reported among metal-exposed workers. In Kano, metal workers have demonstrated respiratory, skin, and ocular symptoms alongside elevated concentrations of manganese, lead, chromium, and nickel. In contrast, Nigerian panel beaters exposed to lead have reported fatigue, weakness, and numbness.<sup>27,31,34</sup> Comparable evidence from Ghana, Pakistan, and Kenya has also documented substantial heavy-metal exposure among automobile and related informal-sector workers.<sup>11-15</sup> The broader symptom profile observed in the present study may reflect exposure to mixtures of metals rather than a single toxicant, since clinical effects vary according to the metal involved, magnitude and duration of exposure, and individual susceptibility.<sup>17,18</sup> Nevertheless, these manifestations are inherently non-specific and may also arise from infectious, environmental, lifestyle or other occupational factors; consequently, they should not be interpreted as evidence of heavy-metal toxicity in isolation.

Physical examination identified findings that are compatible with chronic toxic-metal exposure. Mee's lines and skin hyperpigmentation occurred exclusively among technicians, affecting 18.7% and 72.9%, respectively, whereas neither was observed among schoolteachers. Such nail and cutaneous abnormalities have been described in chronic metal exposure, particularly arsenic toxicity.<sup>35,36</sup> Mee's lines have been reported in association with arsenic poisoning, while hyperpigmentation is a recognised cutaneous manifestation of chronic arsenic exposure.<sup>32,33</sup> However, these findings lack sufficient specificity to establish heavy-metal toxicity, particularly in a population potentially exposed to multiple metals. Their occurrence should therefore be regarded as supportive clinical evidence requiring confirmation by biological monitoring rather than as diagnostic markers.

**Table 3: Physical examination findings by occupational specialization among automobile technicians**

| Clinical findings      | Mechanic<br>n = 57<br>Frequency (%) | Spray Painters<br>n = 30<br>Frequency (%) | Panel Beaters<br>n = 18<br>Frequency (%) | Battery Repairers<br>n = 12<br>Frequency (%) | Auto Electricians<br>n = 38<br>Frequency (%) | Test of significance        |
|------------------------|-------------------------------------|-------------------------------------------|------------------------------------------|----------------------------------------------|----------------------------------------------|-----------------------------|
| Mee's lines            |                                     |                                           |                                          |                                              |                                              |                             |
| Yes                    | 15 (26.3)                           | 4 (13.3)                                  | 5 (27.8)                                 | 1 (8.3)                                      | 4 (10.5)                                     | $\chi^2 = 6.25$ ; p = 0.182 |
| No                     | 42 (73.7)                           | 26 (86.7)                                 | 13 (72.2)                                | 11 (91.7)                                    | 34 (89.5)                                    |                             |
| Skin hyperpigmentation |                                     |                                           |                                          |                                              |                                              |                             |
| Yes                    | 40 (70.2)                           | 26 (86.7)                                 | 14 (77.8)                                | 9 (75.0)                                     | 24 (63.2)                                    | $\chi^2 = 5.19$ ; p = 0.273 |
| No                     | 17 (29.8)                           | 4 (13.3)                                  | 4 (22.2)                                 | 3 (25.0)                                     | 14 (36.8)                                    |                             |

 $\chi^2$ : Pearson's chi-square test**Table 4: Clinical manifestations according to laboratory-confirmed heavy metal exposure status among participants**

| Clinical manifestation | Laboratory-confirmed<br>exposure<br>n = 188<br>Frequency (%) | Unconfirmed<br>exposure<br>n = 122<br>Frequency (%) | Crude OR (95% CI)   | p-value | Adjusted OR (95% CI) † | p-value |
|------------------------|--------------------------------------------------------------|-----------------------------------------------------|---------------------|---------|------------------------|---------|
| General body pain      | 84 (44.7)                                                    | 24 (19.7)                                           | 3.30 (1.94 – 5.61)  | <0.001* | 1.69 (0.89 -3.20)      | 0.108   |
| Recurrent fever        | 113 (60.1)                                                   | 43 (35.2)                                           | 2.77 (1.73 – 4.44)  | <0.001* | 1.51 (0.88 – 2.60)     | 0.138   |
| Catarrh                | 132 (70.2)                                                   | 65 (53.3)                                           | 2.07 (1.29 – 3.32)  | 0.002*  | 1.44 (0.85 – 2.47)     | 0.177   |
| Vomiting               | 82 (43.6)                                                    | 53 (43.4)                                           | 1.01 (0.64 – 1.59)  | 0.976   | 0.83 (0.49 – 1.39)     | 0.474   |
| Abdominal pain         | 87 (46.3)                                                    | 42 (34.4)                                           | 1.64 (1.02 – 2.63)  | 0.039*  | 1.70 (0.99 - 2.91)     | 0.055   |
| Diarrhoea              | 78 (41.5)                                                    | 45 (36.9)                                           | 1.21 (0.76 – 1.945) | 0.418   | 0.76 (0.43 – 1.32)     | 0.326   |

†: Adjusted for age, sex, and occupational group; OR: odds ratio; CI: confidence interval; \*Statistically significant (p&lt;0.05)

The absence of Burton's lines, wrist drop, dermatitis and peripheral neuropathy in both groups is noteworthy. Classical clinical signs of heavy-metal toxicity may occur predominantly with substantial or prolonged toxicity and may not be evident during earlier or lower-level exposure.<sup>20</sup> Thus, the absence of overt neurological or dermatological toxicity despite the high prevalence of laboratory-confirmed exposure suggests that clinical examination alone may have limited sensitivity for identifying biologically significant exposure. This finding strengthens the rationale for incorporating objective biomonitoring into occupational health surveillance.

Laboratory-confirmed heavy-metal exposure occurred in 60.6% of participants and was markedly more common among technicians than schoolteachers (81.9% vs 39.4%; OR 6.99, 95% CI: 4.15–11.77). Among technicians, aluminium, chromium, nickel and cadmium were the most frequently elevated metals. This substantially greater exposure burden among technicians supports an occupational contribution and is consistent with previous Nigerian evidence demonstrating elevated metal concentrations among automobile and other metal workers.<sup>6-8,27</sup> The occurrence of confirmed exposure among schoolteachers, however, indicates that occupational exposure is unlikely to be the sole pathway of heavy-metal uptake in the study population. Because environmental, dietary and other non-occupational exposure sources were not investigated, their contribution cannot be established from the present findings. In crude analyses, laboratory-confirmed exposure was associated with general body pain, recurrent fever, catarrh and abdominal pain. However, none of these associations remained statistically significant after adjustment for age, sex and occupational group. This attenuation is important because the crude relationships may partly reflect differences in demographic and occupational characteristics between exposed and unexposed participants. In particular, occupational group is strongly related to both exposure status and symptom burden, making confounding an important consideration. The adjusted findings therefore provide limited evidence for an independent association between laboratory-confirmed exposure and the individual clinical manifestations assessed in this study.

The absence of significant adjusted associations should not, however, be interpreted as evidence that heavy-metal exposure was clinically inconsequential. Heavy metals can exert diverse biological effects, and manifestations may

depend on the specific metal, dose, duration, route of exposure and host characteristics.<sup>17-19</sup> Moreover, biomonitoring can identify internal exposure before clinically recognisable toxicity becomes apparent.<sup>21,22</sup> The high prevalence of laboratory-confirmed exposure despite the absence of classical signs, and the loss of statistical significance after adjustment, highlight the complementary roles of biological monitoring and clinical assessment. Overall, the findings indicate a substantial occupational heavy-metal exposure burden among automobile technicians in Kano Metropolis, with several associated but non-specific clinical manifestations. The results support strengthening occupational health surveillance in automobile workshops by incorporating periodic biological monitoring alongside clinical assessment and preventive measures. The consistency of the exposure pattern with evidence from other low- and middle-income settings underscores the broader occupational-health challenge posed by informal automobile repair activities.<sup>11-15</sup>

## STUDY LIMITATIONS

This study has some limitations. First, its cross-sectional design precludes establishing temporality or causality; findings should therefore be interpreted as associations. Differences between technicians and schoolteachers in age, sex, education, and occupational characteristics may introduce confounding. Although analyses adjusted for age, sex, and occupational group, residual confounding from unmeasured factors remains possible. Moreover, schoolteachers, despite being recruited from the same metropolitan area, may not have constituted an optimally matched comparison group.

Second, heavy-metal exposure was assessed using a single blood measurement, which primarily reflects recent or current internal burden and may not capture cumulative exposure. In addition, composite exposure classification may also obscure metal-specific effects, although we assessed individual metal concentrations and abnormality patterns. Reliance partly on self-reported symptoms may also have introduced recall and reporting bias, despite standardised assessment and complementary clinical and laboratory evaluations. Small occupational subgroups, particularly battery repairers, limited the power of subgroup analyses. Assessment of multiple clinical outcomes may also increase the likelihood of chance associations. Despite these limitations, the study is strengthened by multi-metal biological monitoring, standardised clinical assessment, a comparison group, and

a high response rate. The findings provide useful evidence of occupational heavy-metal exposure among automobile technicians and support integrating biological monitoring into occupational health surveillance.

## CONCLUSION

Automobile technicians in Kano Metropolis demonstrated a substantially greater burden of laboratory-confirmed heavy-metal exposure and a higher prevalence of selected clinical manifestations than schoolteachers. However, the clinical manifestations were largely non-specific, and the associations between laboratory-confirmed exposure and individual clinical outcomes were attenuated and no longer statistically significant after adjustment for age, sex, and occupational group. The absence of classical signs of severe heavy-metal toxicity despite the high prevalence of biological exposure further underscores the limited sensitivity of clinical assessment alone for detecting occupational heavy-metal burden. These findings highlight the importance of integrating objective biological monitoring with periodic clinical assessment and appropriate workplace exposure-control measures within occupational health surveillance programmes for automobile technicians. Strengthening preventive measures and routine biomonitoring may facilitate earlier identification of excessive exposure and support timely occupational health interventions.

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## Conflict of interest

None declared.

## REFERENCES

1. Sonuga OO, Sonuga AA, Orimadegun BE, Anetor JI. Interactions between toxic metals and serum micronutrient level in auto-mechanics in Ibadan Metropolis, Nigeria: a pilot study. *Biol Trace Elem Res* 2025; 203(9): 4458-4465.
2. Anyanwu BO, Ezeji for AN, Igweze ZN, Orisakwe OE. Heavy metal mixture exposure and effects in developing nations: an update. *Toxics* 2018; 6(4): 65.
3. Jomova K, Alomar SY, Nepovimova E, Kuca K, Valko M. Heavy metals: toxicity and human health effects. *Arch Toxicol* 2025; 99(1): 153-209.
4. Ali H, Khan E, Ilahi I. Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *J Chem* 2019; 2019: 6730305.
5. Adejumo OA, Enikuomehin AC, Ogunleye A, Osungbemi WB, Adelosoye AA, Akinbodewa AA, et al. Cardiovascular risk factors and kidney function among automobile mechanic and their association with serum heavy metals in Southwest Nigeria: a cross-sectional study. *PLoS One* 2023; 18(10): e0292364.
6. Adejumo BI, Isu MO, Uchuno GA, Dimkpa U, Emmanuel AM, Oke OM, et al. Serum level of lead, zinc, cadmium, copper and chromium among occupationally exposed automotive workers in Benin City. *Int J Environ Pollut Res* 2017; 5(1): 70-79.
7. Saliu A, Adebayo O, Kofoworola O, Ogunowo B, Ismail A. Comparative assessment of blood lead levels of automobile technicians in organised and roadside garages in Lagos, Nigeria. *J Environ Public Health* 2015; 2015: 976563.
8. Alli LA. Blood level of cadmium and lead in occupationally exposed persons in Gwagwalada, Abuja, Nigeria. *Interdiscip Toxicol* 2015; 8(3): 146-150.
9. Nkwoada AU, Alisa CO, Amakom CM. Pollution in Nigerian auto-mechanic villages: a review. *IOSR J Environ Sci Toxicol Food Technol* 2018; 12(7): 43-54.
10. Nwobi NL, Nwobi JC, Adejumo EN, Usiobeigbe OS, Adetunji OA, Atulomah NO, et al. Blood lead levels, calcium metabolism and bone-turnover among automobile technicians in Sagamu, Nigeria: implications for elevated risk of susceptibility to bone diseases. *Int J Occup Saf Ergon* 2021; 27(3): 705-713.
11. Cobbina SJ, Edu AR, Bosso EE, Bampoe E, Gautam S. Impact of industrial activities on soil quality in urban settings: a study of heavy metal concentrations in Lamashegu, Ghana. *Discover Soil* 2025; 2(1): 1-20.
12. Dartey E, Gyamfi O. Assessing contamination levels and risk of toxic elements in soils from automobile workshop centre in Asante Mampong, Ghana. *Chem Afr* 2023; 7: 929-940.
13. Ahmad I, Khan B, Khan S, Khan MT, Schwab AP. Assessment of lead exposure among automobile technicians in Khyber Pakhtunkhwa, Pakistan. *Sci Total Environ* 2018; 633: 293-299.
14. Khan K, Room SA, Bacha AU, Nabi I, Ahmad S, Younas M, et al. Assessment of heavy metals among auto workers in metropolitan city: a case study. *Front Public Health* 2023; 11: 1277182.
15. Odongo OA, Moturi WN, Obonyo MA. Influence of task-based airborne lead exposures on blood lead levels:

- a case study of informal automobile repair artisans in Nakuru town, Kenya. *Environ Geochem Health* 2020; 42: 1893-1903.
16. Ataro Z, Geremew A, Urgessa F. Occupational health risk of working in garages: comparative study on blood pressure and haematological parameters between garage workers and Haramaya University community, Harar, Eastern Ethiopia. *Risk Manag Healthc Policy* 2018; 11: 35-44.
  17. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. *Interdiscip Toxicol* 2014; 7(2): 60-72.
  18. Witkowska D, Slowik J, Chilicka K. Heavy metals and human health: possible exposure pathways and the competition for protein binding sites. *Molecules* 2021; 26(19): 6060.
  19. Saad AAA, El-Sikaily A, Kassem H. Essential, non-essential metals and human health. In: *Pollution status, environmental protection, and renewable energy production in marine systems*. New York: Nova Science Publishers, Inc.; 2016. p. 87-135.
  20. Jannetto PJ, Cowl CT. Elementary overview of heavy metals. *Clin Chem* 2023; 69(4): 336-349.
  21. Santonen T, Mahiout S, Alvito P, Apel P, Bessems J, Bil W, et al. How to use human biomonitoring in chemical risk assessment: methodological aspects, recommendations, and lessons learned from HBM4EU. *Int J Hyg Environ Health* 2023; 249: 114139.
  22. Hopf NB, Rousselle C, Poddalgoda D, Lamkarkach F, Bessems J, Schmid K, et al. A harmonized occupational biomonitoring approach. *Environ Int* 2024; 191: 108990.
  23. Bolarinwa OA. Sample size estimation for health and social science researchers: the principles and considerations for different study designs. *Niger Postgrad Med J* 2020; 27(2): 67-75.
  24. Alasia D, Iyagba A. The blood lead, blood pressure connection: an evaluation of apparently healthy lead exposed workers in Nigeria. *Occup Dis Environ Med* 2019; 7: 75-90.
  25. Charan J, Biswas T. How to calculate sample size for different study designs in medical research? *Indian J Psychol Med* 2013; 35(2): 121-126.
  26. Elemile MG, Kio JO, Abolarin IO, Makanjuola OJ. Knowledge and socio-demographic determinants of occupational hazard prevention among automobile mechanics in Akure South Local Government, Ondo State, Nigeria. *Res J Health Sci* 2019; 7(3): 237-245.
  27. Sani A, Abdullahi IL. Evaluation of some heavy metals concentration in body fluids of metal workers in Kano metropolis, Nigeria. *Toxicol Rep* 2017; 4: 72-76.
  28. World Health Organization. WHO STEPS surveillance manual: the WHO STEPwise approach to chronic disease risk factor surveillance. Geneva: WHO; 2008. Available at: <https://www.who.int/ncds/surveillance/steps/manual/en/> [Last accessed on 2026, May 5].
  29. Filipoiu DC, Bungau SG, Endres L, Negru PA, Bungau AF, Pasca B, et al. Characterization of the toxicological impact of heavy metals on human health in conjunction with modern analytical methods. *Toxics* 2022; 10(12): 716.
  30. Andrew D, Robertson G, Bramwell M, Raja K. Recommended reference intervals for copper and zinc in serum using the US National Health and Nutrition Examination Surveys (NHANES) data. *Clin Chim Acta* 2023; 546: 117397.
  31. Kassy CW, Uchegbu CK, Ango TJ. Symptoms associated with low threshold lead poisoning among roadside and organized panel beaters in Enugu Metropolis, Nigeria. *J Health Pollut* 2021; 11(29): 210303.
  32. Sharma S, Gupta A, Deshmukh A, Puri V. Arsenic poisoning and Mees' lines. *QJM* 2016; 109(8): 565-566.
  33. Tang GT, Elakis J, Scardamaglia L. Cutaneous manifestations and treatment of arsenic toxicity: a systematic review. *Skin Health Dis* 2023; 3(4): e231.
  34. Omotosho IO. Oxidative stress indices as markers of lead and cadmium exposure toxicity in auto technicians in Ibadan, Nigeria. *Oxid Med Cell Longev* 2019; 2019: 3030614.
  35. Bello O, Naidu R, Rahman MM, Liu Y, Dong Z. Lead concentration in the blood of the general population living near a lead-zinc mine site, Nigeria: exposure pathways. *Sci Total Environ* 2016; 542(Pt A): 908-914.
  36. Morton J, Sams C, Leese E, Garner F, Iqbal S, Jones K. Biological monitoring: evidence for reductions in occupational exposure and risk. *Front Toxicol* 2022; 4: 836567.

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