



ASSESSMENT OF PULMONARY FUNCTION, OXIDATIVE STRESS, AND HEMATOLOGICAL CHANGES IN CHRONIC SMOKERS

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ABSTRACT

Background: Cigarette smoking is a major risk factor for pulmonary dysfunction, exerting harmful effects through interconnected physiological, biochemical, and hematological mechanisms. In addition to impairing lung function, smoking induces oxidative stress, systemic inflammation, and alterations in hematological parameters, contributing to tissue injury and disease progression.

Objective: To evaluate smoking-induced changes in pulmonary physiology, antioxidant defense systems, and associated hematological alterations.

Methods: A comparative cross-sectional study was conducted including smokers (n = 60) and age-matched non-smokers (n = 60) from Lahore. Pulmonary function was assessed using spirometry, measuring forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and FEV₁/FVC ratio. Oxidative stress was evaluated by serum malondialdehyde (MDA), while antioxidant status was assessed via superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx). Hematological parameters including hemoglobin (Hb), hematocrit (Hct), total leukocyte count (TLC), and platelet count were also measured. Statistical analysis was performed using independent t-test and Pearson correlation, with p < 0.05 considered significant.

Results: Smokers demonstrated a significant reduction in pulmonary function parameters compared to non-smokers: FEV₁ (2.10 ± 0.45 vs 3.05 ± 0.50 L), FVC (3.00 ± 0.60 vs 3.80 ± 0.55 L), and FEV₁/FVC ratio (70.2 ± 6.5% vs 80.5 ± 5.8%), all **p < 0.001**. Biochemically, smokers showed significantly elevated MDA levels (5.8 ± 1.2 vs 3.1 ± 0.9 μmol/L, **p < 0.001**) and reduced antioxidant enzyme activity (SOD, catalase, GPx; **p < 0.001**). Hematological analysis revealed higher hemoglobin (15.8 ± 1.2 vs 14.2 ± 1.0 g/dL, **p < 0.001**) and hematocrit levels (48 ± 4% vs 42 ± 3%, **p < 0.001**), along with elevated total leukocyte count (9.8 ± 2.1 vs 6.5 ± 1.8 ×10⁹/L, **p < 0.001**) and mild

thrombocytosis ($p < 0.05$). A significant negative correlation was observed between MDA and FEV₁ ($r = -0.62$, $p < 0.001$).

Conclusion: Smoking significantly impairs pulmonary function and disrupts antioxidant defense systems, accompanied by hematological alterations such as polycythemia and leukocytosis. These findings highlight the combined role of oxidative stress, systemic inflammation, and physiological dysfunction in the pathogenesis of smoking-related pulmonary disease.

Keywords: Smoking, Pulmonary Function, Oxidative Stress, Antioxidants, Hematology, Polycythemia, Inflammation

INTRODUCTION

Cigarette smoking remains one of the leading causes of preventable morbidity and mortality worldwide, contributing significantly to respiratory and cardiovascular diseases (1). Tobacco smoke contains a complex mixture of reactive oxygen species (ROS), free radicals, and toxic compounds such as nicotine, carbon monoxide, and tar that directly damage pulmonary tissue and vascular endothelium (1,2). Chronic exposure leads to airway inflammation, mucus hypersecretion, narrowing of airways, and progressive decline in lung function. Spirometric parameters such as FEV₁ and FVC are widely used to assess these impairments and are essential indicators of obstructive and restrictive lung disease (3).

Smoking also produces significant morphological changes in the respiratory system. One of the earliest and most important effects is damage to the cilia lining the respiratory epithelium, which form a vital component of the pulmonary defense mechanism (4). Cigarette smoke rapidly paralyzes ciliary movement and may eventually destroy ciliated epithelial cells entirely, impairing their ability to clear mucus, bacteria, dust particles, and toxic substances from the airways. Reduction in ciliary beat frequency leads to mucus retention and the development of smoker's cough, chronic bronchitis, and increased susceptibility to respiratory infections (5).

Long-term smoking further reduces the number of functional ciliated cells and causes the remaining cilia to become shorter and less effective, resulting in accumulation of mucus and pollutants within the lungs, airway obstruction, and reduced pulmonary capacity. Encouragingly, cessation of smoking allows gradual regeneration and recovery of ciliary function, although restoration of normal mucociliary clearance may take several months (6).

In addition, cigarette smoke directly and indirectly stimulates the release of inflammatory cytokines that promote chronic pulmonary inflammation by attracting and activating macrophages, neutrophils, and T-lymphocytes within lung tissue.

Persistent inflammatory activity contributes to airway remodeling, alveolar destruction, and progression toward chronic obstructive pulmonary disease (COPD) (6,7). Smoking also induces oxidative stress by increasing free radical production while reducing antioxidant defenses, creating a redox imbalance that promotes cellular injury (7). Malondialdehyde (MDA) serves as a marker of lipid peroxidation, whereas enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx) maintain redox balance and protect against oxidative damage (5,8).

In addition, smoking affects hematological parameters (8,9). Chronic hypoxia results in increased hemoglobin and hematocrit, while systemic inflammation elevates leukocyte and platelet counts (10). These hematological alterations contribute to increased blood viscosity and cardiovascular risk. Emerging evidence also suggests that smoking-induced systemic inflammation and oxidative stress may interact synergistically, exacerbating disease progression (10). This study evaluates the combined physiological, biochemical, pathological, and hematological effects of smoking.

MATERIALS AND METHODS

This comparative cross-sectional study was conducted on 120 male participants aged 20–40 years, divided into two groups comprising smokers ($n = 60$) with a history of ≥ 5 pack-years and age-matched non-smokers ($n = 60$) serving as healthy controls. Participants with known chronic respiratory

diseases, cardiovascular disorders, diabetes mellitus, or those taking antioxidant supplementation were excluded from the study.

Pulmonary function tests were performed using a calibrated spirometer in accordance with standard guidelines. The parameters recorded included forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and the FEV₁/FVC ratio.

For biochemical analysis, venous blood samples were collected under aseptic conditions. Oxidative stress was assessed by measuring malondialdehyde (MDA) levels using the thiobarbituric acid reactive substances (TBARS) assay. Antioxidant status was evaluated by determining the activity of key enzymes, including superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx).

Hematological analysis was carried out using an automated hematology analyzer to measure hemoglobin (Hb), hematocrit (Hct), total leukocyte count (TLC), and platelet count.

All data were expressed as mean $\pm$ standard deviation. Statistical comparisons between groups were performed using the independent sample t-test, while Pearson correlation analysis was applied to assess relationships between variables. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was conducted using SPSS version 25.

RESULTS

The findings presented in Table 1 indicate that smokers have significantly impaired pulmonary function compared to non-smokers, reflecting reduced airflow and ventilatory efficiency. As shown in Table 2, this decline is accompanied by increased oxidative stress along with a marked reduction in antioxidant defense mechanisms, suggesting an imbalance between free radical production and neutralization. The hematological alterations observed in Table 3 point toward a compensatory response to chronic hypoxia, as well as underlying systemic inflammation. Furthermore, the correlation analysis in Table 4 demonstrates that higher oxidative stress is associated with poorer lung function, while better antioxidant status correlates with improved pulmonary performance; additionally, inflammatory markers show a positive relationship with oxidative stress, emphasizing the interconnected roles of oxidative damage and inflammation in smoking-related pulmonary dysfunction.

Table 1: Comparison of Pulmonary Function Parameters Between Smokers and Non-Smokers

Parameter	Smokers	Non-Smokers	p-value
FEV ₁ (L)	2.10 $\pm$ 0.45	3.05 $\pm$ 0.50	<0.001
FVC (L)	3.00 $\pm$ 0.60	3.80 $\pm$ 0.55	<0.001
FEV ₁ /FVC (%)	70.2 $\pm$ 6.5	80.5 $\pm$ 5.8	<0.001

Table 2: Comparison of Oxidative Stress and Antioxidant Status Between Smokers and Non-Smokers

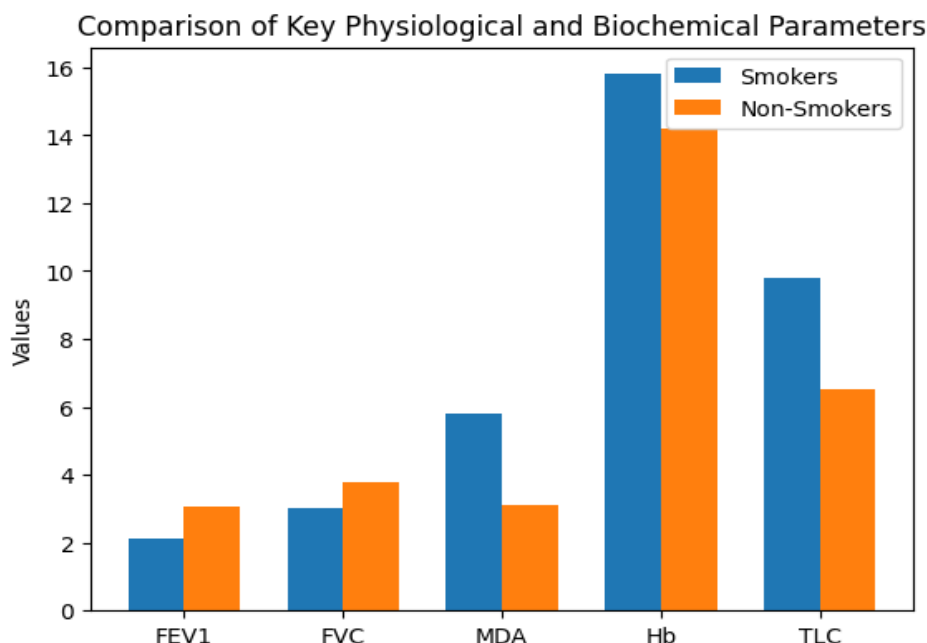
Parameter	Smokers	Non-Smokers	p-value
MDA (μ mol/L)	5.8 $\pm$ 1.2	3.1 $\pm$ 0.9	<0.001
SOD (U/mL)	1.8 $\pm$ 0.4	2.9 $\pm$ 0.5	<0.001
Catalase (kU/L)	38 $\pm$ 6	55 $\pm$ 7	<0.001
GPx (U/L)	42 $\pm$ 8	60 $\pm$ 9	<0.001

Table 3: Comparison of Hematological Parameters Between Smokers and Non-Smokers

Parameter	Smokers	Non-Smokers	p-value
Hemoglobin (g/dL)	15.8 $\pm$ 1.2	14.2 $\pm$ 1.0	<0.001
Hematocrit (%)	48 $\pm$ 4	42 $\pm$ 3	<0.001
Total Leukocyte Count ($\times 10^9$ /L)	9.8 $\pm$ 2.1	6.5 $\pm$ 1.8	<0.001
Platelets ($\times 10^9$ /L)	320 $\pm$ 60	270 $\pm$ 50	<0.05

Table 4: Correlation Analysis Between Oxidative Stress, Antioxidants, and Pulmonary Function

Variables Compared	Correlation Coefficient (r)	p-value	Interpretation
MDA vs FEV ₁	-0.62	<0.001	Strong negative correlation
MDA vs FEV ₁ /FVC	-0.55	<0.001	Moderate negative correlation
SOD vs FEV ₁	+0.58	<0.001	Moderate positive correlation
TLC vs MDA	+0.48	<0.01	Moderate positive correlation



DISCUSSION

The findings of this study confirm that smoking significantly impairs pulmonary function and disrupts oxidative balance. The reduction in spirometric parameters reflects airway obstruction, small airway remodeling, and loss of lung elasticity, consistent with early features of chronic obstructive pulmonary disease (COPD) (11). These functional impairments are primarily driven by chronic inflammation, protease-antiprotease imbalance, and structural damage to alveolar walls.

Elevated malondialdehyde levels indicate increased lipid peroxidation, while reduced antioxidant enzyme activity (SOD, catalase, GPx) suggests depletion of endogenous protective mechanisms (12,13). This oxidative imbalance contributes to membrane damage, mitochondrial dysfunction, and activation of pro-inflammatory signaling pathways, thereby accelerating tissue injury and disease progression (14). Furthermore, oxidative stress may impair nitric oxide bioavailability, leading to endothelial dysfunction and contributing to both pulmonary and systemic vascular pathology.

Hematological changes, including polycythemia and leukocytosis, further highlight the systemic impact of smoking. Increased hemoglobin and hematocrit are likely compensatory responses to chronic hypoxia, while elevated leukocyte counts reflect ongoing systemic inflammation (15). Platelet activation and aggregation may also be enhanced, increasing thrombotic risk. These alterations collectively increase blood viscosity, reduce microvascular perfusion, and predispose individuals to cardiovascular complications (16).

Importantly, the interaction between oxidative stress and inflammation appears to play a central role in smoking-induced pathology. Reactive oxygen species not only directly damage cellular structures but also amplify inflammatory cascades, creating a vicious cycle that perpetuates lung injury and systemic effects. This synergistic interaction may explain the progression from subclinical dysfunction to overt cardiopulmonary disease (17). Overall, the present findings reinforce the concept

that smoking exerts multi-system effects through interconnected physiological, biochemical, and hematological pathways.

CONCLUSION

Smoking causes significant deterioration in pulmonary function, increases oxidative stress, reduces antioxidant defenses, and alters hematological parameters. These combined effects contribute to the development and progression of pulmonary disease.

LIMITATIONS

The study was limited by a relatively small sample size and inclusion of only male participants. The cross-sectional design also limits causal interpretation.

Recommendations

Further longitudinal studies with larger and more diverse populations are recommended. The role of antioxidant therapy should also be explored.

Disclaimer: None

Conflict of Interest: None

Funding: None

Authors' Contribution

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Final Approval of Version: All authors approved the final version.

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