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Original Article

Assessing the Impact of Air Pollution and Cardiopulmonary Diseases through General Public Knowledge, Attitude, and Practice

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ABSTRACT

Lahore, Pakistan, is one of the most polluted cities in the world, with annual PM2.5 levels almost 20 times the WHO-recommended limit. To our knowledge, no peer-reviewed knowledge, attitude, and practice study on air pollution and cardiopulmonary health has been done in Pakistan. This descriptive cross-sectional study set out to explore knowledge of indoor and outdoor pollution sources; awareness of the cardio-pulmonary health impacts of air pollution; attitudes towards reducing exposure to air pollution; self-protective measures; and demographic factors associated with knowledge, attitude, and practices. Using convenience sampling, 604 people (16-60 years) were enrolled. A culturally adapted, validated, self-report questionnaire was applied; Statistical Package for the Social Sciences v27.0 was used for the chi-square test and Kruskal-Wallis's test ($p < 0.05$). The mean age was 28.57 ± 10.35 years; 53.8% were female. The majority of people (77%) had good knowledge, and 92.5% had favorable attitudes towards reducing pollution. But only 59.4% of frequent cooks had adequate safety practices, and just 29.1% identified cooking as a considerable source of indoor pollution. Knowledge was significantly associated with gender ($\chi^2 = 27.01$, $p < 0.001$), education ($\chi^2 = 125.42$, $p < 0.001$), and occupation ($\chi^2 = 41.62$, $p < 0.001$). Only education was a significant predictor of adequate practice ($\chi^2 = 9.41$, $p = 0.024$). There was a significant knowledge-attitude-practice gap. Specific campaigns, environmental health promotion, and policy change are crucial. Longitudinal and multi-city studies are needed to build an equitable environmental health policy.

Keywords: Air Quality, Cardiopulmonary Diseases, Public Health, Smog, Urban Pollution.

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INTRODUCTION

Air pollution can be described as any kind of contamination of an indoor or outdoor environment by a chemical, physical or biological agent that interferes with the natural properties of the air (Rajagopalan, 2018) It occurs in various forms, which are gaseous pollutants, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), the carbon monoxide (CO), and ground-level ozone (O_3), and particulate matter of different sizes (Xing *et al*., 2016). Of these, PM 2.5 particles smaller than 2.5 micrometers are believed to be the most dangerous to health because of their capability to penetrate deep into pulmonary alveoli and translocate to the systemic circulation (Rajagopalan, 2018). Ambient air pollution by itself is said to cause about 4.2 million premature deaths annually, with an additional 3.8 million deaths because of household air pollution due to solid fuel burning (World Health Organization, 2021). A historic study estimated that 2.9 years of life per person is a worldwide average annual loss due to air pollution, equating to a healthcare shift to tobacco smoking (Lelieveld *et al*., 2020). The 2021 Global Air Quality Guidelines by the WHO made further demands to ensure that no amount of air pollution is safe and narrowed the recommended annual PM 2.5 level to 5 μg/m3 (W.H.O, 2021). The majority of deaths caused by pollution are in low and middle-income countries (LMICs), which are overpopulated, rapidly industrializing, and poorly regulate the environment (Manisalidis *et al*., 2020).

The affected body organs have been the lungs and heart, closely related when it comes to air pollution (Rajagopalan, 2018). PM 2.5 activates pulmonary inflammation, alveolar architecture, mucocilia, and epithelial barrier dysfunction, which play a role in the pathogenesis of COPD, asthma, and lung cancer (Adeloye *et al*., 2022; Nwanaji-Enwerem et al., 2020; Turner *et al*., 2020; Feng *et al*., 2016). PM 2.5 and gaseous pollutants contribute to endothelial dysfunction, vascular oxidative stress, and systemic inflammation, speeding up atherosclerosis and predisposing to myocardial infarction, stroke, and heart failure (Rajagopalan, 2018; Munzel *et al*., 2018; Cai *et al*., 2016). New evidence goes on to implicate long-term exposure to pollution as a factor in type 2 diabetes mellitus and metabolic syndrome (Eze et al., 2015). NO_2 exacerbates asthma and diminishes respiratory immunity defenses (Huangfu *et al*., 2020). SO_2 brings bronchoconstriction and exacerbations of pre-existing COPD (Xingye Zhou *et al*., 2024). Ground-level ozone is linked to cardiovascular death and the function of the lungs. A combination of these pollutants is a multi-pathway, multi-organ health threat (Rajagopalan, 2018).

South Asia has become the most polluted region of the world, due to the combined effect of rapid urbanization, increasing populations, rise in industrial activities, automobile emissions, burning of refuse in farms, and extensive use of solid fuels (HEI Global Health Research Committee, 2018; Rajagopalan, 2018). In 2022, the IQAir World Air Quality Report ranked Pakistan as the highest of the top three countries in the world in terms of air quality pollutants, with national annual mean levels of PM 2.5 around fifteen times higher than the WHO-recommended value of 5 μg/m3 (IQAir, 2023). Pakistan is a lower-middle-income nation with a population of more than 230 million people that has a two-fold problem of outdoor and indoor air pollution, which is complicated by an inadequately developed regulation system and irregular application of the National Environmental Quality Standards (NEQS) (Nasir *et al*., 2019; Iqbal *et al*., 2018; Pakistan Bureau of Statistics, 2023; Zarei *et al*., 2024).

Lahore, among the Pakistani cities, holds a very worrying position. Lahore, which accommodates a population of over 15 million, has been ranked as the most polluted city on the planet by the IQAir yearly index with an annual mean of PM 2.5 of 97.4 μg/m3 per 1 in 2022, almost twenty times the WHO yearly standard (IQAir, 2023; Ahmad *et al*., 2021). In winter smog season between October and February, there is a high frequency where PM 2.5 concentrations surpass 500 μg/m^3, and school closures and health crises are experienced (IQAir, 2024). It has multifactorial sources of this pollution; vehicular pollution, industrial pollution and the presence of traditional brick kilns in the urban periphery, large-scale burning of agricultural residues, construction dust pollution, and domestic combustion of solid fuels are all contributing factors to the sustained pollution burden of Lahore (Rasheed *et al*., 2015; Al Jazeera, 2024; Junaid *et al*., 2018; Yamin et al., 2019; Mirza, 2018; Khan et al., 2018). The outcomes can be quantified in the disease profile of the city, where there are high rates of respiratory diseases, asthma exacerbation, and cardiovascular hospitalization during smog events (GBD Causes of Death Collaborators, 2018; Fayyaz *et al*., 2020; Khan *et al*., 2020; Naz *et al*., 2017).

One of the validated and broadly implemented methodologies of public health research that characterizes population awareness of health risks, attitudinal barriers to behavior change, and informs the design of specific health communication interventions is the knowledge, attitude, practice surveys (Zarei *et al*., 2024). KAP studies are specifically useful in the area of environmental health since protective actions against air pollution, like respiratory protection use, switching to cleaner cooking fuels, and avoiding high-exposure environments, are seldom taken up where there is no accurate knowledge of risk (Cori *et al*., 2020). Similar KAP investigations in Oman, Singapore, and China have discovered high discrepancies in societal awareness of indoor air pollution sources (Unni *et al*., 2022; Al-Shidi *et al*., 2021; Guo *et al*., 2016). A KAP study, allowing to model the current study, carried out in Jeddah, Saudi Arabia, in 2023, sampled 649 people, and discovered that, although most of them were aware of outdoor air pollution, the knowledge gap was still in relation to indoor sources, and the use of precaution was higher among females and older people (Alahmadi *et al*., 2023).

Regardless of this expanding world literature on KAP, no peer-reviewed study has been conducted to comprehensively evaluate the knowledge, attitudes, and practices of the general Pakistani population concerning air pollution and its cardiopulmonary health effects. This is especially pronounced considering the special pollution situation unique to Lahore due to the brick kilns, crop burning, and worn-out two-stroke vehicles (Arshad *et al*., 2022; Nasim *et al*., 2018). Without any local evidence-based baseline data, it is impossible to create public health campaigns for the needs of people in Lahore.

It is hypothesized that although the general population of Lahore is aware of outdoor air pollution, there is a large gap between knowledge, attitudes, and practices, specifically regarding indoor pollution and its impact on cardiovascular health. Moreover, it is proposed that personal characteristics such as level of education, gender, and occupation are the major predictors of health knowledge and taking protective measures against air pollution.

The study was undertaken to comprehensively assess the knowledge, attitude, and practice of the general public of Lahore, Pakistan, about air pollution and its impact on cardiovascular and pulmonary health - an area of study with no previous peer-reviewed literature in Pakistan, despite the country's dire air pollution status. The problem the study resolved is the lack of local evidence-based data on public knowledge in one of the world's most polluted cities, where Lahore's annual average PM2.5 concentration was nearly 20 times the WHO level (W.H.O, 2021). This lack of baseline makes designing public health programs and policies difficult. The study was designed to identify respondents' knowledge of indoor and outdoor sources of air pollution, gauge their awareness of the role of air pollution in the development of cardiovascular and lung conditions (such as asthma, chronic obstructive pulmonary disease, and cardiovascular disease), assess their willingness to take action to avoid exposure to air pollution, and measure their self-protective practices. Most importantly, this study evaluated the level of knowledge participants had specifically regarding air pollution's effect on their cardiovascular health, as well as the level of self-protective practices, and the association between levels of knowledge and levels of practice across different demographics (Xing *et al*., 2016). The research also mapped the sources of information that influence public opinion and tested demographic predictors, such as gender, education level, occupation, and whether or not an individual has a chronic illness, that predict variation in knowledge and health-protective practices. A key problem identified and tackled is the knowledge-attitude-practice gap: while general knowledge is high and positive attitudes are nearly universal, protective practices - especially those concerning indoor pollution from cooking - were far from optimal, suggesting that knowledge alone is not enough to lead to health-protective behavior.

METHODS AND MATERIALS

Study Design

The current study was a cross-sectional, descriptive, observational research, which used a self-administered questionnaire to determine the knowledge, attitudes, and practices of the general population in Lahore, Pakistan, with respect to air pollution and its related cardiopulmonary health implications. Cross-sectional study designs are generally considered to be adequate and scientifically valid when it comes to KAP surveys, since the study design makes it possible to evaluate several variables at once among a specific population at the same time (Setia, 2016). The data collection was done after January 2026, as per the timeline of the University of the Central Punjab, Lahore, approved by the Institutional Review Board (IRB). The research was conducted and planned following the laid-down ethical codes in conducting a study involving human subjects.

Study Setting and Population

The research was carried out in the provincial city of Lahore, the second largest city of Pakistan, and the capital of the Punjab province, which has over 15 million inhabitants. The choice of the location of the study, Lahore, was based on the fact that it has a long-standing history of air quality crisis, having been rated as one of the most polluted major cities in the world based on the IQAir annual global air quality index, with recorded yearly average PM 2.5 concentrations of about nineteen times the WHO recommended guideline of 5 μg/m3 (IQAir, 2023). The target population was the adult citizens in the general population of Lahore, irrespective of their work, level of education, and health conditions. The study was not limited to any clinical or institutional setting since the goal was to describe the knowledge, attitudes, and practices of the general community instead of a particular subgroup.

Sample Size Calculation

The sample size for this study was calculated using Daniel's formula for cross-sectional studies (Wayne Daniel *et al*., 2018), which is expressed as:

$$n = Z^2P(1-P) / d^2$$

In this formula, n represents the minimum required sample size; Z is the standard normal deviation corresponding to a 95% confidence level, with a value of 1.96; P is the expected prevalence or proportion of the target outcome in the population, set at 0.5 (50%) to maximize the sample size estimate and ensure adequate statistical power in the absence of a prior local prevalence estimate; and, d is the margin of error, set at 0.20 (20%). Substituting these values yields a minimum required sample size of 384 participants. Accounting for an anticipated non-response and incomplete questionnaire rate of approximately 10–15%, the target sample size was set at 600 participants. The study ultimately enrolled and analyzed 604 participants who met all inclusion criteria.

Sampling Technique

The sampling method was non-probability convenience sampling, used to recruit participants from the general population of Lahore. This method was chosen due to its feasibility of reaching a geographically spread urban population and its appropriateness to survey-based research performed by in-field community outreach. The questionnaire was physically administered, whereby willing respondents were face-to-face in community and academic settings where they were invited to take part. Only people who passed the pre-established inclusion criteria and signed a voluntary informed consent were included.

Data Collection Tool

The study utilized a self-administered questionnaire designed in a structured format to be used in this study as an instrument of data collection by modifying the open-access questionnaire that was tested and validated in a previous KAP study carried out by Alahmadi *et al*. (2023) in Jeddah, Saudi Arabia (Alahmadi *et al*., 2023). The instrument used was adapted to the unique sources of pollution in Lahore, the local language, and the socioeconomic and cultural context of the Pakistani people. Such adaptations were the removal of those items that did not fit the local context, modification of the options in indoor pollution sources to incorporate burning incense (common in Pakistan), and modification of demographic categories to reflect the Pakistani educational and occupational framework. Face validity and content appropriateness of the questionnaire were checked before administration. The complete questionnaire was laid out in four sections. The demographic data were gathered in the first section, which comprised six items: gender, age, marital status, educational level, occupational status, and the presence of any chronic or specifically cardiopulmonary disease. The second part evaluated air pollution awareness and had ten questions. It also contained binary yes/no items that assessed knowledge about the concepts of outdoor and indoor air pollution, knowledge about the causes of the two, and the connection between indoor and outdoor pollution.

It also contained a three-point scale item with a question about the perceived severity of pollution around the participant (low, moderate, and severe) and multiple select items with questions about the sources that contribute to outdoor air pollution and indoor air pollution. Knowledge of understanding the relationship between air pollution and cardiopulmonary diseases was evaluated in the third section and included seven items. These were binary yes/no questions on whether they felt that air pollution could cause cardiopulmonary disease, and whether it is a contributing factor to such conditions as asthma or COVID-19. One of the multiple-choice questions required the participants to name the factors that they believed were associated with cardiovascular or pulmonary diseases. They were also asked to determine the sources from which they had acquired information about the negative health impacts of air pollution and whether they felt that moving to a less polluted neighborhood would make their health better. The fourth part measured practices related to reducing exposure to air pollution and consisted of six items, such as how many people cook regularly, what their health condition was before cooking, whether they used any ventilation measures during cooking, and whether the participants had ever tried to minimize their exposure to either outdoor or indoor air pollution.

Scoring System

A grading method was established whereby the degree of knowledge and practice was measured in the number of correct answers to the relevant questions in the questionnaires. Whenever a correct response was made regarding knowledge, one point was awarded, and when an incorrect or unanswered response was given, a score of zero was awarded. The overall knowledge score was determined by adding the correct responses to all knowledge items in Sections 2 and 3, creating a possible maximum of 12 points (previously chosen to be scored) on the knowledge score. In the practice section, every reported protective behavior received one point, with a maximum practice score of five points possible. In the case of knowledge, participants who scored 75% or higher of the possible score were considered to know well; participants who scored 50-74% were considered to know fairly; and those who scored below 50% were considered to know poorly (Fathy *et al*., 2020). In the case of practice, participants who scored 60% or higher of the possible score were considered to be adequately practicing, and hence those who scored less than 60% were considered inadequately practicing.

Ethical Considerations

The Ethical Review Committee and Institutional Review Board (IRB) of the University of the Central Punjab (UCP), Lahore, Pakistan, under the guidance of the Office of Research, Innovation, and Commercialization (ORIC), granted ethical approval to conduct this study. The research was accepted as a Final Year Project (FYP) in the Faculty of Pharmaceutical Sciences. Before the questionnaires were administered, each of the participants received a participant information statement in writing that clearly stated the purpose of the study, its voluntary nature, confidentiality, and the expected use of their information. Each participant was informed of the study and gave his/her consent to participate. There was no point where any kind of identifying information, like names, national identification numbers, or contact information, was collected. There was anonymization of the responses of the participants, and all the data obtained were kept in a safe place. The freedom to drop out of the study at any stage without any penalty was clearly explained to the subjects.

Inclusion and Exclusion Criteria

Study participants were eligible to take part in the study provided that they belonged to the general population in Lahore, Pakistan; were aged between 16 and 60 years (inclusive); and signed a written informed consent to take part in the study voluntarily. The sample was not eligible to take part in the study when they were below 16 years or above 60 years; when they were not residents of Lahore at the time the survey was conducted; when they did not fill the self-administered questionnaire; or when they were not citizens of Pakistan, which was the exclusion criterion adopted upon which the instrument was built (Lelieveld *et al*., 2020).

Statistical Analysis

Statistical package of the social sciences (SPSS), version 27.0 (IBM Corp., Armonk, NY, USA) was used to enter, clean, and analyze all data. Descriptive statistics were employed to describe the sample of the study, as well as to summarize the answers to all items of the questionnaire. Frequencies and percentages were used to specify categorical variables such as demographic variables and individual responses to the questionnaires. Continuous variables, age, and knowledge and practice scores were reported as averages with standard deviations (mean SD). The chi-squared test was used as an inferential statistical test to determine the statistical significance of the associations between the categorical demographic variables, such as gender, marital status, educational level, and occupational status, and the categorized levels of knowledge and practices. As for age, the Kruskal-Wallis non-parametric test was used due to the non-normality of this variable in the categories of knowledge and practice. The p-value of 0.05 was taken as the statistical significance of all analyses.

RESULTS AND FINDINGS

Demographic Characteristics

Out of 604 participants who had filled out the questionnaire, they were incorporated in the final analysis. The average age of the participants who were studied was 28.57 ± 10.35 years. In terms of gender, there were 279 (46.2%) male and 325 (53.8%) female participants. In terms of marital status, 354 (58.6%) participants were single, and 250 (41.4%) were married. Regarding educational level, most of them had an undergraduate degree (335, 55.5%), postgraduate education (118, 19.5%), secondary education (116, 19.2%), and noneducational level (35, 5.8%). Students (272, 45%), employed (201, 33.3%), unemployed (69, 11.4%), and housewives (62, 10.3%) formed the largest occupational group. In terms of chronic disease status, 122 (20.2%) of the participants suffered a chronic disease, and 482 (79.8%) did not. 44 participants (7.3%) had cardiopulmonary disease, with 23 (3.9%) having cardiovascular diseases, 17 (2.9%) having asthma, and 12 (2.1%) having other respiratory diseases. The entire demographic composition is given in Table 1.

Table 1
Distribution of the Studied Participants According to Their Demographic Characteristics

Variable	n (%)
Age (years) (mean ± SD)	28.57 ± 10.35
Gender	
Male	279 (46.2)
Female	325 (53.8)
Marital Status	
Married	250 (41.4)
Single	354 (58.6)
Education Level	
Secondary Education	116 (19.2)
Undergraduate	335 (55.5)
Postgraduate	118 (19.5)
No Formal Education	35 (5.8)
Occupation	
Employed	201 (33.3)
Unemployed	69 (11.4)
Housewife	62 (10.3)
Student	272 (45)
Having a chronic disease?	
Yes	122 (20.2)
No	482 (79.8)
Do you have any cardiopulmonary diseases?	
Yes	44 (7.3)
No	560 (92.7)
If having a cardiopulmonary disease, what is it? (N.:44)	
Cardiovascular Diseases	23 (3.9)
Asthma	17 (2.9)
Other Respiratory Diseases	12 (2.1)

Note. *n = 604, SD = Standard Deviation*

Knowledge Domain Results

Knowledge of Air Pollution

Table 2 shows the distribution of the knowledge of the participants regarding air pollution. Most of the respondents (567, 93.9%) indicated that they were aware of the meaning of outdoor air pollution, but a smaller percentage (507, 83.9%) were aware of the meaning of indoor air pollution. On the question as to whether they believed that cooking was the most significant source of indoor air pollution, 176 respondents (29.1%), and 428 respondents (70.9%), respectively, said yes and no. There were 351 participants (58.1%) who considered indoor air pollution to contribute to outdoor air pollution, and 253 (41.9%) believed indoor air pollution may not contribute to outdoor air pollution. The huge majority, 564 (93.4%), had the feeling that the air surrounding them was polluted. Out of the people who had marked pollution in their environment, 293 respondents (48.5%) considered it as severe, 261 (43.2%) as moderate, and 50 (8.3%) as low. About the sources of outdoor air pollution, 539 respondents (89.2%) said that they were aware of the causes of outdoor air pollution. The most commonly identified contributors were factories (488, 80.8%), industrial facilities (427, 70.7%), dust particles (326, 54.0%), fossil fuels (267, 44.3%), power plants (176, 29.1%), and oil refineries (139, 23.0%). In terms of indoor air pollution, 503 participants (83.3%) said that they were aware of the causes of indoor air pollution. Smoking (480, 79.6%), burning incense (356, 58.9%), heating devices (229, 37.9%), and uncleaned furniture (203, 33.6%) were the most common identified indoor contributors.

Knowledge of Air Pollution and Cardiopulmonary Diseases

Those who felt that air pollution had the potential to lead to cardiopulmonary disease were 536(88.7%) out of 604 participants (see Table 3), and those who felt otherwise were 68 (11.3%) out of 604 participants (see Table 3). Of the total respondents (510, 84.4%) said that air pollution is a contributor to asthma or other illnesses like COVID-19, with only 94 (15.6%) disagreeing. On a list of factors associated with cardiovascular or pulmonary diseases, outdoor air pollution was the most selected (486, 80.6%), global climate change (357, 59.1%), indoor air pollution (199, 32.9%), and extreme temperatures (174, 28.8%). Self-awareness (334, 55.3%), social media (288, 47.7%), scientific published articles (162, 26.8%), friends (99, 16.4%), and news (17, 2.8%) were the main channels through which the participants were informed about the negative health impacts of air pollution.

Table 2

Distribution of Studied Participants According to Their Knowledge about Air Pollution

Variable	Yes n (%)	No n (%)
Do you understand the meaning of outdoor air pollution?	567 (93.9)	37 (6.1)
Do you understand the meaning of indoor air pollution?	507 (83.9)	97 (16.1)
Would you consider cooking to be the major cause of indoor air pollution?	176 (29.1)	428 (70.9)
Do you think indoor air pollution could cause outdoor air pollution?	351 (58.1)	253 (41.9)
Do you think the air around you is contaminated by pollutants?	564 (93.4)	40 (6.6)
If so, how much would you scale the pollution around you?		
Low	50 (8.3)	
Moderate	261 (43.2)	
Severe	293 (48.5)	
Do you know the causes of outdoor air pollution?	539 (89.2)	65 (10.8)
Which of these do you think contributes to outside air pollution? (More than one option can be selected)		
Factories	488 (80.8)	
Fossil Fuels	267 (44.3)	
Industrial Facilities	427 (70.7)	
Dust Particles	326 (54)	
Power Plants	176 (29.1)	

Oil Refineries	139 (23)	
Do you know the causes of indoor air pollution?	503 (83.3)	101 (16.7)
Smoking	480 (79.6)	
Burning Incense	356 (58.9)	
Heating Devices	229 (37.9)	
Uncleaned Furniture	203 (33.6)	

Note. *n = 604*

Table 2

Participants' Knowledge About the Association of Air Pollution with Cardiopulmonary Diseases, Factors Related to Cardiopulmonary Diseases, and Sources of Information on the Effect of Air Pollution on their Health

Variable	**n (%)**
Do you believe that air pollution could be a cause of cardiopulmonary diseases?	
Yes	536 (88.7)
No	68 (11.3)
In your opinion, does air pollution contribute to asthma or other diseases like COVID-19	
Yes	510 (84.4)
No	94 (15.6)
Do you think the following is related to cardiovascular or pulmonary diseases?	
Global climate change	357 (59.1%)
Outdoor air pollution	486 (80.6)
Extreme temperatures	174 (28.8)
Indoor air pollution	199 (32.9)
How did you find out that air pollution could hurt your health?	
Social media	288 (47.7)
Friends	99 (16.4)
Scientifically published articles	162 (26.8)
Self-awareness	334 (55.3)
News	17 (2.8)

Note. *n = 604*

Knowledge Score Distribution

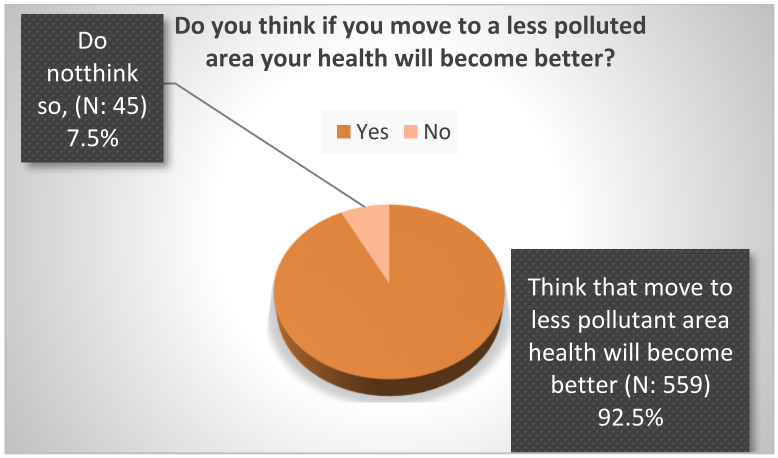
By the knowledge scoring system, 465 participants (77%) were found to have good knowledge, 103 participants (17.0%) were found to have fair knowledge, and 36 participants (6.0%) were found to have poor knowledge of air pollution and its cardiopulmonary health effects, as shown in Table 5.

Attitude Domain Results

When it comes to the attitudes of the participants towards the reduction of exposure to air pollution, most of them were positive. Of all the participants (92.5%), 559 people felt that by moving to a less polluted locality, their health would be better, and 45 participants (7.5%) did not hold the same opinion as presented in Figure 1 and Table 6.

Figure 1

Percentage Distribution of the Participants' Responses about Moving to A Less Polluted Area for Improved Health



Note. *n = 604*

Practice Domain Results

Table 4 shows the practice findings of the study. Among 604 respondents to the question about cooking, 306 (50.6%) indicated that they cook every day, and 298 (40.4%) do not. Of those who cook daily (n=306), 278 (90.8%) said that their health was well prior to them starting to cook, and 28 (9.2%) said it was not well. Among the 302 participants who were questioned about ventilation practice during cooking, 238 (78.8%) of all indicated that they used measures to ventilate the air during cooking, with 64 (21.2%) not doing so. Among ventilating measures, the most widely used ones were the exhaust fan (172, 57.8%), the opening of the kitchen window (149, 50.2%), and the exhaust hood (119, 40.2%). On active attempts to limit exposure to pollution, 360 of 604 participants (59.6%) have attempted to limit their exposure to outdoor air pollution, and 242 (40.4%) did not. Regarding indoor air pollution, of 604 participants (52.3%), 316 attempted to reduce indoor exposure, and 288 (47.7%) did not.

Table 3

Participants' Practices Regarding Lowering Exposure to Air Pollution

Variable	n (%)
Cooking experience	
Do you cook daily? (n.:604)	
Yes	306 (50.6)
No	298 (40.4)
If yes, how was your health before you started cooking? (n.:306)	
Well	278 (90.8)
Not well	28 (9.2)
Practices for Lowering Exposure to Air Pollution	
Do you use measures to ventilate the air while cooking? (n.:302)	
Yes	238 (78.8)
No	64 (21.2)
If yes, which of these methods do you use? (n.:302)	
Open the kitchen window	149 (50.2)
Exhaust fan	172 (57.8)

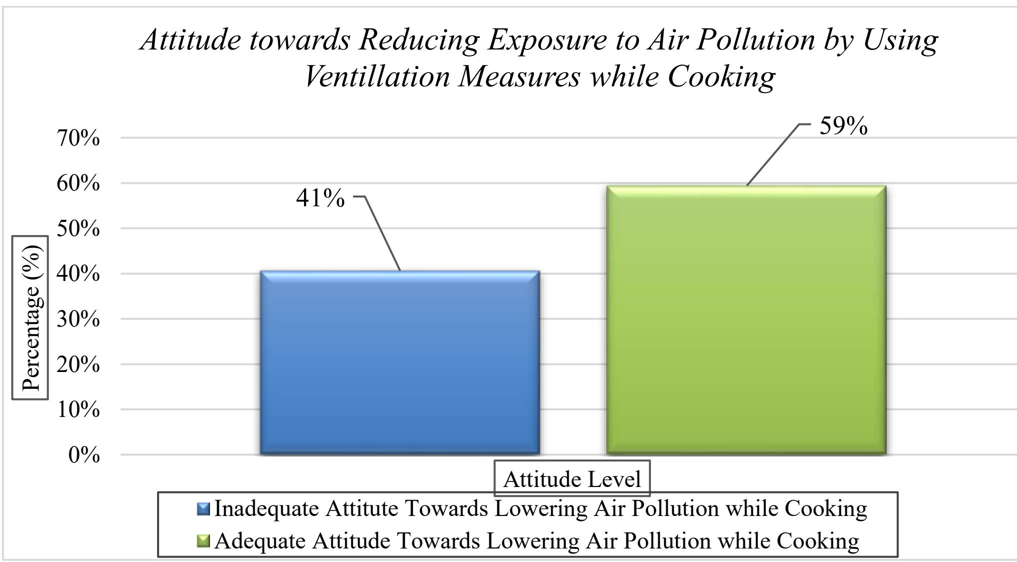
Exhaust hood	119 (40.2)
Have you ever tried any ways to lower your exposure to outdoor air pollution?	
Yes	360 (59.6)
No	242 (40.4)
Have you ever tried any ways to lower your exposure to indoor air pollution? (n.:604)	
Yes	316 (52.3)
No	288 (47.7)

Practice Score Distribution

According to the practice scoring system, 165 (59.4%) participants among those who participated in the practice part of the questions, depending upon their cooking habits, achieved an adequate practice, and 113 (40.4%) participants achieved an inadequate practice, as shown in Figure 2 and Table 6.

Figure 2

Percentage Distribution of the Participants' Attitude Towards Lowering Exposure to Air Pollution While Cooking



Association Between Demographic Variables and Knowledge Levels

Table 5 shows the chi-square tests of the relationships between demographic factors and knowledge levels. It was statistically significant between gender and level of knowledge (27.01, $p < 0.001$), with females showing higher percentages (277, 45.8%) of good knowledge than males (188, 31.1%). Knowledge level was also strongly linked to marital status ($\chi^2 = 9.55$, $p = 0.008$), with the highest percentage of participants with good knowledge being single (292, 48.3%). It was noted that knowledge was significantly associated with educational level ($\chi^2 = 125.42$, $p < 0.001$).

The highest number of participants with good knowledge were undergraduates (273, 45.1%), then postgraduate (105, 17.3%), and lastly, secondary education (80, 13.2%). The level of knowledge ($\chi2 = 41.62$, $p < 0.001$) was significantly linked with occupation, with students making the highest proportion of occupational good knowledge scorers (229, 37.9%), then employed (151, 25.0%), housewives (47, 7.7%), and unemployed (38, 6.2%). Knowledge level ($\chi^2 = 28.65$, $p < 0.001$) and presence of a cardiopulmonary disease ($\chi^2 = 7.63$, $p = 0.022$) were significantly connected with the presence of a chronic disease.

Table 4

Relationship between Participants' Knowledge about Air Pollution and their Demographic Characteristics

Variable	Knowledge Level			X2	p-value
	Poor n (%)	Fair n (%)	Good n (%)		
Age (Mean ± SD)	31.69 ± 10.46	29.76 ± 11.12	28.06 ±10.12		
Gender					
Male	24 (3.9)	67 (11.09)	188 (31.1)		
Female	12 (1.9)	36 (5.9)	277 (45.8)	27.01	<0.001
Marital status					
Married	22 (3.6)	46 (7.6)	173 (28.6)		
Single	14 (2.3)	57 (9.4)	292 (48.3)	9.55	0.008
Educational level					
Secondary Education	5 (0.8)	31 (5.1)	80 (13.2)		
Undergraduate	15 (2.4)	47 (7.7)	273 (45.1)	125.42	<0.001
Postgraduate	1 (0.1)	12 (1.9)	105 (17.3)		
No Formal Education	15 (2.4)	13 (2.1)	7 (1.1)		
Occupation					
Employed	15 (2.4)	35 (5.7)	151 (25)		
Unemployed	13 (2.1)	18 (2.9)	38 (6.2)		
Housewife	5 (0.8)	10 (1.6)	47 (7.7)	41.62	<0.001
Student	3 (0.4)	40 (6.6)	229 (37.9)		
Having a chronic disease					
Yes	18 (2.9)	29 (4.8)	75 (12.4)		
No	18 (2.9)	74 (12.2)	390 (64.5)	28.65	<0.001
Do you have any cardiopulmonary diseases?					
Yes	3 (0.4)	14 (2.3)	27 (4.4)		
No	33 (5.4)	89 (14.7)	437 (72.3)	7.63	0.022

Association Between Demographic Variables and Practice Levels

Table 6 shows the associations between the demographic variables and the level of practice. There was no statistically significant correlation between gender and level of practice ($\chi^2 = 2.15$, $p = 0.142$). Similarly, there was no significant correlation between marital status and practice ($\chi^2 = 1.34$, $p = 0.247$).

There was a statistically significant correlation between educational level and occupation ($\chi^2 = 3.01$, $p = 0.389$). Having a chronic disease ($\chi^2 = 1.91$, $p = 0.166$), having a cardiopulmonary disease ($\chi^2 = 0.004$, $p = 0.951$), and attitude of the participants towards moving to a less polluted area ($\chi^2 = 0.458$, $p = 0.499$) were all non-significantly related to the level of and practice ($\chi^2 = 9.41$, $p = 0.024$) with postgraduate participants showing the highest percentage of adequate practice (48, 17.2%).

Table 5

Relationship between Participants' Practice Related to Air Pollution and their Demographic Characteristics (n: 278)

Variable	Practice Level		X2	p-value
	Adequate N (%)	**Inadequate N (%)**		
Age (Mean ± SD)	28.03 ± 8.91	29.65 ± 10.44		
Gender				
Male	53 (19.06)	46 (16.5)		
Female	112 (40.2)	67 (24.1)	2.15	0.142
Marital status				
Married	63 (22.6)	51 (18.3)		
Single	102 (36.6)	62 (22.3)	1.34	0.247
Educational level				
Secondary Education	26 (9.3)	21 (7.5)		
Undergraduate	88 (31.6)	65 (23.3)		
Postgraduate	48 (17.2)	19 (6.8)	9.41	0.024
No Formal Education	3 (1.07)	8 (2.8)		
Occupation				
Employed	41 (14.7)	37 13.3)		
Unemployed	24 (8.6)	11 (3.9)		
Housewife	34 (12.2)	20 (7.1)	3.01	0.389
Student	66 (23.7)	45 (16.1)		
Having a chronic disease				
Yes	27 (9.7)	26 (9.3)		
No	138 (49.6)	87 (31.2)	1.91	0.166
Do you have any cardiopulmonary diseases?				
Yes	12 (4.3)	8 (2.8)		
No	153 (55.03)	105 (37.7)	0.004	0.951
Do you think if you move to a less polluted area, your health will become better?				
Yes	154 (55.3)	103 (37.05)		
No	11 (3.9)	10 (3.5)	0.458	0.499

Note. *n = 604, SD = Standard Deviation*

Figure 3

Relationship between Participants' Knowledge about Air Pollution and their Attitude Regarding Moving to a Less Polluted Area for Improvement in Health

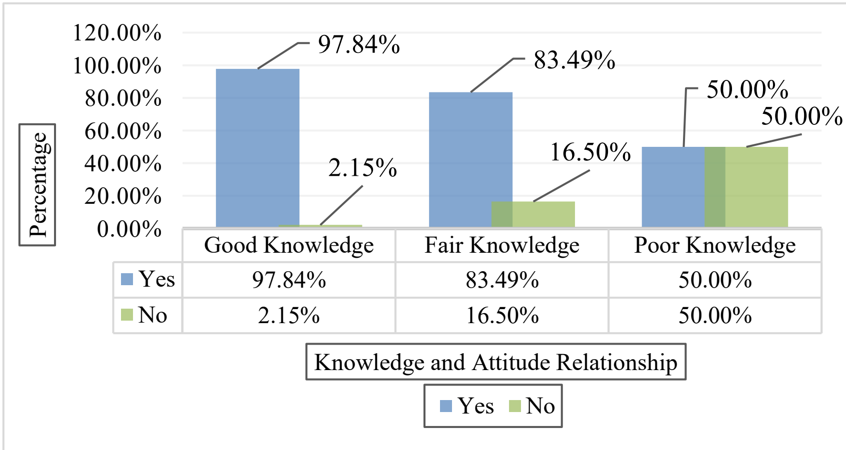
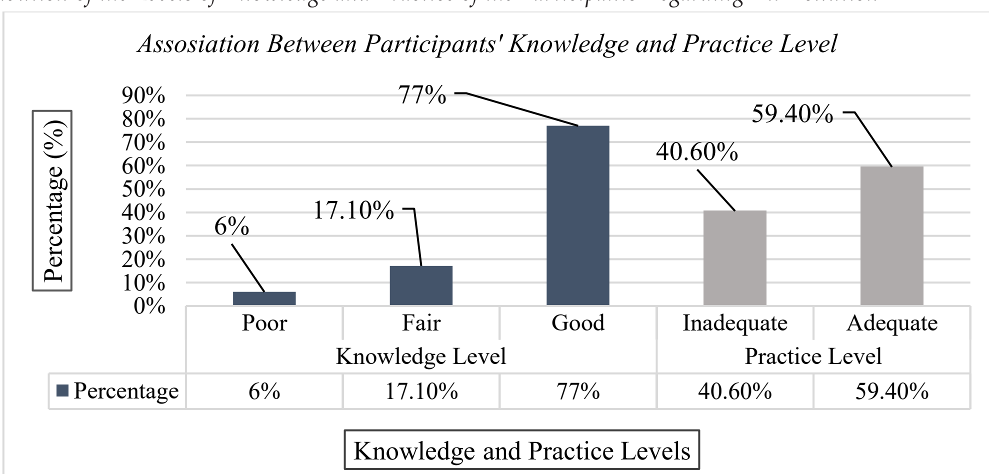


Figure 4

Percentage Distribution of the Levels of Knowledge and Practice of the Participants Regarding Air Pollution



DISCUSSION

This study measured the general population of Lahore, Pakistan, in terms of their knowledge, attitudes, and practices towards air pollution and cardiopulmonary health implications. It is the first of such KAP studies ever in Lahore, one of the most air-polluted cities in the world (Marco Pandolfi *et al*., 2018; Xing *et al*., 2016). The key results are that most participants exhibited excellent overall knowledge (76.9%), very positive attitudes (92.5%), moderate protection practices (27.3% of the total 604 participants, adequate), and there were strong demographic correlations observed in the domains of knowledge and practice.

Knowledge

The large percentage of those participants whose knowledge was good (76.9%) is probably due to the acute nature of the Lahore smog crisis that has been the national media conversation over the last ten years or so, thus acting as informal public health education (Turner *et al*., 2020). This is in line with other urban polluted environments that have been massively polluted, where the experience of extreme pollution events is linked to high public awareness (World Health Organization, 2021). The results are favorable to the Saudi study, where only 23 percent of the Jeddah participants were rated as having good knowledge

(Lelieveld *et al*., 2020), or a KAP study in Oman, where the awareness of the health effects of air pollution was also low among the general population (W.H.O, 2021). Although the general knowledge scores were high, a significant gap was observed in the sources of indoor air pollution. Just 29.1% of respondents cited cooking as a significant source of indoor air pollution - a vital conclusion considering the prevalence of biomass fuel use and open-flame cooking in Pakistani homes (Manisalidis *et al*., 2020; Nwanaji-Enwerem *et al*., 2020). The same gap was indicated in the Saudi study, with only 8.3 recognizing cooking as a major source of indoor pollution (Lelieveld *et al*., 2020), which indicates that indoor pollution is not clearly recognized in comparison to the outdoor pollution in various cultural and geographic settings. The most prevalent identified outdoor sources were factories (80.8%) and industrial facilities (70.7%), which is in line with the preponderance of industrial emissions in the pollution landscape of Lahore (Feng et al., 2016), but the less common sources were diffuse oil refineries (23.0%) and power plants (29.1%).

Attitudes

The views on the issue of preventing pollution were also very favorable, with 92.5% of the surveyed people agreeing that they would experience a positive health gain upon moving to a less polluted environment. The near universality of the positive attitudes in Lahore is probably due to the concrete and immediate experience of the impact of seasonal smog on everyday life, which makes the health effects of pollution personally relevant to the urban population (Turner *et al*., 2020). Nevertheless, the wide disparity between positive attitudes and a sufficient level of practice (27.3%) supports the existence of a knowledge-attitude-practice gap (Rajagopalan, 2018).

Practice

The overall level of preventive practices was moderate. Among those who cook regularly, 78.8% had some means to ventilate in the kitchen, with most having exhaust fans (57.8%) and open windows (50.2%). These numbers, though positive, mean that more than every fifth of those who cook used no precautions regarding ventilation, which is a direct and adjustable risk of being exposed to indoor pollution (Manisalidis *et al*., 2020). In the case of outdoor contamination, 59.6% of the respondents had tried preventive actions, and 52.3% had tried prevention measures of indoor contamination. These levels of practice were significantly lower than those found in the Saudi study, where 93.1% of respondents engaged in cooking ventilation practices (Lelieveld *et al*., 2020)- a difference which, probably, reflects structural inhibition such as poverty, poor housing infrastructure, and poor access to clean cooking technologies in Lahore, and not motivation or attitudes (Muhammad Nadeem *et al*., 2025; Cai *et al*., 2016).

Demographic Associations

The level of knowledge had a significant relationship with gender (χ^2 =27.01, $p < 0.001$), with higher percentages of good knowledge exhibited by females. This trend has been credited to increased health awareness and exposure of females to health-related information in their domestic roles (Lawrence, 2015). Educational level showed the best correlation with knowledge (χ^2 = 125.42, $p < 0.001$), which is consistent with a large body of literature that formal education is one of the strongest predictors of health and environmental literacy (Kasdagli *et al*., 2024). Knowledge was highly correlated with occupation (χ^2 = 41.62, $p < 0.001$), and students constituted the largest group of good knowledge scorers, presumably because they had more access to academic and digital sources of information (Manisalidis *et al*., 2020). Knowledge was also significantly correlated with the presence of chronic disease (χ^2 = 28.65, $p < 0.001$) and cardiopulmonary disease χ^2 = 7.63, $p = 0.022$), which aligns with the findings that personal health experience is a motivator of health information-seeking behavior (HEI Global Health Research Committee, 2018). To practice, educational level was the only notable demographic predictor (χ^2 = 9.41, $p = 0.024$), indicating that although there are multiple factors to predict the knowledge acquisition, the knowledge translation into protective behavior is more specifically conditioned by the formal education and resources it provides (IQAir, 2023).

CONCLUSION

The majority of the participants were well informed about outdoor and indoor air pollution, but failed to recognize cooking as one of the main sources of indoor pollution. Respondents linked air pollution to cardiopulmonary diseases, and self-awareness and social media became the main sources of information. The greatest contributors to cardiopulmonary disease were found to be tobacco smoke and outdoor air pollution. The level of knowledge and practices was significantly different according to the gender, education level, and occupational status, and females, undergraduate students, and people with a history of disease showed relatively high knowledge scores. Attitudes were mostly favorable, but protective behaviour was still suboptimal, especially in males and those with the lowest levels of educational attainment, which validates the existence of a knowledge-attitude-practice gap in this group. These results highlight how specific public health interventions, such as the incorporation of environmental health literacy into educational curricula, increasing real-time air quality notifications, and structural policy measures, such as the regulation of brick kilns and vehicle emission regulations, are necessary. Longitudinal studies and intercity research in Pakistan in the future are necessary to develop the national evidence base to achieve a fair environmental health policy.

STRENGTHS AND LIMITATIONS

The main strength of this study is that it is novel since it is the first KAP research on air pollution among the general population of Lahore, based on a validated, adapted instrument of a published reference study (Lelieveld *et al*., 2020) with a sufficient sample size that meets minimum requirements. Nonetheless, there are multiple restrictions to consider. The cross-sectional design excludes the possibility of causal inference (Pakistan Bureau of Statistics, 2023). Data in self-administered questionnaires are vulnerable to social desirability and recall bias (Chittaranjan Andrade *et al*., 2020). The generalizability to other Pakistani cities is also geographically restricted to Lahore, and confounding factors such as household income were not measured.

RECOMMENDATIONS AND FUTURE DIRECTIONS

Despite its limitations, the study is an important and unique addition to the body of research literature, being the first KAP study on air pollution in the general population of Lahore, providing a key evidence base for public health interventions in one of the world's most polluted cities. The study provides evidence of a knowledge-attitude-practice gap with implications for intervention design. In terms of recommendations, the study suggests tailored public health interventions on indoor air pollution, specifically cooking-related risks, which are not well understood; for promoting environmental health literacy in schools and universities; increased real-time monitoring and public alert systems on air quality; and structural policy actions such as brick kiln regulation, vehicle emission standards and incentives for adopting cleaner cooking fuels, particularly among lower educated and poorer households. As recommendations for future research, the authors suggest studies that can capture the causal links between knowledge, attitudes and actual behavioral change over time; comparative studies across Pakistan's cities to establish an evidence base for the country; inclusion of objective measures of behaviour rather than relying on self-reported practices; and quantitative estimates of household income and structural determinants to understand the reasons why high knowledge levels do not translate into adequate protective behaviour.

DECLARATION

Ethical Consideration: This study strictly adhered to the Declaration of Helsinki and relevant national and institutional ethical guidelines. Informed consent was obtained. All procedures performed in this study were consistent with the ethical standards of the Helsinki Declaration. Before data collection, ethical approval was obtained from the Institutional Review Board of the University of Central Punjab, Lahore. Individuals participated voluntarily, and written informed consent was obtained before administration of the questionnaire. The participation was confidential, ensuring data collection was anonymous without the use of personal identifiers throughout the study.

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