

Haematological Effects of Acetylene Fume Exposure among Welders: A Comparative Cross-Sectional Study

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Abstract

Background: Welders are chronically exposed to complex mixtures of metal fumes and combustion gases, including acetylene, which may affect haematological health. This study evaluated the impact of acetylene fume exposure on haematological parameters among welders compared to non-welders, and explored how age and duration of exposure influence these parameters. **Methods:** A comparative cross-sectional study was conducted involving 200 participants (100 welders and 100 non-welders). Standard haematological indices were measured and analyzed using t-tests, ANOVA, Pearson correlation, and Multiple regression was used to assess the effect of exposure duration on red blood cell (RBC) count, adjusting for age as a potential confounder. **Results:** Welders exhibited significantly lower platelet counts, mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) compared to controls ($p < 0.05$). RBC counts did not differ significantly between groups; however, within welders, haematological parameters, including haemoglobin, RBC count, and platelet count, varied significantly with age and exposure duration. The decrease in platelet counts may reflect oxidative stress-mediated impairment of megakaryopoiesis induced by chronic exposure to metal and gas fumes. Although regression analysis adjusting for age showed no statistically independent effect of exposure duration on RBC count, unadjusted analyses and correlations indicated that longer exposure durations were associated with lower RBC counts. **Conclusion:** While overall RBC counts did not differ significantly between welders and controls, prolonged exposure to acetylene fumes was significantly associated with reduced RBC counts among welders, indicating potential cumulative toxicity. Occupational health interventions, including routine haematological monitoring and enhanced protec-

tive measures, are recommended to safeguard the haematological health of welders.

Keywords

Welders, Acetylene Fumes, Haematological Parameters, Red Blood Cell Count, Platelet Count, Exposure Duration, Haematotoxicity

1. Introduction

Occupational exposure to hazardous chemical substances continues to be a critical public health concern, particularly in industrial environments where workers are routinely exposed to toxic agents. Among such workers, welders are especially vulnerable due to their continuous exposure to complex mixtures of metal fumes, gases, and other by-products generated during various welding processes [1]. Welding plays an indispensable role in construction, manufacturing, automotive industries, and infrastructure development, contributing significantly to economic growth and industrial progress. However, these benefits are frequently counterbalanced by serious occupational health risks, particularly in environments where safety regulations are weak, inconsistently applied, or poorly enforced [2]-[4]. Welders are regularly exposed to hazardous fumes, including metal oxides, carbon monoxide, and nitrogen dioxide, which have been associated with respiratory illnesses, neurological disorders, and haematological abnormalities [5] [6]. These health risks are compounded in low-resource settings where the use of personal protective equipment (PPE) is limited and industrial hygiene practices are insufficient [7] [8].

Welding fumes are composed of fine particulate matter and gaseous by-products that vary depending on the type of metal being welded, the welding process used, and the shielding gases or fuel gases involved [3]. One of the most commonly used gases in oxy-fuel welding and cutting is acetylene, valued for its high flame temperature, which can reach over 3000°C when combined with oxygen [9]. However, the same high temperatures that make acetylene effective for industrial purposes also result in the generation of toxic decomposition products, including carbon monoxide, nitrogen oxides, unburned hydrocarbons, and particulate-bound metal oxides [4] [9] [10].

These fumes, when inhaled regularly, pose serious health risks. Epidemiological studies and toxicological research have shown that chronic exposure to welding fumes is associated with respiratory diseases (e.g., chronic bronchitis, pneumonitis), neurological impairments, carcinogenic effects, and systemic toxicity, particularly involving the haematopoietic system [3]. The particulate and gaseous components of welding fumes can enter the bloodstream through alveolar diffusion, where they induce oxidative stress, inflammation, and genotoxicity—pathways that can disrupt normal hematopoiesis and immune function [11] [12].

In developing regions such as Nigeria, where informal welding workshops are widespread and largely unregulated, the health risks are magnified by the lack of adequate personal protective equipment (PPE), poor ventilation, and minimal awareness of occupational safety protocols [13] [14]. Welders in such settings are often exposed to toxic fumes over long durations without proper health surveillance, increasing the likelihood of developing chronic haematological and systemic disorders [15] [16].

This study, therefore, aims to explore the haematological implications of exposure to acetylene-based welding fumes, particularly focusing on the context of Aba Metropolis, Nigeria, where welding is a common livelihood but occupational safety measures remain grossly inadequate. By examining changes in blood parameters among welders, the study seeks to shed light on the systemic effects of prolonged exposure and provide data to support improved workplace safety standards and health interventions.

2. Materials and Methods

2.1. Study Area

This study was conducted in Aba, a prominent urban center located in Abia State, in the South East geopolitical zone of Nigeria. Aba serves as the commercial hub of Abia State and plays a significant role in regional economic activities, especially in small- and medium-scale manufacturing, metal works, and informal sector enterprises such as welding and fabrication.

Geographically, Aba is situated at Latitude 5°7'0"N and Longitude 7°22'0"E. As of the 2023 population estimate, the city has an approximate population of 1,189,000, making it the second-largest commercial city in South Eastern Nigeria and one of the most densely populated urban areas in the region. Aba is ranked 9th by population among cities in Nigeria, underscoring its demographic significance and economic vibrancy.

The city is cosmopolitan, drawing people from diverse ethnic, cultural, and occupational backgrounds. It is well known for its industrial clusters, artisan hubs, and bustling markets such as the Ariaria International Market, one of the largest markets in West Africa. Due to the high concentration of informal workshops and low-cost manufacturing units, welding is a common occupation, often carried out in unregulated environments with minimal safety oversight—making Aba a relevant location for studies related to occupational health risks, particularly those associated with exposure to welding fumes.

2.2. Study Design

This study is a comparative cross-sectional study aimed at evaluating the haematological effects of prolonged acetylene fume exposure among welders. The investigation involves two groups: a test group comprising welders with occupational exposure to acetylene fumes, and a matched control group without such exposure. Data collection will occur at a single point in time, and comparisons will be made

between the two groups to assess differences in haematological parameters.

2.3. Study Population

The study population consists of adult welders currently employed in Aba Metropolis who have been continuously exposed to acetylene fumes for at least one year. Welders must be aged 18 years or older and have no known chronic haematological or significant systemic diseases. The control group includes non-welding individuals from the same geographical region, matched by age and other relevant demographic factors, who have no occupational exposure to welding fumes or similar hazards and meet the same health criteria. All participants must provide informed consent prior to enrollment.

2.4. Inclusion Criteria

- 1) Age \geq 18 years.
- 2) Welders: currently employed and performing tasks involving acetylene, with \geq 1 year of continuous exposure.
- 3) Controls: individuals without occupational exposure to welding fumes or similar hazards.
- 4) Absence of known chronic haematological disorders (e.g., sickle cell disease, thalassemia) or systemic diseases likely to affect haematological parameters (e.g., liver or kidney disease).
- 5) Willingness to provide informed consent and undergo venous blood collection.
- 6) All participants must provide informed consent prior to inclusion in the study.

2.5. Exclusion Criteria

- 1) Individuals below 18 years.
- 2) Welders with $<$ 1 year of exposure to acetylene fumes.
- 3) History of blood transfusion within the preceding six months.
- 4) Current use of medications or treatments that could alter haematological indices (e.g., anticoagulants, chemotherapeutic agents).
- 5) Unwillingness or inability to provide informed consent or undergo blood collection.
- 6) Smoking status was not assessed; therefore, participants with active tobacco use could not be excluded. This represents a potential confounding factor for haematological outcomes, particularly white blood cell count and haemoglobin concentration.

2.6. Data Collection

Socio-demographic information was obtained from all participants through the administration of a structured questionnaire. The questionnaire captured relevant variables including age, sex, duration of occupational exposure, and other perti-

nent personal and occupational details.

2.7. Sample Collection

Venous blood samples were collected from each participant using standard aseptic venepuncture techniques. Approximately 2 mL of blood was drawn into EDTA anticoagulant tubes specifically designated for haematological analysis. Each sample was properly labelled with a unique identifier and transported under appropriate conditions to the laboratory for immediate processing.

2.8. Laboratory Analysis

Haematological parameters were measured using an automated haematology analyzer (Sicuro Hemia 5D). The parameters assessed included red blood cell (RBC) count, haemoglobin concentration, white blood cell (WBC) count, platelet count, and red cell indices (mean corpuscular volume, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentration). All analyses were performed according to the manufacturer's instructions and standard laboratory protocols to ensure accuracy and reliability.

2.9. Statistical Analysis

Data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0. Continuous variables were summarized using means and standard deviations. Comparisons between the test and control groups were conducted using the Independent Samples t-test, while analysis of variance (ANOVA) was employed to assess differences among multiple subgroups where applicable. Pearson's correlation coefficient was calculated to evaluate the relationship between duration of exposure to acetylene fumes and haematological parameters. Parameters showing statistically significant correlations were further analyzed using multiple linear regression to determine the predictive effect of exposure duration. Specifically, the regression model for red blood cell (RBC) count included age as a covariate to adjust for its potential confounding effect, given its correlation with years of occupational exposure. Regression assumptions, including linearity, normality of residuals, and multicollinearity, were checked, and variance inflation factors (VIF) were calculated. Statistical significance was defined at a p-value less than 0.05.

3. Results

A total of 200 participants were included in the study, comprising 100 individuals in the Test group (welders exposed to acetylene fumes) and 100 individuals in the Control group (non-welders). The mean age of the Test group was 35.84 ± 9.21 years, while the mean age of the Control group was 34.00 ± 8.86 years.

The Comparison of haematological parameters between the two groups is summarized in **Table 1**. There were no statistically significant differences observed in haemoglobin concentration (Hb), packed cell volume (PCV), red blood cell count

(RBC), total white blood cell count (TWBC), or mean corpuscular volume (MCV) between welders and non-welders ($p > 0.05$). However, welders demonstrated significantly lower platelet counts ($130.76 \pm 56.45 \times 10^9/L$) compared to controls ($155.04 \pm 44.07 \times 10^9/L$; $t = -3.390$, $p = 0.001$). Additionally, mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were significantly reduced in welders (MCH: 27.22 ± 2.02 pg vs. 29.30 ± 1.62 pg; $t = -8.019$, $p < 0.001$; MCHC: 30.25 ± 1.97 g/dL vs. 32.33 ± 1.90 g/dL; $t = -7.604$, $p < 0.001$). These findings suggest a potential adverse effect of acetylene fume exposure on platelet counts and red blood cell indices.

Table 1. Comparison of some haematological parameters between welders exposed to acetylene fumes and non-welders.

| Parameters | TEST N = 100 | CONTROL N = 100 | t-value | p-value ($p \leq 0.05$) |
|---------------------|--------------------|--------------------|---------|------------------------------|
| Hb (g/dl) | 12.32 ± 1.19 | 12.25 ± 1.12 | 0.433 | 0.665 |
| PCV (L/L) | 0.42 ± 0.03 | 0.42 ± 0.04 | -0.664 | 0.507 |
| RBC ($10^{12}/L$) | 4.34 ± 0.40 | 4.38 ± 0.39 | -0.654 | 0.514 |
| TWBC ($10^9/L$) | 4.48 ± 0.83 | 4.56 ± 0.66 | -0.690 | 0.491 |
| PLT ($10^9/L$) | 130.76 ± 56.45 | 155.04 ± 44.07 | -3.390 | 0.001 |
| MCH (pg) | 27.22 ± 2.02 | 29.30 ± 1.62 | -8.019 | <0.001 |
| MCHC (g/dl) | 30.25 ± 1.97 | 32.33 ± 1.90 | -7.604 | <0.001 |
| MCV (fl) | 88.16 ± 6.90 | 88.92 ± 5.08 | -0.893 | 0.373 |

Haematological parameters among welders exposed to acetylene fumes were compared across four age groups (11 - 20, 21 - 30, 31 - 40, and 41 - 50 years) as shown in **Table 2**. Significant differences were observed in several parameters with age. Haemoglobin concentration (Hb) varied significantly across groups ($F = 4.829$, $p = 0.004$), with the highest mean Hb recorded in the 31 - 40 years group (13.00 ± 1.48 g/dL). Packed cell volume (PCV) also differed significantly ($F = 10.026$, $p < 0.001$), with the 31 - 40 years group showing the highest mean value (0.44 ± 0.03 L/L).

Red blood cell count (RBC) decreased significantly with increasing age, with the 41 - 50 years group having the lowest mean count ($4.06 \pm 0.32 \times 10^{12}/L$; $F = 13.082$, $p < 0.001$). Total white blood cell count (TWBC) showed significant variation among age groups ($F = 5.257$, $p = 0.002$), with the youngest group (11 - 20 years) exhibiting the highest mean count ($6.00 \pm 0.02 \times 10^9/L$).

Platelet counts (PLT) differed significantly with age ($F = 8.416$, $p < 0.001$), with the 31 - 40 years group showing the highest mean platelet count ($159.43 \pm 50.97 \times 10^9/L$). No significant differences were found in mean corpuscular haemoglobin (MCH) ($p = 0.065$) or mean corpuscular haemoglobin concentration (MCHC) ($p = 0.200$) across age groups. However, mean corpuscular volume (MCV) varied significantly ($F = 4.585$, $p = 0.005$), with younger age groups (11 - 20 and 21 - 30

years) displaying higher mean MCV values.

These findings indicate that age influences several haematological parameters in welders exposed to acetylene fumes, suggesting potential age-related vulnerability or adaptive changes to occupational exposure.

Table 2. Comparison of the haematological parameters of welders exposed to acetylene fumes according to age group.

| Parameters | 11 - 20 N = 4 | 21 - 30 N = 32 | 31 - 40 N = 28 | 41 - 50 N = 36 | f-value | p-value ($p \leq 0.05$) |
|---------------------|------------------|-------------------|-------------------|-------------------|---------|------------------------------|
| Hb (g/dl) | 12.00 ± 0.05 | 12.16 ± 0.55 | 13.00 ± 1.48 | 11.98 ± 1.24 | 4.829 | 0.004 |
| PCV (L/L) | 0.43 ± 0.01 | 0.41 ± 0.02 | 0.44 ± 0.03 | 0.41 ± 0.03 | 10.026 | <0.001 |
| RBC ($10^{12}/L$) | 4.72 ± 0.01 | 4.46 ± 0.39 | 4.52 ± 0.34 | 4.06 ± 0.32 | 13.082 | <0.001 |
| TWBC ($10^9/L$) | 6.00 ± 0.02 | 4.44 ± 0.77 | 4.37 ± 0.98 | 4.43 ± 0.64 | 5.257 | 0.002 |
| PLT ($10^9/L$) | 85.00 ± 0.00 | 99.88 ± 56.20 | 159.43 ± 50.97 | 141.00 ± 48.32 | 8.416 | <0.001 |
| MCH (pg) | 26.50 ± 0.10 | 27.43 ± 2.07 | 26.44 ± 2.46 | 27.72 ± 1.49 | 2.489 | 0.065 |
| MCHC (g/dl) | 29.18 ± 0.05 | 30.04 ± 1.00 | 30.87 ± 3.19 | 30.08 ± 1.28 | 1.577 | 0.200 |
| MCV (fl) | 91.08 ± 0.05 | 91.29 ± 4.49 | 85.44 ± 5.86 | 87.16 ± 8.56 | 4.585 | 0.005 |

The haematological parameters of welders exposed to acetylene fumes were analyzed based on their years of occupational exposure, grouped into six categories (1 - 5, 6 - 10, 11 - 15, 16 - 20, 21 - 25, and 26 - 30 years). The results are presented in **Table 3**.

A statistically significant difference was observed in haemoglobin concentration (Hb) across the exposure groups ($F = 14.864$, $p < 0.001$). The highest mean Hb (13.43 ± 1.31 g/dL) was recorded among welders with 11 - 15 years of exposure, while the lowest value (10.90 ± 0.96 g/dL) occurred in those with 26 - 30 years of exposure. Similarly, packed cell volume (PCV) increased significantly up to 15 years of exposure and subsequently declined, with the lowest PCV in the 26 - 30 years group (0.39 ± 0.02 L/L; $F = 26.481$, $p < 0.001$).

Red blood cell count (RBC) varied significantly across groups ($F = 15.464$, $p < 0.001$), peaking in the 6 - 10 years group ($4.85 \pm 0.28 \times 10^{12}/L$) and declining progressively thereafter, with the lowest count observed in the longest exposure group ($4.01 \pm 0.45 \times 10^{12}/L$). Total white blood cell count (TWBC) also showed a significant difference ($F = 2.885$, $p = 0.018$), with the highest mean in the 11 - 15 years group ($4.82 \pm 0.68 \times 10^9/L$) and the lowest in the 26 - 30 years group ($3.68 \pm 0.88 \times 10^9/L$).

Platelet count (PLT) differed significantly with exposure duration ($F = 11.669$, $p < 0.001$), increasing from $97.14 \pm 56.14 \times 10^9/L$ (1 - 5 years) to a peak of $193.00 \pm 20.31 \times 10^9/L$ (16 - 20 years), before declining in the 21 - 25 and 26 - 30 years groups.

Mean corpuscular haemoglobin (MCH) and mean corpuscular volume (MCV) also showed statistically significant variations ($F = 8.698$ and 12.550 respectively, $p < 0.001$), with the highest MCH (28.95 ± 1.76 pg) and MCV (97.75 ± 4.12 fL)

recorded in the 16 - 20 years group. Mean corpuscular haemoglobin concentration (MCHC) showed modest but statistically significant variation across the groups ($F = 2.343$, $p = 0.047$).

Table 3. Comparison of the haematological parameters of Welders exposed to acetylene fumes according to Year of Exposure.

| Parameters | 1 - 5 N = 28 | 6 - 10 N = 16 | 11 - 15 N = 24 | 16 - 20 N = 8 | 21 - 25 N = 16 | 26 - 30 N = 8 | f-value | p-value ($p \leq 0.05$) |
|---------------------|-----------------|------------------|-------------------|------------------|-------------------|------------------|---------|------------------------------|
| Hb (g/dl) | 12.13 ± 0.59 | 12.10 ± 0.74 | 13.43 ± 1.31 | 13.10 ± 0.43 | 11.55 ± 0.96 | 10.90 ± 0.96 | 14.864 | <0.001 |
| PCV (L/L) | 0.40 ± 0.25 | 0.42 ± 0.01 | 0.45 ± 0.02 | 0.45 ± 0.01 | 0.40 ± 0.02 | 0.39 ± 0.02 | 26.481 | <0.001 |
| RBC ($10^{12}/L$) | 4.40 ± 0.36 | 4.85 ± 0.28 | 4.16 ± 0.31 | 4.54 ± 0.13 | 4.10 ± 0.16 | 4.01 ± 0.45 | 15.464 | <0.001 |
| TWBC ($10^9/L$) | 4.59 ± 0.90 | 4.31 ± 1.12 | 4.82 ± 0.68 | 4.23 ± 0.36 | 4.49 ± 0.34 | 3.68 ± 0.88 | 2.885 | 0.018 |
| PLT ($10^9/L$) | 97.14 ± 56.14 | 117.75 ± 35.28 | 175.50 ± 53.25 | 193.00 ± 20.31 | 113.50 ± 35.35 | 112.50 ± 24.05 | 11.669 | <0.001 |
| MCH (pg) | 27.86 ± 1.79 | 25.10 ± 2.77 | 26.87 ± 1.22 | 28.95 ± 1.76 | 28.18 ± 1.08 | 26.65 ± 0.16 | 8.698 | <0.001 |
| MCHC (g/dl) | 30.24 ± 0.89 | 29.03 ± 0.97 | 30.85 ± 3.58 | 29.60 ± 0.53 | 30.88 ± 0.56 | 30.35 ± 0.59 | 2.343 | 0.047 |
| MCV (fl) | 92.15 ± 4.06 | 86.30 ± 6.86 | 83.50 ± 1.15 | 97.75 ± 4.12 | 87.00 ± 9.51 | 84.55 ± 4.86 | 12.550 | <0.001 |

KEYS: Hb—Haemoglobin, PCV—Packed Cell Volume, RBC—Red Blood Cell count, TWBC—Total White blood cell count, PLT—Platelet count, MCH—Mean Cell Haemoglobin, MCHC—Mean Cell Haemoglobin Concentration, MCV—Mean Cell Volume.

Table 4. Pearson correlation between duration of exposure and haematological parameters.

| Parameter | Pearson Correlation with Exposure Duration | p-value (2-tailed) | Interpretation |
|-----------|-----------------------------------------------|--------------------|---------------------|
| Hb | -0.195 | 0.052 | Not significant |
| PCV | -0.113 | 0.264 | Not significant |
| RBC | -0.387 | <0.001 | Significant (trend) |
| TWBC | -0.178 | 0.076 | Not significant |
| PLT | 0.173 | 0.086 | Not significant |
| MCH | 0.086 | 0.393 | Not significant |
| MCHC | 0.116 | 0.250 | Not significant |
| MCV | -0.213 | 0.033 | Significant |

Pearson correlation analysis was conducted to assess the relationship between the duration of exposure to acetylene fumes and various haematological parameters among welders, as shown in **Table 4**.

A statistically significant negative correlation was observed between exposure duration and red blood cell (RBC) count ($r = -0.387$, $p < 0.001$), indicating a moderate inverse relationship. This suggests that longer exposure is associated with a reduction in RBC count, which may reflect the cumulative haematotoxic effects of acetylene fumes.

Although haemoglobin (Hb), packed cell volume (PCV), and total white blood cell count (TWBC) also showed negative correlation trends with exposure duration ($r = -0.195$, -0.113 , and -0.178 respectively), these were not statistically sig-

nificant ($p > 0.05$). Mean corpuscular volume (MCV) also demonstrated a weak but statistically significant negative correlation ($r = -0.213$, $p = 0.033$); however, the correlation was of low strength and thus of limited clinical relevance.

Other haematological indices, including platelet count (PLT), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC), showed no significant correlations with exposure duration ($p > 0.05$).

Overall, the results indicate that among all measured parameters, RBC count exhibited the strongest and most statistically significant inverse relationship with duration of exposure, supporting the hypothesis that prolonged welding exposure may impair erythropoiesis or increase red cell destruction.

A multiple linear regression analysis was performed to assess the effect of acetylene fume exposure duration on red blood cell (RBC) count among welders, with age included as a covariate to account for its potential confounding effect.

The regression equation was:

$$\text{RBC Count (10}^{12}/\text{L)} = 5.039 + 0.012 \times (\text{Exposure Duration}) - 0.020 \times (\text{Age})$$

After adjusting for age, exposure duration was not a statistically significant predictor of RBC count ($p = 0.852$), and age showed a borderline negative association ($p = 0.082$). High variance inflation factors (VIFs > 8) indicate substantial collinearity between age and exposure duration, suggesting that the independent effects should be interpreted cautiously. Nevertheless, unadjusted analyses, Pearson correlation, and ANOVA consistently indicated that longer exposure durations are associated with lower RBC counts, supporting a cumulative haematotoxic effect of acetylene fume exposure.

4. Discussion

This study examined the haematological impact of occupational exposure to acetylene fumes among welders. Most haematological parameters such as haemoglobin (Hb), packed cell volume (PCV), red blood cell count (RBC), total white blood cell count (TWBC), and mean corpuscular volume (MCV) showed no significant differences between welders and non-welders. However, significant reductions were observed in platelet count (PLT), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) in welders.

The observed decrease in platelet count suggests a mild thrombocytopenic effect, potentially linked to prolonged exposure to toxic substances in welding fumes. A plausible biological mechanism is that oxidative stress induced by reactive oxygen species (ROS) from both acetylene combustion by-products and particulate metal fumes may impair megakaryopoiesis—the process by which megakaryocytes in the bone marrow produce platelets. ROS can damage hematopoietic progenitor cells or disrupt the bone marrow microenvironment, reducing platelet production or accelerating platelet clearance from circulation. This mechanism is consistent with previous reports linking metal fume exposure to thrombocytopenia [3] [17] [18].

It is important to note that isolating the specific haematotoxic effects of acety-

lene gas versus particulate metal fumes is inherently challenging. Welders are exposed to a complex mixture of combustion products—including acetylene, carbon monoxide, and nitrogen oxides—as well as metal oxide particles (e.g., iron, manganese, chromium). These components may have additive or synergistic toxic effects on haematopoiesis, oxidative stress pathways, and systemic inflammation. Therefore, the observed haematological changes cannot be attributed solely to acetylene exposure, but rather reflect the cumulative impact of the complex welding fume mixture.

The observed reductions in MCH and MCHC may reflect subtle disruptions in haemoglobin synthesis or red cell integrity, potentially due to oxidative damage from chronic fume exposure [6] [19]. These early changes could precede overt anemia, warranting longitudinal monitoring. Interestingly, parameters such as Hb, PCV, RBC, TWBC, and MCV did not differ significantly, contrasting with reports of anemia and leukocytosis in welders [20]. Variations in exposure duration, safety practices, fume composition, and individual susceptibility could explain these discrepancies.

Age-stratified analysis revealed that haematological profiles varied across age groups, likely reflecting combined effects of aging and cumulative exposure. Hb and PCV peaked in the 31 - 40 age group, then declined in older welders (41 - 50 years), suggesting optimal erythropoiesis in mid-adulthood followed by a potential decline due to aging or long-term exposure [21] [22]. The accompanying reduction in RBC supports this hypothesis. TWBC was highest in the youngest group (11 - 20 years), possibly indicating a more reactive immune system or acute inflammation, whereas levels stabilized in older welders—perhaps reflecting immune adaptation or decline [23]. Platelet counts were highest in the 31 - 40 group but declined in both younger and older age groups, potentially due to variable thrombopoietic activity and bone marrow response [24]. MCV was significantly higher in younger individuals, suggesting regenerative marrow activity or newer erythrocytes, while the decline in older welders may indicate aging or chronic microcytic shifts [25]. No significant age-related changes were found in MCH or MCHC, suggesting these indices may be less responsive to age or exposure in this cohort.

Exposure duration had a clear influence on haematological parameters, indicating a dose-dependent effect. Hb and PCV peaked in welders with 11 - 15 years of exposure, and then declined markedly in those with over 20 years, particularly in the 26 - 30 years of Exposure group. This trend may reflect initial adaptation or a healthy worker effect, followed by haematopoietic suppression due to prolonged toxin exposure [3] [22]. RBC counts followed a similar pattern, with a notable decline in those with long-term exposure, suggesting cumulative bone marrow suppression or erythrocyte damage [17] [19]. TWBC also declined after 25 years of exposure, possibly indicating compromised immune function [23]. PLT counts increased up to 16 - 20 years of exposure, possibly as a reactive response, but declined thereafter, consistent with the proposed oxidative stress-mediated impair-

ment of megakaryopoiesis [18] [24]. MCH and MCHC were lowest in the 6 - 10-year exposure group, suggesting early disruptions in haemoglobin synthesis. MCV showed significant fluctuations, peaking at 16 - 20 years, which may reflect compensatory or morphological shifts in red cells [25].

Correlation analysis further supported these findings. A significant negative correlation was observed between exposure duration and RBC count ($r = -0.387$, $p < 0.001$), indicating progressive erythrocyte decline with increased exposure. Although correlations with Hb, PCV, and TWBC were not statistically significant, observed trends suggested a cumulative toxic effect, in line with known latency in occupational haematotoxicity [18] [19]. MCV showed a weak but significant negative correlation with exposure duration ($r = -0.213$, $p = 0.033$), indicating subtle morphological changes in red cells. No significant correlations were found for MCH, MCHC, PLT, or TWBC, possibly due to individual variability in exposure, protective measures, nutrition, and genetics. Moreover, some haematological effects may not follow a linear progression but exhibit threshold or biphasic responses [22].

Age-adjusted multiple linear regression confirmed that exposure duration was not an independent predictor of RBC count after accounting for age ($p = 0.852$), and age showed a borderline negative association ($p = 0.082$). High variance inflation factors (VIFs > 8) indicated substantial collinearity between age and exposure duration, suggesting caution in interpreting independent effects. Nevertheless, the unadjusted correlation and ANOVA results indicate a biologically meaningful decline in RBC counts with longer exposure, consistent with cumulative haematotoxicity from chronic welding fume exposure [3] [6] [17].

A key limitation of this study is the lack of assessment of smoking status. Smoking is a recognized confounder of haematological parameters, particularly white blood cell count and haemoglobin concentration. Failure to adjust for smoking may have influenced some of the observed haematological differences between groups. Future studies should incorporate detailed smoking history and other lifestyle factors to better isolate the effects of acetylene fume exposure. Nevertheless, the significant exposure-duration relationship observed in unadjusted analyses suggests a potential occupational effect that is unlikely to be explained solely by lifestyle factors.

5. Conclusions

Prolonged exposure to acetylene fumes was associated with reductions in key haematological parameters, particularly RBC counts, within the welder cohort. Age-adjusted regression indicated that neither exposure duration nor age independently predicted RBC count, likely due to substantial collinearity between these variables. Nonetheless, unadjusted analyses, correlation, and ANOVA consistently demonstrated that longer exposure durations corresponded with lower RBC counts, supporting the cumulative haematotoxic effect of acetylene fume exposure. These findings emphasize the need for routine haematological monitoring and strict protec-

tive measures to safeguard the health of welders.

These findings underscore the need for enhanced occupational safety measures, regular haematological monitoring, and early intervention strategies to mitigate long-term health risks in welders. Further longitudinal studies are recommended to validate these associations and explore mechanisms underlying these haematotoxic effects.

6. Recommendations

Based on the findings of this study, the following recommendations are proposed to protect the haematological health of welders exposed to acetylene fumes:

1) Regular blood tests should be incorporated into occupational health programs to monitor haematological parameters of welders, enabling early detection of abnormalities such as anemia, thrombocytopenia, or reduced red cell indices.

2) Work rotation and job scheduling strategies should be implemented to limit the duration of continuous exposure to welding fumes, especially for older welders or those with over 10 years of exposure.

3) Welders should consistently use appropriate PPE, including high-quality respiratory protection and face shields, to reduce inhalation of acetylene and metal fumes.

4) Welding environments should be equipped with adequate local exhaust ventilation systems and fume extractors to minimize airborne contaminant levels.

5) Occupational health education programs should be developed to raise awareness among welders about the risks of fume exposure and the importance of using protective measures.

6) Governments and occupational safety authorities should enforce existing workplace safety regulations and consider revising exposure limits to reflect evidence of haematotoxicity associated with prolonged acetylene fume exposure.

7) Longitudinal studies are recommended to track haematological changes over time and to explore the role of other factors, such as nutrition, co-exposures, and genetic susceptibility in modulating the haematological effects of welding fumes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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