

Effects of Air Pollution on Cardiovascular Function, Heart Rate Variability, and Oxidative Stress in Young Adults

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ABSTRACT

Background: Air pollution is an established environmental risk factor for cardiovascular disease, yet its early subclinical effects in young adults remain underexplored.

Objective: To evaluate the impact of ambient air pollution on cardiovascular parameters, heart rate variability (HRV), and oxidative stress markers in young adults.

Methods: A comparative cross-sectional study was conducted among 120 participants aged 18-30 years, divided into high- and low-exposure groups based on ambient air quality levels. Blood pressure and HRV were assessed. Serum malondialdehyde (MDA) was measured as a marker of oxidative stress. Statistical analysis was performed using SPSS version 26.

Results: The high-exposure group showed significantly elevated systolic and diastolic blood pressure ($p < 0.001$) and reduced HRV indices. MDA levels were significantly increased ($p < 0.001$). Air pollution exposure was identified as an independent predictor of cardiovascular dysfunction.

Conclusion: Air pollution is associated with early cardiovascular alterations, autonomic imbalance, and oxidative stress in young adults, indicating increased long-term cardiovascular risk.

INTRODUCTION

Air pollution has emerged as a major contributor to global cardiovascular morbidity and mortality [1].

Fine particulate matter (PM_{2.5}) and gaseous pollutants induce oxidative stress, systemic inflammation, and endothelial dysfunction, leading to adverse cardiovascular outcomes [2,3].

While most research has focused on older populations, recent evidence suggests that young adults may also experience early cardiovascular changes due to environmental exposure [4].

Heart rate variability (HRV) is a sensitive marker of autonomic nervous system function and is widely used to assess cardiovascular health. Reduced HRV reflects autonomic imbalance and is associated with increased cardiovascular risk.

Additionally, oxidative stress markers such as malondialdehyde (MDA) provide insight into cellular damage induced by pollutant exposure.

Despite increasing concern, there is limited data from central India evaluating cardiovascular and oxidative stress responses to air pollution in young adults.

This study aims to address this gap.

MATERIALS AND METHODS

Study Design and Population

A comparative cross-sectional study was conducted among 120 healthy young adults aged 18–30 years.

Participants were categorized into high- and low-exposure groups based on ambient air quality index levels.

Inclusion and Exclusion Criteria

Participants with no history of cardiovascular or respiratory disease were included. Smokers, individuals with chronic illness, or recent infections were excluded.

Cardiovascular Assessment

Blood pressure was measured using standard protocols. HRV was assessed using electrocardiographic recordings and analyzed for time-domain parameters.

Biochemical Analysis

Blood samples were collected for estimation of malondialdehyde (MDA) as a marker of oxidative stress.

Statistical Analysis

Data were analyzed using SPSS version 26. Independent t-tests, correlation, and regression analyses were performed. A p-value < 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics

The demographic characteristics of participants were comparable between groups (Table 1).

Table 1. Baseline Characteristics of Study Participants.

Variable	Low Exposure (n=60)	High Exposure (n=60)	p-value
Age (years)	23.4 ± 2.8	23.9 ± 3.1	0.412
Male/Female (n)	32/28	34/26	0.713
BMI (kg/m ²)	22.6 ± 2.3	22.9 ± 2.5	0.528

Blood Pressure

The high-exposure group demonstrated significantly higher systolic and diastolic blood

pressure compared to the low-exposure group (p < 0.001) (Table 2; Figure 1).

Table 2. Comparison of Blood Pressure between Groups.

Parameter	Low Exposure	High Exposure	p-value
SBP (mmHg)	112.4 ± 8.6	124.8 ± 10.2	<0.001*
DBP (mmHg)	72.6 ± 6.4	81.9 ± 7.5	<0.001*

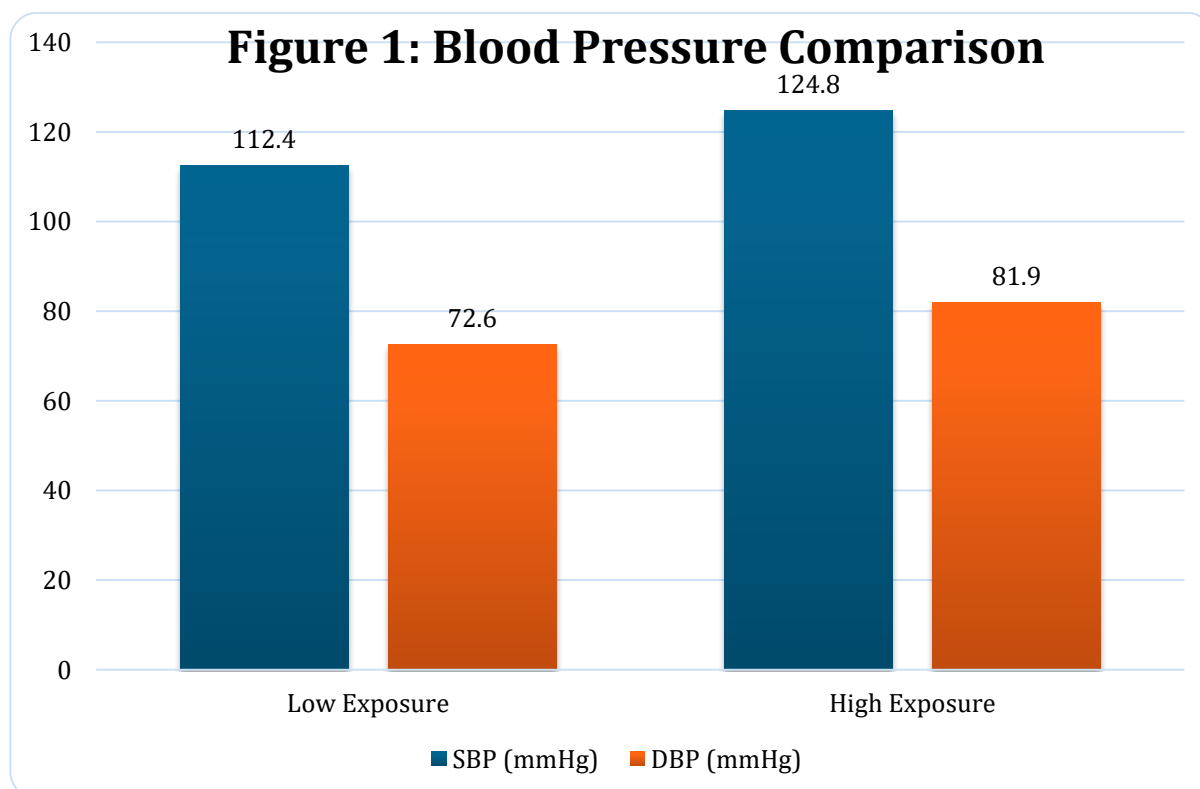


Figure 1. Bar Graph Showing Systolic and Diastolic Blood Pressure in Both Groups.

Heart Rate Variability

HRV parameters were significantly reduced in the high-exposure group, indicating autonomic imbalance (Table 3; Figure 2).

Table 3. Comparison of HRV Parameters.

Parameter	Low Exposure	High Exposure	p-value
SDNN (ms)	52.3 ± 10.5	38.7 ± 9.2	<0.001*
RMSSD (ms)	42.1 ± 8.7	29.5 ± 7.9	<0.001*

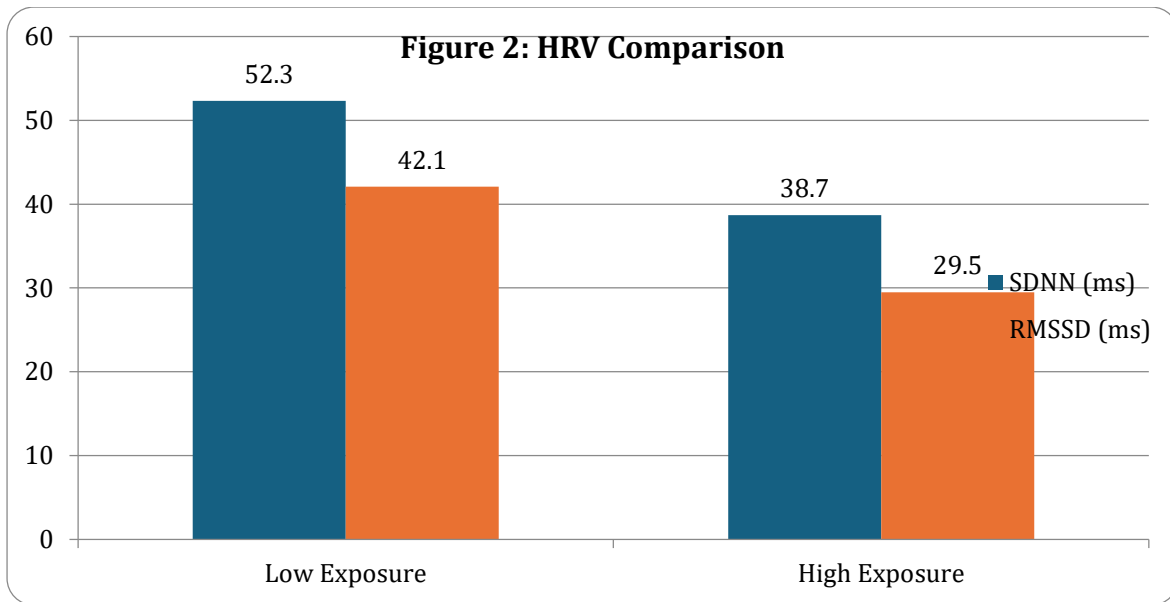


Figure 2. Bar Graph Showing Reduced HRV Parameters in High-Exposure Group.

Oxidative Stress

MDA levels were significantly elevated in the high-exposure group ($p < 0.001$) (Table 4; Figure 3).

Table 4. Comparison of Oxidative Stress Marker (MDA).

Parameter	Low Exposure	High Exposure	p-value
MDA (nmol/mL)	2.1 ± 0.6	4.8 ± 1.3	$<0.001^*$

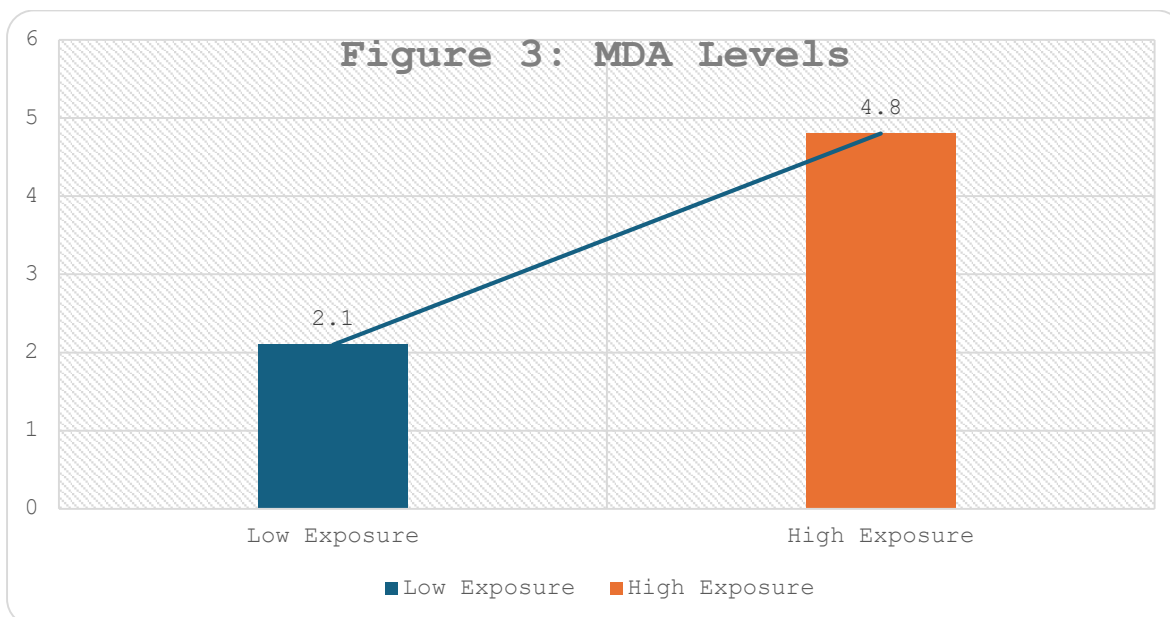


Figure 3. Bar Graph Showing Elevated MDA Levels In High-Exposure Group.

Correlation and Regression

Air pollution exposure showed a positive correlation with systolic blood pressure ($r = 0.61$, $p < 0.001$) and MDA ($r = 0.64$, $p < 0.001$), and a negative correlation with HRV

(SDNN: $r = -0.58$, $p < 0.001$). Regression analysis identified air pollution exposure as an independent predictor of cardiovascular dysfunction (Table 5; Figure 4).

Table 5. Regression Analysis for Predictors of Systolic Blood Pressure.

Variable	B coefficient	Standard error	P-value
Air Pollution Exposure	0.72	0.10	$<0.001^*$

Age	0.05	0.03	0.061
BMI	0.04	0.02	0.074

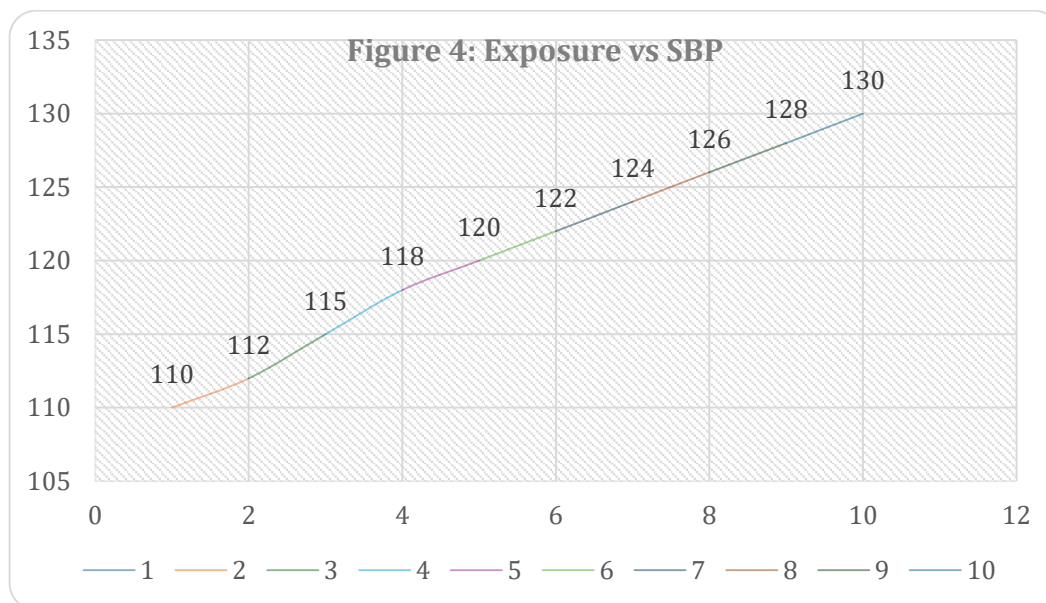


Figure 4. Scatter Plot Showing Correlation between Air Pollution Exposure and Systolic Blood Pressure.

DISCUSSION

The present study demonstrates that air pollution is associated with early cardiovascular changes in young adults. Elevated blood pressure and reduced HRV suggest autonomic dysregulation, while increased MDA levels indicate oxidative stress [5, 6].

These findings support the hypothesis that air pollution contributes to cardiovascular risk through oxidative stress and inflammatory mechanisms [6,9]. Even in healthy individuals, chronic exposure may initiate subclinical changes that predispose to future disease [4, 10].

From a clinical perspective, early screening of cardiovascular parameters in young adults exposed to high pollution levels may aid in risk stratification. Preventive strategies including lifestyle modification and pollution control measures are essential [7,8].

However, the cross-sectional design limits causal inference, and exposure assessment based on ambient data may not reflect individual exposure levels. Further longitudinal studies are needed.

CONCLUSIONS

Air pollution is associated with increased blood pressure, reduced HRV, and elevated oxidative stress in young adults. These findings highlight the importance of early detection and preventive interventions.

Additional Information

Disclosures

Human subjects: Consent was obtained from all participants. Institutional ethics approval was obtained.

Conflicts of Interest

The authors declare no conflicts of interest.

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