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Original Article

Comparative study of hematological parameters among smokers and nonsmokers in Basra city, Iraq

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ABSTRACT

Background: Hematological parameters are significantly affected by both immediate and prolonged exposure to smoking. The objective of this investigation is to evaluate the influence of cigarette smoking on hematological parameters among male students enrolled at Basrah University in Iraq.
Methods: The study comprised a total of seventy male participants, divided into two groups: smokers (n = 35) and nonsmokers (n = 35). Each participant provided a 5 ml venous blood sample to analyze the complete blood count using a hematology analyzer (Spinreact, Spincell 3).
Results: Cigarette smokers exhibit notably elevated levels of Red Blood Cells (RBC) counts, Hemoglobin (HGB), Red Cell Distribution Width-CV (RDW-CV), granulocytes%, and platelets%, whereas Mean Corpuscular Volume (MCV) and lymphocytes% are notably lower among smokers. On the other hand, Hematocrit percentage (HCT), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), and White Blood Cells (WBC) counts show no significant difference between cigarette smokers and nonsmokers. In contrast, Red Cell Distribution Width-SD (RDW-SD), Mid-range cell percentage (MID%), Mean Platelet Volume (MPV), Distribution Width (PDW), Platelet Plateletcrit percentage (PCT), Platelet-Lymphocyte Cell Ratio (P_LCR) and Platelet-Lymphocyte Cell Count (P_LCC) demonstrate no substantial variance between the two groups at the statistical significance threshold.
Conclusion: This investigation concludes that tobacco cigarette smoking leads to detrimental alterations in hematological parameters, posing health risks.

Introduction

Tobacco smoking poses a significant public health challenge worldwide, representing a leading cause of preventable diseases and fatalities [1]. Nicotine-containing tobacco smoking has emerged as a prevalent addiction, evolving into a global epidemic in contemporary society [2]. Despite widespread awareness regarding the health risks associated with cigarette smoking, its prevalence remains notably high particularly in developing nations, presenting an ongoing and substantial public health issue [3]. Based on statistics provided by the World Health Organization (WHO), approximately 2.4 billion individuals globally have engaged in tobacco consumption through smoking, chewing, snuffing, or dipping [4].

Tobacco smoke, along with nicotine and other harmful substances, is initially absorbed into the lungs which can cause Chronic Obstructive Pulmonary Disease (COPD) [5], subsequently enters the bloodstream, from where it is distributed across the body. This makes blood an ideal biological sample for investigating the systemic effects of tobacco smoke exposure [6]. Nevertheless, these toxic components travel through the body by diverse means, leading to harm and numerous conditions, including cardiovascular diseases, anemia, altered blood viscosity, hypoxia [7]. Hypertension, inflammation, stroke, coagulation abnormalities, and respiratory ailments [8,9]. Additionally, cigarette smoking expedites the development of various cancers, including pancreatic cancer, kidney cancer, lung cancer, oropharyngeal cancer, liver cancer, and colon cancer [10].

Similarly, it also elevates the pH levels in the stomach, leading to the occurrence of peptic ulcers and gastric diseases [8]. Moreover, cigarette smoking affects the hematological system by increasing concentrations of eosinophils, basophils, monocytes, lymphocytes, platelets, and macrophages. It also raises the levels of hemoglobin (HGB) and Red Blood Cells (RBCs) in the bloodstream [11]. The exact mechanism underlying the cardiovascular dysfunction associated with smoking remains unclear. However, it is hypothesized that these effects stem from

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abnormalities in blood rheology [1]. Several investigations have indicated that cigarette smoking is the reason for around a 20 % to 25 % rise in the peripheral blood White Blood Cells (WBC) count.

The researchers highlight a robust correlation between smoking and various cellular constituents of the blood. Notably, the link between smoking and WBC count has been firmly established [8]. Several studies have consistently shown that smokers exhibit elevated WBC counts compared to nonsmokers [9], although conflicting findings have emerged in certain subpopulations [9,12].Similar to the last example, there have been reports of contradictory findings about the correlation between smoking and platelet counts, as well as some RBC indices [12]. To elucidate potential health implications for cigarette smokers, particularly given the prevalence of smoking among students at Basrah University, the present study aimed to compare the impact of cigarette smoking on selected hematological parameters between age-matched nonsmoking controls and smokers.

Material and Methods

Subjects and duration of research study

This research was conducted at the College of Education at the University of Basra – Qurna in the period from February to April 2023. The study included 70 samples of students, 35 samples from student smokers (study group) aged 18–30. Additionally, a randomly chosen cohort of 35 nonsmoking students (the control group) within the same age range was included. The study aimed to assess the hematological characteristics of both smokers and nonsmokers.

Inclusion criteria

Only male individuals who provided consent were sequentially evaluated for eligibility in this investigation. The age range of the participants spanned from 18 to 30 years. Participation was voluntary and anonymous. Individuals who had a smoking history of $\geq$ 1 cigarette daily for a minimum of one year were classified as smokers. Control subjects, deemed healthy based on appearance, were chosen; these individuals had never smoked and were not exposed to passive smoking.

Exclusion criteria

Excluded from participation in this study were females due to the potential influence of the menstrual cycle and contraception on Complete Blood Count parameters (CBC) [13]. Also excluded were individuals who declined to provide a blood sample, as well as those who engaged in both cigarette and Narghile smoking or other forms of smoking.

The participants included in the study did not have any severe health conditions, history of respiratory tract infections within the past three months, renal diseases, hypertension, diabetes mellitus, infections, active liver and kidney diseases, chronic pancreatitis, gastrointestinal disorders, history of ischemic heart disease, iron deficiency, thalassemia or endocrine disorders. Furthermore, individuals using medications such as nonsteroidal anti-inflammatory drugs, aspirin, immunomodulatory drugs, antibiotics, thiazide diuretics, steroids, or any medications known to affect CBC parameters, such as NSAIDs or other antiplatelet aggregation drugs, and those who had donated or received blood in the preceding 6 months, were omitted from the research analysis.

Ethical clearance

All participants provided informed consent after receiving a detailed explanation of the study's objectives. Additionally, this study received approval from the ethical committee of the University of Basrah, College of Education-Qurna.

Blood samples analysis

Under aseptic conditions, a Venous blood sample was collected in the morning hours from all study subjects in the morning between 8:00 AM and 11:00 AM to avoid the effect of diurnal variation on blood counts after an overnight fast. 5 mL of blood sample was collected into vacuum tubes containing Ethylenediaminetetraacetic acid (EDTA) and mixed gently before analysis of Complete Blood Count (CBC).

Participants were instructed to refrain from smoking for a minimum of 45 min to 1 h before blood collection. Subsequently, all blood samples underwent analysis using a hematology analyzer (Spinreact, Spincell 3) to determine various hematological parameters. These parameters included White Blood Cells (WBC) count, Mean Corpuscular Hemoglobin (MCH), Hemoglobin (HGB), Mean Corpuscular Hemoglobin Concentration (MCHC), Red Blood Cells (RBC) count, Red Cell Distribution Width-CV (RDW-CV), Mean Corpuscular Volume (MCV), Platelet-Lymphocyte Cell Count (P_LCC), Platelet Plateletcrit percentage (PCT), Red Cell Distribution Width-SD (RDW-SD), Mid-range cell percentage (MID%), Lymphocyte percentage (LYM%), and Granulocyte percentage (GRAN%), as well as Platelet count (PLT), Platelet-Lymphocyte Cell Ratio (P_LCR), Mean Platelet Volume (MPV), Distribution Width (PDW), and Hematocrit percentage (HCT).

Statistical analysis

A comparison between the control and smoking groups was conducted utilizing an independent sample *t*-test, with a significance of $<$ 0.05. Statistical analysis was carried out utilizing IBM SPSS Statistics (version 27 for Windows) and the R program (version 4.0.3 for Windows).

Results

Our study included seventy healthy adult males, comprising 35 smokers and 35 nonsmokers, based on specific criteria, Hematological parameters were assessed using an auto-analyzer for all participants, and the data were subsequently tabulated and analyzed. Utilizing the independent sample *t*-test, a significant differences were observed in RBC and HGB values, which were higher in smokers, along with an elevated RDW-CV. These findings indicate potential alterations in these hematological measures due to smoking. Additionally, MCV was significantly lower in smokers than nonsmokers, suggesting possible changes in RBC morphology. Conversely, MCHC, MCH, HCT, and RDW-SD did not exhibit significant differences between the two groups. (Table 1, Fig. 1).

On the other hand, WBC parameters (WBC count, LYM%, MID%, and GRAN%), vary in the control and smoking groups, using independent sample *t*-test. It showed a significant difference in parameters of LYM% and GRAN%, suggesting that smoking may impact these immune-related parameters. Specifically, LYM% is lower in the smoking group compared

Table 1
Comparison of RBC parameters between smokers and nonsmokers.

Parameters	control	smoking	T-test	p-value
RBC	5 ± 0.3	5.4 ± 0.43	4.464	<0.001
HGB (g/dL)	15.26 ± 0.8	16.09 ± 1.24	3.308	0.002
HCT %	44.32 ± 2.84	45.72 ± 3.82	1.733	0.088
MCV (fL)	88.37 ± 5.02	85.39 ± 6.49	2.147	0.035
MCH (pg)	30.41 ± 1.49	30.1 ± 3.82	0.450	0.065
MCHC (g/dL)	34.25 ± 1.07	35.08 ± 3.09	1.505	0.137
RDW-CV (%)	12.48 ± 0.89	13.23 ± 1.51	2.548	0.013
RDW-SD (fL)	50.47 ± 3.28	49.28 ± 3.69	1.427	0.158

(RBC, Red Blood Cells; HGB, Hemoglobin; HCT, Hematocrit percentage; MCV, Mean Corpuscular Volume; MCH, Mean Corpuscular Hemoglobin; MCHC, Mean Corpuscular Hemoglobin Concentration; RDW-CV, Red Cell Distribution Width-CV; RDW-SD, Red Cell Distribution Width-SD).

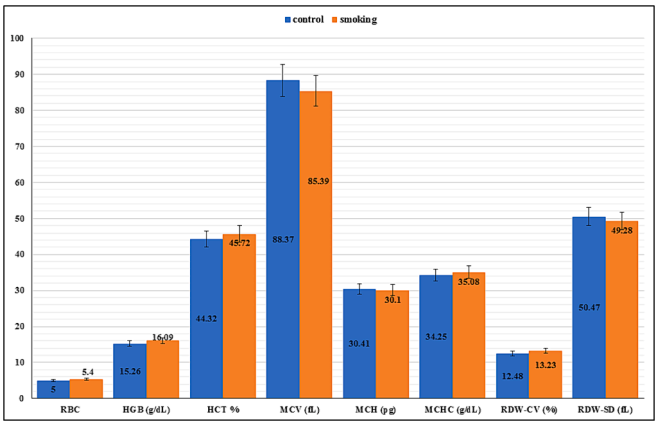

Fig. 1. Bar diagram showing RBC Parameters between smokers and nonsmokers.

to the control group, while GRAN% is higher in the smoking group. However, no significant differences were observed in parameters of WBC and MID% (Table 2, Fig. 2).

Furthermore, the comparison of different PLT parameters between the groups of smokers and nonsmokers utilizing the independent sample *t*-test showed a notable distinction ($p < 0.05$) solely in PLT count, indicating a higher platelet count in the smokers' group in comparison to the nonsmokers' group. Conversely, no significant differences in MPV, PDW, PCT, P_LCR, and P_LCC between the analyzed groups at the specified probability level (Table 3,Fig. 3).

Discussion

The act of smoking cigarettes has numerous adverse effects on human health, correlating with increased risks of various chronic ailments that reduce lifespan and diminish overall well-being[14]. According to statistics provided by the ALA (American Lungs Association) in a 2011 report, cigarette smoking was accountable for about 20 % of deaths in the USA [15]. In this recent investigation, hematological parameters were utilized for comparative evaluation between university students who smoke and those who do not in Basrah. The findings from this study revealed notable distinctions in the hematological profiles of individuals; specifically, RBC, Hb, and RDW-CV levels were markedly higher in smokers compared to nonsmokers, while MCV was significantly lower. Conversely, there were no significant variances observed in HCT, MCH, and MCHC levels between the groups.

The investigation indicated a substantial rise in the overall count of RBC and the concentration of HGB among individuals who smoke in contrast to those who do not. These results align with the findings of numerous other researchers [16].

Cigarette smoke contains approximately 4000 compounds, with major toxic substances including carbon monoxide (CO), nicotine, and tars. When inhaled, CO rapidly diffuses across alveolar capillaries and binds strongly with hemoglobin, forming carboxyhemoglobin (HbCO) with a binding capacity 200–250 times greater than that of oxygen (O_2). This reaction leads to tissue hypoxia, diminishing Hb's ability to deliver

Table 2
Comparison between WBC parameters between smokers and nonsmokers.

Parameters	control	Smoking	T-test	p-value
WBC (10^3/μL)	5.67 + 2.02	6.88 + 3.04	1.960	0.065
LYM%	43.22 + 15.06	37.08 + 12.4	2.861	0.048
MID%	15.11 + 8.19	12.61 + 8.71	2.236	0.221
GRAN%	41.35 + 20.32	50.29 + 18.77	2.911	0.042

(WBC, White Blood Cells; LYM%, Lymphocyte percentage; MID%, Mid-range cell percentage; GRAN%, Granulocyte percentage).

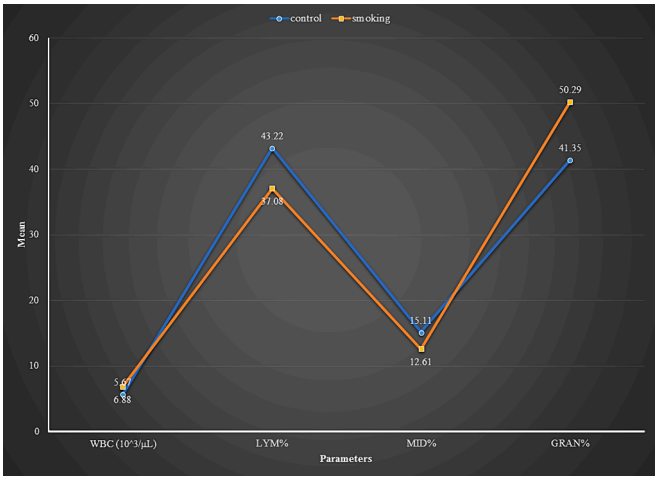

Fig. 2. Bar chart showing WBC parameters between smokers and nonsmokers.

Table 3
Comparison between Platelet parameters between smokers and nonsmokers.

Parameters	Control	Smoking	T-test	p-value
PLT (10^3/μL)	135.31 ± 32.43	151.83 ± 35.79	2.023	0.047
MPV (fL)	9.95 ± 1.12	9.85 ± 1.22	0.368	0.714
PDW (fL)	14.5 ± 2.25	14.63 ± 3.02	0.198	0.844
PCT %	0.13 ± 0.04	0.14 ± 0.04	1.406	0.164
P_LCR (%)	34.84 ± 12.27	31.78 ± 8.87	1.193	0.237
P_LCC (10^3/μL)	44.03 ± 15.18	46.26 ± 15	0.618	0.539

(PLT, Platelet count; MPV, Mean Platelet Volume; PDW, Distribution Width; PCT, Platelet Plateletcrit percentage; P_LCR, Platelet-Lymphocyte Cell Ratio; P_LCC, Platelet-Lymphocyte Cell Count).

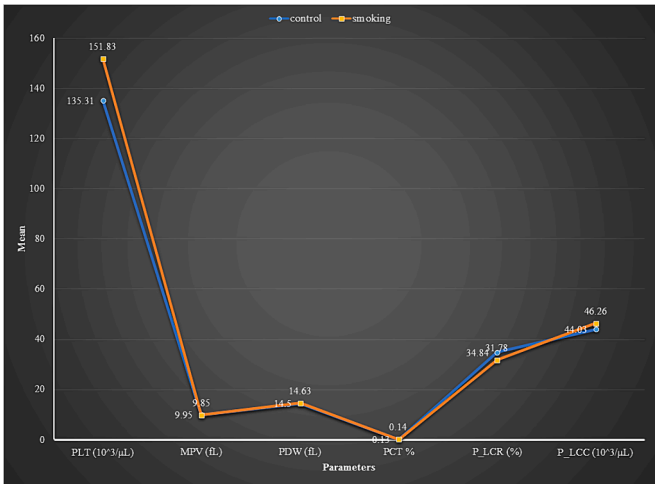

Fig. 3. Observed Platelets parameters for smokers and nonsmokers.

oxygen to tissues. Consequently, the cells of the juxtaglomerular apparatus in the kidney detect this hypoxia, prompting the secretion of erythropoietin hormone [17], which directly stimulates red bone marrow stem cells [18], initiating erythropoiesis and resulting in increased levels of HCT, Hb, and RBCs [19]. Enhanced erythropoietin production occurs in hypoxic conditions, leading to increased erythrocyte production. Therefore, the rise in HCT and Hb levels consequent to heightened RBC production is a predictable outcome.

Furthermore, the presence of carbon monoxide in tobacco smoke leads to an increase in capillary permeability, which in turn leads to a reduction in plasma volume. Polycythemia, also known as

erythrocytosis, is a disorder that is characterized by an increasing percentage of RBCs in the blood volume. This result is similar to the condition being mimicked. Elevated hematocrit (HCT) readings [20], which are a reflection of this rise, are present.

An increase in RBC count raises the viscosity of blood in smokers, reducing its flow velocity. This impaired blood flow efficiency can lead to clot formation [1,21], elevating the risk of clot-related complications such as stroke, pulmonary embolism, heart attack, or deep vein thrombosis [22]. Consequently, smoking represents a significant preventable risk factor for cardiovascular disease and mortality [23]. Positive outcomes have been observed among smokers who experience a swift normalization of several hematological abnormalities upon quitting smoking [21,22]. Furthermore, the risk of adverse effects diminishes rapidly after smoking cessation [23], which is particularly crucial for young smokers without other risk factors such as obesity, hypertension, or diabetes [23]. These individuals have a promising future if they commit to quitting smoking.

Hakim *et al* [24] observed that rising HbCO levels decrease oxygen transfer to tissues. Nicotine present in tobacco induces peroxidation of erythrocyte membranes, impeding the delivery of oxygen to bodily tissues and prompting increased RBC production along with elevated levels of Hb and HCT.

MCV, MCH, and MCHC serve as vital RBC indices used to assess the average size and hemoglobin content of erythrocytes. Comparing our MCV findings with existing literature presents challenges due to inconsistencies; several studies [25] have noted an increase in MCV, contrary to our results, which showed significantly lower MCV levels in smokers compared to nonsmokers. Our study observed a decrease in MCV among smokers than nonsmokers ($p < 0.5$), aligning with a prior investigation [26]. Additionally, we identified higher MCH and MCHC levels in the smoker group, although statistical significance was not established. These results are in line with findings from other researchers [16,27], which may be due to our study's smaller sample size, younger age group, and subjects with a relatively shorter smoking duration.

The RDW examination is a standard and cost-effective blood test commonly included in CBC count. This diagnostic tool aids in identifying anemia and is synonymous with anisocytosis. Elevated RDW levels may suggest heightened impaired erythropoiesis or RBC destruction (hemolytic anemias), possibly due to folic acid, vitamin B12, and iron deficiencies or from blood transfusions. Furthermore, elevated RDW levels have been linked to cardiovascular and pulmonary illnesses [28].

In recent studies, RDW has emerged as a predictor of all-cause and cardiac mortality in population-based investigations [29]. Presently, the exact nature of the correlation between RDW and mortality or morbidity remains unclear, and the connection is merely an association.

In this study, RDW values were notably higher among smokers compared to nonsmokers, a finding consistent with the research of [29] and [30]. However, this contrasts with the findings of (27). The likely reason behind this discrepancy is persistent subclinical inflammation. Smoking has been independently linked to various inflammatory markers, including elevated levels of high-sensitivity C-reactive protein (hs-CRP), soluble tumor necrosis factor-alpha, VCAM-1, ICAM-1, and E-selectin, all recognized as surrogate markers of inflammation [31].

Past investigations have presented conflicting outcomes concerning the influence of smoking on WBC counts. However, our analysis revealed no statistically significant elevation in WBC counts among smokers compared to nonsmokers. This discovery aligns with the findings of [31] but contrasts with the results reported by [25,26]. Even while cigarette smoking is known to cause changes in WBC count, the particular mechanism by which these changes occur is not completely understood. It is possible that a systemic inflammatory response caused by smoking might be responsible for the increased number of white blood cells that are present in the body [1]. Furthermore, smoking may be associated with an acute or chronic inflammatory response that is caused by particles from cigarette smoke if smoking is positively associated with greater WBC and hs-CRP levels [30].

The inflammatory activation of the bronchial tube, which has the potential to progress into chronic bronchitis, could be linked to elevated inflammatory markers in the blood [32]. Cigarette smoke in its gaseous form contains more than 10 organic radicals per puff [32], which can trigger the activation and subsequent release of numerous proinflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), from epithelial cells. These cytokines play a role in the activation and differentiation of white blood cells [33]. Induced inflammation may increase the synthesis and release of white blood cells from the bone marrow via a complicated interplay involving a number of different growth factors [33]. Another proposed mechanism is that nicotine stimulates the release of catecholamines, which could result in an increase in WBC counts [34]. The differences between the results of our study and published studies could be attributed to the younger age group (18–30 years) that was targeted in our study or to the sample size in our investigation, alcohol habit of participants, smoking dose and duration, etc.

The current study's discovery that the smokers group exhibited notably higher granulocytes% and lower lymphocyte% compared to nonsmokers aligns with Mohamed *et al* [27], the higher percentage of granulocytes and lower percentage of lymphocytes in the smokers compared to non-smokers can be explained by several possible reasons. Smoking causes chronic inflammation [35], which can lead to a constant stimulation of the immune system and thus can lead to an increased production of granulocytes, such as neutrophils, which are the first responders to inflammation, which stimulates the immune system continuously and leads to an increased production of granulocytes, this is consistent with [36]. Furthermore, exposure to harmful chemicals in cigarette smoke can trigger an immune response that raises granulocyte levels. Additionally, smoking introduces various toxins [37], that can suppress lymphocyte production and function, leading to a decrease in their numbers. these reasons, in addition to the duration of smoking, the doses used, the type of cigarettes, and the habits associated with it, such as smoking hookahs and drinking alcohol, etc., are all possible reasons for these differences.

However, contrary findings, such as those by [38], have shown an increase in both these parameters. The literature presents varying reports on the increase in one or more types of WBC [31], prompting further investigation into the reasons for these discrepancies [39]. Neutrophils are recognized for producing cytotoxic substances that can negatively impact lung function. Therefore, the heightened number of neutrophils observed in smokers in this study could potentially lead to compromised pulmonary function [40].

The observed increase in granulocyte percentage among smokers in this study could potentially be linked to immune activation associated with tissue inflammation. Conversely, the decreased lymphocyte count among smokers in this study was not unexpected. The activation of the sympathetic nervous system is heightened during systemic stress, leading to increased cortisol release, which is associated with a reduction in the percentage of blood lymphocytes [41]. Additionally, nicotine is known to stimulate the sympathetic nervous system [42]. Therefore, it is plausible that smoking or using other tobacco products may lead to a similar decrease in lymphocyte percentage. Previous research has indicated that smokers may exhibit decreased lymphocytes, particularly cytotoxic T cells or CD8 + T cells [43]. These variations in T lymphocytes could potentially increase smokers' vulnerability to developing neoplastic growths and infections [21].

Additionally, only the platelet (PLT) count value (151.83 x 103/μL) was notably elevated in smokers compared to nonsmokers (135.31 x 103/μL). This study's findings are consistent with previous research [25]. Mobarrez *et al* [10] suggested that acute smoking could result in endothelial damage, contributing to an increase in platelet count. Furthermore, platelet production is regulated by hormonal mechanisms that may be disrupted by smoking, leading to heightened platelet production. Cigarette smokers were found to have elevated circulating

thrombopoietin levels, a humoral growth factor released in response to increased platelet production [44]. This observation may be due to higher thrombopoietin levels in smokers than nonsmokers, stimulating platelet production and resulting in increased PLT counts [45]. Smoking also triggers oxidative stress, which enhances platelet activation and aggregation, as well as endothelial injury caused by nicotine [46], demonstrating a positive correlation with platelet count [25].

However, a non-significant increase in platelet (PLT) count was observed between smokers and nonsmokers [4,47]. Nevertheless, no significant changes were detected in other platelet indices between the two groups (Table 3 and Fig. 3). These results align with findings in existing literature, where several studies also reported no significant effects on PDW and MPV [4,25]. Significant variations in platelet indices were found in just a small percentage of the investigations that were published. Both of these studies revealed that smoker groups had significantly lower MPV [47]. which was in direct opposition to our findings. Additionally, another research found that smoker groups had greater PDW outcomes [10,26] which was again in direct opposition to our findings.

Conclusion

Can be concluded that persistent cigarette smoking induces a state of prolonged hypoxia in the body due to the contents of the smoke, leading to a notable increase in RBC count, HGB count, granulocyte count, and PLT count. This rise in cell count and hemoglobin concentration results in heightened blood viscosity and decreased blood flow velocity among smokers, potentially predisposing them to conditions like deep vein thrombosis, stroke, and pulmonary embolism. The study also suggests that reducing cigarette consumption leads to improvements in certain hematological parameters, indicating the sensitivity of these parameters to changes in smoking habits. Considering these alterations in blood parameters in otherwise healthy young men with no additional risk factors, reducing smoking habits may positively impact hematological measures, thus potentially reducing the risk of future cardiovascular and respiratory complications. “Despite the important findings of this study, some limitations should be noted that may affect the full generalizability of the results. One such limitation is that detailed information on smoking duration and dosage, represented by the number of cigarette packs/year, was not collected for each participant. In addition, some participants declined to answer questions related to smoking behaviors, such as alcohol consumption. Therefore, these points should be taken into account when interpreting the results, and future studies that take these factors into account in more detail may be necessary.”

Ethical publication statement

The research was adhered to relevant ethical of our study. All participants provided informed consent after receiving a detailed explanation of the study’s objectives. Additionally, this study received approval from the ethical committee of the University of Basrah, College of Education-Qurna. The privacy or rights were not violated, and neither was the personal information, such as photographs, etc.

CRediT authorship contribution statement

Safa Mohammed Hussein: Methodology, Data curation. **Huda Hasan Aziz:** Writing – original draft. **Wurood Hameed Abed:** Methodology. **Kadhim Fadhil Kadhim:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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