RESEARCH ARTICLE

Journal of Ecophysiology and Occupational Health, *Vol 23(3), DOI 10.18311/jeoh/2023/34029, 153-161, September 2023*

ISSN (Print): 0972-4397
ISSN (Online): 0974-0805

Hazardous Impact of Coal Dust on Hematological Parameters of Underground Coal Mine Workers

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Abstract

Due to the nature of their work, coal miners have historically faced significant exposure to large amounts of dust, placing them at a heightened risk. The present study was conducted to explore the hazardous effects of inhalation of coal dust on the haematological parameters of underground coal miners. 120 underground coal miners (60 workers having 5-10 years of experience and the other 60 having 10-20 years of experience) and 62 matched non-exposed to coal dust subjects as control from the locality were recruited for the study. After obtaining consent, different physiological parameters were measured, and blood was collected for assessment of haematological parameters. Observations revealed that there were lower mean values of total RBC count, haemoglobin level, MCV, PCV, MCHC and MCH in coal mine workers whereas mean values of Red Cell Distribution Width (RDW) and ESR were increased in the workers group. Further, coal dust exposure causes increased total leucocyte to count as well as a differential count of lymphocyte, neutrophil, monocyte, and eosinophil in the workers group but, a decreased differential count of basophils was detected among coal dust-exposed workers. All the changes in haematological parameters were found to occur experience-dependent and maximum changes were observed in workers having 10-20 years of working experience. There is a significant likelihood of coal mine workers experiencing changes in their blood composition, which suggests the harmful impact of coal dust on this group. Further, haematological parameters will help health professionals to screen any pathologic conditions and may help to prevent coal dust exposure-associated haematological disorders and complications thereof.

Keywords: Coal Miners, Complete Blood Count, ESR, Haemoglobin, RBC, WBC

1. Introduction

Coal dust consists of a variety of organic and inorganic compounds, including carbon, hydrogen, oxygen, nitrogen, inorganic minerals, quartz, and trace metals, along with their respective oxides[1]. Few per cent to more than 50 per cent (by weight) can be the inorganic portion of coal. Only a very small portion of the mineral matter is made up of trace metals, which can also include cadmium, boron, copper, iron, arsenic, nickel, cobalt, antimony, zinc, copper, and lead. Iron and aluminium tend to be the predominant metals in coals[2]. An earlier experimental study reported the cytotoxic and carcinogenic properties of some of these trace elements[2]. Mica, titanium, pyrite, kaolin, calcite, magnesium, sulfur, sodium, and silica are common contaminants of mineral and elemental nature. As the quality of coal progresses from peat to lignite, sub-bituminous, bituminous, and anthracite, there is a corresponding increase in the proportion of carbon relative to other chemicals and mineral contaminants[3]. The United States Mine Safety and Health Administration (MSHA) states that "Any respirable dust in the mine atmosphere is considered respirable coal mine dust to which miners are exposed and, when measured, is counted for determining compliance with the respirable dust standard"[4].

Inhalable coal mine dust present in the underground coal mine contains 40-95 % refined coal and the remaining are splinters contributed by rock dusting, grazing the ceiling and deck and diesel equipment used in the underground coal

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Article Received on: 09.06.2023 Revised on: 24.07.2023 Accepted on: 28.07.2023

mines[5-6]. In general, the dust produced throughout delve is roughly appraised to be around 3% of the entire weight of the things being excavated[7]. Drilling, blasting, loading, unloading, and transportation are the major practices contributing to the generation of coal dust[8]. The probability of a dust particle amassing in the respiratory airways is determined by the size of the particle or its aerodynamic diameter, this term refers to the diameter of a particle that possesses an equivalent settling velocity to that of a particle with a unit density (1g/cm^3)[9]. An aerodynamic diameter greater than 10μm and a median cut-off point of 4μm characterize the respirable dust[9].

The emission of coal dust leads to faulty air circulation, reduces air quality and results in exposure of workers who spend extended durations and engage in more intensive activities in underground environments of coal mines[10]. In continuation, both long-time and higher-intensity exposure to coal dust funnelled the coal mine workers to severe health impairment along with other ecological and environmental problems[11,12]. Coal mining is reported to be associated with numerous adverse health effects which include cardiovascular, pulmonary, neurological, renal, haematological and musculoskeletal disorders[13]. Additionally, the documented negative health effects associated with coal dust encompass various conditions such as hypertension, headaches, psychological issues, and multisystemic disabilities including the gastrointestinal system, respiratory system, cardiovascular system, excretory system, etc besides the association of carcinogenesis[14-16].

However, very few reports of the haematological effects of coal dust on underground coal miners of West Bengal led us to undertake the current study. This study presents the findings of coal dust exposure on coal miners from West Bengal, India, focusing on various haematological parameters including haemoglobin levels, total red and white blood cell counts, differential white blood cell count, Erythrocyte Sedimentation Rate (ESR), different haematological indices. The objective is to conduct a comprehensive health risk assessment that can contribute to the development of effective healthcare strategies.

2. Materials and Methods

2.1 Study Population and Sampling Method

The study focused on recruiting workers who were exposed to coal dust from two underground coal mines in the Raniganj area of West Bengal, India. The study objectives and details were communicated to the employees, and those who expressed interest were recruited in this study and duly signed consent forms were received from each study participant. The selection of the study population was carried out utilizing a simple random sampling technique. Inclusion criteria includes a minimum of 5 years of working experience in underground coal mines and willingness to participate in the study. Exclusion criteria includes those who had a chronic illness for the last 1 year and those who were unwilling to participate in the study. Likewise, control subjects, including office personnel, dispensary staff, security personnel, and executives, were also selected using the same sampling method. Special attention was given to ensuring that these individuals did not have unmediated contact with subterranean coal particles. The sample size for the present work was determined by utilizing the single proportion formula, taking into consideration factors such as the preferred confidence level, random sampling error, preciseness (for population >10,000), and the estimated measure of the altogether pervasiveness of metabolic syndrome amide the underground workers. The anticipated prevalence of the haematological disorder among coal miners in India was considered as 50%. The sample size calculation was performed using the following formula:

$$n = z^2pq/d^2$$

Therefore, considering a non-response rate of 20%, the calculated sample size amounts to 115.248. Consequently, a total of 120 workers exposed to subterranean coal dust as well as 62 unexposed associates were assessed for various selected parameters in the study. The study received its ethical consent from the Institutional Human Ethical Committee (No: HMC/IEC/BU/01).

2.2 Collection of Different Physiological Variables

Standard procedures were employed to measure different physiological variables of coal miners, including height (cm), weight (kg), resting heart rate (beats/min), and systolic and diastolic blood pressure (mm-Hg). Body surface area (m^2) was determined using a height-weight nomogram, and Body Mass Index (BMI) was calculated using Quetelet's index.

2.3 Measurement of Coal Dust Exposure Level

Data on employee dust exposure was collected from the records (for the last 3 months) in the dust detection (safety) department of the respective coal mine. The workers' dust exposure was measured during their working hours at various underground work sites using personal dust samplers by the safety department.

2.4 Determination of the Various Haematological Parameters in Blood

The various haematological parameters Total Red Blood Cells (TRBC) count, Total White Blood Cells (TWBC) count,

Table 1. Physical, physiological and body composition of control (n = 62) and underground coal mine workers (n = 120)

Parameters	Control (n = 62) Mean±SD	Coal mine workers having experience of 5-10 years (n = 60) Mean±SD	Coal mine workers having experience 10-20 years (n = 60) Mean±SD
Age (Years)	44.73±7.19	32.1±6.84 ^{a**}	43.1±6.04 ^{b**}
Weight (Kg)	64.51±10.12	59.51±13.51	55.56±9.33 ^{a*}
Height (m)	1.61±0.31	1.63±0.14	1.61±0.39
SBP (mm Hg)	122.0±9.16	139.6±4.94 ^{a*}	148.16±5.13 ^{a**}
DBP (mm Hg)	78.14±6.12	92.94±6.22 ^{a*}	96.54±5.22 ^{a**}
BMI (Kg/m^2)	26.15±1.98	22.13±2.01	21.08±2.29 ^{a**}
BSA (m^2)	1.66±0.22	1.65±0.20	1.61±0.16 $^{a*, b*}$
Heart rate (beats/min)	80.0±4.34	89.56±3.28 ^{a*}	90.86±4.78 ^{a*}

Significance level based on one-way ANOVA, P<0.05. Tukey's posthoc test was used to find significant differences between selected groups; a: compared to the control group, b: compared to work experience 5-10 years group. *P<0.05, **P<0.01.

differential count of WBC, platelet count, Red Cell Distribution Width (RDW), Packed Cell Volume (PCV), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) were estimated from anti-coagulated blood samples using a Mindray BC-3000 Plus automated haematology analyzer (Mindray Bio-medical electronics Co., Ltd., China). Calibration and quality control were performed as per the manufacturer's recommendations.

2.5 Determination of Differential Leucocyte Count (DLC)

Anti-coagulated blood was also used for differential leukocyte count. Thin blood film was drawn in a clean grease-free glass slide and after that, it was stained with Leishman's stain. The stained film was examined under a microscope[17].

2.6 Determination of Erythrocyte Sedimentation Rate (ESR)

The anticoagulant blood was taken into ESR tubes exactly up to the '0' mark to measure Erythrocyte Sedimentation Rate by the Westergren method[17]. The reading was taken after 1 hour and 2 hours.

2.7. Measurement of Hemoglobin (Hb) Content

Blood Hb content was assessed using the cyanmethemoglobin method, where haemoglobin is converted to cyanmethemoglobin by the presence of cyanide and ferricyanide in the Drabkin solution and the Hb content was reported in grams per decilitre (gm/dL) of blood[18].

3. Results

Physiological data of coal dust-exposed underground coal miners and the non-exposed population was presented in Table 1 and coal dust exposure data were presented in Table 2.

Table 2. Coal dust exposure data

Mines	Coal dust concentration(mg/m3) Mean (Range)
Coal Mine 1	1.21 (0.46-1.88)
Coal Mine 2	1.37 (0.49-1.69)

The total RBC count (million/cu.mm) of the two underground coal mine workers groups and the control group individuals have been put on a view in Figure 1. The total RBC (million/cu. mm) of underground workers with more than 10-20 years of experience was substantially lower compared to control group participants (p<0.001) and underground workers with 5 to 10 years of experience (p<0.05).

Figure 2 portrays the packed cell volume percentage (PCV%) of the two underground coal mine worker groups and the control group individuals. In our study, we observed that the PCV% of underground employees with more than 10-20 years of working experience was considerably lower (p<0.001) when compared to control participants, as well as when compared to underground workers with 5 to 10 years of experience (p<0.1).

The MCV (fL), MCH (pg/cells), MCHC (gm/dL) and haemoglobin (gm/dL) of two underground coal mine workers groups and control group individuals are represented in Figure 2. We observed that the MCV (fL), MCH (pg/cells) and haemoglobin (gm/dL) of coal mine workers with more than 10-20 years of working experience were considerably lower ($p<0.001$) when compared to control subjects and when compared to underground workers with 5 to 10 years of experience ($p<0.001$). MCHC (gm/dL) and haemoglobin in the individuals having more than 10-20 years of working experience in the coal mine was found to be significantly lower ($p<0.01$) in comparison to control subjects and when compared to underground workers having 5 to 10 years of experience ($p<0.05$).

RDW (red cells distribution width) and Erythrocyte Sedimentation Rate (ESR) of two underground coal mine workers groups and control group subjects are presented in Figures 1 and 2. In our study, we observed that RDW and ESR of Individuals having more than 10-20 years of working experience were notably elevated in contrast to control individuals (the level of significance $p<0.001$) and also juxtapose to underground workers having 5 to 10 years of experience ($p<0.01$).

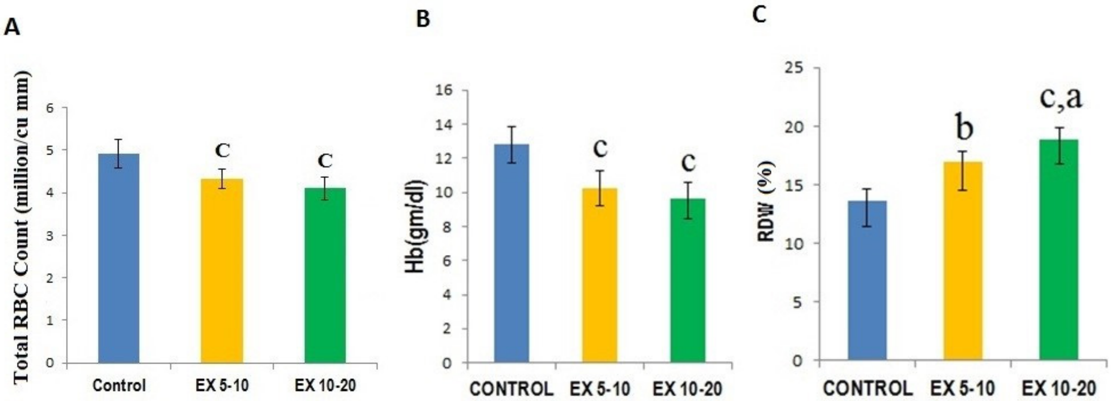

Figure 1. Total RBC Count (million/cu mm), haemoglobin (gm/dL) and red cell distribution width (%) of underground coal mine workers [EX 5-10: 5-10years of experience, n = 60] and [EX 10-20: 10-20 years of experience, n = 60] and the control group [n = 62] subjects. Data presented as Mean ± SD. ### Significance level based on one-way ANOVA, P<0.001. Tukey's post hoc test was used to find significant differences between selected groups. EX5-10 and EX10-20 groups were compared with a control group and EX10-20 was compared with EX5-10. a: P<0.05, b: P<0.01, c: P<0.001, absence of any letter indicates not significant.

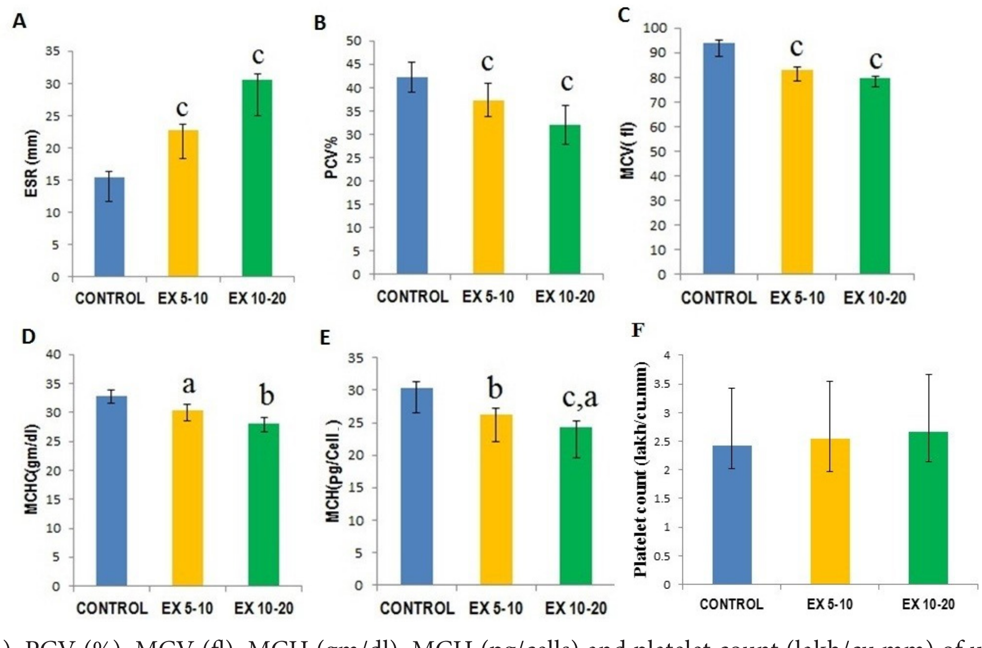

Figure 2. ESR (mm), PCV (%), MCV (fl), MCH (gm/dl), MCH (pg/cells) and platelet count (lakh/cu.mm) of underground coal mine workers [EX 5-10: 5-10years of experience, n= 60] and [EX 10-20: 10-20 years of experience, n= 60] and the control group [n=62] subjects. Data presented as Mean ± SD. ### Significance level based on one-way ANOVA, P<0.001 [except platelet count]. Tukey's post hoc test was used to find significant differences between selected groups. EX5-10 and EX10-20 groups were compared with a control group and EX10-20 was compared with EX5-10. a: P<0.05, b: P<0.01, c: P<0.001, absence of any letter indicates not significant.

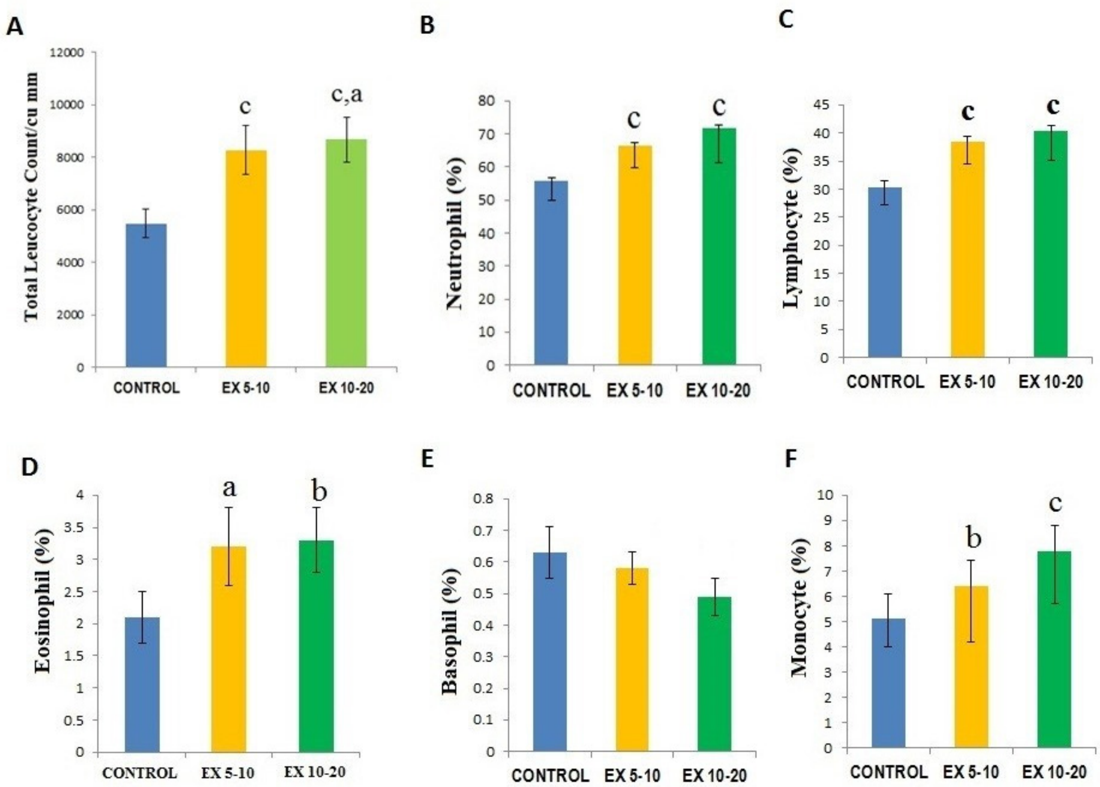

Figure 3. Total Leucocyte count (per cu. mm), differential count of Neutrophil (%), Lymphocyte (%), Eosinophil (%), Basophil (%) and Monocyte (%) of underground coal mine workers [EX 5-10: 5-10years of experience, n= 60] and [EX 10-20: 10-20 years of experience, n = 60] and the control group [n = 62] subjects. Data presented as Mean ± SD. ### Significance level based on one-way ANOVA, P < 0.001 [except Basophil (%)]. Tukey's post hoc test was used to find significant differences between selected groups. EX5-10 and EX10-20 groups were compared with a control group and EX10-20 was compared with EX5-10. a: P<0.05, b: P<0.01, c: P<0.001, absence of any letter indicates not significant.

Figure 3 shows the total leucocyte count (cells/l) and differential counts of neutrophil, lymphocyte, monocyte, eosinophil, and basophil in two underground coal mine worker groups and control group individuals. Here we observed that the TLC and differential count of neutrophils, lymphocytes, monocyte, and eosinophil among the workers having more than 10-20 years of working experience was significantly higher (p<0.001) when compared to control subjects as well as when compared to underground workers having 5 to 10years of experience (p<0.001).

Eosinophil (%) of underground coal mine workers group having more than 10-20 years of experience was significantly higher (p<0.01) in comparison to control subjects and found to be statistically significant when compared to underground workers having 5 to 10 years of experience to control group (p<0.05). Basophil (%) were observed to fluctuate but were statistically insignificant in the entire group (all two underground coal mine workers group and control group).

The Platelet count (lakh/cu.mm) of two underground coal mine workers group and control group subjects are presented in Figure 2F. The platelet count was changed but was statistically insignificant in all groups under the consideration of the study (all two underground coal mine workers group and control subjects).

4. Discussion

From a workplace standpoint, underground coal mine workers were subjected to hard working conditions, rigid work schedules, and physical and mental stress, as well as coal dust containing lead, copper, arsenic, aluminium, iron, zinc, and silica. Haematological indicators are fundamental elements in evaluating a person's health and are illustrative of a wide range of human disorders. As a result, these indicators are crucial for the diagnosis of various diseases and the observation of workers' occupational health. The current study evaluated various haematological parameters in underground coal mine workers.

In these selected group of coal mine workers, haemoglobin concentration (Hb), Total Red Cell Count (TRBC), Packed Cell Volume (PCV), Mean Cell Volume (MCV) and Mean Cell Hemoglobin (MCH) values were significantly lower than those of the unexposed population. The decrease in total RBC count in exposed subjects in the present study is indicative of microcytic anaemia. However, the reduced haemoglobin concentration and reduced PCV may not be due to nutritional deficiency as both groups were matched by socio-economic status. We hypothesized that this might be due to an increase in immature erythrocytes in the circulation in anticipation to maintain the normal total RBC count when exposed to various stressful conditions as experienced by underground coal mine workers. Moreover, low haemoglobin levels in underground coal mine workers might be the result of compromised haemoglobin synthesis in bone marrow or might be due to low haemoglobin concentration within the RBC[13]. Therefore, reduction in Hb concentration and PCV are indicative of the anaemic condition,[18] and the reduction in Mean Corpuscular Haemoglobin Concentration (MCHC) could be a result of impaired heme biosynthesis in the bone[19]. Also, reduction in the MCV (measures of the size of the RBC), MCH (determines the amount of Hb per RBC) and MCHC (indicates the amount of Hb per unit volume) are indicative of anaemia among the exposed underground mine workers[20]. These results are well in agreement with studies on coal mine workers of different geographical origins as reported by Mojiminiyi, Jude *et al.*, and Erhabor *et al*[21-23]. Earlier reports also revealed that lead in the coal dust interferes with the hematopoietic system, more particularly with hemoglobin synthesis by inhibiting the activity of the enzymes involved in heme biosynthesis[24,25].

However, a case-control study done in India among construction workers exposed to cement dust reported significantly reduced Hb, PCV and MCV whereas MCHC increased significantly[26].

According to the current study, exposed coal mine workers had considerably greater erythrocyte sedimentation rates than non-exposed controls and is well corroborated with the finding of Erhabor *et al*[23]. The ESR is a straightforward, affordable, and useful technique for determining inflammation. In healthy individuals, the ESR is largely stable and is influenced by erythrocyte and plasma characteristics. An illness caused by infections or a considerable quantity of tissue necrosis is frequently linked to a reasonably high ESR[27].

Along with a Complete Blood Count (CBC) test, Red Cell Distribution Width (RDW) is a routine examination to explore heterogeneity in erythrocyte size[28]. RDW was found to be significantly higher in exposed workers relative to the unexposed controls and the increment was found to be work experience-dependent (workers having more than 10-20 years of experience). Prior research has demonstrated a correlation between elevated Red Cell Distribution Width (RDW) and the onset of conditions such as coronary artery disease, heart failure, stroke, and peripheral artery disease[28-32]. Further, RDW values are also correlated with inflammatory bowel disease[33] as well as pulmonary functions[33,34]. Acute myocardial infarction and heart failure can also be predicted by the determination of RDW[35,36]. Thus, working experience-dependent increase in RDW values in two underground workers groups are at greater risk of inflammation, altered pulmonary function and cardiovascular ailment[37].

Increased but statistically insignificant platelet counts were observed in exposed underground coal mine workers as compared to the control group (non-exposed workers) and in the workers with higher versus lower work experience. This might be due to the disruptive action of stress factors in the coal mine set up on erythropoietic tissue or might be an adaptation of erythropoietic tissue to a stressor-induced reduced viability of circulating cells[38]. Elevated platelet counts serve as an indicator of a stressful environment, which could result in the enlargement of RBC or haemoconcentration[39] because of coal dust and this phenomenon is attributed to the overproduction of hematopoietic regulatory elements, including colony-stimulating factors, erythropoietin, and thrombopoietin, by the stromal cells and macrophages present in the bone marrow[40]. Inflammation is reported to cause the release of factors like Tumour Necrosis Factor –α that may stimulate the production of platelets from bone marrow[26]. Therefore, it is feasible to speculate the occurrence of inflammation-induced alteration in plate count in coal mine workers.

In the present study, the differential leucocyte count was significantly higher in subjects exposed to coal dust than that of non-exposed controls and a positive correlation between the differential leucocyte counts with the duration of exposure to coal dust was also exist. The results of this study presented evidence of alteration in differential leucocyte count in underground coal mine workers. But only exposed workers having more than 5 years of experience showed significant changes in differential leucocyte count as compared to unexposed non-workers residing in the same location. Alteration in peripheral leukocyte level can be treated as a significant marker in tissue inflammation due to various causes[37]. Thus, alteration in leucocyte count highlighted the fact that underground coal mine workers experienced higher inflammatory outcomes. Results of the differential count revealed that both neutrophil and eosinophil counts were higher in underground coal mine workers and the major contributor to total leucocyte count. Heightened eosinophil numbers are well correlated with parasitic infection, allergies and respiratory diseases and thus results of increased eosinophil count in underground coal mine workers having more than 5 years of experience pointed out the higher prevalence of these conditions. Neutrophils are recruited at the first site of injury caused by the inflammatory response due to infection or other causative agents. The observed rise in eosinophils exhibited statistical significance in the present study and the presence of particles triggers an inflammatory response that results in the accumulation of eosinophils[41]. However, the differential count of monocyte was found to be higher in the coal dust-exposed worker group as compared to the non-worker group. Blood monocytes were reported to serve as emergency response team members and dispatched to injury sites to execute pro-inflammatory tasks[42]. Further, lymphocyte count was found to be higher in coal mine workers implying the altered immune responses as the occurrence of lymphocytosis was reported in individuals having differential immune responses and reactions[43]. Also, the increased number of lymphocytes in exposed underground coal mine workers having more than 5 years of experience implied the compromised ability of the immune system resulting in lymphocytosis[44]. The statistically significant elevation in TLC and lymphocytes observed in the present study can be attributed to chronic inflammation in the lungs resulting from recurrent exposure to coal dust containing heavy metals such as crystalline silica-alumina[45]. Earlier reports demonstrated that, upon exposure to crystalline silica, the innate immune response is triggered, characterized by the release of proinflammatory cytokines. This, in turn, leads to the infiltration of inflammatory cells such as neutrophils, macrophages, and lymphocytes[46].

Taken together, we hypothesized that short-term exposure to different stressors in the working environment (harsh working environment, unaccommodating work schedule, work stress etc) impacted the already developed components of peripheral blood, but long-term exposures to these stressors target bone marrow directly to exert its impact. This may be the plausible explanation for significant change in most of the haematological parameters among underground coal mine workers having experience of more than 5 years.

5. Conclusion

In conclusion, the results of this study revealed that occupational exposure to different stressors by underground coal mine workers in the underground set-up caused haematological disorders and make these populations vulnerable to adverse cardio-respiratory health, inflammation, infection, cancer development etc. Because of the unawareness of the hazardous health outcome of different stressors, underground coal mine workers did not take any safe and precautionary measures which eventually resulted in adverse haematological alterations. Further, we suggested that the studied parameters might be considered as biomarkers of sub-clinical health effects and highlighted the need for frequent monitoring of occupational health risks in this population.

6. Acknowledgements

The authors are grateful to all the study participants for their kind consent to participate in this study.

7. References

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