Research Report

Spirometric Assessment of Pulmonary Function in Road-side Vendors: A Pilot Study

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Abstract: Although much is known about the chronic effects of air pollution on pulmonary function, short-term changes in response to pollution levels over days, weeks and months have been less well documented. Such investigation requires field studies using portable equipment. Therefore, we studied forced vital capacity (FVC), forced expiratory volume in 1 second, and peak expiratory flow rate using a conventional hand-held spirometer, in a sample of Hong Kong roadside vendors (n = 21; age, 48.7 ± 13.4 yr) across 2 days (n = 14), 4 weeks (n = 10), and 3 months (n = 7). In addition, exhaled carbon monoxide was measured, and percent carboxyhemoglobin derived. There was no difference in pulmonary function between a weekday and the weekend. Only FVC decreased over 4 weeks and 3 months compared with initial testing, but this was not associated with pollution level. Our results support that the technology of hand-held spirometry needs to be advanced to detect potential short-term changes in the real world context, in pulmonary function including small airway reactivity and airway closure. Future generations of this technology need to provide the capacity for more detailed spirometry suitable for field studies.

Key words: road-side vendors, spirometry, pulmonary function, air pollution

Introduction

The adverse chronic effects of air pollution on pulmonary function have been well documented [1–5], and the role of air pollution in predisposing acute respiratory illness has been established [2, 6, 7]. Air quality and pollution in Hong Kong are becoming an increasing health care and environmental concern [8]. As a result, there are initiatives under way to reduce vehicle emissions, and to disseminate public health information. Unlike the effects of smoking, the impact of pollution on societal health is only now becoming apparent. As a basis for recommending pollution controls and measuring the effect of pollution on lung health, means to assess the short- as well as the long-term effects of pollution and elucidate the underlying mechanisms of lung injury are needed.

Comparable to the effects of smoking, air pollution may affect small as well as large airways, leading to obstructive airway disease, restrictive lung disease, and lung cancer. Although the mechanisms underlying pollution-related lung pathology have yet to be detailed, their long-term effects are likely to be preceded by episodic airway and lung irritation resulting in short-term fluctuations in lung function. There is evidence to support a reversible component in lung function after an

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individual is removed from vehicle exhaust [9]. In Hong Kong, roadside vendors seldom have breaks from exposure to air pollution. They typically position their stalls in highly trafficked areas. Roadside vendors are not well educated, have low incomes necessitating that they work long hours every day without breaks. As a group, they are likely to have a higher prevalence of smoking than does a more educated cohort.

The short-term as well as the long-term effects of pollution, superimposed on the effects of cigarette smoking are of clinical importance to physical therapists for several reasons. First, physical therapists may be required to manage the acute symptoms as well as the long-term effects of pollution. Second, they may be required to treat patients who are experiencing acute or long-term effects of pollution as secondary conditions. Third, pollution exposure as well as smoking is an important consideration in the management of the perioperative or mechanically ventilated patient. Fourth, physical therapists need to be increasingly involved in public health campaigns and in the formulation of policy related to pollution control.

To capture short-term daily, weekly, and monthly fluctuations in pulmonary function in response to pollution level, spirometric studies need to be conducted in the field as opposed to the pulmonary function laboratory. Such study requires the use of small, reliable, portable spirometric testing devices. Therefore, we investigated whether measuring basic spirometry using a hand-held spirometer in individuals exposed to variable levels of air pollution in their work would detect short-term fluctuations in pulmonary function; and second, whether such changes would reflect the air pollution index on a given day. Short-term changes were defined as changes that occurred over days, weeks, and months.

Methods

Subjects and research design

A convenience sample of Hong Kong roadside vendors (n = 21; age, 48.7 ± 13.4 yr) was recruited for study in the Mongkok district of Hong Kong. We selected Mongkok, a district known to have high emissions and pollution measures. Mongkok also has a culture of roadside vendors selling newspapers, food, and confectionery items. The study and consent form were approved by the institutional ethics review committee for human research. The research design involved basic spirometric testing for days (a weekday and a day on the weekend) (n = 21), weeks (4 weeks) (n = 10) and months (3 months) (n = 7).

General procedures

On the initial testing day, subjects were oriented to the study and provided informed signed consent. Heights and weights were recorded. Subjects completed a survey questionnaire that included their age and gender, medical history, medications, smoking history, and work history as a roadside vendor. They also reported any symptoms such as eye, nose, throat, sinus irritation, and history of cough.

The air pollution index (API) for the various districts of Hong Kong is published daily by the Environmental Protection Department of the government of Hong Kong [8]. Mongkok is one of the districts with a roadside air pollution station where the API is calculated. The API converts the pollution levels to a value ranging from 0 to 500, with 0 to 25 being low pollution, 26 to 50 medium, 51 to 100 high, 101 to 200 very high, and 201 to 500 severe. We obtained the API and the level of severity for each of the testing days.

Specific procedures

The Pony Graphic Cosmed (Italy) hand-held spirometer is one of many such spirometers that are used clinically as well as in the field, and is known to have good reproducibility [10]. We selected this device because of its size, measurement rigor, ease of application, and transportability to field sites. Established standards of the American Thoracic Society (ATS) were used in the spirometry testing [11]. Five research assistants were trained in the standardized use of the hand-held spirometry, and were responsible for collecting the demographic and spirometric data. ATS standards require standardizing the subject's position, standardizing the test instruction, and repeating the requisite forced expiratory maneuver at least three times to obtain reliable measures for forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory flow rate (PEFR). Testing was conducted initially on one weekday (Monday) and 1 day on the weekend (Saturday) to establish whether differences existed between the 2 days, given that there are fewer vehicles on the road on the weekend. Testing was repeated 4 weeks later, and again 3 months after the initial testing. In addition, oxygen saturation was assessed using a pulse oximetry (SpO_2) (Nonin Medical, MN).

Exhaled carbon monoxide (CO) was measured using the Micro CO monitor (MicroMedical, Kent, UK). The CO monitor also converts the concentration of expired CO to percent carboxyhaemoglobin (% COHb). Reliability of these measures when conducted in an established standardized manner is reported to be ± 3% [10]. Prior to the study, the CO monitor was calibrated against CO of known concentration.

Statistical analysis

SPSS (Windows Version 10) was used to analyze the data and included descriptive statistics for summarizing the subject demographics and variable data. Paired student's *t* tests were used to compare the variables of interest for differences in days of the week; and repeated analysis of variance (ANOVA) was used to analyze measures over weeks and months. The significance level was set at 0.05.

Results

The demographic data of the subjects are summarized in Table 1. Of the 63 subjects approached, 21 subjects (12 women and nine men) agreed to participate in the study. Five subjects were current smokers, four of whom had smoked less than one pack a day for the past 5 years. One ex-smoker quit 3 years prior to the study. None of the remaining subjects had ever smoked. Smokers had higher CO levels and FVC compared to non-smokers (CO: 18.4 ± 6.4 ppm in smokers vs. 5.7 ± 2.4 ppm in non-smokers, $p < 0.001$; FVC: 3.2 ± 1.0 L in smokers vs. 2.2 ± 0.8 L in non-smokers, $p = 0.04$).

After the initial lung function measurements, seven subjects withdrew from the study. Comparison of lung function data between a weekday and a day on the weekend in the remaining 14 subjects showed no differences in the six spirometric measures regardless of the difference in the API between the 2 days (42 vs 62) (Table 2). The majority of these subjects declined to participate twice a week (this was deemed interfering with their business), thus, only weekday measurements were available for subsequent analysis.

Ten subjects agreed to lung function measurement after 4 weeks and seven subjects, after 3 months. To maximize statistical power, all data points available (i.e., n = 21 at initial testing; n = 10 at 4 weeks; and n = 7 at 3 months) were used in the repeated ANOVA; appropriate fixed models using the subjects as random and time as fixed factors were employed. The FVC decreased from initial testing to the fourth week, but was unchanged at 3 months. Because of dropouts, the study's statistical power was compromised. Whether the apparent trends toward deterioration in lung function would have achieved statistical significance if subjects had not dropped out is not known (Table 3). The Figure displays FVC for the seven subjects who completed the 3 months of measurements.

The above analyses were repeated after stratification by smoking status. The change in FVC became more marked (p = 0.015), and the decrease in FVC over time more apparent in smokers (initial test: 3.2 ± 1.0 L; 4 weeks: 2.42 ± 0.45 L; 3 months: 2.27 ± 0.14 L) compared with non-smokers (day 1: 2.2 ± 0.88 L; 4 weeks: 2.08 ± 0.59 L; 3 months: 2.12 ± 1.04 L). On average, the smokers were 9 years younger than non-smokers (mean age for smokers 44.6 ± 17.42 years compared to 53.4 ± 12.7 years for non-smokers).

Sixteen of the 21 subjects completed the questionnaire. Of these, all reported working more than 8 hours per day over the 3 months of the study. Four (25%) subjects rated their working environment as "acceptable", while the remainder rated it "polluted or heavily polluted". Five (31%) subjects complained of frequent cough, two of whom (13%) complained of cough with sputum. All subjects who complained of cough associated it with air pollution. Five subjects complained of an allergic reaction or running nose, and one complained of experiencing frequent shortness of breath. One subject reported taking bronchodilator medication, yet none reported a diagnosis of respiratory disease. Two other subjects were taking "long-term medication", one for hypertension and the other for a skin condition. Three (19%) subjects participated in "exercise" (swimming and ball games) on a "regular" but infrequent basis (twice per month). Correlation analysis between the variables of interest in the questionnaires

Table 1. Descriptive data (mean ± standard deviation) for the sample of roadside vendors (n = 21)

Age (yr)	48.7 ± 13.4
Gender (female:male)	12 : 9 (57% : 43%)
Height (cm)	158 ± 5.7
Weight (kg)	63 ± 10.2
Smokers:nonsmokers	5:16 (24%:76%)

Table 2. Lung function data (mean ± standard deviation) for a weekday and a day on the weekend (n = 14)

Variable	Weekday	Day on the weekend	% Difference	*p**
FVC (L)	2.6 ± 0.8	2.5 ± 0.7	2.9	0.36
FEV_1 (L)	2.3 ± 0.7	2.3 ± 0.7	0.1	0.97
PEFR (L/s)	5.2 ± 2.0	5.4 ± 1.9	4.1	0.42
CO (ppm)	8.3 ± 9.5	9.0 ± 8.9	8.4	0.44
% COHb	1.3 ± 1.5	1.4 ± 1.4	7.6	0.58
SpO_2 (%)	97.8 ± 0.7	97.6 ± 0.7	0.2	0.50

FVC = forced vital capacity; FEV_1 = forced expiratory volume in 1 second; PEFR = peak expiratory flow rate; CO = exhaled carbon monoxide level; % COHb = % carboxyhaemoglobin; SpO_2 = oxygen saturation measured with a pulse oximeter. *Significance level: $p < 0.05$.

Table 3. Lung function data (mean ± standard deviation) over 3 months

Variable	Initial testing (I) n = 21	4 weeks (II) n = 10	3 months (III) n = 7	Multiple comparison *post-hoc* test results	p
API	42	46	63		
FVC (L)	2.57 ± 0.99	2.19 ± 0.53	2.18 ± 0.90	(I) ≠ (II), (III)	0.046*
FEV_1 (L)	2.24 ± 0.78	2.12 ± 0.43	2.11 ± 0.87		0.91
PEFR (L/s)	5.19 ± 2.16	5.14 ± 1.56	4.86 ± 2.13		0.39
CO (ppm)	7.49 ± 8.36	9.06 ± 10.2	9.31 ± 11.9		0.32
% COHb	1.32 ± 1.27	1.47 ± 1.62	1.53 ± 1.94		0.15
SpO_2 (%)	97.7± 1.20	97.6 ± 1.79	96.9 ± 1.13		0.26

API =air pollution index; FVC = forced vital capacity; FEV_1 = forced expiratory volume in 1 second; PEFR = peak expiratory flow rate; CO = exhaled carbon monoxide level; % COHb = % carboxyhaemoglobin; SpO_2 = oxygen saturation measured with a pulse oximeter. *Significance level: $p < 0.05$.

and the six lung function parameters was not undertaken due to the small sample size.

Discussion

Physiologic and clinical considerations

There have been a few reports of reduced FEV_1, PEFR, oxygen saturation, and increased exhaled CO level in response to pollution [3, 9], though our sample revealed a less clear trend. Based on the work of Ulfvarson and colleagues [9], impairment of pulmonary function, i.e., FVC and FEV_1, observed in stevedores and garage workers, was reversible after a few days away from pollution exposure. Unlike the subjects reported in the study by Ulfvarson and colleagues [9], half of the subjects in the present study had been roadside vendors for over 5 years, working 7 days a week, with no major breaks from pollutant exposure. Despite a difference in API recorded between weekend days and weekdays, the immediate effect of pollution on lung function was not reflected by the spirometry measurements.

We observed a decrease in FVC but not FEV_1 in roadside vendors over the course of 4 weeks. The chief pollutants from engine combustion are oxides of nitrogen, hydrocarbons, and carbon monoxide [9]. Nitrogen oxides cause airway inflammation leading to bronchoconstriction, which may be detected by a decrease in FEV_1 and PEFR. In addition, pollutants can exist in aerosols [12]. Large aerosolized particles are deposited in the large and medium-sized airways, but small particles may reach the alveoli, causing irritation and eventual fibrosis of the alveolar wall. Although concentrations of nitrogen dioxide and particle size were not measured in this study, differences in particulate composition of the pollution on the test days in our study may explain the decrease in FVC observed in our subjects.

Age was ruled out as a factor to explain the decrement in FVC given that the 3-month period of the study

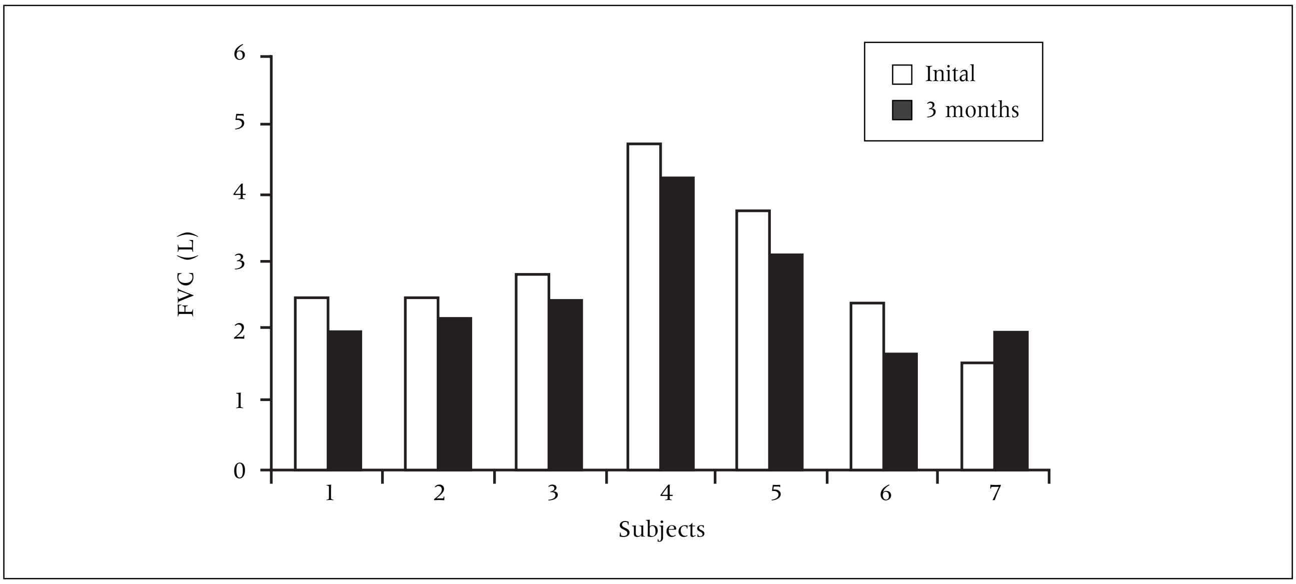

Figure. Within subject comparison of forced vital capacity (FVC) of the initial and 3-month measurements (n = 7).

was too short to observe any predicted decline. Specifically, the annual rates of decline for the age groups of interest are between 19 and 35 mL for men and between 15 and 29 mL for women [13]. The mean decrease in FVC found in our study was 390 mL (range, 310–780 mL), which far exceeded that predicted by age alone. Even so, small decrements in FVC from air pollution have demonstrable public health consequences [14].

Smoking has well-documented deleterious effects on respiratory function and is associated with chronic bronchitis, emphysema, and bronchial carcinoma [15]. As expected, we observed higher levels of exhaled CO and carboxyhaemoglobin percentage in the smokers. The decrease in FVC over the course of the study was predictably greater among smokers (decreases of 30% in smokers and 3.6% in non-smokers), despite the fact that our smokers were younger than the non-smokers by 9 years.

The API varied both during the week of the initial testing days and over the weeks and months of the study. These differences did not appear to produce marked effects in the roadside vendors' lung function parameters. This could be explained by the small sample size. The degree to which airways become desensitized to irritants, and the basis for differences in airway sensitivity from one individual to the next, is not known.

The precise mechanisms underlying the damage to the lungs from pollution have not been clearly elucidated. Comparable to smoking, there are likely to be acute effects reflected by airway irritation and mucous production and a reversible smooth muscle component involving the small airways, which underlie the chronic effects of pollution. In terms of categorization of the pathology, mucous obstruction and increased airway reactivity may predispose the lungs to an obstructive component; and chronic long-term airway and lung inflammation may predispose fibrosis and decreased lung compliance, hence a restrictive component. Despite marked changes in the API over the course of this study, neither of these pathological categories was consistently reflected in the basic spirometric measures of FVC, FEV_1, PEFR, exhaled CO, and % carboxyhaemoglobin.

Further investigation of the short-term changes in pulmonary function in Hong Kong roadside vendors is needed to extend this work both with respect to small airways as well as large airways. In addition, the value and cost-benefit of routine monitoring warrants study. Until emission control standards have been enforced and the roadside becomes a safer place to work, vendors may be at significant health risk in the short and long term. Minimally, breaks from the polluted environment may be beneficial [9], but the practicality of such a recommendation in occupations most at risk, such as roadside vendors, is dubious. Seventy-five percent of our subjects rated their work environment as polluted or heavily polluted. They had no breaks from their work and felt unable to change their environmental circumstances.

Methodological considerations

Methods for describing and understanding the natural history of pollution injury to the lungs are needed as a basis for formulating pollution control legislation, health care policy, prevention strategies, and physical therapy as well as other health care management. Use of the conventional hand-held spirometer may not be able to detect changes in pulmonary function secondary to the short-term effects of pollution because basic spirometry reflects the integrity and function of the larger airways as opposed to small airways that may be injured due to air pollution. In addition, the relationship between the effects of air pollution coupled with smoking and their interaction is unclear and warrants further investigation. Of interest, our sample consisted primarily of women. Although an increasing number of young women in Hong Kong smoke, the numbers are considerably less than men.

Another possibility for not identifying fluctuations in pulmonary function related to pollution is that the variation in pollution levels, based on the API across testing days, may not have been sufficiently extreme to have impacted differentially on airway and lung function. The days with levels of 42 and 46 are within the medium range of pollution severity, and the day with a level of 63 was in the high range. The probability of detecting impaired pulmonary function in subjects over time may have been increased if measures had been conducted on days with at least one level of pollution severity apart, e.g., a day with medium pollution vs. a day with very high or severe pollution. Alternatively, the API as an index of pollution may lack sensitivity. Furthermore, the API is a cumulative composite index. Different pollutants may have differential effects on airway and lung function, thus, individual indices may be of more importance in evaluating the impact of pollution on health.

The need for an understanding of acute effects of lung pollution as well as the chronic effects is clear. Methods to conduct trials of serial monitoring of potential changes in lung function in the field need to be developed. Pulmonary function assessed using the hand-held spirometer may be limited. Portable spirometric systems that are sensitive and reliable are needed to measure small airway reactivity in response to acute exposure to air pollution in the field. Furthermore, analysis of the pollution may be important in terms of its constituents, as each may have a differential influence on lung function. In addition, smoking is widespread in Asia in general and likely to be particularly so among roadside vendors. Trials involving spirometry in the field need to control for recent exposure to tobacco.

From a practical point of view, we had some difficulty in both recruiting subjects initially and having subjects agree to repeated tests over 3 months. This may reflect a lack of any demonstrable immediate benefit to the roadside vendor. In addition, although testing time was only 15 minutes, participants expressed concern about lost sales during that time. Future larger-scale trials may need to consider remunerating vendors to encourage participation in longitudinal studies.

Conclusions

Our results support that the short-term effects of air pollution on large airways are not consistently related to fluctuations in the gross level of pollution based on the API in Hong Kong, suggesting its effects are mediated through other, yet to be identified, mechanisms. Alternatively, differences in the primary constituents of the pollution yield differential effects on airways and lung function. Despite its apparent advantages as a field tool, the conventional hand-held spirometer may be limited in its usefulness in detecting potential short-term fluctuations in pulmonary function due to pollution in the field. Thus, more detailed spirometric study of the small airways in particular, is warranted. We propose that the next generation of hand-held spirometers have the capacity for more detailed spirometric testing to assess small as well as large airway function. With such technology, short-term changes with respect to air pollution and other irritants could be captured in the field.

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