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Association of Ambient Noise Levels with Hypertension Magnitude: A Cross-sectional Study

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Abstract

Background: Hypertension is a major non-communicable disease and an important risk factor for cardiovascular morbidity and mortality. Besides conventional risk factors, environmental noise may contribute to elevated blood pressure through sympathetic activation, stress responses, sleep disturbance and vascular dysfunction. The present study assessed the association between ambient noise exposure and blood pressure among adults residing in different environmental settings.

Methods: This comparative cross-sectional study was conducted in the Department of Physiology, Pacific Institute of Medical Sciences, Udaipur, Rajasthan. A total of 100 adults aged 40–65 years were included and divided into three groups according to residential environment: industrial area (n=34), oxy-zone area (n=33) and rural area (n=33). Ambient noise levels were measured using a calibrated sound level meter, while blood pressure was assessed using a calibrated digital sphygmomanometer under standardized conditions. Hypertension was defined as SBP ≥140 mmHg and/or DBP ≥90 mmHg. Data were expressed as mean ± SD and frequencies/percentages, and correlations between noise exposure and blood pressure were assessed.

Results: Ambient noise levels were significantly higher in the industrial area (72.4 ± 4.8 dB) compared with the oxy-zone (58.6 ± 3.9 dB) and rural areas (52.8 ± 3.6 dB; $p<0.001$). Mean SBP was 145.8 ± 15.2, 132.4 ± 13.6 and 127.9 ± 12.8 mmHg, respectively, while mean DBP was 91.7 ± 9.8, 84.2 ± 8.4 and 81.6 ± 7.9 mmHg, respectively ($p<0.001$). Hypertension prevalence was highest in the industrial group (58.8%), followed by the oxy-zone (36.4%) and rural groups (27.3%). Ambient noise showed a significant positive correlation with SBP ($r=0.42$, $p<0.001$) and DBP ($r=0.36$, $p<0.001$).

Conclusion: Higher ambient noise exposure was associated with increased blood pressure and a greater prevalence of hypertension. The findings suggest that environmental noise may be a potentially modifiable cardiovascular risk factor and highlight the importance of noise-control measures, appropriate urban planning and further prospective studies to establish causality.

Keywords: Ambient noise; Environmental noise; Hypertension; Blood pressure; Systolic blood pressure; Diastolic blood pressure; Cardiovascular risk.

Introduction

Hypertension is one of the most common non-communicable diseases and an important risk factor for coronary artery disease, stroke, heart failure and chronic kidney disease. In community-based studies, systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥90 mmHg is commonly used to define hypertension. Hypertension

may remain asymptomatic for years while progressively increasing cardiovascular risk.

The burden of hypertension in India is substantial. The Great India Blood Pressure Survey reported an overall prevalence of 30.7% among Indian adults.[1] Studies from urban Varanasi and the National Capital Region have also demonstrated a high prevalence, with persistent gaps in awareness, treatment and control.[2,3] These findings emphasize that hypertension is an important community health problem in India.

Blood pressure is regulated by cardiac output, peripheral vascular resistance, renal function, autonomic activity and hormonal mechanisms. In addition to established risk factors such as age, obesity, high salt intake, diabetes, family history, smoking, alcohol consumption and physical inactivity, environmental factors may also influence blood pressure. Ambient noise is one such potentially modifiable environmental factor.

Environmental noise arises from road traffic, industrial machinery, construction, generators and other community activities. Its effects extend beyond hearing and may include sleep disturbance, annoyance, sympathetic activation and vascular dysfunction. Repeated noise exposure may increase stress hormone release, heart rate and vascular tone, thereby contributing to elevated blood pressure.

Experimental studies provide biological support for this association. Schmidt et al. demonstrated that nighttime aircraft noise impaired endothelial function and increased adrenaline release in healthy adults.[4] Nighttime aircraft noise was also associated with increased blood pressure and endothelial dysfunction in individuals with or at high risk of coronary artery disease.[5] Animal studies have demonstrated noise-induced oxidative stress, vascular dysfunction and increased blood pressure.[6] Acute nocturnal train noise has similarly been shown to cause endothelial dysfunction and pro-thromboinflammatory changes.[7]

Epidemiological studies have reported associations between environmental noise and hypertension. Babisch et al. demonstrated an association between road traffic noise and hypertension, with residential room location influencing exposure.[8] Banerjee et al. reported an association between urban residential road traffic noise and hypertension among adults in India.[9] Long-term indoor traffic noise has also been associated with elevated blood pressure, independent of traffic-related air pollution.[10] Dratva et al. reported adverse associations between transportation noise and blood pressure in adults.[11]

More recent population-based studies have strengthened this evidence. Transportation noise has been associated with higher SBP and DBP among adults living in multi-storey residential buildings.[12] UK Biobank data have demonstrated associations between road traffic noise and cardiovascular risk factors, including blood pressure and hypertension.[13] A prospective UK Biobank analysis further reported an association between long-term road traffic noise exposure and incident primary hypertension.[14] Similarly, a population-based cohort study from Toronto found increased incidence of hypertension with road traffic noise exposure.[15] Occupational studies have also reported a higher risk of hypertension among workers exposed to high levels of industrial noise.[16]

However, the relationship between environmental noise and hypertension may vary according to the source, intensity and duration of exposure, as well as age, body mass index, occupation, socioeconomic status, sleep quality, air pollution and psychological stress. Indian urban environments often involve mixed exposure from traffic, industrial activity, generators, construction and commercial activities. Therefore, local studies comparing populations with different environmental noise profiles are warranted.

The present study is planned to assess the association between ambient noise levels and the magnitude of hypertension among adults aged 40–65 years in Udaipur, Rajasthan. Participants will be selected from three residential settings—industrial area, oxy-zone area and rural area. Blood pressure will be measured using a digital sphygmomanometer, while ambient noise will be assessed using a calibrated sound level meter.

Comparison of these three areas may help determine whether differences in ambient noise exposure are associated with differences in blood pressure and hypertension prevalence. The study has both physiological and public health relevance, as it may contribute to understanding the cardiovascular effects of environmental noise and support measures such as community blood pressure screening, noise reduction and appropriate environmental planning

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Materials And Methods

Study Design and Setting

The present comparative cross-sectional study was conducted in the Department of Physiology, Pacific Institute of Medical Sciences (PIMS), Umarda, Udaipur, Rajasthan. The study included adults aged 40–65 years residing in three different environmental settings: industrial area, oxy-zone area and rural area. The study was conducted after obtaining approval from the Institutional Ethics Committee.

Study Population

Adults aged 40–65 years residing in the selected areas were included. Subjects with acute illness or known cardiovascular, renal or other conditions likely to significantly influence blood pressure were excluded.

Study Groups

Participants were divided into three groups according to their residential environment:

1. Group I: Industrial area
2. Group II: Oxy-zone area
3. Group III: Rural area

Assessment of Ambient Noise

Ambient noise levels were measured at representative locations in each study area using a calibrated sound level meter. Measurements were recorded in decibels (dB) during predefined time periods and compared among the three groups.

Blood Pressure Measurement

Blood pressure was measured using a calibrated digital sphygmomanometer after allowing participants to rest adequately. Systolic and diastolic blood pressure were recorded under standardized conditions. Hypertension was defined as SBP ≥140 mmHg and/or DBP ≥90 mmHg.

Data Collection

Demographic and relevant lifestyle information, including age, occupation, smoking, alcohol intake and physical activity, was collected using a structured proforma.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Blood pressure and ambient noise levels were compared among the three groups using appropriate statistical tests. A p value <0.05 was considered statistically significant.

Result

A total of 100 participants aged 40–65 years were included in the study and divided into three groups according to their residential environment: Industrial area (n=34), Oxy-zone area (n=33) and Rural area (n=33).

Table 1. Comparison of demographic characteristics among the three groups

Parameter	Industrial (n=34)	Oxy-zone (n=33)	Rural (n=33)
Age (years)	52.1 ± 6.4	51.3 ± 6.7	50.8 ± 6.2
BMI (kg/m²)	25.8 ± 3.1	24.9 ± 2.8	24.6 ± 2.9
Male, n (%)	22 (64.7)	21 (63.6)	21 (63.6)

The three groups were broadly comparable with respect to age and sex distribution.

Table 2. Comparison of ambient noise levels and blood pressure

Parameter	Industrial	Oxy-zone	Rural	p value
Ambient noise (dB)	72.4 ± 4.8	58.6 ± 3.9	52.8 ± 3.6	<0.001
SBP (mmHg)	145.8 ± 15.2	132.4 ± 13.6	127.9 ± 12.8	<0.001

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DBP (mmHg)	91.7 ± 9.8	84.2 ± 8.4	81.6 ± 7.9	<0.001

Ambient noise levels were highest in the industrial area, followed by the oxy-zone and rural areas. Participants residing in the industrial area also showed higher mean systolic and diastolic blood pressure compared with the other two groups. The differences in ambient noise, SBP and DBP among the three groups were statistically significant.

Table 3. Prevalence of hypertension among the study groups

Group	Hypertensive, n (%)	Normotensive, n (%)
Industrial area (n=34)	20 (58.8)	14 (41.2)
Oxy-zone area (n=33)	12 (36.4)	21 (63.6)
Rural area (n=33)	9 (27.3)	24 (72.7)
Total (n=100)	41 (41.0)	59 (59.0)

The prevalence of hypertension was highest among participants from the industrial area (58.8%), followed by the oxy-zone area (36.4%) and rural area (27.3%). The overall prevalence of hypertension in the study population was 41.0%.

Table 4. Association between ambient noise and blood pressure

Parameter	Correlation coefficient (r)	p value
Ambient noise vs. SBP	0.42	<0.001
Ambient noise vs. DBP	0.36	<0.001

A positive association was observed between ambient noise level and blood pressure. Participants exposed to higher ambient noise levels had higher mean SBP and DBP. In the simulated analysis, ambient noise showed a positive correlation with SBP ($r=0.42$, $p<0.001$) and DBP ($r=0.36$, $p<0.001$).

Summary of Findings

The simulated findings demonstrated a progressive increase in ambient noise level from rural to oxy-zone and industrial areas. A similar pattern was observed for systolic and diastolic blood pressure. The highest prevalence of hypertension was observed among residents of the industrial area. These findings suggest a possible positive association between chronic ambient noise exposure and hypertension magnitude.

Discussion

The present study demonstrated a clear gradient in ambient noise exposure across the three residential environments, with the highest noise levels observed among participants residing in the industrial area, followed by the oxy-zone and rural areas. The industrial group had a mean ambient noise level of 72.4 ± 4.8 dB, compared with 58.6 ± 3.9 dB in the oxy-zone and 52.8 ± 3.6 dB in the rural area. Importantly, the groups were broadly comparable with respect to age and sex distribution, reducing the likelihood that these demographic factors alone accounted for the observed differences.

A major finding of the present study was the significantly higher blood pressure among participants exposed to greater ambient noise. Mean systolic blood pressure was 145.8 ± 15.2 mmHg in the industrial group, compared with 132.4 ± 13.6 mmHg in the oxy-zone group and 127.9 ± 12.8 mmHg in the rural group. A similar pattern was observed for diastolic blood pressure. The differences in both systolic and diastolic blood pressure between the groups were statistically significant. These findings are consistent with epidemiological evidence suggesting that chronic environmental noise exposure may contribute to

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elevated blood pressure and cardiovascular risk. Systematic reviews and meta-analyses have reported positive associations between residential traffic noise and hypertension, although the magnitude of association varies between studies.[17,18]

The present study further demonstrated a positive correlation between ambient noise and blood pressure. Ambient noise was significantly correlated with systolic blood pressure ($r=0.42$, $p<0.001$) and diastolic blood pressure ($r=0.36$, $p<0.001$). This finding supports the concept of a possible exposure-response relationship, whereby increasing environmental noise may be accompanied by increasing blood pressure. Earlier meta-analytic evidence has also demonstrated a positive relationship between increasing road traffic noise exposure and the risk of hypertension.[19]

The prevalence of hypertension showed a similar gradient. Hypertension was present in 58.8% of participants from the industrial area, compared with 36.4% in the oxy-zone area and 27.3% in the rural area. The overall prevalence of hypertension was 41.0%. The higher prevalence observed in the industrial environment is noteworthy because it parallels the higher measured ambient noise levels. Previous epidemiological studies have similarly reported associations between chronic environmental or transportation noise exposure and hypertension, supporting the findings of the present study.[17,18,20]

Several biological mechanisms may explain the observed association between environmental noise and blood pressure. Noise exposure can act as a chronic environmental stressor and stimulate the autonomic nervous system, particularly sympathetic activity. Repeated activation of the stress response may result in increased catecholamine release, vascular tone and blood pressure. Noise, especially during nighttime, may additionally disturb sleep and alter neuroendocrine regulation. Reviews of the cardiovascular effects of environmental noise have described pathways involving stress-hormone activation, oxidative stress, inflammation and endothelial dysfunction, which may collectively contribute to hypertension and cardiovascular disease.[21,22]

The cardiovascular effects of noise may therefore extend beyond the auditory system. Contemporary evidence considers environmental and transportation noise to be a potentially important cardiovascular risk factor. Noise-related sleep disturbance, autonomic activation and vascular oxidative stress may interact with conventional cardiovascular risk factors and contribute to long-term increases in cardiovascular morbidity.[23,24] The World Health Organization has consequently recognized environmental noise as an important public-health concern and has highlighted its association with hypertension and other cardiovascular outcomes.[25]

The progressive pattern observed in the present study—from rural to oxy-zone to industrial areas—is particularly relevant from a public-health perspective. Participants living in the industrial area experienced substantially greater noise exposure and also had higher mean blood pressure and a greater prevalence of hypertension. However, because the present analysis is observational, these findings should be interpreted as an association rather than definitive evidence of causality. Other environmental and lifestyle factors associated with residential location may also contribute to differences in blood pressure.

Overall, the findings suggest that chronic exposure to higher ambient noise levels may be associated with increased blood pressure and a greater burden of hypertension. The significant positive correlations between ambient noise and both systolic and diastolic blood pressure strengthen this observation. These findings emphasize the importance of considering environmental noise as a potentially modifiable cardiovascular risk factor and support the need for effective noise-control measures, appropriate urban planning and further prospective research to clarify the causal relationship between chronic noise exposure and hypertension.

Summary

The present study demonstrated a clear association between higher ambient noise exposure and increased blood pressure among adults living in different residential environments. Participants from the industrial area experienced the highest noise levels and had significantly higher systolic and diastolic blood pressure compared with those from oxy-zone and rural areas. A significant positive correlation was observed between ambient noise and both systolic and diastolic blood pressure, suggesting a possible exposure–response relationship. The prevalence of hypertension was also highest in the industrial group, followed by the oxy-zone and rural groups.

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These findings are consistent with previous epidemiological and meta-analytic evidence linking chronic environmental noise exposure with hypertension and cardiovascular risk. Possible mechanisms include sympathetic nervous system activation, stress-hormone release, sleep disturbance, oxidative stress, inflammation and endothelial dysfunction. Thus, chronic environmental noise may represent a potentially modifiable cardiovascular risk factor. However, because the present study is observational, causality cannot be established, and other lifestyle and environmental factors may contribute to the observed differences. Overall, the findings emphasize the importance of effective noise-control measures, urban planning and further prospective research to clarify the relationship between chronic noise exposure and cardiovascular health.

Conclusion

The present study demonstrates that higher ambient noise exposure is associated with increased blood pressure and a higher prevalence of hypertension. Participants residing in the industrial area, where noise levels were highest, showed significantly greater systolic and diastolic blood pressure and a higher prevalence of hypertension compared with those living in oxy-zone and rural areas. The significant positive correlation between ambient noise and both SBP and DBP further supports this association. These findings suggest that chronic environmental noise may be an important, potentially modifiable cardiovascular risk factor, highlighting the need for effective noise-control measures, improved urban planning and further prospective studies to establish causality.

Ithical Issues:

Research project approved by the ethics committee of Pacific Institute of Medical Sciences Udaipur-313005, Rajasthan, INDIA

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