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Effect of motor vehicle pollution on lung function, fractional exhaled nitric oxide and cognitive function among school adolescents

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Abstract. – **OBJECTIVE:** Motor vehicle emission is a major cause of environmental pollution, which threatens human health. This study aimed to investigate the effect of motor vehicle pollution on lung function, fractional exhaled nitric oxide (FeNO), and cognitive function among students studying in a school located in a traffic-polluted area.

SUBJECTS AND METHODS: In this cross-sectional study, students were recruited based on their apparent healthy status, same age, gender, height, weight, ethnicity, and homogenous educational, socio-economic status, and living backgrounds. Initially, 200 students, 100 from school-1 located in motor vehicle polluted area (exposed group) and 100 from school-2, located away from motor vehicle polluted area (control group) were recruited. After clinical history, 68 students were selected, 34 from school-1 and 34 from school-2. These students were exposed to motor vehicle pollution for 6 h a day, 5 days a week for a total period of 2 years. Lung function test parameters were recorded using a Spirometer, fractional exhaled nitric oxide (FeNO) was measured by Niox Mino, and cognitive function was recorded using the Cambridge Neuropsychological Test Automated Battery (CANTAB).

RESULTS: The lung function test parameters, Forced Vital Capacity (FVC) (p=0.03); Forced Expiratory Volume in First Second (FEV_1) (p=0.02); and cognitive function parameter motor screening task (MOT) mean latency (p=0.04) were decreased among the students who were studying in school situated in traffic-polluted area compared to those students who were studying in school which was located away from the traffic-polluted area. However, no significant difference was noted in FeNO between the groups.

CONCLUSIONS: Motor vehicle pollution showed an association with decreased respiratory and cognitive functions among students studying in schools located in traffic-polluted areas. Environmental protection organizations must establish standards to minimize motor vehicle pollutants and develop strategies to control vehicle emission to reduce pollution and disease burden.

Key Words:
Motor vehicle pollution, Schools, Lung Function, FeNO, Cognitive Function.

Introduction

Environmental pollution is a global leading health problem, affecting ecosystems and human health. Motor vehicular exhausts have become a substantial source of air pollution and are major causes to climate change, which pose a threat to human health, and have caused worldwide concerns in the environmental and biological sciences community, due to their noxious effects on the biosphere[1].

Motor vehicle activities cause combustion of fuel, abrasion, and the weathering of pavement materials, which can release fine pollutants into the environment[2]. The most frequently reported pollutants in vehicular exhausts are high concentrations of ultrafine particulates (UFP),

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oxides of nitrogen (NOx), carbon monoxide (CO), nitrogen (N), and sulfur oxides (SO_2)[3-5]. Moreover, unburned hydrocarbons, particulate matter (PM 2.5), polycyclic aromatic hydrocarbons (PAHs), benzene, formaldehyde are also components of motor vehicle pollution. In addition, road dust, tire wear, and brake wear contribute to non-combustion emissions from motor vehicles[6,7]. The motor vehicle pollutants are persistent and non-degradable. Therefore, they may remain for long periods in the roadside environment[3,5].

The literature shows an increased risk of respiratory problems in people who live near the main highways[3,8]. Exposing school children to motor vehicle environmental pollutants during their physiological development may lead to long-lasting health problems[8]. Due to difficulties in exposure assessment, limited research work has been carried out, and evidence is inadequate for establishing a relationship between motor vehicle pollutants, respiratory, and intellectual health problems. Considering the health hazards of traffic-related air pollution, particularly in school age adolescents, the aim of this study was to investigate the lung function, FeNO, and cognitive function of adolescents studying in a school located near traffic-polluted areas compared to the students studying in a school situated away from motor vehicle-polluted areas.

Subjects and Methods

In this study, two different schools located in two separate areas of Riyadh, Saudi Arabia were selected. The first school was situated near a motor vehicle-polluted area, within 200 m of the main traffic road[9]. This school was considered motor vehicle pollutant-exposed school (exposed group, school-1). The second school was located away from motor vehicle-polluted areas, at a minimum of 1,500 m away from the main traffic road. This school was considered a school less exposed to motor vehicle pollutants (control group, school-2).

Selection of Students

All the students were recruited based on their voluntary involvement and healthy status and were matched by age, height, weight, gender, nationality, regional, socioeconomic, cultural background, and the admission criteria of their schools. For example, a student who attends school #1 was matched with a student of the same age, gender, height, weight, socioeconomic status, and class level who attends school #2. This matching was to ensure valid and reliable comparisons between the groups. Initially, 200 students (100 from school-1 and 100 from school-2) were registered. The clinical history and examination of each of the student were conducted to decide whether or not to include them in the study. After clinical history, 68 students were selected, 34 from school-1 and 34 from school-2. The age of school-1 group was 13-16 years (mean age 15.70±0.52) and school-2 group age was 13-16 years (mean age 15.79±0.59).

Exclusion Criteria

The known cases of gross anemia, obesity, diabetes mellitus were excluded as these conditions impair respiratory and cognitive functions. Students with extraordinary grades or dropouts in their previous examinations were not included in the study, to minimize differences of knowledge and skills[10]. The known cases of asthma, COPD, pulmonary tuberculosis or malignancy, cigarette, shisha smokers, previous history of abdominal or chest surgery, and exposure to any factory that produces dust or fumes were excluded as well[11-12]. Students whose family members, such as father or mother, were cigarettes smokers were also excluded from the study to minimize the passive smoking effect on the lung functions. Moreover, students with clinical history of vision problems, anxiety, attention deficit, musculoskeletal disorders, and those on sedatives and who had sleep disturbance history were also excluded from the study. Furthermore, students whose residence was located near a motorway or in polluted areas were also excluded[10-13].

Measurements of Motor Vehicle Pollutants

The concentration of motor vehicle pollutants and gases was recorded. The procedures include passive sampling and measurement e.g., diffusion-based methods on an absorbent and active sampling with pumps. Airborne particles were sampled mostly using integrated sampling systems recorded with defined inlets, sampler surfaces, filter substrates, holders, pumps, and flow controllers. The pollutants were recorded every 15 min, over a 24-h period during the study. PM 10 and PM2.5 were sampled using MP 101-09 air sampler (Environment S.A., France), respectively. NOx was sampled using air sampler model AC-32, CO using CO 12M, and VOCs using VOC 72M all from Environment S.A., Poissy, France, respectively.

Spirometry

The ventilatory lung function parameters were determined using an electronic "spirometer SPIROVIT SP-1 (Schiller, Baar, Switzerland)". The entire procedure was based on the guidelines of the American Thoracic Society of Standardization 2005[14]. The students were educated about the entire maneuver, and were encouraged to practice the test procedure before performing the pulmonary function test. The lung function test parameters were performed in standing position with a nose clip. A new disposable sterile mouthpiece was used for each participant to prevent any cross infection.

Fractional Exhaled Nitric Oxide [FeNO]

The "Fractional Exhaled Nitric Oxide [FeNO] was measured using a Niox Mino (Aerocrine, Solna, Sweden)". The FeNO device was pre-calibrated at manufacturing levels for 300 individuals. The tests were recorded at a fixed time of the day to minimize the diurnal variation. The test procedures were established as per "American Thoracic Society/ERS Standardization for FENO"[15].

Cognitive Function

The cognitive function testing was performed using "CANTAB research software (version 6. 0.37, Cambridge cognition" about 20 min were required to complete the task. The Motor screening task (MOT) was recorded to screen the visual, movement, and overall comprehension. The findings were expressed as the standard score of mean latency (MOT ML). In addition, Spatial Span (SSP) test assessed the working memory capabilities[16]. The student's response was based on recalling the test pattern in forward or reverse order. This study also recorded the Stockings of Cambridge (SOC) test, used to determine the planning executive function[16].

Ethics Approval

This investigation was approved by the "Institutional Review Board, College of Medicine, King Saud University, Riyadh, Saudi Arabia (Ref #E-16-2124)" and written consent was obtained from the parents or guardians.

Statistical Analysis

The data were analyzed by using the "Statistical Package for Social Sciences (SPSS for Windows, version 21.0; IBM, Armonk, NY, USA)". The descriptive statistics were presented as means and standard deviations (Mean±SD); unpaired Student's *t*-test (parametric test) was applied to test the difference in the means between the variables. The level of significance was considered at $p < 0.05$.

Results

The mean age, height, weight, and BMI of students enrolled in school-1 was age 15.7±0.5 years, height 171.1±7.2 cm, weight 62.8±14.6 kg, and BMI 21.2±4.6 (kg/m^2). The mean age of students enrolled in school-2 was 15.7±0.5 years, height 173.7±6.6 cm, weight 64.4± 12.8 kg, and BMI 21.2±3.5 (kg/m^2). In both schools, students attended the classes for 6 h a day, 5 days a week for a total period of 2 years (Table I).

The lung function parameters "Forced Vital Capacity FVC" (p=0.03), "Forced Expiratory Volume in First Second FEV_1" (p=0.02) (Table I), cognitive function parameter MOT mean latency (p=0.04) (Table II) were decreased among the students who were studying in school # 1 located in traffic-polluted area compared to the students who were studying in school # 2 which was located away from the traffic-polluted area. However, no significant difference was noted in FeNO between the groups (Table II). This study also recorded the motor vehicle pollutants including "Nitrogen dioxide, oxides of nitrogen, carbon monoxide, particulate matter, poly-aromatic hydrocarbons" (Table III). The motor vehicle pollutants concentration was higher adjacent to school #1, located near to motor vehicle polluted area compared to school #2, located faraway from the motor vehicle polluted area (Table III).

Discussion

Traffic-related pollutants are of great concern and can cause respiratory illness. This study identified an association with impaired lung function parameters "Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV_1) (Table I, Figure 1) and cognitive function parameter (MOT mean latency)" (Table II) among the students studying in school situated in traffic-pol-

Table I. Comparison of anthropometric variables, lung function, and FeNO between students whose school was situated adjacent to the motor vehicle polluted area compared to students whose school was situated faraway from the motor vehicle polluted areas.

Parameter	School #1 (n = 34) (Exposed group)	School #2 (n = 34) (Control group)	*p*-value
Age (years)	15.70 ± 0.52	15.79 ± 0.59	0.517
Height (cm)	171.14 ± 7.20	173.70 ± 6.68	0.131
Weight (kg)	62.88 ± 14.66	64.47 ± 12.80	0.636
BMI (kg/m^2)	21.29 ± 4.60	21.25 ± 3.50	0.967
FVC (lit)	4.20 ± 0.73	4.64 ± 0.96	0.037
FEV_1 (lit/sec)	3.67 ± 0.61	4.00 ± 0.69	0.026
FEV_1/FVC (%)	87.06 ± 7.22	87.09 ± 7.57	0.990
PEF (lit/ sec)	7.54 ± 1.83	7.85 ± 1.65	0.474
FEF 25% (lit/sec)	7.14 ± 1.77	7.29 ±1.59	0.711
FEF 50% (lit/sec)	4.90 ± 1.14	5.01 ± 1.38	0.713
FEF 75% (lit/sec)	2.32 ± 0.95	2.53 ± 0.98	0.390
FeNO (ppb)	31.70 ± 21.46	31.47 ± 23.08	0.965

School #1: (Exposed group) located near to motor vehicle polluted areas; School #2: (Control Group) located faraway from the motor vehicle polluted areas; Values are presented in Mean ± SD.

luted area compared to those students studying in school which was located away from the traffic-polluted area. However, no significant difference was noted in FeNO between the groups (Table II).

Lung Functions

Spirometry is a widely used pulmonary function test to describe the various pathophysiological aspects of the lung function. It has been reported that children studying in schools located close to motorways or high-traffic roads are exposed to high concentration motor vehicle pollutants and exhibit an increased incidence of childhood asthma and other respiratory problems. The chemical components of traffic emissions are associated with pulmonary toxicity[17]. The motor vehicle exhaust is rich in nanoparticles[18] and contains various toxic substances, including benzene and polyaromatic hydro-carbons, and therefore, may greatly contribute to health problems[18]. High levels of these particles, mainly CO can cause cough, impaired lung function, slow reflexes, impaired thoughtful capabilities by decreasing the oxygen-carrying capacity of hemoglobin[19]. Similarly, the present study identified a decrease in lung function and cognitive function among the students who were studying in school located in traffic-polluted area.

An increased incidence of respiratory illnesses has been allied with air pollution, particularly in young adolescents[20]. Langkulsen et al[21] observed that the lung functions of school children aged 10-15 years decreased with an increased concentration of air pollution. Lee et al[22] determined the adverse impact of fine-particle air pollution on pulmonary function and found that fine particles negatively affect respiratory health. Furthermore, Son et al[23] reported that exposure to air pollution causes decreased FVC. Similarly, Gauderman et

Table II. Comparison of cognitive function of students whose school was situated adjacent to motor vehicle polluted area compared to students whose school was situated faraway from the motor vehicle polluted areas.

Parameter	School #1 (n = 34) (Exposed group)	School #2 (n = 34) (Control group)	*p*-value
MOT correct latency	951.73 ± 271.51	842.97 ± 160.87	0.040
SSP	5.94 ±.168	6.08 ± 1.71	0.772
SOC	5.70 ±. 167	5.73 ± 1.92	0.947

School #1: (Exposed group) located near to motor vehicle polluted areas; School #2: (Control Group) located faraway from the motor vehicle polluted areas. Values are presented in Mean ± SD; MOT: Motor screening task; SSP: Spatial Span (SSP) test; SOC: Stockings of Cambridge.

Table III. Motor vehicle pollutants concentration between schools situated adjacent to and faraway from the motor vehicle polluted areas.

Pollutants	Pollutant Measurements Adjacent to School #1 (Exposed group)	Pollutant Measurements Adjacent to School #2 (Control group)
NO (ppb)	50.61	8.00
NO2 (ppb)	38.00	16.20
NOX (ppb)	88.61	24.41
CO (ppm)	0.88	NA
Benzen (ppb)	1.23 ± 1.07	NA
Toluene (ppb)	2.67 ± 2.42	NA
PM2.5 (ug/m^3)	187.05	50.40

Pollutant measurements adjacent to school #1, located near to motor vehicle polluted area (Exposed group); Pollutant measurements adjacent to school #2, located faraway from the motor vehicle polluted area (Control Group).

al[8] observed the effect of traffic-related pollutants on the lungs of school aged adolescents. They found that children who lived within 500 m of a motorway had considerable deficits in forced expiratory volume in 1 s (FEV_1), and maximum mid expiratory flow rate (MMEF), compared to children who lived at least 1500 m from a motor expressway. Chang et al[24] investigated the relationship between fine particulate matter (PM) air pollutants and the lung function among 12-16-year-old high school students. They reported that FVC had significant negative association with exposure to high concentrations of PM and an increase in CO was associated with the reduction in FVC and FEV_1. The present study also reported similar findings as Gauderman et al[8] and Chang et al[24].

Fractional Exhaled Nitric Oxide (FeNO)

FeNO is a simple and noninvasive test to assess the inflammatory status of the lungs of children and adults with respiratory airway disease[25]. FeNO testing has recently received much attention for diagnosing and monitoring respiratory dis-

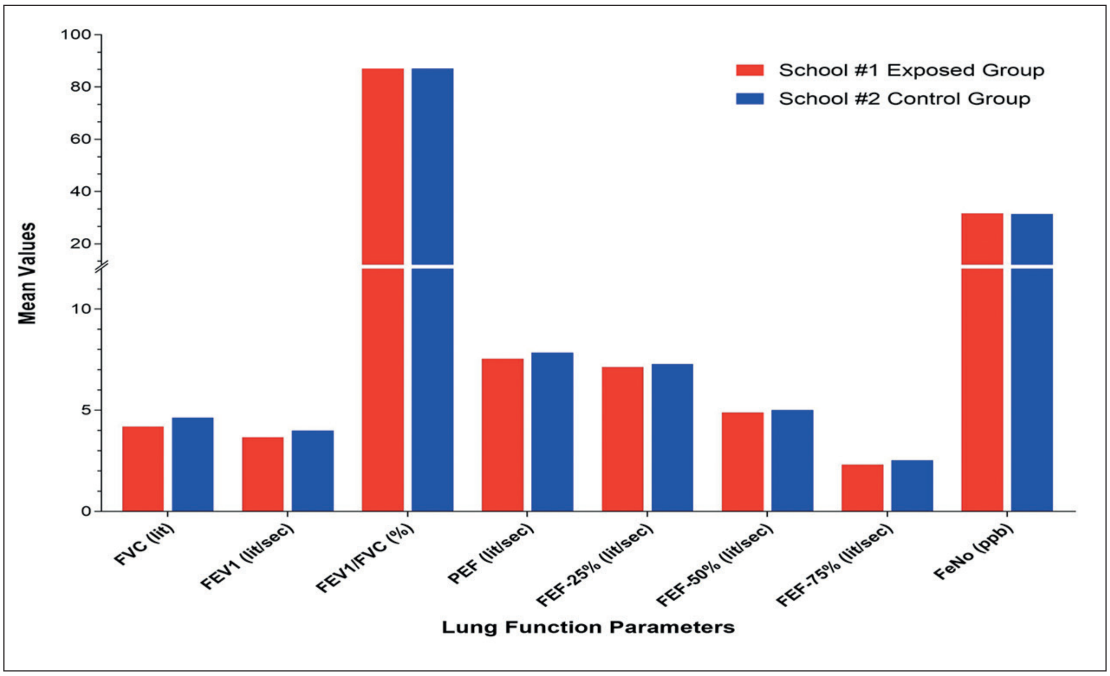

Figure 1. Lung function and FeNO between students whose school was situated adjacent to and faraway from the motor vehicle polluted areas.

eases. The level of FeNO may be influenced by environmental factors, including environmental air pollution[26]. Eckel et al[27] examined the effect of Traffic-related air pollution (TRAP) exposure on airway inflammation by relating exhaled nitric oxide (FeNO) among school children. The authors found that exposure to TRAP was associated with elevated levels of FeNO.

Adamkiewicz et al[28] reported that exposure to ambient air pollution mainly NO and PM2.5 are allied with an increase in pulmonary inflammation, mainly FeNO. In another study[29], a positive correlation was found between FeNO and children's exposure to vehicular emissions. However, in this present study, FeNO was slightly increased in the students who were exposed to MVP.

Cognitive Function

The human brain plays an essential role in recognizing, controlling, and coordinating various body functions. Brain function involves multiple brain regions. Therefore, understanding the brain is not simple or straightforward. Cognitive functions refer to intellectual processes, which include attention, memory, understanding and solving problems, and making decisions. A well-examined determinant of cognitive development is the environment, and different environments can facilitate or hinder the development[30].

This study identified that Motor Screening Task (MOT) was delayed among the students who were studying in school situated in traffic-polluted area, compared to those students who were studying in school which was located away from the traffic-polluted area. The deposition of environmental pollutants and translocation to extra-pulmonary sites is essential to understand which environmental pollutants affect secondary organs. Elder et al[31] reported that ultrafine and fine particles enter into the lungs, penetrate pulmonary tissue, and reach other organs, including the brain[31]. The blood-brain barrier prevents the entry of hazardous particles in the brain. However, certain particles and gases cross the blood-brain barrier, pass through the endothelial-cell tight junctions, and disrupt the barrier by triggering inflammatory responses. The inhaled particles may be translocated into the brain *via* the olfactory nerve, which directly connects the nose and brain[32]. These researches showed that environmental pollutants might easily enter the lungs and reach the brain.

Sunyer et al[33] investigated the neurological impact of air pollution in children and reported that early exposure to air pollution can cause functional interruptions in brain maturation and the loss of neurobehavioral aptitudes. Guxens et al[34] performed an epidemiological study on the neuropsychological effects of air pollution. The researchers reported white-matter lacerations and vascular pathology in the olfactory bulb, frontal cortical and subcortical areas, which may be the basis for the cognitive insufficiencies and behavioral deficiencies, observed in children and elderly individuals exposed to pollutants.

Calderón-Garcidueñas et al[35] studied the impact of environmental metals on the brains of young urbanites and found that metal neurotoxicity is a substantial risk of brain damage among urban populations. Children and adults with constant exposure to a contaminated urban atmosphere, road traffic, ignition, and industry-associated metals may exhibit noteworthy neuro inflammation in their frontal lobes. Many investigations[36,37] have shown a negative link between road traffic-related environmental pollution and children's reading abilities and memories. The authors found that central processing skills, including reading and memorizing details were affected by environmental pollution. It is possible that traffic-related particles may cause oxidative stress and exert adverse effects on central nervous system functions, which could manifest as cognitive impairment[38].

Traffic-related ambient air pollution is allied with cognitive function impairment[39]. In post-mortem studies, Calderón-Garcidueñas et al[39] "observed the signs of amplified intensities of inflammatory mediators, β-amyloid an indicator of oxidative damage, and blood brain barrier disturbance in the brains of people who belonged to cities with high levels of air pollution. It is an established fact that β-amyloid is an important protein causing Alzheimer's disease and cognitive function impairment[40]. Children residing in polluted city were more likely to display white matter hyper-intensities in the prefrontal cortex than those residing in a city with lower levels[41]. There is increasing evidence[41] that air pollution can cause brain damage, neuro inflammation, neurodegeneration, and decreased cognitive ability.

In general, the results of the present study are noteworthy, but similar to any other literature, this study has a few limitations. Being aware of them, it is hoped to elucidate the difficulties encountered in this study and ensure a future refined version of this investigation with better conclusions. This cross-sectional study impedes to find the cause-and-effect relationships. An attempt was made to control some confounders, the exposure to pollutants other than vehicle emissions which may not be recorded. The selection of a small geographical unit adversely affects the stability of respiratory and cognitive health events. This study attempted to account for this impact by using 2-year minimum stay period of students in the same school, but selecting a large sample size; however, it was difficult, as exposure points were variable in the city. Therefore, large sample sized studies on the students with appropriate exposure to motor vehicle pollutants should be conducted along with lung function, FeNO, and cognitive function measurements to reach better conclusions.

Conclusions

Exposure to motor vehicle pollution demonstrates a relationship with decreased lung function and cognitive function among students who study in schools adjacent to motor vehicle polluted areas. However, this study could not notice any change in the FENO levels between the groups. This study provided an insight into the avenues for further researche into exposure analysis of motor vehicle emission, environmental pollution, and health problems faced by people residing adjacent to motor vehicle polluted areas. There is an acute need to take preventive measures to minimize the health hazards associated to traffic allied pollution.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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