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ORIGINAL RESEARCH

Pulmonary effects of active smoking and secondhand smoke exposure among adolescent students in Juárez, Mexico

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Background: Youth smoking trends among Latin American countries, including Mexico, are on the rise. Notably, although the high prevalence of smoking in teens has been well documented in the literature, few studies have evaluated the impact of smoking and secondhand smoke (SHS) exposure on their respiratory system.

Objective: To investigate the effects of smoking and SHS exposure on the respiratory health and lung function among eighth-grade students in Juárez, Mexico.

Methods: A cross-sectional study was undertaken on a sample of convenience. The study outcomes centered on evaluating 300 students' lung function by spirometry (forced expiratory volume in 1 second [FEV_1], forced expiratory volume in 1 second/forced vital capacity ratio [FEV_1/FVC], and forced mid-expiratory flow rate [$FEF_{25\%–75\%}$]) and their respiratory health (smoking behavior and SHS exposure) by their self-reported responses to a standardized respiratory questionnaire. The study outcomes were compared among three distinct groups: 1) nonsmokers/nonexposed to SHS; 2) nonsmokers/exposed to SHS; and 3) smokers.

Results: The majority of the study participants were 14 years old (85%), females (54%), who attended eighth grade in a public school setting (56%). Approximately, half reported being of low socioeconomic status (49%) and nonsmokers/exposed to SHS (49%). The lung function parameters of smokers were found to be lower (FEV_1 =62.88±10.25; FEV_1/FVC =83.50±14.15; and $FEF_{25\%–75\%}$ =66.35±12.55) than those recorded for the nonsmokers/exposed to SHS (FEV_1 =69.41±11.35; FEV_1/FVC =88.75±15.75; and $FEF_{25\%–75\%}$ =78.90±14.65) and significantly reduced when compared to the nonsmokers/nonexposed to SHS (FEV_1 =79.14±13.61; FEV_1/FVC =94.88±21.88; and $FEF_{25\%–75\%}$ =87.36±17.02) ($P<0.001$). Similarly, respiratory complaints were more prevalent among smokers and those exposed to SHS when compared to nonsmokers/nonexposed to SHS.

Conclusion: Our findings suggest that initiation of cigarette smoking and, to a lesser extent, exposure to SHS in adolescence leads to increased respiratory symptoms and reduction of pulmonary function test values. Public health initiatives that aim to prevent smoking initiation, assist in cessation, and lessen SHS exposure of adolescents need to be school-based and employed as early as middle school.

Keywords: adolescents, smoking, secondhand smoke exposure, respiratory symptoms, lung function

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Introduction

The global tobacco epidemic is rapidly shifting from developed to developing countries.[1] It is estimated that six million adults[2] and ~100,000 adolescents[3] die each year from tobacco-related causes. More than 80% of those deaths occur in developing

countries.[2] Youth smoking trends among Latin American countries, including Mexico, are on the rise. In Mexico, even though the prevalence of tobacco use among adults has slowly decreased to 18.9%, smoking among adolescents (13–15 years old) has increased to 27.5%.[1] Notably, the increases in rates are driven by increases in tobacco use by young females.[4]

Tobacco smoke and its by-products affect the respiratory tract and lungs of adolescents, who either actively smoke or are exposed to secondhand smoke (SHS) produced by their parents, relatives, and/or friends.[5] Active smoking[6,7] and SHS[8,9] are associated with multiple adverse respiratory health outcomes including higher rates of asthma, infections of the upper and lower respiratory tract, and reduced lung function. Adolescents may be especially at risk because their lungs are still developing and active cigarette smoke and/or SHS exposure are considered to be health hazards to their respiratory health[10] and, therefore, pose a serious pediatric health problem.[11]

To date, global studies have confirmed that cigarette smoking by adults is the major cause of both COPD and chronic respiratory symptoms, such as chronic cough, increased phlegm production, wheezing, and dyspnea.[12–15] Additionally, active smoking by healthy adults has been reported to cause declines in lung function,[16,17] as evidenced by the accelerated loss of forced expiratory volume in 1 second (FEV_1), [18] and reductions in forced expiratory volume in 1 second/forced vital capacity ratio (FEV_1/FVC) and forced mid-expiratory flow rate ($FEF_{25\%–75\%}$).[19,20]

By comparison, fewer studies have examined the effects of active smoking and SHS exposure on the respiratory system of adolescents. The scarcity of research conducted among adolescents may be attributed to several limiting factors including: ethical considerations which prohibit the use of minor-aged youth in acute smoking experiments,[21,22] methodological difficulties inherent in health assessment studies of young people,[21,22] and a developing but incomplete understanding of the exact mechanisms responsible for causing the adverse effects observed on the respiratory health of adolescent smokers[23] and those exposed to SHS.[24]

However, increases in respiratory symptoms[25] and reductions in lung function[26] have been historically documented in adolescents who smoke and are exposed to SHS. It has been reported that respiratory problems such as asthma, cough, phlegm, and wheezing are significantly more likely to occur among adolescent smokers and those exposed to SHS than their nonsmoking counterparts.[27,28] More recent studies of schoolchildren who report actively smoking or being exposed to SHS have found increases in cough, phlegm production, wheezing, bronchial reactivity, IgE levels, eosinophilia, and sensitization to aeroallergens.[29–31] Considering these findings and the strong relationship of atopy and IgE to asthma,[31] active smoking and SHS exposure may not only alter the developing lungs structure and function[32,33] but may also augment the exposed adolescent's level of atopy[31] and subsequently increase their risk to develop asthma.[34,35]

Similarly, active smoking and SHS exposure in adolescence can have a significant effect on several pulmonary function parameters, including reductions in FEV_1, FEV_1/FVC, and $FEF_{25\%–75\%}$,[5,19,20,25,26] in some cases by as much as 5%–10%.[36] Moreover, a positive correlation has been reported between the respiratory symptoms and reduction in lung function of adolescents who do not smoke but are exposed to SHS and the number of cigarettes smoked by adults at their home.[26,37,38]

These findings are important because lung function tests may be used to identify deterioration of respiratory function among adolescents prior to the appearance of clinical symptoms. The resulting information can then be used to implement health promotion strategies that help prevent or reduce the incidence of respiratory diseases. Thus, the objective of the present study was to investigate the effects of smoking and SHS exposure on the respiratory health and lung function among eighth-grade students in Juárez, Mexico.

Methods

Study setting

The present study was conducted in Ciudad Juárez, Mexico. Ciudad Juárez stands on the Rio Grande, across the US border from its sister cities of El Paso, Texas, and Las Cruces, New Mexico. Ciudad Juárez is a growing industrial city in the state of Chihuahua and represents the eighth largest city in Mexico with a population of more than 1.3 million inhabitants, 42% of whom are reported to be less than 18 years old.[39]

Study design, study population, and sampling strategy

A cross-sectional study was conducted on a sample of convenience. The population studied comprised 300 eighth-grade students (137 male and 163 female), ages 13 to 15 years, who attended middle schools in Juárez, Mexico. Students were systematically selected (every third of three) from existing clinical files and recruited to participate during their annual medical checkup visit at three main community clinics within the city limits of Juárez, Mexico.

A sample size of 100 participants was selected from each clinic for a total of 300. The three clinics were selected on

the basis of their organizational size (≥25 health care staff members including doctors and nurses), number of complete adolescent patient records (≥300), and geographical location (within 20 km from the center of city).

The three medical directors of the community-based clinics were contacted using a letter prepared by the investigators through the School of Medicine, Universidad Autónoma de Ciudad Juárez (UACJ). The letter asked the medical directors to grant permission to the investigators to seek parental consent to recruit eighth-grade student participants and to be given access to their medical records.

Entry criteria

Entry criteria for the student participants in the study included the following: 1) eighth-grade student status in one of the middle schools in Juárez, Mexico; 2) complete medical records; 3) willingness to complete a questionnaire and undergo pulmonary function tests (PFTs); and 4) absence of a diagnosis of atopy or asthma by a clinician.

Data collection tools

Data gathering took place in two stages. The first stage involved a nurse-administered questionnaire. The questionnaire used in this study was a modified version of the Global Youth Tobacco Survey (GYTS) questionnaire with an additional section on respiratory health.[40] The GYTS questionnaire offered several advantages: it is a validated instrument; it is specifically developed for use with middle-school students; it could be completed in a short period of time (≤15 minutes); and the study investigators had used it in their previous research.[41,42]

Section 1 of the survey contained three questions pertaining to the students' demographic characteristics (additional information on socioeconomic status [SES] as determined by household income was extracted from administrative patient records). Section 2 contained three questions assessing the participating students' smoking practices. Section 3 contained four questions dealing with the students' self-reported exposure to SHS. Finally, Section 4 of the questionnaire contained eight questions on respiratory health. Questions in Sections 1–3 were categorical in nature and closed in format. Section 4 used a five-point Likert-type scale to score the eight respiratory symptoms (1= "Never" to 5= "Every day"). The questionnaire is shown in Table S1.

The second stage of data collection included the completion of PFTs by the adolescent participants in accordance with the American Thoracic Society/European Respiratory Society taskforce guidelines.[43,44] The PFTs measured in this study were the FEV_1, FEV_1/FVC, and $FEF_{25\%–75\%}$. These tests were performed by a blinded, trained physician using a computerized spirometer, Spirotrac 6800 (Vitalograph, Lenexa, KS, USA) equipped with an electronic sensor. The spirometer was calibrated through the use of the appropriate software at the beginning of each testing day. The best of three successfully completed maneuvers was used for analysis. PFTs were measured with the students in standing position and as appropriate for their height, weight, age, and sex.

Study outcomes

The study outcomes centered on evaluating the students lung function by spirometry (FEV_1, FEV_1/FVC, and $FEF_{25\%–75\%}$) and their respiratory health (smoking behavior and SHS exposure) by their self-reported responses to a standardized, nurse-administered respiratory questionnaire. The study outcomes were compared among the three distinct student groups: 1) nonsmokers/nonexposed to SHS; 2) nonsmokers/exposed to SHS; and 3) smokers.

Statistical analysis

The investigators used χ^2 tests to determine the comparability between the three groups of students on sociodemographic variables and smoking-related characteristics. Multivariant analysis of variance (MANOVA) and follow-up univariate analysis of variance (ANOVA) were used to compare the three groups based on age, sex, school setting, SES, lung function parameters, and presence and frequency of respiratory symptoms. All data analyses were conducted using the SPSS 18.0 statistical software package and the results were considered statistically significant at a value of $P<0.05$.

Ethical considerations

All study procedures and instruments were reviewed and approved by the Ethics Committees of each participating community clinic as well as the Institutional Review Board at UACJ. Prior to the participants' enrollment in the study, the investigators secured written parental informed consent and active student assent, as is culturally appropriate in Mexico. No monetary or nonmonetary incentive was offered to the participating students or their parents.

Results

Study subjects

There were 357 students invited to take part in the study; 300 (84%) agreed to participate, 52 refused, and five were ineligible because they had been previously diagnosed with asthma. Comprehensive recording of relevant medical

information took place for all 300 eighth-grade student participants. The participants' sociodemographic characteristics are presented in Table 1. Briefly, the majority of the students were 14 years old (85%) and slightly more than half were female (54%). The majority attended public schools (56%) and were of low SES (49%).

Smoking prevalence

In the present study, the self-reported student smoking prevalence was 29.6% (n=89), with another 49.1% of the students being nonsmokers/exposed to SHS and only 21.3% being nonsmokers/nonexposed to SHS. Of the 89 students who were smokers, 43.8% (n=39) indicated they had initiated smoking at or before the age of 10 years. Over a third of male students reported being smokers (37%); the proportion was significantly lower among females (23%). Almost 33% of students attending public schools were smokers; the proportion was significantly lower for those attending private schools. Smoking prevalence varied by sex, school setting, and SES, with male students ($P<0.001$), attending a public school setting ($P<0.001$), and belonging to the low SES category ($P<0.001$) having a significantly higher smoking prevalence (Table 1).

SHS exposure

The overall SHS exposure of students was 49.1%. Approximately, 69% of the male students reported being exposed to SHS. Moreover, female students ($P<0.001$) attending a private school setting ($P<0.001$) and belonging to a high SES category ($P<0.001$) were significantly less likely to have been exposed to SHS than their male, public school attending, low SES counterparts (Table 1).

PFTs

PFTs were performed to determine if the adolescent smokers and the nonsmokers/exposed to SHS experienced any adverse respiratory health effects when compared to the nonsmokers/nonexposed to SHS. The PFT results for the three groups are presented in Table 2. A consistent trend was observed toward a significant reduction of all three pulmonary function parameters measured between the three groups (Table 2). Additionally, it is worthy to note that the decrease in $FEF_{25\%-75\%}$ was significantly and inversely correlated with the number of cigarettes the adolescent students smoked per day ($P<0.001$). However, no statistically significant correlation was detected with FEV_1 or FEV_1/FVC and the number of cigarettes smoked per day ($P<0.430$ and $P<0.526$, respectively).

Respiratory symptoms

The investigators tested for differences between the three distinct groups (ie, nonsmokers/nonexposed to SHS, nonsmokers/exposed to SHS, and smokers) based on their self-reported frequencies of eight respiratory symptoms. The results of the comparisons are shown in Table 3. "Morning cough", "shortness of breath when walking", "shortness of breath during

Table 1 Sociodemographic variables by smoking status

Sociodemographic variables	Smoking status						
	Nonsmokers/ nonexposed to SHS n=64 (21.3%)	Nonsmokers/ exposed to SHS n=147 (49.1%)	Smokers n=89 (29.6%)	Total n=300 (100%)	*P*-value*		
					A	B	C
Age					<0.045	<0.350	<0.268
13 years old	10 (15.6)	4 (2.7)	9 (10.1)	23 (7.7)			
14 years old	49 (76.6)	133 (90.5)	72 (80.9)	254 (84.6)			
15 years old	5 (7.8)	10 (6.8)	8 (9.0)	23 (7.7)			
Sex					<0.001	<0.001	<0.378
Male	18 (28.1)	94 (63.9)	51 (57.3)	137 (45.7)			
Female	46 (71.9)	53 (36.1)	38 (42.7)	163 (54.3)			
School setting					<0.001	<0.001	<0.484
Public	26 (40.6)	87 (59.2)	55 (61.8)	168 (56.0)			
Private	38 (59.4)	60 (40.8)	34 (38.2)	132 (44.0)			
Socioeconomic status					<0.001	<0.001	<0.325
Low (<10,000 Mexican pesos)	13 (20.3)	81 (55.1)	53 (59.5)	147 (49.0)			
Middle (10,001–25,000 Mexican pesos)	21 (32.8)	45 (30.6)	22 (24.7)	88 (29.3)			
High (>25,000 Mexican pesos)	30 (46.9)	21 (14.3)	14 (15.8)	65 (21.7)			

Notes: *Sociodemographic distributions are significantly different at $P<0.05$ level using χ^2 tests. A, Test between nonsmokers/nonexposed to SHS and nonsmokers/exposed to SHS groups; B, test between nonsmokers/nonexposed to SHS and smokers groups; C, test between nonsmokers/exposed to SHS and smokers groups.
Abbreviation: SHS, secondhand smoke.

Table 2 Pulmonary function test variables by smoking status†

Pulmonary variables	Smoking status					
	Nonsmokers/nonexposed to SHS n=64	Nonsmokers/exposed to SHS n=147	Smokers n=89	*P*-value*		
				A	B	C
FEV_1	79.14±13.61	69.41±11.35	62.88±10.25	<0.010	<0.001	<0.255
FEV_1/FVC	94.88±21.88	88.75±15.75	83.50±14.15	<0.290	<0.010	<0.350
$FEF_{25\%–75\%}$	87.36±17.02	78.90±14.65	66.35±12.55	<0.010	<0.001	<0.040

Notes: †Mean ± standard deviation. *Pulmonary function test distributions are significantly different at $P<0.05$ level using χ^2 tests. A, Test between the nonsmokers/nonexposed to SHS and nonsmokers/exposed to SHS groups; B, test between the nonsmokers/nonexposed to SHS and smokers groups; C, test between the nonsmokers/exposed to SHS and smokers groups.
Abbreviations: SHS, secondhand smoke; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; $FEF_{25\%–75\%}$, forced mid-expiratory flow rate.

exercise", and "getting tired easily" were more prevalent among the adolescent smokers and the nonsmokers/exposed to SHS when compared to the nonsmokers/nonexposed to SHS. No significant differences were discovered with "daytime cough", "wheezing", "phlegm production", and "pain in the chest", although a consistent trend of higher prevalence was observed when the nonsmokers/nonexposed to SHS students were compared with the ones who were nonsmokers/exposed to SHS and those who smoked (Table 3).

Discussion

Overall, ~30% of the eighth-grade students who participated in this study indicated they were smokers and close to 50% self-reported being nonsmokers/exposed to SHS. These smoking and SHS exposure prevalence rates are consistent with the findings reported by previous research among adolescent students in Juárez, Mexico, which found a smoking prevalence and SHS exposure of 26.1% and 53.2%, respectively.[41]

Cigarette smoking and SHS exposure, to a lesser extent, are known to increase CO levels[45] and cause tissue hypoxia,[46] leading to shortness of breath, getting tired easily, and reduction in exercise tolerance.[47] This suggests that peripheral vasoconstriction, induced by the adrenergic effects of nicotine,[46] along with the production of CO impair the body's ability to efficiently diffuse and transport oxygen and act as added stressors in the precipitation of cardiovascular and respiratory disease.[48–50]

It is generally assumed that adolescent smokers may not have respiratory problems because of their relatively short smoking history. However, the results of the current study indicate that adolescents who were exposed to SHS and especially those who self-reported being smokers were at a substantially increased risk for developing smoking-related respiratory symptoms. Additionally, and even though smoking-related respiratory health problems do not fully manifest themselves until adulthood, the present study demonstrates the detrimental effects of smoking and SHS exposure on several pulmonary function parameters among adolescents.

Specifically, it was discovered that $FEF_{25\%–75\%}$, which demonstrates the function of small airways, was

Table 3 Respiratory symptom variables by smoking status†

Respiratory variables	Smoking status					
	Nonsmokers/nonexposed to SHS n=64	Nonsmokers/exposed to SHS n=147	Smokers n=89	*P*-value*		
				A	B	C
Morning cough	1.92±1.12	3.64±1.34	4.38±1.42	<0.001	<0.001	<0.040
Daytime cough	2.25±1.50	3.15±1.55	4.10±1.26	<0.180	<0.001	<0.020
Wheezing	1.45±0.46	2.74±1.08	3.20±1.24	<0.010	<0.001	<0.180
Phlegm production	2.02±1.17	3.00±0.92	3.26±1.34	<0.120	<0.010	<0.258
Shortness of breath when walking	1.28±0.98	3.10±1.25	3.90±1.38	<0.001	<0.001	<0.010
Shortness of breath during exercise	1.64±0.79	3.25±1.10	4.36±1.26	<0.001	<0.001	<0.010
Getting tired easily	1.40±0.88	3.10±1.28	3.60±1.16	<0.001	<0.001	<0.145
Pain in the chest	1.20±0.85	1.34±0.78	1.50±0.90	<0.380	<0.160	<0.320

Notes: †Mean ± standard deviation (1= Never, … , 5= Every day). *Respiratory symptoms distributions are significantly different at $P<0.05$ level using χ^2 tests. A, Test between the nonsmokers/nonexposed to SHS and nonsmokers/exposed to SHS groups; B, test between the nonsmokers/nonexposed to SHS and smokers groups; C, test between the nonsmokers/exposed to SHS and smokers groups.
Abbreviation: SHS, secondhand smoke.

significantly and inversely correlated with SHS exposure. Our results are in agreement with the findings of Casale et al,[51] who investigated the effect of SHS exposure on the pulmonary function of 143 children, ages 6–11 years old, and found the $FEF_{25\%–75\%}$ to be significantly reduced in the exposed group. Similarly, Dold et al[52] demonstrated an inverse correlation between the number of cigarettes smoked per day by parents and the pulmonary test results of their 9–11-year-old children. These results corroborate the more recent findings reported by Merghani and Saeed,[53] who studied 135 young male students (9–14 years old) in Khartoum, Sudan, and found the FEV_1 and FVC to be significantly lower in the SHS-exposed group than the nonsmoker control group.

Our study also found the $FEF_{25\%–75\%}$ to be significantly and inversely correlated with the number of cigarettes our adolescent participants smoked per day. Other studies confirm our findings. In 2005, Urrutia et al conducted a cross-sectional, multicenter survey of a general population of young adults in Europe. The authors reported FEV_1, FEV_1/FVC, and $FEF_{25\%–75\%}$ values that were significantly lower among young smokers.[54] Additionally, in 2008, Vianna et al studied the effects of smoking on the lung functions of 2,063 young people in Brazil and found a significant association between smoking and lower FEV_1/FVC ratio and respiratory symptoms.[55]

The present study has a number of significant strengths. Our results show that initiation of cigarette smoking and, to a lesser extent, exposure to SHS in adolescence leads to increased respiratory symptoms and reduction of PFT values. This is explained by virtue of the fact that cigarette smoke is known to elicit acute changes in respiratory function including alterations in resistance to airflow, coughing, and irritation of the airways.[5–10] Therefore, our research findings provide much-needed evidence in support of the need to implement tobacco reduction and cessation counseling for adolescents.

The findings of the present study are also constrained by a few limitations. Our study design was cross-sectional in nature, and thus, it can only imply association but not causation. The study used a convenience sampling of eighth-grade students, who attended one of the three participating community clinics. Consequently, the participants may not be representative of all students or even persons in this age group and the findings may not be generalizable. The data were collected only from adolescents who were current students. Therefore, the rates reported in this study may be underestimates. It has been well established in the literature that smoking rates among student dropouts are much higher than the rates of students who attend school regularly.[56] The majority of the primary outcome measures such as smoking behaviors, SHS exposure, and respiratory symptom scores were based on self-reporting by adolescents and, therefore, subject to under- or overreporting. However, the scientific literature has examined the validity of adolescents' self-reported smoking behaviors when compared to biological indicators (eg, cotinine) and found it to be in agreement.[57] Finally, our study did not account for the possible confounding effect that environmental pollution exposure may have played among the study participants.

Conclusion

Smoking prevalence and SHS exposure was high among eighth-grade students, especially among males, who resided in a low socioeconomic setting in Ciudad Juárez, Mexico. Our findings suggest that initiation of cigarette smoking and, to a lesser extent, exposure to SHS in adolescence leads to increased respiratory symptoms and reduction of PFT values. To be most effective, public health initiatives that aim to prevent smoking initiation, assist in cessation, and lessen SHS exposure of adolescents need to be school-based and employed as early as middle school.

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Disclosure

The authors report no conflicts of interest in this work.

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Supplementary material

Table S1 Adaptation of the Global Youth Tobacco Survey questionnaire

Demographic characteristics		
How old are you?	_____ years old	
What is your sex?	a. Male	b. Female
What kind of school do you attend?	a. Public	b. Private
Smoking behaviors		
Ever smoked a full cigarette?	a. Yes	b. No
Started smoking at or before 10 years old?	a. Yes	b. No
If yes, how old were you when you started?	_____ years old	
Currently smoke?	a. Yes	b. No
Have you smoked a cigarette, even if only one puff, in the last 30 days?	a. Yes	b. No
Secondhand smoke exposure		
Do you have one or more parents who smoke?		
If yes, who?	a. Yes	b. No
a. Father		
b. Mother		
c. Both		
Do you have one or more close friends who smoke?	a. Yes	b. No
Do you live in a home where in the last 30 days others smoked in your presence?	a. Yes	b. No
In the last 30 days, were you around others who smoked in places outside your home?	a. Yes	b. No
Respiratory symptoms*		
In the last 30 days, have you experienced one of the following?		

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Everyday (5)
Morning cough					
Daytime cough					
Wheezing					
Phlegm production					
Shortness of breath when walking					
Shortness of breath during exercise					
Getting tired easily					
Pain in the chest					

Notes: *All items are weighted equally. Mean score is calculated across all items within each domain.