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The Impact of Air Pollution on Lung Function: A Case Study on the Rickshaw Pullers in Dhaka City, Bangladesh

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A B S T R A C T

Background: Exposure to air pollution adversely affects the respiratory system. This study aimed to assess the lung capacity of rickshaw pullers in Dhaka city, Bangladesh and their exposure to polluted air and determine their perception toward air pollution-induced disorders.
Methods: In this survey, a questionnaire and spirometry analysis were used to measure the lung function of 35 subjects, who were nonsmokers and had no prior respiratory problems. A SP10BT spirometer was used in a standing position to measure the forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), FEV_1/FVC, and peak expiratory flow (PEF). Data were analyzed using independent t-test.
Results: The mean values of FVC, FEV_1, and PEF were significantly lower in the experimental group (urban rickshaw pullers) than the control group (rural rickshaw pullers) ($P < 0.001$). FEV_1/FVC was also lower, while the difference was not significant. The majority of the subjects had various seasonal and environmental disorders since coming to Dhaka, and 46% of the respondents mostly had eye irritation, fever, and cough during winter, which decreased their ability to pull their rickshaws.
Conclusion: Air pollution had a measurable adverse impact on the pulmonary function of the urban rickshaw pullers compared to the rural control group.

1. Introduction

Air pollution (outdoor and indoor) is a key environmental determinant of human health [1]. The air quality in the metropolises of many developing countries is abnormally poor due to the population density in these countries, which leads to the constant exposure of a large number of people to high concentrations of air pollutants [2-4]. Ambient air pollutants, especially the fine particulate matter ($\leq PM_{2.5}$ μm), is considered to be a major threat to the urban inhabitants of developing countries [5-7]. Extensive research has documented the association between airborne particles and various health disorders [1,5,8,9]. For instance, cardiovascular and respiratory disorders are associated with high rates of mortality and morbidity and are significantly concomitant with exposure to inhalable airborne particles [10-13]. Evidence suggests that more than two million deaths could be attributed to lung and respiratory impairment due to exposure to fine particulate matter each year worldwide [14,15].

According to the Health Effects Institute (HEI), air pollution was the fifth highest mortality risk factor globally in 2017, accounting for approximately 4.9 million deaths [16]. In developing countries, traffic pollution is regarded as

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A major public health concern [8]. $PM_{2.5}$ has been specifically associated with the increased risk of respiratory disorders such as bronchitis and asthma [17, 18], which in turn leads to increased rate of premature deaths [6]. Chronic obstructive pulmonary disease (COPD) is the third most common cause of mortality across the world and is ranked ninth based on the disability adjusted life-years index [19-21]. Air pollution is also responsible for fatal diseases such as cancer and heart attack [22, 23] and has been linked to adverse pregnancy outcomes, such as preterm delivery and low birth weight [24-26].

Reduced annual gross domestic product and economic loss in countries could also be attributed to air pollution and the resulting health disorders. The studies regarding air pollution in Malaysia, China, India, Taiwan, Hong Kong, Nepal, and other countries have demonstrated the association between the induced health impacts and economic costs due to air pollution [27-30]. Furthermore, statistics suggest that air pollution is responsible for roughly 3,580 premature deaths per annum in Dhaka city, Bangladesh [31]. According to Aktar and Shimada (2014), approximately 1,210 deaths would be reduced annually if PM10 decreased to the proposed Bangladesh National Ambient Air Quality Standard (BNAAQS) [32]. In addition, the resulting annual benefit would be 97.3 million US dollars, equivalent to 4.1% of the gross national income of Dhaka city [32].

Few studies have been focused on the lung function associated with air pollution in Bangladesh. Recent findings have indicated that the forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), FEV_1/FVC, and peak expiratory flow (PEF) rate were significantly lower in an urban experimental group compared to a control group [33]. Ultra-fine particulate matter has been reported to largely influence the reduction of the lung function [34]. The HEI also reported that 123,000 individuals died in Bangladesh in 2017 due to indoor and outdoor air pollution [16].

The present study aimed to assess the lung function capacity of the rickshaw pullers in Dhaka city in comparison to a control group of rural rickshaw pullers. The research hypothesis was that since urban rickshaw pullers spend a large portion of the day on the streets of Dhaka, they may experience significant respiratory issues. Secondly, this study aimed to evaluate the perception that air pollution affects the health disorders in the experimental group (rickshaw pullers). This was the first study regarding the health effects of air pollution on urban rickshaw pullers in Bangladesh following high exposure to air pollutants.

2. Materials and Methods

2.1. Study Area

Dhaka is a growing megacity where developmental activities, industrialization, and the rapid urbanization of the surrounding areas has resulted in the potential of this city to become the second most unlivable city in the world. Dhaka is densely populated, and the inhabitants experience environmental pollution on a daily basis. Approximately 1,200 brick kilns and thousands of industries are situated inside and in the outskirts of Dhaka.

In this study, two upazilas (sub-districts) were selected. Figure 1 depicts the Dhaka metro upazila of Dhaka district, which was selected as the experimental group, and Fatickchari upazila of Chattogram district (in purple), which was selected as the control group. Fatickchari upazila is located approximately 100 kilometers from the main town of Chattogram and 270 kilometers from Dhaka city. The area has no significant sources of air pollution, such as heavy traffic volume, brick kilns, and construction activities, and is mainly occupied by a large, dense forest and hill region.

2.2. Sample Collection

The values of FVC, FEV_1, FEV_1/ FVC%, and PEF were determined using a spirometer (Model: SP10BT; Contec spirometer, Beijing, China. No chemical is required for this instrument.) with the flow rate of 0-16 l/s and volume of 0-10 l/s. Data were collected randomly from 35 male respondents, who were selected from the urban area (experimental group) and the rural area (control group). The subjects in both groups (totally 70 participants) were within the age range of 20-50 years.

In Dhaka, a rickshaw puller typically works 10-12 hours per day. In the present study, the subjects in the control group typically worked 8-10 hours per day. Those with smoking habits and a history of cardiovascular diseases were excluded from the study. Participation in the study was voluntary, and written informed consent for lung function testing was obtained from the participants. The respondent remained in a standing position during the test . Before data collection, the researcher explained the techniques to the subjects for blowing air into the spirometer. Three consecutive exhales were collected, and the highest value for each respondent was recorded. The values of the spirometry variables were expressed as the percentage of the predicted values. The demographic data on the subjects in both groups were also collected on age, gender, height, and weight. An oral questionnaire was used to record the perception of the rickshaw pullers in the experimental group toward their health status.

The study protocol was approved by the Ethics Committee of the Department of Environmental Sciences of Stamford University, Bangladesh.

2.3. Data Analysis

Data analysis was performed in SPSS version 20, and the map of the study area was processed using the ArcGIS 10.2.1 tools. In addition, the Microsoft Excel software was used for data presentation and drawing the tables and charts. Independent t-test was performed to identify the siginificance difference between two groups at 0.001 level.

3. Results and Discussion

3.1 Demographic Characteristics

In total, 70 participants were enrolled in the study, including 35 respondents from the urban areas of Dhaka (experimental group) and 35 respondents from the rural areas of Chattogram (control group) (Table 1). On average, the subjects worked 12 hours a day. According to the results, the rickshaw pullers who lived and worked in Dhaka were exposed to high concentrations PM2.5 as Dhaka is one of the most polluted cities in the world [34,35].

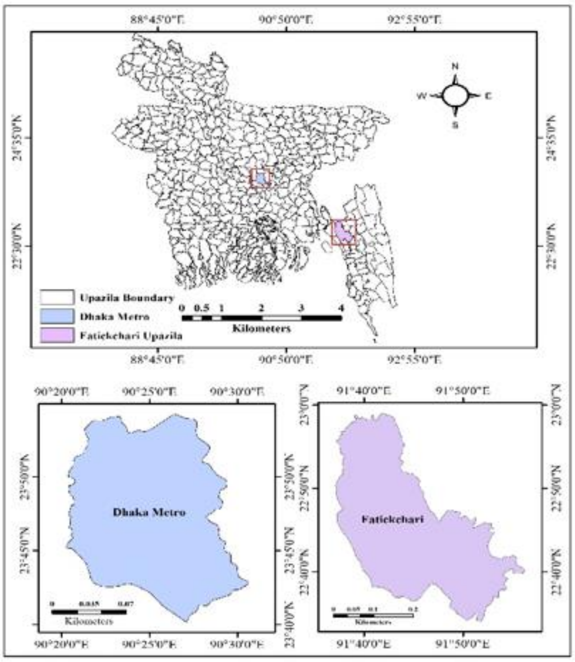

Figure 1: Geographical Location of Control and Experimental Groups in Study Area

3.2. Status of Spirometry Analysis

Table 2 shows the mean rates of FVC, FEV_1, FEV_1/FVC, and PEF, as well as the standard deviation of the values in the FVC was 55.21% of the predicted value for the experimental group and 71.93% in the control group. In addition, FEV_1 was lower in the experimental group compared to the control group. The PEF value was estimated at 66.58% of the predicted value in the experimental group, which denoted concerns regarding the lung function of the subjects. On the other hand, the FVC, FEV_1, and PEF values were significantly lower in the experimental group compared to the control group ($P < 0.001$), while the FEV_1/FVC value was almost similar in the two groups.

In a similar study by Akther *et al.* (2012), the FCV and FEV_1 of healthy male adolescents aged 13-18 in the urban slum areas of Bangladesh were significantly lower compared to controls (healthy male adolescents aged 13-18 years in rural areas) ($P < 0.05$). In the mentioned study, the FEV_1/FVC and PEF values were also lower in the experimental group, while the difference in this regard was not considered significant [33].

Several studies have denoted variable findings regarding lung function in terms of air pollution-induced health

Table 1: Demographic Characteristics of Subjects

Age Category (Years)	**Age Range of the Targets (N=35)**			
	Experimental		**Control**	
	Frequency	**Percent**	**Frequency**	**Percent**
20-25	6	17.1	4	11.4
26-30	4	11.4	6	17.1
31-35	4	11.4	5	14.3
36-40	3	8.6	7	20.0
41-45	9	25.7	8	22.9
46-50	9	25.7	5	14.3
Total	35	100	35	100.0
Weight Category (Kg)	**Weight Category of Targets (N=35)**			
	Experimental		**Control**	
	Frequency	**Percent**	**Frequency**	**Percent**
41-50	4	11.4	6	17.1
51-60	13	37.1	13	37.1
61-70	13	37.1	13	37.1
71-80	5	14.3	3	8.6
Total	35	100	35	100.0
Height Category (cm)	**Height Category of Targets (N-35)**			
	Experimental		**Control**	
	Frequency	**Percent**	**Frequency**	**Percent**
141-150	8	22.9	11	31.4
151-160	11	31.4	15	42.9
161-170	16	45.7	9	25.7
Total	35	100	35	100.0
Education	**Education Level of Targets (N-35)**			
	Experimental		**Control**	
	Frequency	**Percent**	**Frequency**	**Percent**
Below Primary	8	22.9	6	17.1
Primary	19	54.3	20	57.1
Secondary	6	17.1	8	22.9
Above Secondary	2	5.7	1	2.9
Total	35	100	35	100.0
Years	**Years of Living in Dhaka (N-35)**			
	Experimental		**Control**	
	Frequency	**Percent**	**Frequency**	**Percent**
Below 1 year	5	14.3	-	-
1-5	5	14.3	-	-
6-10	6	17.1	-	-
11-15	6	17.1	-	-
16-20	6	17.1	-	-
Above 20 Year	7	20.1	-	-
Total	35	100	-	-

disorders [4, 29, 34]. In the present study, the lower FVC, FEV_1, FEV_1/FVC%, and PEF in the experimental group compared to control group was possibly due to air pollutants [33, 36-38]. On the other hand, the lower rates of FVC and FEV_1 and higher FEV_1/FVC % denoted the moderate impairment of lung function as a restrictive type of pulmonary function [33]. In this regard, Akther *et al.* (2019) reported a negative correlation between ultra-fine particles and the PEF measurements of the residents of Dhaka [34]. According to the mentioned study, the inhalation of ultra-fine particles had a measurable impact on lung efficiency. During the Olympics in Beijing (China), the particulate matter levels declined by 50%, which corresponded to the increased PEF by 17% in women and 13% in men [39]. Based on the aforementioned studies, it could be inferred that the rickshaw pullers in the present study were affected by air pollution more significantly compared to the control group.

3.3. Lung Function Test of the Experimental Group Based on the Year of Living in Dhaka

Figure 2 depicts the lung capacity of the rickshaw pullers based on the number of the years of living in Dhaka city. According to the findings, the rickshaw pullers who lived in Dhaka for less than one year had the highest values. On the other hand, those living in Dhaka for more than 20 years had an average FVC rate of less than 50% of the expected value, as well as the PEF and FEV_1 values of close to 50%. The lung function capacity of those living in Dhaka decreased over time, ultimately resulting in the increased severity of their lung disorders. Therefore, it could be inferred that chronic exposure to high concentrations of fine air particles is associated with increased respiratory symptoms and decreased lung function [33].

3.4. Age Group versus Lung Function

Figure 3 shows the mean predicted values of FVC, FEV_1, FEV_1/FCV%, and PEF based on the age of the subjects in the experimental group. Accordingly, the mean FEV_1 value was highest in the subjects aged 26-30 years, while the mean FVC and PEF values were highest in those aged 31-35 years. On the other hand, the mean FVC was lowest in the subjects aged 41-45 years, while the mean FEV_1 and PEF was lowest in those aged 46-50 years. Therefore, it could be concluded that older ages was consistently associated with decreased pulmonary function.

3.5. Perception of Air Pollution in the Experimental Group

Table 3 shows the general perception of air pollution as expressed by the rickshaw pullers in the experimental group. Among 35 respondents, 51.4% considered air pollution as an environmental pollution, while 80% believed air pollution was increasing every day in Dhaka, and 82.9% assumed air pollution caused human health disorders.

Table 2: Mean Rates of Predicted Values of FVC, FEV_1, FEV_1/FVC, and PEF in Study Groups (35 subjects per group)

Lung Function Test	Experimental		Control		*P* Value
	Mean (%)	STD	Mean (%)	STD	
FVC Prediction	55.21	11.83	71.93	13.14	$P < 0.001$
FEV_1 Prediction	61.38	12.29	78.33	15.49	$P < 0.001$
FEV_1/FVC	93.17	6.18	92.99	6.86	$P > 0.001$
PEF Prediction	66.58	12.80	109.13	23.04	$P < 0.001$

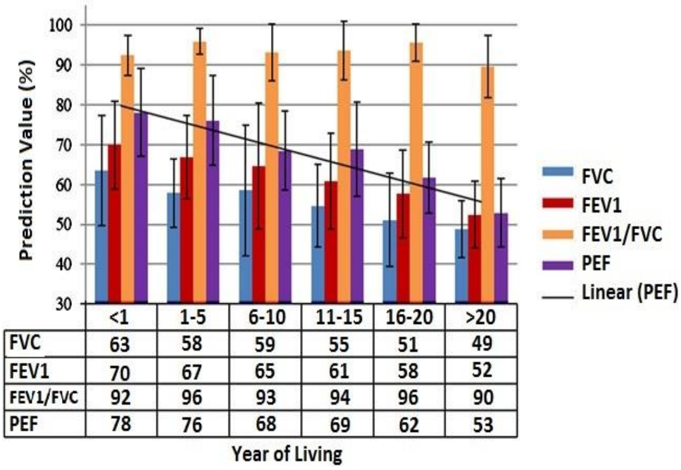

Figure 2: Lung Function Capacity Based on Living in Dhaka

Furthermore, the subjects claimed that after moving to Dhaka for livelihood, their health condition had deteriorated (77.1%).

In addition 54.3% of the respondents reported that their health condition deteriorated due to air pollution, especially in winter. Therefore, a correlation could be deduced between health disorders and winter. A large proportion of the respondents (46%) stated that they suffered from various diseases (mostly eye irritation, fever, and cough) during winter, which reduced their ability to pull rickshaw.

According to the information in Table 4, 54% of the rickshaw pullers rarely or never suffered from skin disorders. Not surprisingly, 64% of the respondents suffered from eye irritation occasionally, usually or extremely. Moreover, a near majority of 49% experienced breathlessness. The lung test and survey results also demonstrated that air pollution was a major factor in these disorders in the rickshaw pullers. Some of the studies conducted on different occupational groups have also indicated that air pollution may be correlated with decreased lung capacity, which in turn affects breathing and leads to eye irritation and other similar syndromes [33,34, 40].

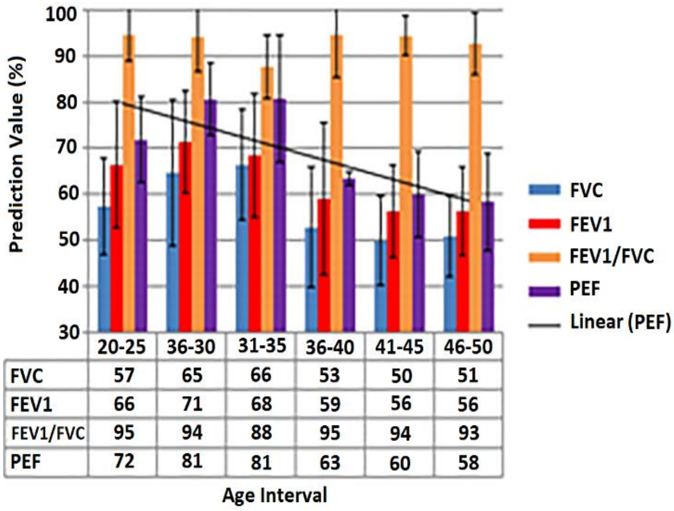

Figure 3: Lung Function Capacity Based on Age

Table 3: General Perception of Air Pollution in Subjects (n = 35)

	Yes	No
	Frequency (%)	Frequency (%)
Do you think air pollution is considered an environmental pollution?	18 (51.4)	17 (48.6)
Do you think air pollution is increasing in Dhaka city?	28 (80)	7 (20)
Do you know polluted air affects human health?	29 (82.9)	6 (17.1)
Do you think your health has deteriorated after coming to Dhaka?	27 (77.1)	8 (22.9)
Do you think air pollution is the major cause to deteriorate your health?	19 (54.3)	16 (45.7)

Table 4: Perception of Health Impacts of Rickshaw Puller (n=35)

Characteristics	Frequency	Percent	Cumulative %
Do you suffer from Recurring headaches?			
Never	17	49	49
Rarely	12	34	83
Occasionally	4	11	94
Usually	2	6	100
Do you suffer from skin disorders?			
Never	2	6	6
Rarely	17	48	54
Occasionally	15	43	97
Usually	1	3	100
Do you suffer from frequent cough?			
Never	9	26	26
Rarely	17	48	74
Occasionally	9	26	100
Do you suffer from high blood pressure?			
Never	18	51	51
Rarely	15	43	94
Occasionally	2	6	100
Do you suffer from breathlessness?			
Never	7	20	20
Rarely	11	31	51
Occasionally	15	43	94
Usually	1	3	97
Extremely	1	3	100
Do you suffer from eye irritation?			
Never	7	20	20
Rarely	6	17	37
Occasionally	17	49	86
Usually	4	11	97
Extremely	1	3	100
Do you feel vomiting because of pollution?			
Never	15	43	43
Rarely	14	40	83
Occasionally	4	11	94
Usually	2	6	100

4. Conclusion

Air pollution is significantly correlated with morbidity. According to the results of this study, the rates of FVC, FEV_1, and PEF were significantly lower among the rickshaw pullers in the experimental group in Dhaka compared to the rural rickshaw pullers in the control group ($P < 0.001$). However, FEV_1/FVC was not significantly different between the two groups. We did not observe a single PEF of higher than 80% of the predicted value in the experimental group, while the FVC, FEV_1, and PEF rates were approximately 50% of the expected values in the subjects who have lived in Dhaka city for over 20 years. Therefore, it could be concluded that the lung function capacity of the urban rickshaw pullers decreased over time, thereby increasing the risk of severe pulmonary syndromes.

In response to the survey portion of this study, the majority of the rickshaw pullers stated that they suffered from different seasonal and environmental disorders after moving to Dhaka. Furthermore, the near majority of the urban participants in the experimental group reported eye irritation and breathing difficulty. Overall, it could be stated that the poor air quality in Dhaka gives rise to various health disorders, which may also occur in the other residents of Dhaka city. Since the sample sizes of the study was not diverse in terms of age, more accurate observations could be attained with a larger sample size or assessment of other urban populations.

Authors' Contributions

A.A.N., created the concept, study design, and data collection; A.K.M., data collection and analysis; MD.S.H., preparation of the draft report, study design; W.S.C., revision of the manuscript and research supervision. All the authors approved the final version of the manuscript for publication.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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