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Association of Household Air Pollution with Chronic Respiratory Symptoms and Health-Related Quality of Life

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Abstract

Introduction: Background: Household air pollution (HAP) remains a major environmental risk factor contributing to respiratory morbidity and reduced quality of life in low- and middle-income populations.
Objective: To determine the association between HAP, chronic respiratory symptoms, and health-related quality of life (HRQoL) among adults.
Methodology: This was an analytical cross sectional study carried out from March 2023 to February 2024. A multi-stage sampling technique was employed to pick 390 participants from households in urban and peri-urban areas. Sociodemographic, household air pollution, chronic respiratory symptoms and health-related quality of life were explored using a validated instrument through structured interviews with a pre-designed questionnaire. The applied methods were Chi square, independent samples t-test and multivariable regression analyses.
Results: Among 390 participants, 56.15% (219) were exposed to high HAP while 43.85% (171) had low exposure. Chronic respiratory symptoms were significantly more frequent in the high-exposure group, including chronic cough (40.18% vs 16.96%), dyspnea (49.32% vs 21.64%), wheezing (31.51% vs 12.28%), sputum production (33.33% vs 13.45%), and recurrent respiratory infections (30.14% vs 14.62%) (all $p<0.05$). Mean overall HRQoL scores were significantly lower in high-exposure participants (62.08 ± 9.33) compared to low-exposure participants (70.38 ± 8.41; $p<0.001$). Multivariable analysis showed that high HAP was independently associated with chronic respiratory symptoms (AOR=3.18, 95% CI: 2.01–5.02) and reduced HRQoL ($\beta = -6.92$, $p<0.001$).
Conclusion: HAP is significantly associated with increased respiratory symptoms and reduced HRQoL among adults.
Keywords: household air pollution, chronic respiratory symptoms, HRQoL, biomass fuel, risk factor.

Introduction

Household air pollution (HAP) is still a significant environmental and public health problem, especially in low- and middle-income countries where a large fraction of households use solid fuels for cooking and heating, including wood, charcoal, crop wastes, coal and animal excrement [1,2]. Poor ventilation and cooking methods and indoor exposure to smoke have been largely responsible for the high concentration of fine particulate matter ($PM_{2.5}$), carbon monoxide, nitrogen oxides, sulfur dioxide, and volatile organic compounds [3]. These pollutants can reach deeply into the respiratory tract, causing long-lasting inflammation of the airways, impaired lung function and making the lungs more vulnerable to acute and chronic respiratory diseases [4].

Overall, exposure to HAP has been consistently linked to a wide range of respiratory symptoms such as chronic cough, sputum production, wheezing, dyspnea and recurrent respiratory infections [5]. Chronic respiratory diseases like COPD, chronic bronchitis, asthma and interstitial lung disease are developed and advanced after repeated exposure to the indoor pollutants [6,7]. Women, children, older adults and people who spend longer periods of time indoors are especially vulnerable as they have higher exposure to indoor cooking and exposure environments. Although there has been progress in providing access to cleaner fuels in some areas, the use of traditional fuels and biomass still contributes to high burden of HAP-related morbidity that is preventable [8].

In addition to clinical implications, chronic respiratory disease has a significant impact on HRQoL which is a multidimensional construct that includes physical functioning, psychological well-being, social participation, and overall health perceptions [9,10]. The symptoms of asthma frequently interfere with daily functioning, exercise tolerance, sleep, productivity and emotional distress which decreases quality of life [11]. Assessment of HRQoL together with respiratory symptoms gives a comprehensive picture of disease burden because of the functional and psychosocial consequences that are not captured from clinical measurements [12].

HAP has a disproportionate impact on developing countries, where people suffer more because of socio-economic factors, low availability of safe energy sources, small households, and poor indoor air quality [13]. There are several studies that have shown that HAP is linked to respiratory disease, but relatively fewer that have looked at chronic respiratory symptoms and the impact of HAP on health related quality of life in the exposed population. Furthermore, there are different regional variations in the way households use fuels, housing conditions, cultural practices and environmental characteristics, which calls for regionally produced evidence to better explain these relationships.

Research Objective

To determine the association between HAP, chronic respiratory symptoms, and HRQoL among adults using a cross-sectional study design.

Methodology

Study Design and Setting

The study was an analytical cross sectional study carried out in the Department of Community Medicine, Khyber Medical University, Peshawar, Pakistan. HAP, chronic respiratory symptoms and HRQoL were assessed in relation to each other among the urban and peri-urban households in Peshawar. A community-based approach was used to ensure that participants had different exposures to HAP and to provide representative data on household fuel use, cooking methods, housing features, and respiratory health.

Study Duration

This study was conducted for 12 months starting from March 2023 to February 2024. This allowed for the recruitment of participants, household surveys, data collection, data verification, and statistical analysis.

Study Population

The study population included adults who were living in selected urban and peri-urban households of Peshawar. Only those who had been residents of their current household for at least one year were deemed to have been exposed to household environmental conditions, in order to guarantee sufficient exposure to household environmental conditions. To ensure independence of observations, one eligible individual was enrolled from each household selected.

Sample size and sampling technique.

There were 390 subjects in total. The sample size was deemed as sufficient to assess the association between the exposure to HAP, chronic respiratory symptoms, and HRQoL with reasonable statistical precision. A multistage sampling method was used. First, the urban and peri-urban communities were identified and then one by one households were identified within the communities. The eligible participants were then sampled consecutively to attain the required sample size.

Inclusion and Exclusion Criteria

The study included adult respondents (age ≥18 years) who were permanent residents of the selected households and had provided informed consent in writing. People with severe cognitive difficulties or communication problems where they were unable to complete a questionnaire, acute respiratory infections on the day of the questionnaire or who did not complete the questionnaire. The analysis did not include responses to the questionnaire.

Data Collection Procedure

Data were obtained from face-to-face interviews by trained data collectors using a structured and pretested questionnaire. Sociodemographic, household cooking fuel, cooking location, ventilation, kitchen characteristics, length of exposure to kitchen smoke, tobacco smoking, dust or fume exposure at work place and prior respiratory diseases were collected. Chronic respiratory symptoms (chronic cough, sputum production, wheezing, shortness of breath and recurrent respiratory infections) were also inquired about. The HRQoL was measured by a validated questionnaire that aimed to measure physical, psychological, social and environmental health. Completed questionnaires were checked daily to insure completeness, consistency and quality of data.

Study Variables and Measurements

HAP was the main exposure measured using fuel type, cooking methods, ventilation measures, and estimated intensity of exposure to HAP (indoor smoke). Households that rely on solid fuels (wood, coal, crop residues, animal dung) for cooking and/or heating were considered to have high exposure to HAP, while households that use cleaner fuels (Liquefied Petroleum Gas – LPG, Electricity) were considered to have low exposure to HAP. Chronic respiratory symptoms and health related quality of life were the main outcome variables. Chronic respiratory symptoms assessed by asking participants about their history of chronic cough, sputum production, wheezing, dyspnea and recurrent respiratory infections. HRQoL scores were derived using the scoring system for the instrument being used and the higher the score the better the perceived quality of life. Other potentially confounding factors such as age, sex, level of education, occupation, smoking, BMI and exposure to dust at work were also documented.

Ethical Considerations

Institutional Research and Ethics committee of Khyber Medical University, Peshawar approved the data collection with ethical clearance. All participants gave informed written consent for the study after it was explained to them.

Statistical Analysis
SPSS version 27.0 was used for data analysis. Continuous variables were summarized as means ± SD or medians (IQR) whereas categorical variables were summarized as frequencies and percentages. The association was tested with Chi-square and independent t-tests, as appropriate. Multivariable logistic regression and linear regression were used and p value of < 0.05 was considered statistically significant.

Table 1 shows the sociodemographic and HAP characteristics of 390 participants. The largest age group was 31–45 years (138, 35.38%), followed by 46–60 years (101, 25.90%), while 54.36% (212) of participants were female. Regarding education, 30.26% (118) had secondary education, and 23.59% (92) had no formal education. Most participants were never smokers (268, 68.72%). In terms of HAP exposure, 56.15% (219) of participants were classified as having high exposure. Biomass fuel use was common, with wood being the most frequent solid fuel (133, 34.10%), and 53.59% (209) of households reported poor ventilation.

Results

Table 1: Sociodemographic and HAP Exposure Characteristics of the Study Participants (N = 390)

Category	Variable	Frequency (n)	Percentage (%)
Age (years)	18–30	94	24.10
	31–45	138	35.38
	46–60	101	25.90
	>60	57	14.62
	Total	390	100.00
Gender	Male	178	45.64
	Female	212	54.36
	Total	390	100.00
Educational Status	No formal education	92	23.59
	Primary education	104	26.67
	Secondary education	118	30.26
	Higher education	76	19.49
	Total	390	100.00
Smoking Status	Never smoker	268	68.72
	Former smoker	43	11.03
	Current smoker	79	20.26
	Total	390	100.00
Primary Cooking Fuel	LPG/Electricity	176	45.13
	Wood	133	34.10
	Crop residues	47	12.05
	Coal/Animal dung	34	8.72
	Total	390	100.00
Kitchen Location	Separate kitchen	221	56.67
	Inside living area	169	43.33
	Total	390	100.00
Ventilation Status	Adequate ventilation	181	46.41
	Poor ventilation	209	53.59
	Total	390	100.00
Daily Exposure to Cooking Smoke	<2 hours	121	31.03
	2–4 hours	164	42.05
	>4 hours	105	26.92
	Total	390	100.00
Overall Household Air Pollution Exposure	Low exposure	171	43.85
	High exposure	219	56.15
	Total	390	100.00

Table 2 presents the association between HAP exposure and chronic respiratory symptoms. A significantly higher proportion of respiratory symptoms was observed among individuals with high exposure. Chronic cough was reported in 40.18% (88) of the high-exposure group compared to 16.96% (29) in the low-exposure group (χ^2=24.83, p<0.001). Similarly, dyspnea was present in 49.32% (108) versus 21.64% (37), and wheezing in 31.51% (69) versus 12.28% (21), respectively (all p<0.001). Chronic sputum production and recurrent respiratory infections also showed significant associations with higher exposure levels.

Table 2: Association between HAP Exposure and Chronic Respiratory Symptoms

Respiratory Symptom	Low Exposure n=171	High Exposure n=219	χ^2	p-value
Chronic cough	29 (16.96%)	88 (40.18%)	24.83	<0.001
Chronic sputum production	23 (13.45%)	73 (33.33%)	20.41	<0.001
Wheezing	21 (12.28%)	69 (31.51%)	19.14	<0.001
Dyspnea	37 (21.64%)	108 (49.32%)	31.86	<0.001
Recurrent respiratory infections	25 (14.62%)	66 (30.14%)	12.71	0.001

Table 3 compares HRQoL scores between exposure groups. All HRQoL domains were significantly lower among participants with high HAP exposure. The overall HRQoL score was 70.38 ± 8.41 in the low-exposure group compared to 62.08 ± 9.33 in the high-exposure group (t=9.28, p<0.001). Physical health showed the greatest difference (72.46 ± 10.18 vs 60.74 ± 11.62, t=10.52), followed by environmental and psychological domains, all indicating significantly reduced quality of life with higher exposure.

Table 3: Comparison of HRQoL Scores According to HAP Exposure

HRQoL Domain	Low Exposure Mean ± SD	High Exposure Mean ± SD	t-value	p-value
Physical Health	72.46 ± 10.18	60.74 ± 11.62	10.52	<0.001
Psychological Health	69.38 ± 9.71	61.53 ± 10.29	7.84	<0.001
Social Relationships	70.94 ± 9.12	65.81 ± 9.76	5.37	<0.001
Environmental Health	68.75 ± 8.93	60.22 ± 10.54	8.66	<0.001
Overall HRQoL Score	70.38 ± 8.41	62.08 ± 9.33	9.28	<0.001

Table 4 shows multivariable logistic regression analysis for predictors of chronic respiratory symptoms. High HAP exposure was independently associated with respiratory symptoms (AOR=3.18, 95% CI: 2.01–5.02, p<0.001). Current smoking (AOR=2.67, p<0.001), poor ventilation (AOR=2.31, p<0.001), occupational dust exposure (AOR=1.88, p=0.010), and age above 45 years (AOR=1.79, p=0.009) were also significant predictors. The model showed good fit (Nagelkerke R^2=0.39, Hosmer–Lemeshow p=0.565).

Table 4: Multivariable Logistic Regression Analysis for Predictors of Chronic Respiratory Symptoms

Variable	Adjusted OR	95% CI	p-value
High HAP exposure	3.18	2.01–5.02	<0.001
Age (>45 years)	1.79	1.16–2.76	0.009
Female gender	1.42	0.91–2.22	0.121
Current smoker	2.67	1.58–4.49	<0.001
Occupational dust exposure	1.88	1.17–3.03	0.010
BMI ≥30 kg/m²	1.24	0.78–1.98	0.357
Poor household ventilation	2.31	1.48–3.60	<0.001

Model statistics: Nagelkerke R^2 = 0.39, Hosmer–Lemeshow χ^2 = 6.74, p = 0.565.

Table 5 presents multiple linear regression analysis for factors associated with overall HRQoL score. High HAP exposure was the strongest negative predictor (β = −6.92, p<0.001), followed by poor ventilation (β = −4.08, p<0.001) and current smoking (β = −3.65, p<0.001). Increasing age also showed a significant negative association with HRQoL (β = −0.18, p<0.001). The model explained a substantial proportion of variance in HRQoL (Adjusted R^2 = 0.43, F = 41.62, p<0.001).

Table 5: Multiple Linear Regression Analysis for Factors Associated with Overall HRQoL Score

Variable	β Coefficient	Standard Error	Standardized β	t-value	p-value
High HAP exposure	-6.92	0.84	-0.46	-8.24	<0.001
Age	-0.18	0.05	-0.19	-3.58	<0.001
Female gender	-1.14	0.71	-0.08	-1.61	0.108
Current smoker	-3.65	0.89	-0.21	-4.10	<0.001
Occupational dust exposure	-2.84	0.81	-0.17	-3.51	0.001
Poor household ventilation	-4.08	0.77	-0.28	-5.30	<0.001

Model statistics: F = 41.62, Adjusted R^2 = 0.43, p < 0.001.

Table 6 demonstrates the association between HAP exposure and categorized HRQoL levels. A significantly higher proportion of poor HRQoL was observed in the high-exposure group (35.62%, 78) compared to the low-exposure group (11.11%, 19), while good HRQoL was more common among low-exposure participants (45.61% vs 13.24%). The association was statistically significant (χ^2=36.58, p<0.001), indicating a strong relationship between higher HAP exposure and poorer quality of life.

Table 6: Association between HAP Exposure Level and Overall HRQoL Category

HRQoL Category	Low Exposure (n=171)	High Exposure (n=219)	χ^2	p-value
Good (>75)	78 (45.61%)	29 (13.24%)	36.58	<0.001
Moderate (50–75)	74 (43.27%)	112 (51.14%)		
Poor (<50)	19 (11.11%)	78 (35.62%)		

Discussion

The continued use of biomass fuels in peri-urban communities in Pakistan is evident in the present study, as 56.15% (219/390) of the participants were exposed to high HAP. This is similar to the findings from the national studies which revealed high levels of PM2.5 in households and ambient environment in Pakistan, which are many times higher than the limit set by WHO [14]. This has been reported in other LMICs where solid fuel continues to be the primary fuel source for indoor air pollution.

Our results showed that there was a strong association of HAP with chronic respiratory symptoms. Chronic cough was significantly higher in the high-exposure group (40.18% vs 16.96%, χ^2=24.83, p<0.001), while dyspnea (49.32% vs 21.64%) and wheezing (31.51% vs 12.28%) were also markedly increased. The findings are similar to those of the multinational PURE study on air pollution, which found that cough, wheeze, and sputum production were significantly associated with exposures to household PM2.5 (OR 1.19–1.26 per IQR increase) [15]. Likewise, a meta-analytic body of evidence also supports the association of biomass smoke exposure with chronic bronchitis and COPD which is mediated by chronic airway inflammation and the decline of lung function.

Our study indicates that high exposure group had a marked decrease in HRQoL compared to the low exposure group (t=9.28, p<0.001), besides respiratory morbidity. All HRQoL domains were significantly impaired, especially physical health. These findings corroborate with a previous study conducted in the Pakistani COPD population that environmental and smoke exposure was a significant factor affecting the HRQoL scores especially in physical and psychological domains [16]. Likewise, pilot studies conducted during periods of increasing air pollution exposure in patients with chronic respiratory disease have shown that air pollution is associated with an impact of HRQoL [17].

A high level of HAP was found to be an independent risk factor for chronic respiratory symptoms in our multivariable regression analysis (AOR=3.18, 95% CI: 2.01–5.02, p<0.001). This is in line with previous studies demonstrating that exposure to solid fuel is a strong and independent association with chronic respiratory disease, even after smoking and socioeconomic status were taken into account [18]. The study also revealed that smoking (AOR=2.67) and poor ventilation (AOR=2.31) were important co-factors and the multi-factorial nature of respiratory disease caused by indoor air pollution.

In terms of the determinants of HRQoL, our linear regression model identified HAP exposure (β=−6.92, p<0.001), poor ventilation (β=−4.08), and smoking (β=−3.65) as factors that negatively predicted HRQoL, explaining 43% of the variance. Evidence indicates that long-term exposure to biomass smoke decreases daily functional capacity and symptom burden, thereby leading to a decrease in the perceived quality of life in populations exposed to biomass smoke [19].

Overall, this study suggests that HAP is a severe double burden in terms of respiratory morbidity as well as on quality of life in a Pakistani community environment. Observed associations are consistent with the findings in the literature worldwide, which suggest a strong association between PM2.5 and biomass smoke exposure with chronic respiratory symptoms and impaired HRQoL in low- and middle-income countries. The results highlight the importance of better household energy transitions, better indoor air quality and public health for indoor air quality reduction.

Strengths and Limitations

The community-based analytical cross sectional nature of this study has the advantage of generalizing the results to urban and peri-urban populations in the setting of a developing country. A relatively large sample size (n = 390) and multistage sampling led to a good representativeness of the different socioeconomic and household exposure groups. Further, the study evaluated chronic respiratory symptoms and HRQoL at the same time with validated instruments, which provided a more comprehensive picture of the health burden of HAP. Multivariable logistic and linear regression analyses were used to adjust for important confounders, including age, smoking status, ventilation and occupational exposure, further strengthening the internal validity of the observed associations. The study has its limitations, though. It is a cross-sectional study, which makes it impossible to draw causal conclusions between HAP and outcomes. Self-reported household fuel use and ventilation conditions were used to quantify exposure, and this exposure assessment may include exposure misclassification caused by not directly measuring indoor pollutants such as PM2.5. Furthermore, there was a possible reporting bias and recall bias in the reporting of respiratory symptoms. Geographically, the study was restricted to a single city which might limit generalizability to the national level.

Conclusion

This study shows a high correlation between domestic air pollution and higher rate of chronic respiratory symptoms as well as significant HRQoL reduction among adults in urban and peri-urban communities. Chronic respiratory symptoms were significantly increased in those exposed to high levels of HAP (AOR = 3.18) and HRQoL scores were significantly lower. The results indicate that HAP is an important modifiable environmental risk factor that is associated with respiratory morbidity and reduced quality of life in low-resource countries. A shift to less reliance on solid fuels, better household ventilation and the adoption of cleaner cooking fuels and technologies may significantly influence the outcomes of respiratory health and well-being in impacted populations.

Author Contributions

All authors contributed equally to the conception and design of the study, data collection, analysis and interpretation of data, drafting and critical revision of the manuscript, and approved the final version for publication. All authors meet the authorship criteria of the ICMJE and agree to be accountable for all aspects of the work.

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Declarations

Ethical statement: Institutional Research and Ethics committee of Khyber Medical University, Peshawar approved the data collection with ethical clearance. All participants gave informed written consent for the study after it was explained to them.

Competing interests: The authors declare that they have no known competing interests.

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