

Prevalence and Predictors of Hematological Abnormalities among Automotive Mechanics Working in Cotonou and Neighboring Cities, Benin

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Abstract

Background: Automotive mechanics in low-resource settings face chronic exposure to genotoxic agents, and occupational exposure to chemical hazards in workshops has been associated with hematological toxicity; however, evidence from Benin remains limited. This study aimed to characterize the occupational profile of informal automotive mechanics in Benin and examine associations between work specialty, employment duration, personal protective equipment (PPE) use, multi-trade exposure, and hematological abnormalities. **Methods:** We conducted a cross-sectional study (June-December 2024) among male mechanics in Cotonou and nearby cities in southern Benin. Sociodemographic characteristics, occupational history, PPE use, and workshop exposure type were collected using standardized questionnaires. Peripheral blood was analyzed with an automated hematology analyzer. Hematological abnormalities

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were defined using both internationally validated and locally recommended thresholds, and multivariable logistic regression identified independent predictors. **Results:** The cohort included 298 male mechanics: 236 automobile, 29 diesel, and 33 motorcycle mechanics. Overall PPE use was low (19.4%). Significant differences across specialties were observed for red blood cell indices and leukocyte subsets. Diesel mechanics had the highest prevalence of microcytic normochromic anemia (27.6%, $p = 0.004$), and automobile mechanics had the highest macrocytosis prevalence (17.9%, $p = 0.036$). Longer employment duration was associated with higher MCH/MCHC, lower platelet counts, and higher thrombocytopenia frequency, while microcytosis was more frequent among workers with ≤ 22 years employment. In contrast, microcytosis was markedly less frequent among PPE users (5.5% vs. 16.6%, $p = 0.034$). In multivariable analyses, PPE use was associated with lower odds of microcytosis (OR = 0.16); older age was associated with macrocytosis (OR = 1.09/year), neutropenia (OR = 1.04/year), and leukopenia (OR = 1.05/year); longer work duration was associated with increased thrombocytopenia odds (OR = 1.04/year). Multi-trade workshop mechanics showed a nonsignificant trend toward increased hematological risk. **Conclusion:** Automotive mechanics in Benin show measurable hematological alterations varying by specialty, exposure intensity, and employment length. These results highlight the need for routine occupational health surveillance and targeted prevention measures, prioritizing PPE use and safer work practices. However, the cross-sectional design precludes causal inference; findings should be interpreted as associative rather than causal. Longitudinal studies with direct exposure assessment are needed to confirm these associations.

Keywords

Benin, Automotive Mechanics, Hematological Abnormalities, Occupational Exposure, Personal Protective Equipment, Thrombocytopenia, Microcytosis

1. Introduction

Chronic exposure to a broad spectrum of chemical and physical hazards in the workplace has been consistently linked to alterations in blood cell counts and other hematological indices [1] [2]. Industrial chemicals such as benzene, polycyclic aromatic hydrocarbons (PAHs), heavy metals (lead, cadmium, chromium), and organic solvents are known to exert toxic effects on the bone marrow, leading to cytopenias, dysplastic changes, and in severe cases, hematological malignancies [3]. Even at low exposure levels, chronic inhalation or dermal absorption of these genotoxic and myelotoxic agents can produce subtle shifts in blood cell counts before progressing to clinically relevant abnormalities such as anemia, neutropenia, lymphopenia, or thrombocytopenia. Consistent with this, a study of shoe manufacturing workers exposed to benzene at air levels of 1 ppm or less found lower white blood cell (WBC) and platelet counts than in unexposed controls,

while progenitor cells were even more sensitive, and genetic susceptibility further modified the risk of benzene-related hematotoxicity [4]. Consequently, monitoring hematological indices in occupationally exposed populations provides a sensitive, non-invasive means of detecting early biological effects and identifying at-risk workers who may benefit from targeted prevention. These effects are particularly relevant in informal work settings, where exposure control is limited and routine medical surveillance is rarely available.

This pattern is further supported by findings from low- and middle-income countries, where studies from West Africa link chronic occupational exposure to petroleum products with measurable hematological changes. In Cape Coast, Ghana, automobile mechanics and sprayers had significantly lower WBC, lymphocyte, monocyte, platelet, and reticulocyte counts than controls, with reduced red cell parameters in mechanics, indicating diminished hematopoietic output [5]. Similarly, in Nnewi, Nigeria, automobile mechanics had lower red blood cell count, hematocrit, mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH), along with higher platelet counts than controls, and several indices worsened with longer exposure [6]. Together, these findings suggest that even without overt poisoning, sustained exposure to petrochemicals can produce early blood abnormalities that support routine hematological surveillance in exposed workers. They also underscore the importance of evaluating whether similar effects occur in other informal automotive settings where multiple exposures coexist.

Automobile repair workshops are a pervasive feature of urban and peri-urban landscapes in Benin, as in much of West Africa, and they employ a large, predominantly informal workforce—mechanics, spray-painters, welders, battery recyclers, and apprentices—who face daily exposure to a complex mix of chemical, physical, and ergonomic hazards. Many apprentices begin garage work at an early age, often before 18, which increases their cumulative exposure over the life course and raises the risk that health effects will appear even by middle age. These risks are amplified by poor ventilation, frequent direct skin contact with fuels, solvents and degreasers, and the absence of systematic use of personal protective equipment (PPE)—exemplified by hazardous practices such as hand-washing with gasoline—alongside irregular access to occupational health services. Together, these factors create a particularly high-risk occupational environment for both young trainees and experienced workers. However, previous occupational health research in Benin has concentrated on sectors other than automotive repair, focusing mainly on factors associated with occupational stress and hypertension [7] [8]. The systemic hematological consequences of chronic, multi-chemical workplace exposure have not yet been evaluated among automobile mechanics in Benin. This evidence gap limits the ability to design prevention strategies tailored to the specific hazards of informal automotive workshops.

Understanding the relationships between specific work-related factors—such as job specialty, duration of employment, use of protective equipment, and co-expo-

sure to welding or painting activities-and the occurrence of hematological abnormalities is therefore essential. Such understanding can help identify modifiable risk factors, pinpoint workers at greatest risk, guide targeted screening, and support low-cost preventive strategies tailored to the realities of informal automotive repair settings. It may also help distinguish whether observed abnormalities are driven primarily by cumulative exposure, specific tasks, or the combined effects of multiple workshop hazards.

This study, therefore, aimed to characterize the occupational profile of informal automotive mechanics in Benin and to examine whether work specialty, employment duration, PPE use, and multi-trade workshop exposure (co-exposure to welding and painting) were associated with hematological alterations. Specifically, we sought to: 1) describe baseline demographic, occupational and behavioral characteristics by specialty and by employment duration; 2) compare hematological parameters across exposure groups; 3) determine the prevalence of selected hematological abnormalities; and 4) identify independent predictors of these abnormalities using multivariable logistic regression. The results are intended to provide an evidence base for occupational health surveillance and for targeted preventive measures in this neglected workforce.

2. Methods

2.1. Study Design and Setting

This cross-sectional study was conducted from June to December 2024 in Cotonou and neighboring cities, including Abomey-Calavi, Porto-Novo, and Ouidah. These sites were selected because they host a dense concentration of informal microenterprises and reflect a wide socioeconomic range, thereby capturing diverse occupational exposures among automotive workers in southern Benin. Prior to recruitment, mixed sensitization sessions were organized both virtually and in person with leaders of professional associations to explain the study objectives and procedures and to support community engagement. Four organizations were involved in participant mobilization: AGPAC (Association des Garagistes Professionnels d'Abomey-Calavi), ABEMA (Association Béninoise des Maintenaniers Automobiles), AMECYPAC (Association des Mécaniciens Cyclomoteurs Professionnels d'Abomey-Calavi), and AMDPEMA (Association des Mécaniciens Diésélistes Professionnels Engagés pour un Meilleur Avenir). The association leaders subsequently granted access to their social media forums, enabling the PI to introduce the study directly to members; they also circulated information and invitations to encourage participation. All participants provided written informed consent, and the study was approved by the Institutional Ethics Committee of the University of Abomey-Calavi and conducted in accordance with the Declaration of Helsinki.

2.2. Study Population and Recruitment

The target population comprised workers in the informal automotive repair sec-

tor, including automobile mechanics, motorcycle mechanics, and diesel mechanics. These occupational groups were selected because they represent core technical trades in the sector and share prolonged work in unregulated workshop environments with potential exposure to benzene, polycyclic aromatic hydrocarbons, solvents, particulate matter, exhaust fumes, lubricants, and metals. Although the technical tasks differ across trades, the exposure pathways overlap substantially, making these groups appropriate for a combined occupational health assessment.

Trained study staff did not approach workers individually. Instead, after the sensitization meetings, interested workers voluntarily presented themselves on the scheduled sampling days, where eligibility was confirmed and informed consent was obtained before enrolment. Sample collection occurred either in the workshops or at designated central sites on pre-agreed dates.

Because invitations were disseminated by association leaders and participation was based on self-presentation, the research team the research team could not track all eligible workers or calculate refusal rates. This community-engaged, volunteer-based recruitment strategy was chosen deliberately, as direct unsolicited approaches by researchers were considered unlikely to be effective in this informal sector, particularly given common fears around blood collection and lack of trust in research participation. However, this approach may introduce selection bias by favoring workers who are more motivated, engaged with their associations, or comfortable with health research, limiting generalizability of findings.

2.3. Inclusion and Exclusion Criteria

Eligible participants were adults' men aged 18 to 65 years who had worked continuously for at least 2 years in one of the target occupational categories and affiliated with at least one of the four professional associations. To reduce confounding, participants had to be clinically healthy at enrolment, with no self-reported smoking, chronic inflammatory disease, active infection, or current use of chronic medications. Individuals younger than 18 years, those who declined participation, current smokers, and participants with an acute systemic infection within 30 days before enrolment were excluded.

2.4. Biochemical and Hematological Assessment

Fasting venous blood samples, 5 mL in total, were collected after an 8-hour overnight fast into K2EDTA Vacutainer tubes. Hematologic parameters were measured on the day of sample collection using a Genrui KT-6300 automated hematology analyzer, following the manufacturer's instructions. Quality control procedures were followed throughout sample handling and analysis to ensure consistency of measurements.

2.5. Data Collection, Definition of Variables, and Outcomes

Trained staff administered standardized questionnaires to collect sociodemo-

graphic information, behavioral factors, and occupational history. The questionnaire captured age, educational level, alcohol consumption, occupational specialty, years of experience, workshop exposure type, and use of personal protective equipment (PPE). This study defined informal automotive mechanics as individuals involved in vehicle repair and maintenance in largely unregulated workshops that function outside formal employment and occupational health systems, with limited infrastructure, inconsistent use of protective equipment, and little or no routine safety oversight. Height and weight were measured using standard procedures, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Alcohol consumption was classified as never or current, with current use defined as regular intake of at least one alcoholic drink per day. Employment duration was defined as the total number of years worked in the target occupational category. Workshop exposure type was classified as single-trade workshop work, meaning mechanical work only, or multi-trade workshop work, meaning workshops where mechanical tasks coexist with welding and painting activities. PPE use referred to regular use of preventive devices such as masks, gloves, and changed work clothes.

The primary outcomes of the study were hematologic abnormalities identified from peripheral blood testing. These outcomes included normocytic normochromic anemia, microcytic normochromic anemia, microcytosis, macrocytosis, neutropenia, lymphopenia, leukopenia, and thrombocytopenia. Secondary hematologic variables included red blood cell (RBC) count, hemoglobin, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), white blood cell (WBC) count, neutrophils, eosinophils, monocytes, lymphocytes, and platelets.

Hematological abnormalities were defined using both internationally validated and locally recommended thresholds [9] [10]. Anemia was defined as hemoglobin < 13.0 g/dL in men and <12.0 g/dL in women, with interpretation based on hemoglobin levels and red-cell indices [9]. Normocytic normochromic anemia was defined as anemia with MCV between 80 - 93 fL and MCHC within the normal range (32 - 36 g/dL), while microcytic normochromic anemia was defined as anemia with MCV < 80 fL and MCHC within the normal range [11]. Other hematologic abnormalities were defined according to standard laboratory cutoffs: microcytosis (MCV < 80 fL), macrocytosis (MCV > 93 fL), neutropenia (neutrophils < 1.5 G/L), lymphopenia (lymphocytes < 1.0 G/L), leukopenia (WBC count < 4.0 G/L), and thrombocytopenia (platelet count < 150 G/L) [10]. These thresholds correspond to widely used international reference ranges and are not analyzer-specific.

2.6. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27. Quantitative variables were summarized as mean with 95% confidence interval (95% CI), while categorical variables were presented as n (%) with 95% confidence interval. Because the

distributions of continuous variables were not assumed to be normal, group comparisons were performed using the Mann-Whitney U test for two-group comparisons. For comparisons across more than two specialty groups, p-values were derived from nonparametric and categorical tests as appropriate.

Categorical outcomes, including hematologic abnormalities, were compared using Pearson's chi-square test and Fisher's exact test as appropriate.

To identify independent factors associated with hematologic abnormalities, separate binary logistic regression models were fitted for each outcome. The regression analyses included age, alcohol consumption, BMI, protective measures, employment duration, PPE use, and workshop exposure type as predictors. PPE use, employment duration, and workshop exposure types were treated as exposure-related covariates. Age and employment duration are correlated in this occupational cohort. Both variables were retained in regression models because age represents a general health and life-course confounder, while employment duration serves as a proxy for cumulative occupational exposure. However, the individual adjusted odds ratios (OR) for age and employment duration should be interpreted with caution, as they do not represent fully independent effects. Regression models estimated adjusted associations between occupational characteristics and each hematologic abnormality, with adjusted OR and 95% confidence intervals (CI) reported for each predictor. p-values were interpreted at the 0.05 significance threshold.

3. Results

3.1. Study Population and Exposure Characteristics

The study cohort comprised 298 male mechanics, including 236 automobile mechanics, 29 diesel mechanics, and 33 motorcycle mechanics. Baseline characteristics stratified by specialty and employment duration are shown in **Table 1**. The whole cohort had a mean age of 37.4 years (95% CI: 35.9 - 38.9), mean employment duration of 20.4 years (18.9 - 22.0), and mean BMI of 23.8 kg/m² (23.3 - 24.4). Regarding education, nearly half of participants (49.2%) had primary schooling, followed by secondary (36.7%), none (11.4%), and higher education (2.7%). Overall, 23.0% worked in co-exposure settings (multi-trade workshops with welding and painting activities).

Age, years of experience, and BMI differed significantly across specialties (all $p < 0.001$), with diesel mechanics being the oldest (46.4 years) and most experienced (30.0 years), whereas automobile mechanics were the youngest (35.5 years) and least experienced (18.3 years). Alcohol consumption was common overall (75.5%) but did not differ significantly by specialty ($p = 0.069$), whereas a significant difference emerged between workers with ≤ 22 years versus > 22 years of employment duration (61.3% vs 89.9%, $p < 0.001$). Education level also varied by specialty ($p = 0.030$), with motorcycle mechanics showing the highest proportion with primary education only (72.7%).

Table 1. Sociodemographic, occupational, and exposure characteristics of the study cohort overall and by specialty and employment duration.

Variable	Specialty				p-value	Employment duration		p-value
	Whole study cohort (n = 298)	Automobile mechanics (n = 236)	Diesel mechanics (n = 29)	Motorcycle mechanics (n = 33)		Low (≤22 years), n = 150	High (>22 years), n = 148	
Age (years)	37.4 (35.9 - 38.9)	35.5 (33.8 - 37.2)	46.4 (42.7 - 50.2)	42.9 (39.4 - 46.5)	<0.001	26.6 (25.3 - 27.8)	48.4 (47.4 - 49.4)	<0.001
Years of experience	20.4 (18.9 - 22.0)	18.3 (16.5 - 20.1)	30.0 (25.6 - 34.3)	27.0 (23.6 - 30.3)	<0.001	8.6 (7.5 - 9.7)	32.5 (31.4 - 33.5)	<0.001
BMI (kg/m ²)	23.8 (23.3 - 24.4)	23.8 (23.3 - 24.3)	27.6 (26.6 - 28.7)	23.7 (22.3 - 25.0)	<0.001	22.2 (21.6 - 22.9)	26.1 (25.5 - 26.7)	<0.001
	n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]		n (%) [95% CI]	n (%) [95% CI]	
Alcohol use	225 (75.5) [70.6 - 80.4]	172 (72.9) [66.9 - 78.3]	23 (79.3) [61.3 - 90.3]	30 (90.9) [76.4 - 96.8]	0.069	92 (61.3) [53.5 - 68.8]	133 (89.9) [84.0 - 93.8]	<0.001
Education level								
None	34 (11.4) [8.1 - 15.6]	27 (11.5) [8.0 - 16.2]	2 (6.9) [1.9 - 22.0]	5 (15.2) [6.6 - 31.7]	0.030	15 (10.0) [6.1 - 16.0]	19 (12.9) [8.4 - 19.4]	0.092
Primary	146 (49.2) [43.4 - 55.0]	109 (46.4) [40.0 - 52.9]	13 (44.8) [28.6 - 62.1]	24 (72.7) [55.8 - 84.8]		66 (44.0) [36.2 - 52.1]	80 (54.4) [46.3 - 62.3]	
Secondary	109 (36.7) [31.3 - 42.4]	91 (38.7) [32.7 - 45.1]	14 (48.3) [31.6 - 65.3]	4 (12.1) [4.8 - 27.3]		63 (42.0) [34.3 - 50.1]	46 (31.3) [24.3 - 39.2]	
Higher	8 (2.7) [1.3 - 5.2]	8 (3.4) [1.7 - 6.6]	0 (0.0) [0.0 - 11.8]	0 (0.0) [0.0 - 10.4]		6 (4.0) [1.8 - 8.5]	2 (1.4) [0.4 - 5.0]	
PPE use								
Yes	55 (19.4) [15.0 - 24.4]	49 (21.9) [16.7 - 27.8]	2 (6.9) [0.9 - 22.8]	4 (12.9) [3.6 - 29.5]	0.099	34 (24.3) [17.5 - 32.2]	21 (14.6) [9.3 - 21.4]	0.050
No	229 (80.6) [75.6 - 85.0]	175 (78.1) [72.2 - 83.3]	27 (93.1) [77.2 - 99.1]	27 (87.1) [70.5 - 96.2]		106 (75.7) [67.8 - 82.5]	123 (85.4) [78.6 - 90.7]	
Co-exposure setting*								
Yes	65 (23.0) [18.3 - 28.4]	56 (23.7) [18.5 - 29.6]	6 (46.2) [19.2 - 74.9]	3 (9.1) [1.9 - 24.3]	0.022	29 (19.9) [13.7 - 27.2]	36 (26.5) [19.3 - 34.8]	0.240
No	217 (77.0) [71.6 - 81.7]	180 (76.3) [70.4 - 81.5]	7 (53.8) [25.1 - 80.8]	30 (90.9) [75.7 - 98.1]		117 (80.1) [72.8 - 86.3]	100 (73.5) [65.2 - 80.7]	

Values are mean (95% CI) for continuous variables or n (column %) [95% CI] for categorical variables. Whole cohort n = 298, unless otherwise indicated. Employment duration was dichotomised at the median (22 years). PPE use: personal protective equipment (mask, gloves, change of work clothes)—reported by 284 participants due to missing data. Co-exposure setting data were reported by 282 participants. p-values: ANOVA for continuous variables across specialties; chi-square or Fisher's exact test for categorical variables. For employment duration, Mann-Whitney U test for continuous, chi-square/Fisher for categorical. *Co-exposure setting refers to a multi-trade workshop environment where mechanical work is performed alongside welding and painting activities. Mechanics in such settings are therefore exposed not only to automotive fuels, solvents, and exhaust fumes but also to welding fumes (containing metals such as chromium, nickel, and manganese) and paint aerosols (containing volatile organic compounds, including benzene and isocyanates).

Use of personal protective equipment (PPE) was low overall (19.4%) and was less frequent among diesel mechanics (6.9%) and motorcycle mechanics (12.9%) than among automobile mechanics (21.9%), although this difference was not statistically significant ($p = 0.099$). In contrast, co-exposure to welding and painting activities was significantly more common among diesel mechanics (46.2%) and least common among motorcycle mechanics (9.1%) ($p = 0.022$).

When participants were stratified by employment duration, the >22-year group was older, had greater work experience, higher BMI, and higher alcohol use, and reported lower PPE use than the ≤ 22 -year group; co-exposure setting did not differ substantially by employment duration. We used a median-based stratification (≤ 22 versus >22 years) to balance group sizes, improve statistical power, and reduce the influence of extreme values on comparisons while preserving a simple, interpretable cut-point for examining duration-related trends.

3.2. Hematological Parameters and Abnormalities in the Study Cohort and by Exposure-Related Covariates

Table 2 summarizes hematological indices and abnormality frequencies for the whole cohort and stratified by work specialty and employment duration. In the whole study cohort ($n = 298$), the prevalence of hematologic abnormalities ranged from 6.0% (lymphopenia) to 17.5% (neutropenia), with macrocytosis observed in 15.2%, leukopenia in 15.4%, microcytosis in 14.4%, microcytic normochromic anemia in 10.1%, normocytic normochromic anemia in 9.4%, and thrombocytopenia in 7.7% of participants.

Table 2. Hematological indices and prevalence of hematologic abnormalities in the study cohort overall and by specialty and employment duration.

Variable	Specialty				p-value	Employment duration		p-value
	Whole study cohort ($n = 298$) [†]	Automobile mechanics ($n = 236$)	Diesel mechanics ($n = 29$)	Motorcycle mechanics ($n = 33$)		Low (≤ 22 years), $n = 150$	High (>22 years), $n = 148$	
RBC (T/L)	5.2 (5.1 - 5.3)	5.1 (5.0 - 5.2)	5.3 (5.0 - 5.5)	4.9 (4.6 - 5.1)	0.028	5.1 (5.0 - 5.2)	5.1 (5.0 - 5.1)	0.303
Hemoglobin (g/dL)	14.0 (13.6 - 14.5)	13.7 (13.5 - 13.9)	13.2 (12.8 - 13.6)	13.0 (12.4 - 13.6)	0.024	13.4 (13.2 - 13.7)	13.7 (13.5 - 14.0)	0.153
Hematocrit (%)	43.7 (43.0 - 44.4)	43.6 (43.0 - 44.1)	42.6 (41.2 - 44.1)	40.4 (38.7 - 42.1)	0.001	43.1 (42.4 - 43.8)	43.1 (42.4 - 43.9)	0.921
MCV (fL)	84.4 (83.3 - 85.4)	85.8 (85.0 - 86.6)	81.7 (79.2 - 84.2)	83.6 (81.8 - 85.3)	0.003	84.5 (83.4 - 85.5)	85.8 (84.9 - 86.7)	0.171
MCH (pg)	26.9 (26.5 - 27.2)	27.0 (26.6 - 27.4)	25.2 (24.2 - 26.1)	26.8 (26.0 - 27.7)	0.004	26.3 (25.8 - 26.8)	27.3 (26.8 - 27.7)	0.003
MCHC (%)	31.1 (30.7 - 31.5)	31.5 (31.2 - 31.8)	30.8 (30.4 - 31.3)	32.1 (31.5 - 32.7)	0.011	31.1 (30.8 - 31.5)	31.8 (31.4 - 32.2)	0.036

Continued

WBC (G/L)	5.2 (5.0 - 5.4)	5.2 (5.0 - 5.4)	5.0 (4.5 - 5.6)	5.5 (4.8 - 6.2)	0.515	5.3 (5.0 - 5.5)	5.2 (5.0 - 5.5)	0.683
Neutrophils (G/L)	2.3 (2.2 - 2.4)	2.2 (2.1 - 2.4)	2.4 (2.0 - 2.8)	2.7 (2.3 - 3.1)	0.019	2.3 (2.2 - 2.5)	2.3 (2.1 - 2.4)	0.344
Eosinophils (G/L)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.2)	0.1 (0.1 - 0.1)	0.1 (0.1 - 0.1)	0.030	0.2 (0.1 - 0.2)	0.1 (0.1 - 0.2)	0.826
Monocytes (G/L)	0.4 (0.3 - 0.4)	0.3 (0.3 - 0.4)	0.3 (0.2 - 0.3)	0.3 (0.3 - 0.4)	0.285	0.3 (0.3 - 0.4)	0.3 (0.3 - 0.4)	0.754
Lymphocytes (G/L)	4.8 (2.4 - 7.3)	2.6 (2.5 - 2.7)	2.3 (2.0 - 2.6)	2.3 (2.0 - 2.7)	0.008	2.5 (2.4 - 2.7)	2.5 (2.4 - 2.6)	0.971
Platelets (G/L)	217.0 (210.1 - 223.9)	218.1 (211.0 - 225.1)	229.3 (206.5 - 252.1)	226.1 (205.4 - 246.8)	0.708	230.5 (221.3 - 239.6)	209.4 (200.9 - 218.0)	0.001
Hematologic abnormalities	n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]	p-value	n (%) [95% CI]	n (%) [95% CI]	p-value
Normocytic normochromic anemia	28 (9.4) [6.5 - 13.2]	20 (8.5) [5.6 - 12.8]	2 (6.9) [1.9 - 22.0]	6 (18.2) [8.6 - 34.7]	0.179	13 (8.7) [5.1 - 14.4]	15 (10.1) [6.2 - 16.1]	0.664
Microcytic normochromic anemia	30 (10.1) [7.0 - 14.0]	19 (8.1) [5.2 - 12.3]	8 (27.6) [14.7 - 45.7]	3 (9.1) [3.1 - 23.6]	0.004	19 (12.7) [8.3 - 19.0]	11 (7.4) [4.2 - 12.9]	0.133
Macrocytosis	45 (15.2) [11.5 - 19.7]	42 (17.9) [13.5 - 23.4]	2 (6.9) [1.9 - 22.0]	1 (3.0) [0.5 - 15.8]	0.036	21 (14.0) [9.3 - 20.5]	24 (16.3) [11.2 - 23.2] [†]	0.576
Microcytosis	43 (14.4) [10.8 - 18.8]	29 (12.3) [8.7 - 17.1]	8 (27.6) [14.7 - 45.7]	6 (18.2) [8.6 - 34.7]	0.070	28 (18.7) [13.2 - 25.7]	15 (10.1) [6.2 - 16.1]	0.036
Neutropenia	52 (17.5) [13.6 - 22.1]	44 (18.7) [14.2 - 24.3]	5 (17.2) [7.5 - 35.3]	3 (9.1) [3.1 - 23.6]	0.394	23 (15.3) [10.4 - 22.0]	29 (19.7) [14.0 - 26.9] [†]	0.319
Lymphopenia	18 (6.0) [3.8 - 9.3]	11 (4.7) [2.6 - 8.2]	3 (10.3) [3.5 - 27.0]	4 (12.1) [4.8 - 27.3]	0.143	11 (7.3) [4.1 - 12.7]	7 (4.7) [2.3 - 9.5]	0.346
Leukopenia	46 (15.4) [11.7 - 20.0]	36 (15.3) [11.2 - 20.4]	7 (24.1) [12.2 - 42.1]	3 (9.1) [3.1 - 23.6]	0.258	19 (12.7) [8.3 - 19.0]	27 (18.2) [12.8 - 25.3]	0.183
Thrombocytopenia	23 (7.7) [5.2 - 11.3]	20 (8.5) [5.6 - 12.8]	3 (10.3) [3.5 - 27.0]	0 (0.0) [0.0 - 10.4] [†]	0.198	7 (4.7) [2.3 - 9.4]	16 (10.9) [6.8 - 17.0] [†]	0.045

Values are presented as mean (95% confidence interval) for continuous variables and n (%) [95% confidence interval] for categorical variables. Percentages are column-specific. p-values are from the chi-square test or Fisher's exact test for categorical variables and from the Mann-Whitney U test for group comparisons where applicable. Continuous variables are summarized with confidence intervals to show estimate precision rather than dispersion. BMI, body mass index; PPE, personal protective equipment; RBC, red blood cell count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; WBC, white blood cell count. T/L = tera per liter ($10^{12}/L$); g/dL = grams per deciliter; % = percent; fL = femtoliter; pg = picogram; G/L = giga per liter ($10^9/L$). [†] For macrocytosis, neutropenia, and thrombocytopenia, the >22 years employment group had n = 147; for all other abnormalities n = 148; * Total N for macrocytosis, neutropenia, and thrombocytopenia was 297; for all other abnormalities n = 298.

Significant differences across the three specialty groups were observed for several RBC indices and WBC subsets. Motorcycle mechanics had the lowest hematocrit (40.4%) and RBC count (4.9 T/L), whereas diesel mechanics had the lowest

MCH (25.2 pg) and automobile mechanics the highest MCV (85.8 fL). Hemoglobin levels were lowest in motorcycle mechanics (13.0 g/dL) and highest in automobile mechanics (13.7 g/dL). Among WBC parameters, neutrophil counts were highest in motorcycle mechanics (2.7 G/L) and eosinophil counts highest in automobile mechanics (0.2 G/L). Lymphocyte counts were significantly lower in diesel and motorcycle mechanics (2.3 G/L) compared to automobile mechanics (2.6 G/L), while platelet counts did not differ significantly by specialty.

Regarding hematological abnormalities by work specialty, the prevalence of microcytic normochromic anemia differed significantly across groups, being most common among diesel mechanics (27.6%) and least common among automobile mechanics (8.1%) ($p = 0.004$). Macrocytosis also showed significant variation, with the highest prevalence in automobile mechanics (17.9%) and the lowest in motorcycle mechanics (3.0%) ($p = 0.036$). Microcytosis exhibited a borderline difference ($p = 0.070$), again most frequent in diesel mechanics (27.6%). In contrast, other abnormalities—including normocytic normochromic anemia, neutropenia, lymphopenia, leukopenia, and thrombocytopenia—did not differ significantly by specialty.

When hematological parameters and abnormalities were compared between workers with ≤ 22 years and those with > 22 years of employment, significant differences were observed in MCH (26.3 vs. 27.3 pg, $p = 0.003$), MCHC (31.1% vs. 31.8%, $p = 0.036$), and platelet count (230.5 vs. 209.4 G/L, $p = 0.001$). Regarding abnormalities, microcytosis was more frequent in workers with ≤ 22 years of employment (18.7% vs. 10.1%, $p = 0.036$), whereas thrombocytopenia was more common in the high-duration group (10.9% vs. 4.7%, $p = 0.045$) (**Table 2**). No other hematological parameters or abnormalities differed significantly by employment duration.

Table 3 compares hematological parameters and abnormalities between PPE users and non-users, and between single-trade vs. multi-trade workshop workers. PPE users were younger (32.0 vs. 38.6 years, $p < 0.001$), had shorter employment duration (15.8 vs. 21.5 years, $p = 0.007$), and lower BMI (22.8 vs. 24.4 kg/m², $p = 0.012$) than non-users, and they had slightly higher MCV (87.2 vs. 85.2 fL, $p = 0.018$). No other hematological indices differed significantly. Regarding abnormalities, microcytosis was markedly less frequent among PPE users (5.5% vs. 16.6%, $p = 0.034$). Microcytic normochromic anemia also tended to be lower (3.6% vs. 11.8%, $p = 0.084$). Other abnormalities showed no statistically significant differences by PPE use.

Table 3. Comparison of hematological parameters and abnormalities according to personal protective equipment use and workshop exposure setting.

Variable	Personal protective equipment (PPE)			Workshop exposure type		
	Non-PPE users (n = 229)	PPE users (n = 55)	p-value*	Single-trade workshop workers* (n = 217)	Multi-trade workshop workers* (n = 65)	p-value*
Age (years)	38.6 (36.9 - 40.3)	32.0 (28.3 - 35.7)	<0.001	36.5 (34.7 - 38.2)	39.7 (36.5 - 43.0)	0.076

Continued

Employment duration (years)	21.5 (19.7 - 23.3)	15.8 (12.2 - 19.4)	0.007	19.4 (17.6 - 21.2)	23.1 (19.6 - 26.7)	0.04
BMI (kg/m ²)	24.4 (23.8 - 24.9)	22.8 (21.7 - 23.8)	0.012	23.9 (23.3 - 24.5)	24.5 (23.4 - 25.5)	0.106
Red blood cells (T/L)	5.1 (5.0 - 5.2)	5.1 (4.9 - 5.2)	0.671	5.1 (5.0 - 5.1)	5.1 (5.0 - 5.3)	0.59
Hemoglobin (g/dL)	13.5 (13.3 - 13.8)	14.0 (13.5 - 14.5)	0.119	13.5 (13.3 - 13.7)	14.0 (13.6 - 14.5)	0.07
Hematocrit (%)	43.1 (42.4 - 43.7)	44.2 (43.0 - 45.4)	0.06	43.2 (42.5 - 43.8)	43.7 (42.7 - 44.7)	0.672
MCV (fL)	85.2 (84.4 - 86.0)	87.2 (85.9 - 88.4)	0.018	85.6 (84.9 - 86.4)	85.3 (83.7 - 87.0)	0.401
MCH (pg)	26.8 (26.4 - 27.2)	27.5 (26.9 - 28.2)	0.155	26.8 (26.4 - 27.2)	27.3 (26.5 - 28.2)	0.251
MCHC (%)	31.4 (31.1 - 31.7)	31.6 (31.0 - 32.2)	0.843	31.3 (31.0 - 31.6)	32.0 (31.4 - 32.7)	0.094
WBC (G/L)	5.3 (5.0 - 5.5)	5.3 (4.8 - 5.8)	0.967	5.3 (5.1 - 5.6)	5.0 (4.6 - 5.4)	0.066
Neutrophils (G/L)	2.3 (2.1 - 2.4)	2.3 (2.0 - 2.7)	0.629	2.3 (2.2 - 2.5)	2.1 (1.9 - 2.3)	0.079
Eosinophils (G/L)	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.2)	0.802	0.1 (0.1 - 0.2)	0.2 (0.1 - 0.2)	0.357
Monocytes (G/L)	0.3 (0.3 - 0.4)	0.3 (0.3 - 0.4)	0.681	0.3 (0.3 - 0.4)	0.3 (0.3 - 0.4)	0.128
Lymphocytes (G/L)	2.5 (2.4 - 2.6)	2.7 (2.3 - 3.1)	0.885	2.6 (2.4 - 2.7)	2.4 (2.2 - 2.7)	0.128
Platelets (G/L)	217.3 (209.7 - 224.8)	227.0 (211.0 - 242.9)	0.138	224.2 (216.2 - 232.2)	203.8 (191.6 - 216.0)	0.026
	n, (%) [95% CI]	n, (%) [95% CI]	p-value	n, (%) [95% CI]	n, (%) [95% CI]	p-value
Normocytic normochromic anemia	21 (9.2%) [6.1 - 13.6]	4 (7.3%) [2.9 - 17.3]	0.795	23 (10.6) [7.2 - 15.4]	4 (6.2) [2.4 - 14.8]	0.345
Microcytic normochromic anemia	27 (11.8%) [8.2 - 16.6]	2 (3.6%) [1.0 - 12.3]	0.084	16 (7.4) [4.6 - 11.6]	8 (12.3) [6.4 - 22.5]	0.212
Microcytosis	38 (16.6%) [12.3 - 22.0]	3 (5.5%) [1.9 - 14.9]	0.034	25 (11.5) [7.9 - 16.5]	12 (18.5) [10.9 - 29.6]	0.148
Macrocytosis	34 (14.9%) [10.9 - 20.1]	10 (18.2%) [10.2 - 30.3]	0.538	33 (15.3) [11.1 - 20.7]	11 (16.9) [9.7 - 27.8]	0.846
Neutropenia	37 (16.2%) [12.0 - 21.6]	13 (23.6%) [14.4 - 36.4]	0.236	35 (16.2) [11.9 - 21.7]	15 (23.1) [14.5 - 34.7]	0.201
Lymphopenia	14 (6.1%) [3.7 - 10.0]	4 (7.3%) [2.9 - 17.3]	0.759	10 (4.6) [2.5 - 8.3]	7 (10.8) [5.3 - 20.6]	0.078
Leukopenia	35 (15.3%) [11.2 - 20.5]	9 (16.4%) [8.9 - 28.3]	0.837	29 (13.4) [9.5 - 18.5]	12 (18.5) [10.9 - 29.6]	0.319
Thrombocytopenia	16 (7.0%) [4.4 - 11.1]	5 (9.1%) [3.9 - 19.6]	0.572	14 (6.5) [3.9 - 10.6]	9 (13.8) [7.5 - 24.3]	0.071

Values are presented as mean (95% confidence interval) for continuous variables and n (%) [95% confidence interval] for categorical variables. Percentages are column-specific. p-values are from the chi-square test or Fisher's exact test for categorical variables and from the Mann-Whitney U test for group comparisons where applicable. BMI, body mass index; PPE, personal protective equipment; RBC, red blood cell count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; WBC, white blood cell count. T/L = tera per liter ($10^{12}/L$); g/dL = grams per deciliter; % = percent; fL = femtoliter; pg = picogram; G/L = giga per liter ($10^9/L$). PPE users: workers who reported regular use of masks, gloves and change of work clothes. *Non-PPE users*: the remainder (n = 229). *Multi-trade workshop workers are mechanics working in settings where welding and painting activities also take place (co-exposure to mechanical, welding and paint-related agents). *Single-trade workshop workers are mechanics working in workshops without welding or painting operations (mechanical work only). Data on personal protective equipment use and workshop exposure type were available for 284 and 282 study participants, respectively.

Workers in multi-trade settings were older (39.7 vs. 36.5 years, $p = 0.076$) and had longer employment (23.1 vs. 19.4 years, $p = 0.040$). They showed significantly lower platelet counts (203.8 vs. 224.2 G/L, $p = 0.026$). Although not significant, they had higher frequencies of microcytic normochromic anemia (12.3% vs. 7.4%), neutropenia (23.1% vs. 16.2%), lymphopenia (10.8% vs. 4.6%) and thrombocytopenia (13.8% vs. 6.5%). The only abnormality approaching significance was thrombocytopenia ($p = 0.071$).

3.3. Multivariable Associations between Occupational Factors and Hematologic Abnormalities

To identify independent predictors of hematological abnormalities, separate logistic regression models were constructed for each outcome, adjusting for age, alcohol, BMI, protective measures and employment duration (**Table 4**). PPE use was independently associated with reduced odds of microcytosis (OR = 0.16, 95% CI: 0.10 - 0.72, $p = 0.017$). Working in a multi-trade setting tended to increase the odds of several hematological abnormalities, though only microcytosis approached significance (OR = 2.17, 95% CI: 0.96 - 4.88, $p = 0.062$). Older age was a significant predictor of macrocytosis (OR per year = 1.09, 95% CI: 1.01 - 1.17, $p = 0.022$), neutropenia (OR = 1.04, 95% CI: 1.00 - 1.07, $p = 0.026$) and leukopenia (OR = 1.05, 95% CI: 1.02 - 1.09, $p = 0.002$). Longer employment duration was associated with increased odds of thrombocytopenia (OR per year = 1.04, 95% CI: 1.00 - 1.09, $p = 0.046$).

Table 4. Multivariable associations between occupational factors and hematologic abnormalities.

Outcome (number of events)	Predictor	OR	95% CI	p-value
Microcytic normochromic anemia (23)	Multi-trade workshop setting	2.04	0.79 - 5.27	0.141
	Age	1.09	1.01 - 1.17	0.022
	PPE use	0.16	0.10 - 0.72	0.017
Neutropenia (47)	Multi-trade workshop setting	2.17	0.96 - 4.88	0.062
	Age	1.04	1.00 - 1.07	0.026
	Multi-trade workshop setting	2.59	0.90 - 7.45	0.079
Lymphopenia (16)	Age	1.05	1.02 - 1.09	0.002
	Multi-trade workshop setting	2.24	0.87 - 5.73	0.093
Thrombocytopenia (21)	Age	1.04	1.01 - 1.09	0.046
	Employment duration	1.04	1.01 - 1.09	0.046

Each hematologic outcome was analyzed using a separate logistic regression model. All models were initially adjusted for age (continuous), alcohol consumption (yes/no), BMI, protective measures (yes/no), and employment duration (continuous). Odds ratios (OR) and 95% confidence intervals (CI). Variables shown are those that reached statistical significance ($p < 0.05$) or were primary predictors of interest. Because some outcomes had few events (microcytic normochromic anemia, lymphopenia, and thrombocytopenia), the events-per-variable ratio in the full model was low, increasing the risk of overfitting. To address this, we conducted sensitivity analyses for these three outcomes using reduced models. These reduced models included only predictors that met either of the following criteria: (1) $p < 0.10$ in univariable analysis, or (2) a priori primary exposures (for microcytic normochromic anemia: PPE use and multi-trade workshop; for lymphopenia: multi-trade workshop only; for thrombocytopenia: multi-trade workshop and employment duration).

4. Discussion

This cross-sectional study is the first to examine the association between occupational characteristics and hematological abnormalities among informal automotive mechanics in Benin. Our main findings are threefold. First, hematological abnormalities were common and varied significantly by work specialty: microcytic normochromic anemia was most prevalent among diesel mechanics (27.6%), macrocytosis among automobile mechanics (17.9%), and microcytosis showed a borderline difference across specialties. Second, regular use of personal protective equipment (PPE) was strikingly low (19.4%), yet in adjusted regression analysis, it was associated with a marked reduction in the odds of microcytosis (OR = 0.16). Third, older age and longer employment duration were associated with macrocytosis, neutropenia, leukopenia, and thrombocytopenia, while co-exposure to welding and painting (multi-trade workshops) showed a tendency toward increased risk, particularly for thrombocytopenia. Taken together, these findings suggest a pattern of association between occupational exposures and hematological abnormalities in this workforce.

The observed associations are consistent with a hypothesis of cumulative occupational hematotoxicity, but this interpretation remains speculative without direct exposure measurements and longitudinal follow-up. In a workforce exposed daily to mixtures of fuels, solvents, welding fumes, paint aerosols, exhaust particles, and metals, chronic exposure could gradually affect marrow function and red-cell production if a causal relationship exists. Mechanistically, benzene and other aromatic hydrocarbons are metabolized to reactive quinones that induce oxidative stress, DNA damage, and apoptosis in hematopoietic progenitor cells, while heavy metals such as lead and cadmium interfere with heme synthesis and iron utilization. However, our study did not measure these specific agents or their metabolites, so mechanistic claims are not supported by our data. The low prevalence of PPE use is particularly important because it suggests that most workers remain exposed without meaningful protection. The strong statistical association of PPE with microcytic outcomes indicates that even simple preventive behavior may be linked to lower odds of hematological abnormalities. Nonetheless, because PPE use was self-reported and no unexposed control group was available, residual confounding (e.g., healthier workers being more likely to use PPE) cannot be excluded. This is notable because the study population works in largely informal settings where engineering controls and formal occupational surveillance are limited. In this context, the observed abnormalities are unlikely to reflect isolated findings; rather, they may represent the combined effect of repeated low-dose exposure, poor workplace hygiene, and insufficient prevention infrastructure, but this interpretation requires confirmation in longitudinal studies with objective exposure assessment.

Our findings align with a growing body of evidence from low- and middle-income countries. Several studies consistently show that occupational exposure in garages, spray-painting shops, fuel stations, and dust-heavy workplaces is asso-

ciated with measurable hematological alterations, supporting the idea that blood indices might serve as early biomarkers of exposure-related toxicity. In Pakistan, auto-repair workers and spray painters showed lower RBC and hemoglobin levels, with painters also exhibiting higher WBC, MCV, and packed cell volume; these effects were influenced by smoking, long working hours, poor ventilation, and other workplace conditions, indicating that exposure risk is shaped by both occupational and behavioral factors [12] [13]. Recently, Badejo *et al.* assessed the hematologic profile of workers occupationally and environmentally exposed to petroleum products in Abuja and its environs, and they found that petroleum product exposure was associated with alterations in hematological parameters, with auto mechanics showing particularly notable differences in WBC, Hemoglobin, and platelet counts compared with other worker groups [14]. Similar hematological patterns were reported in Nigeria and Ghana, where automobile technicians had lower RBC and hematocrit and reduced indices with longer exposure, while mechanics and sprayers in Cape Coast showed reduced hematopoietic output, lower RBC and reticulocyte counts, and poor uptake of safety practices [5] [6]. Evidence from Ethiopia further supports this pattern: garage workers had lower RBC, hemoglobin, hematocrit, and MCV but higher WBC and platelet counts than controls, and petrol station workers showed significant differences in RBC, hemoglobin, eosinophils, and MCV, with some abnormalities worsening with exposure duration [1] [2] [15]. Beving *et al.* reported that long-term low-level exposure to organic solvents among car repair painters and mechanics was associated with reduced erythrocyte counts and increased erythrocyte volume, particularly in painters, compared with unexposed controls [16]. The study also found a shift toward larger erythrocyte size distribution and higher mean platelet volume in the exposed workers, suggesting early hematological effects before clinical symptoms appear [16]. Finally, among automotive body painters exposed to lead, mask use reduced exposure and blood lead levels were inversely associated with RBC, hemoglobin, and hematocrit, reinforcing the potential of simple protective measures to be associated with lower hematological toxicity [17]. Taken together, our results are consistent with international literature and provide the first quantitative estimate of the association between PPE use and hematological outcomes in an informal automotive setting. They also extend prior evidence by showing that these associations are detectable even in a context where multiple exposures co-occur and formal industrial hygiene controls are absent.

One of the most notable findings is the strong statistical association between PPE use and reduced odds of microcytosis. These effect sizes are large enough to be of practical importance if the association is causal, which the current study cannot establish. In our cohort, only 19.4% of workers used PPE regularly, leaving a large majority continuously exposed to agents that may affect bone-marrow function, such as BTEX, PAHs, and heavy metals. The low uptake of PPE is consistent with reports from other West African countries where occupational safety training is rarely provided [5]. However, PPE use in informal settings is often in-

termittent, incomplete, and poorly standardized; therefore, its apparent protective effect could partly reflect broader safety-conscious work practices rather than PPE alone and could also be influenced by self-report bias. In contrast, working in a multi-trade workshop was associated with lower platelet counts (203.8 vs. 224.2 G/L, $p = 0.026$) and a trend towards higher frequencies of several abnormalities, although only microcytosis approached significance in regression (OR = 2.17, $p = 0.062$). The lack of statistical significance may reflect limited power due to small subgroup sizes. Nevertheless, the consistent direction of associations suggests that multi-trade exposure may confer an additional hematological risk. This is important because multi-trade workshops may also have more chaotic work organization, greater overlap of exposures, and fewer opportunities for task-specific protection, which could amplify cumulative toxic burden, if a causal relationship exists.

When considering age and employment duration, older age was independently associated with macrocytosis, neutropenia, and leukopenia. However, the individual adjusted odds ratios for age and employment duration should be interpreted with caution, as these variables are correlated and do not represent fully independent effects. Longer employment duration itself was independently associated with thrombocytopenia (OR = 1.04 per year), consistent with Ibeh *et al.* [6] who found decreasing platelet counts with longer work duration. The finding that macrocytosis was most common among automobile mechanics (17.9%) might be explained by their longer exposure to organic solvents which have been hypothesized to induce significant effects on hematopoiesis [12]. Conversely, microcytosis was more frequent among diesel mechanics (27.6%) and workers with shorter employment duration, possibly reflecting a different mixture of exposures (e.g., diesel exhaust particulates and metals) that interfere with iron metabolism. An alternative explanation is that some of these patterns may also reflect differences in nutritional status, alcohol intake, or unmeasured inflammatory conditions, all of which can influence RBC indices and should be explored in future studies.

The observed association between PPE use and reduced odds of abnormalities suggests that even simple, low-cost interventions—provision of masks, gloves and coveralls, together with basic training—might yield substantial reductions in hematological abnormalities if the association is causal. Health promotion campaigns should target not only mechanics but also workshop owners and professional associations, emphasizing that regular PPE use may be beneficial even without formal regulatory oversight. Furthermore, the higher risk of anemia and microcytosis among diesel mechanics and the higher risk of macrocytosis among automobile mechanics suggest that different trades may have different exposure profiles. For diesel mechanics, reducing exposure to exhaust particulates and metals (e.g., improved ventilation, banning fuel siphoning) could be prioritized. For automobile mechanics, minimizing skin contact with organic solvents and providing adequate hand-cleaning facilities could potentially reduce macrocytosis. The independent association of employment duration on thrombocytopenia implies

that cumulative exposure monitoring might be considered for workers with >20 years in the trade. Regular complete blood count testing could serve as a low-cost screening tool to detect early bone-marrow depression and trigger timely removal from exposure in surveillance context. Finally, the low overall uptake of PPE and lack of safety training highlight the need for policy interventions. Collaborations with professional associations and micro-financing of PPE could be feasible and effective entry points. Beyond individual-level protection, structural measures such as shaded work areas, task zoning, safer solvent substitution, and organized waste handling would likely yield broader risk reduction. Integrating occupational health education into apprenticeship systems may be especially impactful because many workers enter the trade at a young age and remain exposed throughout their working lives.

This study has several strengths. It is the first systematic evaluation of hematological abnormalities among informal automotive mechanics in Benin, filling an important geographic gap. In addition, it is among the few studies to directly compare three distinct specialties within the same informal sector. We collected detailed information on work specialty, employment duration, PPE use, and multi-trade exposure, allowing us to disentangle the associations of different occupational factors. The use of multivariable logistic regression adjusted for key confounders strengthens internal validity. Furthermore, the active engagement of four professional associations facilitated a high participation rate and enhanced representativeness. In addition, the focus on a hard-to-reach informal workforce adds substantial public health relevance, because such workers are often missing from routine occupational surveillance systems.

Several limitations should be acknowledged. First and most importantly, the cross-sectional design and the absence of an unexposed comparison group preclude causal inference. Reverse causation (healthier workers being more likely to use PPE) and residual confounding cannot be ruled out. Exposure assessment relied on self-reported duration and workshop characteristics, without direct air monitoring, which may have introduced non-differential misclassification biasing results toward the null. Small subgroup sizes (diesel mechanics, multi-trade workers) limited statistical power for some comparisons, reflected in wide confidence intervals. We excluded smokers and participants with chronic diseases to reduce confounding, which may limit generalizability to the broader mechanic workforce. We did not measure nutritional status (iron, vitamin B12, folate), which could influence RBC indices independently of occupational factors. Finally, the cross-sectional design cannot capture more severe outcomes such as aplastic anemia or leukemia, which require long-term follow-up. Residual confounding by unmeasured factors such as malaria history, parasitic infections, and prior medication use may also have influenced hematologic values in this setting. Because exposure and outcome were measured at one time point, temporal ordering cannot be established, and the observed associations should therefore be interpreted as hypothesis-generating rather than evidence of causation.

5. Conclusion

In this first cross-sectional study of hematological abnormalities among informal automotive mechanics in Benin, regular use of PPE was associated with lower odds of microcytic anemia and microcytosis, whereas older age, longer employment duration, and multi-trade co-exposure were associated with higher odds of various cytopenias. The overall uptake of PPE was only 19.4%, representing a missed prevention opportunity. Low-cost interventions promoting mask, glove, and protective workwear use, together with trade-specific exposure reduction, could be considered for improving hematological health, but their effectiveness would need to be confirmed in intervention studies. Longitudinal studies with direct exposure assessment and nutritional biomarkers are needed to determine whether the observed associations reflect causal relationships and to guide targeted screening. Future research should also examine dose-response relationships, biomarkers of oxidative stress and genotype relevant metabolic enzymes (e.g., CYP2E1, GSTM1, GSTP1, GSTT1) to better understand inter-individual variability. Collaboration with professional associations and workshop owners will be essential to translate these preliminary findings into sustainable occupational health improvements in Benin and other West African countries.

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Conflicts of Interest

The authors declare no competing interests.

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