

Effects of Smoking on Chest Expansion, Lung Function, and Respiratory Muscle Strength of Youths

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Abstract. [Purpose] Smoking has a direct effect on the respiratory system. The rate of cigarette smoking among young people has continued to increase steadily. The present study quantified and compared the respiratory function of smoking and non-smoking youths. [Subjects] Smoking and non-smoking male participants aged between 15 to 18 years were recruited (n=34 per group). [Methods] Participants were asked to complete a questionnaire relating to smoking habits and the Fagerström test for nicotine dependence questionnaire, and their respiratory function was tested (measurement of chest expansion, lung function test with a spirometer, and assessment of respiratory muscle strength). [Results] All respiratory function tests demonstrated significant differences between the smoking and non-smoking groups. Smokers initiated cigarette smoking between the ages of 15 to 18 years. The most common duration of cigarette smoking was 1-3 years and the degree of nicotine dependence among the youths was at a low level. [Conclusion] This study's findings show that the early effects of cigarette smoking found in youths can lead to problems with the respiratory system. Such information can be used to illustrate the harm of smoking and should be used to encourage young people to quit or avoid cigarette smoking.

Key words: Cigarette smoking, Youth, Respiratory function

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INTRODUCTION

Cigarette smoking is an important worldwide health problem, and it has been reported that 1.7 million Thai youths currently smoke¹⁾. This problem is compounded by the fact that the rate of cigarette smoking in young people continues to steadily increase²⁾. Cigarette smoking carries major health risks with the most cause-specific mortalities being those of respiratory and cardiovascular diseases³⁾. Therefore, smoking habits may affect the respiratory function of youths.

The respiratory function test may indicate deterioration of respiratory function prior to clinical symptoms, and its results can be used to prevent or reduce the incidence of respiratory diseases⁴⁻⁶⁾. Also, the respiratory function test can be conducted in a number of ways, such as measurement of chest expansion⁴⁾, lung volume or flow with spirometry⁵⁾, and respiratory muscle strength⁶⁾. Chest expansion as measured by circumference and diameter is simple and inexpensive⁴⁾. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) are simple, convenient, and non-invasive indices of respiratory muscle strength mea-

sured at the mouth. Respiratory muscle strength depends on the maximal effort of the muscles used in chest expansion during breathing⁶⁾. Spirometry is a physiological test that measures how an individual inhales or exhales volumes of air as a function of time, and it is invaluable as a screening test of general respiratory health⁵⁾. Lung volumes are measured to evaluate the normality of respiratory function⁷⁾.

Some previous studies have demonstrated the effect of smoking on the pulmonary function of adults⁸⁻¹⁰⁾. They showed that smoking decreased pulmonary function including forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), FEV₁/FVC, and forced expiratory flow at 25–75% (FEF_{25-75%})⁹⁾. Cigarette smoking causes deficits in both FEV₁/FVC and FEF_{25-75%} which indicate airway obstruction and small airway disease in adult smokers¹¹⁾. A previous study reported that older symptomatic smokers with histories of large numbers of pack-years had lower FVC levels than non-smokers, while young adult smokers had FVC levels equivalent to or higher than age-equivalent non-smokers¹²⁾. The intensity and duration of smoking by elderly smokers, including the degenerative effect, are likely to have powerful respiratory health effects. However, there is no clear evidence indicating that smoking affects the lung function of youths as severely as in the elderly.

Since inhaling cigarette smoke has been shown to produce acute changes in the lung including alterations in resistance to airflow, cough, and irritation of the airway, the early stage of smoking might affect the respiratory function

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of youths. However, there have been few studies which have investigated the effect of smoking on pulmonary function in adolescents. In previous studies, cigarette smoking was found to have an effect on the lung function of the adolescent boys and girls^{13, 14}. Those studies found that FEV₁/FVC decreased in adolescent smokers of both sexes. Only the pulmonary function test with a spirometer was measured in those studies. Therefore, to clarify the effect of smoking on the respiratory function of smoking and non-smoking youths, we measured and compared their chest expansion, the lung function test using a spirometer, and respiratory muscle strength to learn more about the dangers of cigarette smoking. We hypothesized that early smoking by adolescents would affect chest expansion, lung function, and respiratory muscle strength.

SUBJECTS AND METHODS

Youth male subjects aged 15 to 18 years participated in this cross-sectional study. All the subjects had a body mass index (BMI) in the range of 18.5–23 kg/m². Exclusion criteria were: unable to understand and follow verbal instructions, school athlete, cardiovascular or respiratory disorders, recent breathlessness or chest pain or dizziness, abnormal chest wall, a history of hemoptysis, airborne or contact communicable disease, a history of aneurysm, uncontrolled blood pressure, a history of chest surgery or, a history of neuromuscular disorder affecting the respiratory muscles. Prior to participation in this study, each subject signed an informed consent form to comply with the ethical guidelines dictated by The Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University, Thailand.

The information on smoking habits was obtained through interviews. Subjects who currently smoked cigarettes were classified as smokers and those without a history of smoking cigarettes were classified as non-smokers (N=34 per group). In the present study, those who used to smoke but had since stopped were excluded. Smokers were further asked questions regarding what age they started smoking, the average duration of smoking, and the average number of cigarettes smoked per day. Subjects completed the Fagerström Tolerance Questionnaire for analyzing the degree of nicotine addiction¹⁵.

The respiratory function test consisted of the measurement of chest expansion, the lung function test using spirometry, and respiratory muscle strength. For chest expansion measurements of circumference and diameter, subjects were instructed to fully inhale and exhale in the standing position. The differences between full inhalation and exhalation were recorded as chest expansion⁴. The chest circumference was measured using a tape measurement at 3 levels: at the axilla (4th rib) for upper chest movement, xiphoid process for middle chest movement, and 10th costal cartilage levels for lower chest movement. The chest diameter was measured using a caliper in the anteroposterior (AP) and mediolateral (ML) directions at the xiphisternal junction. A spirometer (Micro plus spirometer, Micro Medical, United Kingdom) was used to measure the lung function.

Table 1. Smoking habits of the smoker group (n=34)

Smoking habits	Percentage (N)
Age started smoking	
• <15 year(s)	29 (10)
• 15–18 years	71 (24)
Duration of smoking	
• <1 month	6 (2)
• 1–3 month(s)	3 (1)
• 4–6 months	3 (1)
• 7–12 months	15 (5)
• 1–3 year(s)	47 (16)
• 4–6 years	20 (7)
• 7–9 years	6 (2)
Number of cigarettes smoked per day	
• ≤10 cigarette(s)	88 (3)
• 11–20 cigarettes	9 (3)
• 21–30 cigarettes	3 (1)
Nicotine dependence	
• Low	91 (31)
• Medium	6 (2)
• High	3 (1)

The lung function parameters measured were forced expiratory volume in the first second (FEV₁) and forced vital capacity (FVC). Prior to measurement, the subjects were instructed and given a rapid and complete inhalation, the demonstration of the test, covering the correct posture for performance, with the head slightly elevated, position of the mouthpiece, and exhalation with maximal force⁵. The respiratory muscle strength was measured using a respiratory pressure meter (Micro Medical, United Kingdom) for maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP)⁶. Subjects were instructed to fully exhale, then inhale rapidly and completely for the MIP test, and fully inhale, then exhale rapidly and completely for the MEP test. All parameters were recorded in three trials, and the best value was the one used in the analysis.

The data of respiratory function were compared between the smoker and non-smoker groups using the independent t-test for normally distributed data or the Mann-Whitney U test for other distributions. Differences were considered statistically significant at $p < 0.05$.

RESULTS

Sixty-eight male subjects aged between 15–18 years were divided in to two groups: smoker (n=34) and non-smoker (n=34) groups. Smoking habits are shown in Table 1. Most subjects started cigarette smoking between the ages of 15 to 18 years (71%). The most common duration of cigarette smoking was 1–3 years (47%) and the maximal number of cigarettes smoked per day was less than or equal to 10 cigarette(s) per day (88%). The majority of youth smokers self-reported a low level of nicotine dependence (91%).

The comparison of the smoker and non-smoker groups is summarized in Table 2. Three major parameters, chest

Table 2. Comparison of parameters between the smoker and non-smoker groups

	Non-smokers (Mean±SD)	Smokers (Mean±SD)
Chest expansion		
Chest circumference		
• Axilla (cm)*	5.71±1.62	4.68±2.03
• Xiphoid process (cm)	5.32±1.68	5.18±2.22
• 10th Costal cartilage (cm)	4.66±1.19	4.24±2.03
Chest diameter		
• AP (cm)*	3.56±0.61	3.06±0.69
• ML (cm)*	3.51±0.44	3.18±0.85
Spirometry		
• FEV ₁ (litre)	2.96±0.62	2.68±0.62
• FVC (litre)*	3.07±0.68	2.68±0.62
Respiratory muscle strength		
• MIP (cmH ₂ O)	77.71±25.78	66.85±22.52
• MEP (cmH ₂ O)*	76.35±21.61	62.53±15.85

* = Significant difference between the smoker and non-smoker groups, $p < 0.05$

expansion, lung function using spirometry, and respiratory muscle strength, were compared. The chest expansion of the non-smoker group was significantly greater than that of the smoker group. There were significant differences in the chest circumference at the axilla level ($p=0.006$), AP chest diameter ($p=0.001$), and ML chest diameter ($p=0.047$), between the smoker and non-smoker groups. FVC and MEP also demonstrated significant differences between the smoker and non-smoker groups ($p=0.018$ and $p=0.004$, respectively).

DISCUSSION

This study evaluated the relationship between cigarette smoking and the respiratory function test among male Thai youths. All parameters measured for the non-smoking youths were higher than those of the youths who did smoke. Chest wall expansion, forced vital capacity, and maximal expiratory muscle strength of the non-smoker group were significantly different from their respective values in the smoker group.

In this study, all parameters of chest expansion of the non-smoking youths were greater than those of the smoking youths. Decreased chest circumference at the axillary level was associated with reductions in the AP and ML diameters. This is because chest expansion at the axillary level represents the upper chest breathing pattern, which utilizes a combination of upward and forward chest movements or the pump-handle movement, as well as upward and outward chest movements or the bucket handle movement. This result suggests that cigarette smoking affects the upper chest expansion of smoking youths. A reduction in chest expansion arising from reduced chest wall motion and flexibility would affect the performance and work of breathing, suggesting a vulnerability to dyspnea.

The relationship between cigarette smoking and the respiratory function test of adolescents has been studied

previously. Gold et al.¹¹⁾ found that FEV₁/FVC decreased among adolescent smokers. Smoking habits and the number of cigarettes smoked per day were associated with the reduction in FEF₂₅₋₇₅. Because our subjects were youths with no apparent respiratory pathology, we did not expect to find advanced impairment of lung function. Indeed, the vast majority of youths demonstrated respiratory function values within the normal range. Additionally, the low level of nicotine dependence, and the intensity and duration of smoking in our youth group were unlikely to cause the intense respiratory health effects that are usually observed in elderly smokers. In this study, FVC of the non-smoker group was significantly greater than that of the smoker group, while there was no significant difference in FEV₁ between the groups. This result suggests that cigarette smoking affects the lung capacity of youth smokers, making the volume that is associated with the FVC test smaller than that of non-smokers. The reduction in FVC of smoker may be explained by the reduction in strength of the respiratory muscles. The results for FVC may have been influenced by the instructions given to subjects, to perform maximal inhalation and then perform maximal exhalation as rapidly and as completely as possible. Hence, the FVC test relies on the strength of respiratory muscles. Cigarette smoking affects the respiratory muscles through the influence of free radicals on the vascular system¹⁶⁾, leading to a reduction in respiratory muscle blood supply which adversely impacts respiratory function.

Our findings in terms of the forced vital capacity of smokers in the early smoking period are consistent with those of previous studies^{14, 17)} that have reported that the early stage of smoking among youths reduces lung function. Even though the average number of cigarettes smoked per day recorded in this study was similar to other studies¹⁷⁾, approximately 10 cigarettes per day, the average duration of cigarette smoking recorded in this study was much less, 1–3 years compared to the 2–5 years reported in other studies.

Thus, the early stage of smoking among youths does cause reduction in the lung function. Inhaled cigarette smoke has been shown to elicit acute changes in respiratory function including alterations in resistance to airflow, coughing, and irritation of the airways. Our research findings may encourage the implementation of smoking cessation counseling for adolescents. The spirometer is commonly used for measuring respiratory function for diagnostic and clinical purposes. However, fluctuations in our data may have been caused by miscommunication with the subjects.

In conclusion, our results show that most of the youth smokers started cigarette smoking between the ages of 15–18 years. The average duration of cigarettes smoking was 1–3 years and the average number of cigarettes smoked per day was less than or equal to 10 cigarettes per day. The degree of nicotine dependence of smoking youths was low. The chest expansion, FVC, and MEP of the non-smokers was significantly greater than those of smokers. These findings show that the early effects of cigarette smoking found in youths may lead to problems with the respiratory system. Such information can be used to illustrate the harm of smoking and should be used to encourage young people to quit or avoid cigarette smoking.

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