Original Investigation

Association of Smoke-Free Laws With Lower Percentages of New and Current Smokers Among Adolescents and Young Adults
An 11-Year Longitudinal Study

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IMPORTANCE Smoke-free laws are associated with a lower prevalence of smoking.

OBJECTIVE To quantify the effect of 100% smoke-free laws on the smoking behavior of adolescents and young adults in a longitudinal analysis.

DESIGN, SETTING, AND PARTICIPANTS Pooled logistic regression and zero-inflated negative binomial regression analysis of participants in the National Longitudinal Survey of Youth 1997 (data from 1997 to 2007), with complete data on initiation of smoking (n = 4098) and number of days respondents reported smoking in the past 30 days (n = 3913).

EXPOSURES Laws for 100% smoke-free workplaces, laws for 100% smoke-free bars, and state cigarette taxes.

MAIN OUTCOMES AND MEASURES Smoking initiation (first report of smoking cigarette), current (for 30 days) smoking, and number of days respondents reported smoking in the past 30 days among current smokers.

RESULTS Laws for 100% smoke-free workplaces, but not bars, were associated with significantly lower odds of initiating smoking (odds ratio, 0.66 [95% CI, 0.44-0.99]). Laws for 100% smoke-free bars were associated with lower odds of being a current smoker (odds ratio, 0.80 [95% CI, 0.71-0.90]) and fewer days of smoking (incidence rate ratio, 0.85 [95% CI, 0.80-0.90]) among current smokers. Taxes were associated with a lower percentage of new smokers but not current smokers among adolescents and young adults. The effect of smoke-free workplace laws on smoking initiation is equivalent to a $1.57 (in 2007 dollars) tax increase. Smoke-free bar laws are associated with lower rates of current smoking, as well as a decrease in the number of days reported smoking among current smokers.

CONCLUSIONS AND RELEVANCE Smoke-free laws are an important tobacco control tool. They not only protect bystanders from secondhand smoke but also contribute to less smoking among adolescents and young adults.

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JAMA Pediatr. 2015;169(9):e152285. doi:10.1001/jamapediatrics.2015.2285

Strong smoke-free laws are an effective public health intervention[1,2] that not only reduce secondhand smoke exposure but are followed by substantial drops in hospitalizations for cardiac and respiratory diseases and lower rates of preterm birth.[3-8] Smoke-free workplace, restaurant, and bar laws are associated with increased voluntary smoke-free policies in the home[9] and less secondhand smoke exposure for children.[10,11] One quasiexperimental study[12] reported 4- to 28-fold reductions in the prevalence of smoking among workers in smoke-free workplaces, restaurants, and bars. Among smokers, 46% reported an increase in motivation to quit, whereas 80% of former smokers said that the laws helped them to quit. A systematic review[13] of the effect of smoke-free laws found that smoke-free workplaces were associated with a 3.8% reduction in the prevalence of smoking and approximately 3 less cigarettes smoked per day per smoker.

There is also some evidence that smoke-free laws influence the smoking behavior of youths.[14,15] Smoke-free laws and policies reduce the visibility of smoking to youth, reflecting a decrease in the social acceptability of smoking.[16] Children in smoke-free homes and youths who worked in smoke-free workplaces are less likely to be smokers.[17] An economic analysis found that smoking restrictions were related to a 3% to 4% reduction in the prevalence of smoking among youths.[18] Although the literature supports an effect of smoke-free laws on adolescent and young adult smoking, all but 2 of the previous studies used repeated cross-sectional data. One study[2] used a longitudinal design, obtaining baseline measures and laws to compare against follow-up behavioral data collected 2 years later. In that study,[2] adolescents who lived in areas with strong smoke-free laws were less likely to become established smokers compared with adolescents who lived in areas that were not covered by strong smoke-free laws. However, the study[2] was geographically limited to Massachusetts and by only 2 time points. Another longitudinal study[19] using 11 years of data from the National Longitudinal Survey of Youth 1997 (NLSY97) found that, compared with no law, state smoke-free bar laws with exemptions, but not 100% laws (vs no law), were associated with a lower probability of initiating smoking. That study,[19] however, included only state, not local, laws, which is an important limitation because much of the strongest smoking legislation is at the local level. That study[19] focused on the effects of bar laws only and treated restaurant laws and workplace laws as covariates.

We used the NLSY97 to conduct a longitudinal analysis of the effects of 100% smoke-free laws enacted at both state and local levels on individual smoking behaviors of youths from 1997 to 2007. Using pooled logistic regression and zero-inflated negative binomial regression, we found that the presence of a 100% smoke-free workplace law is associated with the initiation of adolescent smoking and that the presence of a 100% smoke-free bar law is associated with current smoking and the level of cigarette consumption among current smokers.

At a Glance

- This study uses longitudinal data on adolescents and young adults from 1997 to 2007 to assess whether smoke-free laws and state cigarette taxes were associated with smoking.
- Laws for 100% smoke-free workplaces and cigarette taxes were associated with lower odds of initiating smoking (odds ratio, 0.66 [95% CI, 0.44-0.99]).
- Laws for 100% smoke-free bars were associated with lower odds of being a current smoker (odds ratio, 0.80 [95% CI, 0.71-0.90]) and fewer days of smoking (incidence rate ratio, 0.85 [95% CI, 0.80-0.90]) among current smokers.
- Taxes were associated with a lower percentage of new smokers but not current smokers among adolescents and young adults.

Methods

Smoking Behavior and Individual Characteristics

Longitudinal data on individual characteristics, including smoking behaviors, comes from the US Bureau of Labor Statistics NLSY97,[20] a longitudinal cohort study that provides annual data on youths who were 12 to 18 years of age at baseline (in 1997) and between 25 and 31 years of age at wave 14 (in 2011) and that was designed to study youths as they transition from adolescence to adults in the workforce. The NLSY97 includes 8984 respondents (98 924 person-years of data across 11 years) selected from housing units within primary sampling units obtained from the National Opinion Research Center's 1990 master probability sample of the United States and oversampled non-Hispanic black and Hispanic individuals.[21] Owing to varying levels of attrition and potential reentry into the study across waves of data, 4098 (initiation) and 3913 (cigarette consumption and smoking status) respondents were included in the final analyses.

Sociodemographic Variables

Sex was coded as male or female. Household income at baseline (1997) was coded as an ordinal variable (beginning at 0) as below the federal poverty level, at the poverty level to 199% of the poverty level, 200% to 299% of the poverty level, and 300% or more of the poverty level. Race/ethnicity was coded with separate indicator variables for non-Hispanic black, Hispanic, and mixed race. Current age was entered for each year to account for slight variations in time between waves of data collection.

Smoking Initiation

At baseline in 1997, respondents were asked "Have you ever smoked a cigarette?" In each subsequent wave, respondents were asked whether they had smoked since the last interview. Respondents were coded 0 if they had never smoked and 1 if they reported having smoked since the last interview for that and subsequent waves. When respondents first reported smoking a cigarette, they were removed as observations from subsequent waves of data.

Cigarette Consumption and Smoking Status

Cigarette consumption was measured by the number of days the respondent reported smoking in the past 30 days. Respondents who reported smoking at least 1 day in the past 30 days were categorized as current smokers.

State Cigarette Taxes

Annual average state cigarette tax rates were obtained from *The Tax Burden on Tobacco*.[22] Nominal taxes were converted

to constant 2007 dollars using the average Consumer Price Index for prices of all goods and services purchased for consumption by urban households available from the US Bureau of Labor Statistics (http://www.bls.gov/data/inflation_calculator.htm). We lagged the tax variable by 1 year so that the policy change preceded the behavior measures in our longitudinal models.

Smoke-Free Law Coverage

The NLSY provides county-level geocodes (Federal Information Processing Standard codes) for each respondent. Some smoke-free laws apply to entire states, some to entire counties, some only to unincorporated areas of counties, and some only to specific cities within counties. As described herein and in Gonzalez et al,[23] we separately merged data on smoke-free law coverage for (private) workplaces, restaurants, and bars from the American Nonsmokers' Rights Foundation Local Ordinance Database,[24] which tracks state and local tobacco control laws and regulations over time and across venues, with data from the US Census to compute the probability that a respondent was covered by a 100% smoke-free law each year between 1997 and 2007 based on their current county of residence. Analysts at the American Nonsmokers' Rights Foundation code each law across all jurisdictions into 5 categories: 100% smoke-free (completely smoke-free, without exception), qualified (some exceptions, such as a separate smoking room), moderate (some coverage, but with more exceptions), weak, and no coverage. Our analysis compares respondents living under 100% smoke-free laws with those living under less-than-100% smoke-free laws (qualified, moderate, weak, or no coverage) because previous research demonstrates that 100% smoke-free policies have a substantially larger effect on behavior and health than weaker policies.

Specifically, smoke-free coverage was quantified as the probability of a county resident being covered by a 100% smoke-free law, computed as the percentage of a county population that was covered by a 100% smoke-free law vs a less-than-100% smoke-free law, for each venue taking into account state laws, county laws, and whether or not county laws applied inside cities in that county (which varies from state to state).[23] In 100% smoke-free states or counties with jurisdiction over the incorporated areas, the population covered by a law was the total county population, and the probability of an individual in that county being covered was 1.00. In counties that only had jurisdiction over unincorporated areas or for counties in which cities or towns but not the county enacted laws, the probability was the fraction of the county population covered by the law (<1.00). We lagged smoke-free law variables by 1 year so that the policy change preceded the behavior measures in our longitudinal models.

Statistical Analysis

We conducted 2 analyses, one to evaluate the determinants of initiation of smoking and another to estimate the determinants of current smoking and, among current smokers, intensity of smoking (number of days respondents reported smoking in the last month). The choice of statistical technique was dictated by 3 features of the data. First, the longitudinal design of the data with a dichotomous outcome variable (initiation of smoking) warranted using discrete time survival analysis in which the probability of initiation across time could be predicted by the independent variables (smoke-free laws, sociodemographic variables, and cigarette prices). Second, the data have a nested structure in which behaviors across time are nested within individuals, who are nested within counties. This structure required using a statistical technique that takes into account covariance of behaviors within individuals and individuals within counties. Third, the NLSY97 uses complex sampling with time-varying county-level variables because respondents could move from county to county. This feature of the data precluded the use of other multilevel modeling techniques (eg, hierarchical linear modeling) and led us to use pooled analyses, which involved clustering data at the county level (as opposed to the individual level).

Specifically, we used pooled logistic regression to model initiation of smoking using a person-period data structure (ie, individuals have 1 record for each wave within the data set) and zero-inflated negative binomial regression to model cigarette consumption and current smoking status. These techniques allowed us to obtain estimates that mirror traditional discrete-time survival analysis while accounting for the complex survey design and the fact that people moved into different jurisdictions (and so might be subject to different laws) over time.[25]

We used the same person-period data structure to conduct a zero-inflated negative binomial regression on the number of days respondents reported smoking in order to identify determinants of current smoking and smoking intensity among current smokers. Zero-inflated negative binomial regression was used to account for the high frequency of zeros in the number of days respondents reported smoking. In the zero-inflated negative binomial regression, 2 processes are estimated via an inflation component and a count component. First, the inflation component uses logistic regression to estimate the odds of reports of zero (nonsmoker) compared with reports of nonzero (smoker). In the context of our study, the inflation component represents the odds of nonsmoker status (never smoking or, if smoking has occurred in the past, quitting smoking) compared with the odds of current smoker status (reporting the number of days of smoking in the past 30 days). For ease of interpretation, this odds ratio was converted to odds of being a smoker by dividing the original odds of being a nonsmoker into 1.00. The negative binomial regression portion models number of days respondents reported smoking for smokers. The models tested included the number of days respondents reported smoking across time predicted by the probability of being covered by workplace, restaurant, and bar laws, as well as the demographic covariates.

All analyses included weights provided by the Bureau of Labor Statistics to adjust for sampling design (probability of respondent selection) and nonresponse and to match the demographics of the sample to the general US population.[21] Calculations were conducted with Stata version 12 (StataCorp) using complex survey sampling algorithms.

This research was exempt from institutional review board approval because it used a deidentified data set obtained from the US Bureau of Labor Statistics.

Results

Between 1997 and 2007, 27.8% of the respondents never smoked a cigarette. Among those who initiated smoking, most initiated by 1997, when the mean age was 14.3 years, with 39.1% of respondents reporting smoking a cigarette. An additional 9.6% of respondents reported smoking by 1998, when the mean age was 15.4 years. Rates of initiation decreased rapidly in subsequent waves, with only 0.8% reporting first cigarette use 10 years later (2007), when the mean age was 24.4 years. Among smoking initiates, the number of days of smoking increased from 3.8 in 1997 to 11.2 in 2004 (when the mean age was 21.4 years), where it plateaued to 10.9 in 2007 (when the mean age was 24.4 years).

Consistent with reports based on the number and coverage of laws,[26] respondents reported increased coverage over time, particularly after 2000. No respondent in 1997 had a 100% probability of being covered by a 100% smoke-free workplace law. In 1997, only 11.6% of the respondents had a 100% probability of being covered by a smoke-free restaurant law. Only 11.6% of the respondents had 100% probability of being covered by a smoke-free bar law. In contrast, in 2007, 27.3%, 43.3%, and 36.0% of respondents had a 100% probability of being covered by smoke-free workplace, restaurant, and bar laws, respectively.

Collinearity diagnostics in models containing all variables indicated significant multicollinearity between the smoke-free law variables (with a variance inflation factor [VIF] of 11.81 for restaurants and 9.74 for bars; all other VIFs were 1.97 or lower). Specifically, restaurant and bar laws were highly correlated (r = 0.95); the probability of coverage was the same (ie, within 0.1%) for both types of laws for 87.2% of the data points, with restaurant but not bar laws for 12.2% of the points and bar but not restaurant laws for 0.6% of the points. Therefore, rather than including all 3 smoke-free laws in our analyses, we used bar laws as an indication of smoke-free laws in the hospitality sector. In the final model, the VIFs for the workplace and bar law variables were 1.54 and 1.41, respectively, with all other VIFs 1.33 or smaller.

Smoking Initiation

Demographics

Sex, income, race/ethnicity, and age were significantly related to initiation of smoking (**Table 1**). Male youths were more likely to start smoking than female youths. As the income category increased, the odds of initiating smoking decreased. Black youths had lower odds of initiating smoking than non-Hispanic white youths. For each 1-year increase in age, there was a 0.80 decrease in the odds of starting to smoke.

State Cigarette Taxes

Cigarette taxes were significantly related to initiation of smoking. For each $0.10 increase in taxes, the odds of starting to smoke decreased by a factor of 0.97.

Smoke-Free Laws

The presence of a 100% smoke-free workplace law was significantly associated with the initiation of smoking among youths 1 year later. Youths who were covered by a 100% smoke-free workplace law had only 0.66 the odds of starting to smoke as youths who were not covered by strong (100%) workplace laws. Smoke-free bar laws did not predict the initiation of smoking (P = .90).

Table 1. Initiation of Smoking Among Respondents (Pooled Logistic Regression)[a]

Variable	Odds Ratio (95% CI)
Law (yes vs no)[b]	
Workplace	0.66 (0.44-0.99)
Bar	1.01 (0.82-1.25)
State cigarette tax (per $0.10 in 2007 dollars)[b]	0.97 (0.96-0.99)
Male sex	1.10 (1.01-1.21)
Income[c]	0.95 (0.91-0.995)
Race/Ethnicity	
Non-Hispanic white	1 [Reference]
Black	0.60 (0.53-0.68)
Hispanic	0.86 (0.74-1.003)
Mixed race	1.14 (0.77-1.69)
Age (per year)	0.80 (0.79-0.82)

[a] A total of 4098 respondents had nonmissing values for all variables in all years of data available (1997-2007).

[b] Lagged by 1 year; the corresponding tax elasticity is 0.19.

[c] Per income group above the federal poverty level (0 = below poverty level, 1 = poverty level to 199% of poverty level, 2 = 200%-299% of poverty level, and 3 = 300% or more of above poverty level).

Current Smoking Status and Number of Days Reported Smoking

Demographics

Sex, income, race/ethnicity, and age were significantly related to current smoking status and cigarette consumption (**Table 2**). Being male and older were associated with higher odds of being a current smoker. Black and Hispanic respondents had significantly lower odds of being current smokers. As income increased, the odds of being a current smoker decreased.

There was not a significant difference in the number of days reported smoking between male and female respondents (P = .06). As income increased, people smoked fewer numbers of days. Black and Hispanic youths smoked a fewer number of days than did white youths. The number of days reported smoking increased with age.

State Cigarette Taxes

Tax was not a significant predictor of current smoking (P = .79) or number of days reported smoking (P = .38).

Smoke-Free Laws

Smoke-free bar laws (implemented 1 year prior) were associated with current smoking status and number of days respondents reported smoking. Youths who were covered by 100% smoke-free bar laws had only 0.80 the odds of starting to smoke as youth who were not covered by strong (100%) bar laws. Smoke-free bar laws were also associated with the number of

Table 2. Cigarette Consumption and Current Smoking (Zero-Inflated Negative Binomial Regression)[a]

Variable	Current Smoking Status, OR (95% CI)	No. of Days Reported Smoking, IRR (95% CI)
Law (yes vs no)[b]		
Workplace	0.93 (0.80-1.08)	1.03 (0.96-1.09)
Bar	0.80 (0.71-0.90)	0.85 (0.80-0.90)
State cigarette tax (per $0.10 in 2007 dollars)[b]	1.00 (0.99-1.01)	0.998 (0.995-1.002)
Male sex	1.17 (1.08-1.26)	1.03 (1.00-1.06)
Income[c]	0.87 (0.84-0.91)	0.95 (0.93-0.96)
Race/Ethnicity		
Non-Hispanic white	1 [Reference]	1 [Reference]
Black	0.47 (0.42-0.54)	0.81 (0.77-0.84)
Hispanic	0.60 (0.52-0.68)	0.77 (0.72-0.82)
Mixed Race	1.01 (0.73-1.39)	1.02 (0.92-1.13)
Age (per year)	1.10 (1.09-1.11)	1.034 (1.029-1.038)

Abbreviations: IRR, incidence rate ratio; OR, odds ratio.

[a] A total of 4098 respondents had nonmissing values for all variables in all years of data available (1997-2007).

[b] Lagged by 1 year; the corresponding tax elasticities are not significantly different from 0.

[c] Per income group above the federal poverty level (0 = below poverty level, 1 = poverty level to 199% of poverty level, 2 = 200%-299% of poverty level, and 3 = 300% or more of above poverty level).

days respondents reported smoking. Youths who were covered by 100% smoke-free bar laws smoked 85% fewer days than youths who were not covered by bar laws.

Discussion

To our knowledge, the present study, using national longitudinal data, is the first demonstration of the strong, protective effect of 100% smoke-free laws at the state and local level against smoking among adolescents and young adults. Adolescents and young adults who live in places with 100% smoke-free workplace laws are less likely to start smoking compared with those who do not live under comprehensive legislation. Adolescents and young adults who live in areas with 100% smoke-free bar laws are less likely to be current smokers and, among current smokers, smoke on fewer days, compared with those not protected by strong laws. Higher cigarette taxes are followed by lower odds of smoking initiation but not current smoking or number of days reported smoking. The effects of taxes and smoke-free laws are almost completely independent (VIF = 1.27 for cigarette tax). Smoke-free workplace laws have a powerful effect on the initiation of smoking, equivalent to a $1.57 (in 2007 dollars) tax increase.

The longitudinal nature of the data indicates a predictive relationship between smoke-free laws and initiation of smoking among youths, current smoking status, and cigarette consumption because the laws preceded the recorded behaviors by 1 year. Therefore, one can interpret the findings to mean that institution of 100% smoke-free laws reduces a youth's odds of initiating smoking, current smoking, and cigarette consumption 1 year later and beyond. The effects of smoke-free laws are robust, with effects similar to or larger than other determinants of smoking, including age, sex, race/ethnicity, and poverty level.

The results also demonstrate that the effect of smoke-free policies on smoking among youth are nuanced. Laws affect different aspects of smoking behavior (initiation, current smoking status, and current cigarette consumption) at different points in the life span because the direct effects (preventing people from smoking in the venue) and indirect effects (impacting social norms and views around smoking) of these policies vary with age. Because the initiation of smoking occurs for most youth before they enter the workplace, smoke-free workplace laws likely affect the initiation of smoking by impacting social norms and views around smoking. Bar laws may not affect the initiation of smoking because adolescents have limited exposure to these venues before initiation occurs. However, later in life, when they frequent these venues as young adults, these laws may have direct effects on current smoking status and cigarette consumption.

Our conclusions are generally consistent with the one other analysis[19] of smoking behavior using the NLSY97, which, like the present analysis, did not find a significant association between state-level 100% smoke-free bar laws and the initiation of smoking. The study by Shang[19] did not examine the direct effects of workplace laws but only included a composite measure of state-level smoke-free laws in 11 venues. Shang[19] examined bar laws as predictors of relapse (where the bar laws deterred smoking relapse in adults who were 21 years of age or older) but not number of days of smoking or probability of being a current smoker. The present study is based on a more robust measure of coverage of smoking restrictions than the earlier study by Shang,[19] which examined only state laws and did not isolate the possible influence of workplace laws on behavior. Another difference is that the study by Shang[19] used "no law" as the reference, whereas our analysis uses less than 100% smoke-free coverage (including no law) as the reference group. As a result, Shang[19] found that smoke-free bar laws with exemptions (<100% smoke-free law vs no law) deterred initiation of smoking while 100% smoke-free laws did not. One possible explanation is that Shang[19] did not include local laws; another explanation is that the proportion of youths covered by 100% smoke-free laws was smaller than the proportion covered by laws with exemptions.

Although the current analysis accounts for clustering at the county level, the analysis was not able to account for potential individual-level variance. In particular, the analysis examined behavior across time, nested within counties in the United States. In addition, it is possible that the current analyses failed to detect a relationship between bar laws and initiation of smoking because bar laws were not common when most initiations occurred.

Conclusions

Smoke-free laws are an important tobacco control tool. They not only protect bystanders from secondhand smoke but also deter adolescents from initiating smoking and young adults from being current smokers.

ARTICLE INFORMATION

Accepted for Publication: July 10, 2015.

Published Online: September 8, 2015. doi:10.1001/jamapediatrics.2015.2285.

Author Contributions: Drs Song and Glantz had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Glantz.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Song, Dutra.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: All authors.
Obtained funding: Glantz.
Administrative, technical, or material support: Glantz.
Study supervision: Song, Glantz.

Conflict of Interest Disclosures: None reported.

Funding/Support: This work was funded by National Cancer Institute grants CA-113710 (Dr Dutra), CA-060121 (Drs Glantz and Song), and U01 CA154240 (Dr Neilands) and National Institute on Minority Health and Health Disparities grant P60 MD006902 (Dr Neilands).

Role of the Funder/Sponsor: The funding agencies had no role in the design and conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: This research was conducted with restricted access to Bureau of Labor Statistics data. The views expressed here do not necessarily reflect the views of the Bureau of Labor Statistics.

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