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Relationship between Air Pollution Exposure in Daily Travelling Activities and Health Impact on Primary School Children

*K.L. Mak, W.K. Loh
Division of Science and Technology,
Hong Kong Community College, The Hong Kong Polytechnic University, China
Corresponding Author: K.L. Mak

***Abstract**: This study relates to the pulmonary function of school age children and the air quality of public transport in Hong Kong. It focuses on selected primary five or six students from schools in Hong Kong. A log book and a questionnaire were distributed through the schools to and completed by these students. Each sampled student had to fill in the daily travelling activities and also required to answer questions related to their indoor living conditions. The sampled students were required to conduct a pulmonary function test. The air pollutants such as PM_{10}, $PM_{2.5}$, CO_2, CO and Volatile Organic Compounds (VOCs) were measured following the routes to school and return home of sampled students. A statistical analysis, ANOVA, was performed on the modes of transportation and the lung function test results. It was found that different modes of transportation have significant difference on the student's lung function. It was also found that students who go to school by Mass Transit Railway (MTR) had significant better pulmonary function values than any others. Statistical regression was further applied to quantify the effect of different parameter to pulmonary function.*

***Keyword**: Pulmonary function test; Transportation air quality; Exposure study*

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I. Introduction

In line with the ever increasing living standards in East Asian countries, the demand of energy and the number of vehicles have also been growing. The process of extracting energy from fossil fuels and the incensement of number of vehicles would unavoidably contribute air pollution problems. Many researchers have proved that the impact of air pollution is broad and at the same time affecting the health of whole populations. Hong Kong, one of these South East Asian cities, has serious air pollution problem.

The effects of outdoor pollutants on health are of great public interest. The emission of potentially hazardous substances is increasing with motorization throughout the world. One main source of outdoor air pollution is road traffic, which produces suspended particulates, Nitrogen Oxides, Ozone and Carbon Monoxide. Rosenlund et al. (2009) suggested that traffic-related air pollution exposure is associated with reduced expiratory flows in school age children.

Survey was performed in 2307 nine to ten years old children who had lived in Norway by Oftedal et al. (2008). The outdoor air pollution exposure for each child was assessed by the EPISODE dispersion model, calculating hourly concentrations of Nitrogen Dioxide (NO_2) and particulate matter (PM_{10}, $PM_{2.5}$). Linear regression was further applied for stratified by gender. The result showed that, early and lifetime exposure to outdoor air pollution were associated with reduced peak expiratory flow and reduced forced expiratory flow at 25% and 50% of forced vital capacity, especially on girls. One inter quartile increase of lifetime exposure to NO_2, PM_{10}, $PM_{2.5}$ was associated with changing in adjusted peak respiratory flow. They also found that there was short term effect on NO2 to become stronger with increase time lags, but not on PM. However, in their study, the air pollution exposure was calculated independently from the average modelling. This clearly leads to random error dilute the association between exposure and outcome.

Due to the rapid development of China in last two decades, many researches were carried out in China for indentifying the correlations between ambient air pollutants (SO_2, TSP, NO_2) and the level of children's lung function (FVC, FEV1) in China.

(Wang, 2004; Wang et al., 2003; Peng et al., 2001; Zhang et al., 1996; Dong et al., 1999; Chen et al., 1996; Yin et al., 2005; Liu & Zhang, 2009) Both their results showed that children living in seriously air-polluted area have lower lung function indices than those in lightly air-polluted area. However, in their researches, there are no concrete data about the factors such as children's age, sex related to the growth and development, and family economic status, smoking family members and household fuels. Furthermore, Neuberger et al. (2002) found that SO2 and TSP do not seem to play a role as confounders for NO2. Therefore, further investigations about features of lung function damage due to other ambient air pollution in China are needed.

Poor air quality has been believed to be a main attribute to pulmonary illnesses in children. Many researches were carried out on identifying the relationship between indoor/outdoor air quality and children's pulmonary function. (Jedrychowski et al., 2005; Lee et al., 2011; Kasamatsu et al., 2006) However, few studies have been conducted to establish a direct linkage between air quality of public transportation and pulmonary illnesses. Although the amount of time that expose in transport for children is not as long as in indoor environment like home/school, the concentration of pollutant in transportation is a lot higher than indoor. Therefore, this study tried to establish a direct linkage between children's daily exposure to air quality of public transportation and their current lung function. This study comprised a pulmonary function test on selected children and an air quality survey about the children's typical travelling routes and transportation modes. We then examined, with statistical analysis techniques, how air quality of public transportation affects on the pulmonary function and respiratory illnesses of children. It enabled us to identify the differences (if any) of air pollution exposure impacts on school age children's health with different transportation modes. In our study, we will perform lung function tests for primary school children as well as measuring their height and weight in order to have a general picture about their health in Hong Kong.

II. Methodology

2.1 Questionnaire Survey

Respiratory questionnaire from the American Thoracic Society's was usually used on children's pulmonary function survey. (Constant et al., 2011, K.L. Mak and Loh, 2015) In our research, respiratory health questionnaires and log books were distributed through the schools to students. Information was collected through the parent-completed questionnaires and the student-completed log books. The questionnaire used in this study was mainly adapted and modified from The American Thoracic Society recommended respiratory disease questionnaire and ISAAC II questionnaire. The standardized questionnaire was divided into 2 sections. Section A was to obtain some indoor environment conditions such as home dampness, pets keeping, and tobacco smoking parents. Section B was to ascertain lifetime prevalence of asthma, wheeze as well as the children's respiratory health for the past 12 months. The log books required the students to fill in their route to school and back home for a week.

A letter was sent to each school head explaining the purpose of the study was to carry out an air pollution exposure and general health survey. A meeting was then arranged with responsible teachers to discuss practical aspects of this study. A briefing session was given to the chosen classes to explain the questionnaire design and give some instructions of filling in the questionnaire and log book.

Our study focused on school age children of primary 5 and 6. The age of these children ranged from 10 to 12. Most children stayed at the same school for their primary education. In other words, they had been exposed to the same micro-environment for the last 5 to 6 years. Selected schools were situated at both urban and rural areas in Hong Kong. A total of twelve schools were recruited in this study. The log books aimed to find out the children's travelling pattern and duration of staying in different kinds of transportation. After collecting the questionnaires and log books from the schools, we checked the completeness and exclude the uncompleted ones.

2.2 Pulmonary Function Tests Sampling

Pulmonary function tests are noninvasive diagnostic tests that provide measurable feedback on lung functions. Spirometry is the most common pulmonary function tests, measuring specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled. Spirometry is an important tool used for generating pneumotachographs, which are helpful in assessing conditions such as asthma, pulmonary fibrosis, and cystic fibrosis. In our study, pulmonary function tests were conducted among surveyed school students to assess their lung functions with reference to Paton (2000) suggestions. The pulmonary function tests were conducted by using spirometers (Model: MIR spirobank G). The disposable mouth piece was used in spirometer to conduct lung function test for each student. Prior to performing the test, students were well elaborated on how to blow into the mouth piece. Based on the American Thoracic Society recommendations, each student was asked to perform at least three satisfactory blows and forced expiratory time exceeding 6s. Pulmonary function tests were performed with two identical spirometers by fully trained technicians. Apart from operating the spirometers, trained technicians also measured the height and the weight of each sampled child. The heights and weights were further used to calculate the reference FVC and FEV1 value of each sampled students.

2.3 Air Quality Monitoring

To ascertain the inter-relations between health and air pollution of public transportation in Hong Kong, we decided to obtain health and environmental data directly. An activity log provided information of school age children's traveling routes and modes of transportation used, a lung function test on the children confirmed the self-administered health records, and an air quality survey provided on-site air quality exposure data on different transportations.

As mentioned in previous session, sampled students were required to fill in a log book for their weekly traveling pattern. Air pollutants such as PM_{10}, $PM_{2.5}$, CO_2, CO and Volatile Organic Compounds (VOCs) were monitored along the routes to school and return home of the sampled students. The equipment was maintained at the respiratory level (i.e., 1.5 m above the ground), and also free from any direct obstructions during monitoring. The following equipments were used for monitoring different pollutants:

a. *Particulate Mater*
TSI DUSTTRAK™ Aerosol Monitor Model 8520 was used for instantaneous monitoring of PM_{10} and $PM_{2.5}$. The DUSTRAK was set to 1 minute's interval for sampling.
b. CO_2, CO, Temperature and Relative Humidity
The portable TSI Q-TRAK (Model 8552) was used to monitor instantaneous temperature, relative humidity, CO_2 and PM_{10}. The equipment was set to 1 minute's interval for sampling.
c. *Volatile Organic Compound*
The ppbRAE parts per billion (ppb) Volatile Organic Compound (VOC) Monitor (Model PGM-7240) was used for instantaneous monitoring of Volatile Organic Compound (VOC) at ppb levels. The equipment was set to 1 minute's interval for sampling.

A batch of pre-cleaned 2 liter stainless steel SUMMA canisters was used to collect air samples to analyze VOC in the lab. Integrated VOC air samples were obtained by using mass flow controllers (Model No. FC4104CV-G, Auto flow lnc.) at flow rates of 34 ml/min. After sampling, the canisters were shipped back to the Hong Kong Polytechnic University for further analysis of VOC.

d. Ultrafine Particles
The TSI's P-Trak Ultrafine Particle Counter (UPC) 8525 was used for measuring ultrafine particulate levels. The P-Trak was set to 1 minute's interval for sampling.

2.4 Analysis

A statistical analysis of covariance, ANCOVA, was carried out to identify if there were significant differences between the factors for each of the transportation mode. ANCOVA is a general linear model which blends ANOVA and regression. ANCOVA evaluates whether population means of a dependent variable are equal across levels of a categorical independent variable, while statistically controlling for the effects of other continuous variables that are not of primary interest, known as covariates. Therefore, when performing ANCOVA, the dependent variable means are adjusted to what they would be if all groups were equal on the covariates. For performing ANCOVA analysis, we need to define covariates. Principal analysis was carried out on interested confounding factors and the scores from principal analysis will apply for covariate.

In previous research, the observed lung function is most affected by gender, weight and height. In order to isolate the bias from these three well know factors, these three factors were included for principle factor analysis. Furthermore, there were some risk factors, such as passive smoking and medical history of asthma. Therefore, these two factors were also included for principle factor analysis and then derive results that have been adjusted for all the other factors when examining one factor by ANCOVA.

In our study, ANCOVA was applied for testing if there was significant difference between children's health (self-reported symptoms and results from pulmonary function tests) and different transportation modes.

III. Site Description

We randomly selected twelve schools representing various air-pollution levels in Hong Kong. The locations of each school were plotted at the map in Figure 1. Selected schools were situated at both urban and rural areas in Hong Kong.

IV. Result

4.1 Questionnaire Data Collect

A total of 850 students coming from twelve schools were sampled, 442 boys and 408 girls. Most sampled students have been living in the same districts as their schools. The average height was 148.2cm and weight 41.6kg. Table 1 summarizes the detail statistic of these twelve schools.

Students were asked to fill in the time and the modes of transportation in every journey. Table 2 shows the pattern of travel of the sampled children. It shows that in all 12 schools, most of children use walking as transport mode to go to school. 54% of school children go to school on foot. It can be explained by the education policy of Hong Kong which is most students can study in the same district of living; therefore, most students in Hong Kong can go to school on foot. The second highest transportation mode used is school bus which is 27.8%.

Numerous study have shown that keeping furry pets in house will cause skin diseases, digestive diseases or respiratory diseases to children especially when they play closely to the pets. Furthermore, home condition is well known as having an important contribution to children's health development; therefore, questions related to home condition and also related to health were asked in questionnaire surveys. The result of questionnaire is shown in Table 3.

United States Environmental Protection Agency (USEPA) has concluded that exposure to secondhand smoking can cause lung cancer in nonsmoking children more than smokers. Children who are in phase of physical development are more easily to be affected than adults. Heavy secondhand smoking especially inside the house will damage children health with respiratory disease such as asthma, pneumonia, bronchitis, and lung cancer. Table 3 reveals that over 25.3% of sampled children have smoking family members within the house. Table 3 also reveals that around 3.2% of sampled students were identified as having asthma by doctor.

There are various sources related to indoor air pollution which is adverse health impact and which people are rarely aware of such as incense burning and mosquito repellent burning. In this study, we found that around 12.6% of sampled children have incense burning at home. The use of mosquito repellent burning is not common in Hong Kong because people acknowledge the harm of having it inside the house. Our result shows that less than 5% of sampled children use mosquito repellent burning at home.

4.2 Pulmonary function results

The average pulmonary function results of these twelve schools in Hong Kong is plotted in Figure 2. It shows all of the parameters representing the pulmonary function (Functional Vital Capacity - FVC and Forced Expiratory Volume in 1s - FEV1). Owing to the height and weight difference among each sampled child, the FVC and FEV1 value cannot directly applied for comparison. A common practice of using the percentage between the sampled value and the predicted value (sample / predict) is adopted for comparative analysis, percentage with over 80% are considered as normal person. (Beres et al., 2011; Couriel and Child, 2006). The predicted values are estimated taking into account of the weight and height of each student based on the method of The Global Lung Function Initiative.

4.3 Air Sampling Result

Air samples were further obtained on different modes of transportation as reported by sampled students. The parameters such as PM_{10}, $PM_{2.5}$, CO_2, CO and Volatile Organic Compounds (VOCs) were monitored inside the various transport modes. The average pollutant record of different parameters is shown in Table 4. Our sampling result shows that most of the transportation modes have similar reading in PM_{10} except for school buses. The measured PM_{10} in school buses is nearly 20% higher than any others. Furthermore, school buses recorded the worst air quality with having the largest value of all six pollutants. Railway recorded a relative better air quality with having especially low value of CO_2, CO and TVOC.

4.4 Analysis

After collecting the questionnaire, reliability analysis was performed. Cronbach's Alpha was calculated and equaled to 0.821, which represents acceptable internal consistency of the survey (George and Mallery, 2003; Kline, 1999). A statistical analysis, ANCOVA, was carried out to identify if there were significant differences among different factors.

Significant differences were obtained in the factor of modes of transportation and tobacco smoking parents for both FVC (sample / predict) and FEV1 (sample / predict). Boys have a better performance than girls on both FVC and FEV1. Furthermore, tobacco smoking parents' children has significant poor lung function. For transportation modes, we found that there was a significant difference with FVC and FEV1.

The analysis results showed that students who go to school by school buses have the worst performance in both FVC and FEV1. Students who go to school by railway have the best performance. The statistical Fisher's least significant difference was preformed and the results between each transportation modes are shown in Table 6. The result shows that there are no significant differences between railway, light bus and walking. This represents in statistical point of view, students have equally good performance for using these three transportation modes. A significant difference was recorded between two groups -- group 1: railway, light bus and walking; and group 2: school bus, private car and bus. Our sampling results shown in Table 4 show that the measured PM_{10} in school buses is nearly 20% higher than any others. Furthermore, school buses recorded the worst air quality with the highest value of all six pollutants. Railway recorded a relative better air quality with having especially low value on CO_2, CO and TVOC, and walking recorded second low value on CO_2, CO and TVOC. Together will the better lung function performance of students that using railway and walk, it seems that CO_2, CO and TVOC are more direct affected children's lung function than PM. This explains why students go to school by school buses to have a relatively low performance in lung function test even with the lowest value in $PM_{2.5}$. The poor air quality in school buses (highest values in all measured pollutants) seemed to have a direct effect on student's lung function as well.

We further tried to develop a regression model with FVC (sample / predict) and FEV1 (sample / predict). The lung function value is considered as the dependent variable and the other eight parameters (i.e., Gender, Mode of transportation, Keeping furry pet at home in last 12 months, Tobacco smoking parents, Incense burning at home, Mosquito repellent burning, and A doctor ever said that your child has asthma) are considered as independent variables. Statistical stepwise regression has been applied for developing regression model. The development of each statistical model together with the R-square value and change of R-square value of each model are shown in Table 7.

Relatively high total R-square values i.e., 0.564 and 0.755 are observed for both models. The results show that tobacco smoking parents, transportation modes, and gender are particularly significant factors. The parameter "Tobacco smoking parents" represents around 37.1% and 43.1% of information of the model for FVC (sample / predict) and FEV1 (sample / predict), respectively. "Modes of transportation" represents the other 16.5% and 31.3% information of the model for FVC (sample / predict) and FEV1 (sample / predict), respectively.

V. Conclusion

This study showed the difference of pulmonary function of students in different modes of transportation and also different indoor living conditions. Significant differences were obtained in mean pulmonary function among the different modes of transportation by statistical ANCOVA. The result reveals that students who travel by school buses have the poorest pulmonary function and it can be well explained by the poor air quality sampling result on school buses. At the same time, the best air quality within five sampled transportation modes was railway. Children who travelled on railways to school have the best pulmonary function performance.

Stepwise regression was further applied on identifying the significant parameter to pulmonary function. The parameter "Tobacco smoking parents" and "Modes of transportation" were shown to have a significant contribution to the lung function value. By the change of R-square, we identified that "Tobacco smoking parents" has the major contribution to the model with representing around 37 - 43% information of the model, and "Modes of transportation" representing the remaining 16 – 21%.

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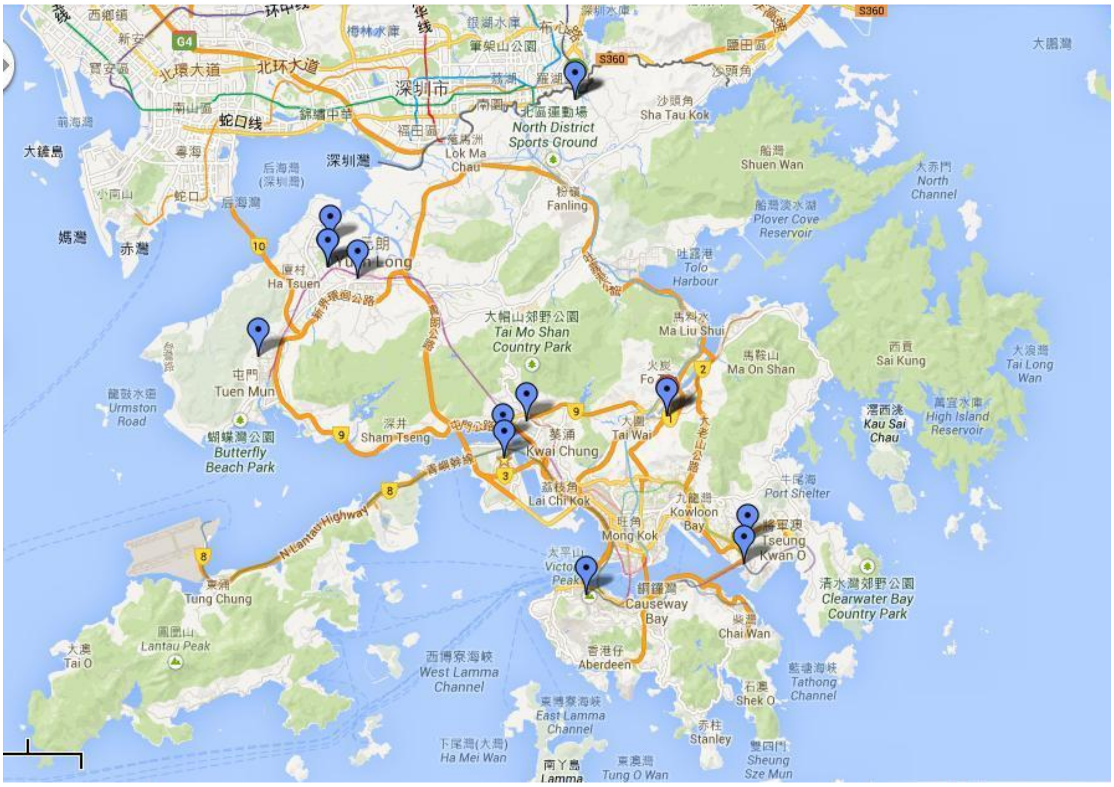

Figure 1: Sampling schools location

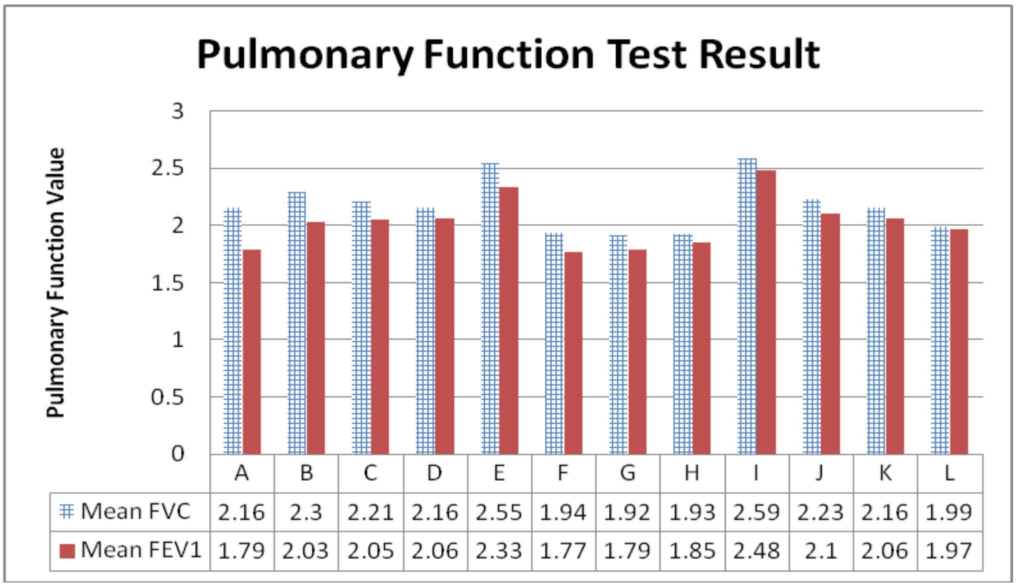

Figure 2: Pulmonary function result

Table 1. The detail statistic of twelve sampled school

Schools	Boys	Girls	Height (m) Mean	Weight (kg) Mean
A	51	50	1.56	45.37
B	30	24	1.48	42.54
C	40	44	1.49	43.65
D	62	48	1.48	43.21
E	35	44	1.51	42.81
F	26	28	1.39	38.66
G	68	36	1.41	37.06
H	22	22	1.4	40.11
I	26	38	1.49	44.63
J	32	22	1.49	38.19
K	30	32	1.52	43.57
L	20	20	1.54	39.45

Table 2: Pattern of travel of sampled children

	School											
	A	B	C	D	E	F	G	H	I	J	K	L
Walking	65	30	60	38	54	20	53	24	32	25	35	24
School Bus	28	14	18	52	11	13	26	11	24	14	15	10
Bus	5	5	1	10	6	5	10	2	6	3	4	0
Light Bus	0	2	1	2	2	9	9	0	0	1	1	1
Railway	0	2	1	1	1	2	3	3	1	8	2	4
Private car	3	1	3	7	5	5	3	4	1	3	5	1

Table 3: Frequency count of questionnaire survey

	School											
	A	B	C	D	E	F	G	H	I	J	K	L
Keeping furry pet at home in last 12 months	14	17	25	18	27	32	15	17	22	19	21	13
Tobacco smoking parents	26	24	14	30	10	18	15	18	12	21	16	11
Incense Burning at home	18	7	16	6	5	7	17	5	7	2	3	14
Mosquito repellent burning	1	3	1	3	0	5	1	3	8	2	7	2
A doctor ever said that your child has asthma	2	1	6	4	3	4	2	1	1	2	1	0

Table 4. The average value of sampled pollutants

	PM_{10} (mg/m^3)	***$PM_{2.5}$ (mg/m^3)***	***Particle count (pt/cc)***	***CO_2 (ppm)***	***CO (ppm)***	***TVOC (ppb)***
Railway	0.199	0.131	10146.36	692.64	2.40	838.18
Bus	0.185	0.111	17669.08	959.95	3.08	934.36
Mini Bus	0.166	0.114	23168.70	779.00	3.10	906.45
Walking	0.192	0.155	23625.29	816.91	2.53	865.03
School Bus	0.239	0.193	29531.61	1021.14	3.16	1081.29

Table 5: ANCOVA result of different factors

Dependent variable	Factor	ANCOVA (Significant value)
FVC (sample / predict)	Mode of transportation	0.000*
	Keeping furry pet at home in last 12 months	0.284
	Tobacco smoking parents	0.003*
	Incense Burning at home	0.347
	Mosquito repellent burning	0.297
FEV1 (sample / predict)	Mode of transportation	0.002*
	Keeping furry pet at home in last 12 months	0.149
	Tobacco smoking parents	0.007*
	Incense Burning at home	0.119
	Mosquito repellent burning	0.175

Table 6: Fisher's least significant difference result

		Walking	School bus	Private car	Bus	Light bus	Railway
FVC (sample / predict)	Walking		0.035*	0.036*	0.003*	0.785	0.757
	School bus			0.784	0.169	0.048*	0.029*
	Private car				0.719	0.049*	0.035*
	Bus					0.016*	0.037*
	Light bus						0.671
FEV1 (sample / predict)	Walking		0.046*	0.0342*	0.003*	0.773	0.686
	School bus			0.755	0.181	0.047*	0.025*
	Private car				0.758	0.043*	0.031*
	Bus					0.018*	0.037*
	Light bus						0.611

Table 7: Statistical model development and R-square change

Dependent variable	Iteration	Included variable	R-square change
FVC (sample / predict)	1	Tobacco smoking parents	0.371
	2	Transportation mode	0.165
	3	Gender	0.028
FEV1 (sample / predict)	1	Tobacco smoking parents	0.431
	2	Transportation mode	0.213
	3	Gender	0.111

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