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RESEARCH REPORT

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A longitudinal analysis of smoke-free laws and smoking initiation disparities among young adults in the United States

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Abstract

Background and Aims: Tobacco control policies may differentially impact smoking initiation among socio-demographic groups. We measured longitudinal associations between exposure to smoke-free laws in grade 12 (modal age 18 years) and patterns of smoking initiation in the United States.

Design: Prospective longitudinal analysis.

Setting and Participants: We used data on US young adults sampled at modal age 18 years from the Monitoring the Future Survey. Baseline data were collected between 2000 and 2017, with the last year of follow-up in 2018. The sample number varied by outcome and time-point, ranging from 7314 to 17 702.

Measurements: Smoke-free law coverage in work-places and hospitality venues (restaurants/bars) was measured as the percentage of the county population covered by each type of law. We examined associations with any past 30-day smoking initiation and daily smoking initiation at modal ages 19/20, 21/22 and 23/24, using Poisson regression and calculating average marginal effects. We explored effect modification by sex, race/ethnicity and parental education by testing the significance of interaction terms.

Findings: Work-place law coverage at modal age 18 was associated with a lower probability of daily smoking initiation at modal ages 21/22 [−2.4 percentage points (p.p.); 95% confidence interval (CI) = −3.9, −0.9] and 23/24 (−2.0 p.p.; 95% CI = −3.9, −0.2). Hospitality law coverage was associated with a lower probability of daily smoking initiation at modal ages 19/20 (−1.6 p.p.; 95% CI = −2.8, −0.4), 21/22 (−2.3 p.p.; 95% CI = −3.7, −0.9) and 23/24 (−1.8 p.p.; 95% CI = −3.6, −0.0). Findings were inconclusive with regard to associations with any past 30-day smoking initiation and with regard to effect modification, after adjusting for multiple testing.

Conclusions: Exposure to smoke-free laws at age 18 appears to be prospectively associated with reduced daily smoking initiation 1–6 years later.

KEYWORDS
Health disparities, health equity, public policy, smoking initiation, smoke-free law, tobacco

INTRODUCTION

While youth smoking has declined in recent years, nearly 8% of young adults aged 18–24 years in the United States reported smoking cigarettes 'every day' or 'some days' in 2018 [1]. Moreover, heterogeneous patterns of smoking initiation among youth and young adults are precursors to persistent socio-economic disparities in adult smoking behavior. For example, youth from households with lower

socio-economic status (SES) are more likely to initiate smoking compared to youth from high-SES households [2, 3]. Intervening to prevent youth smoking remains a focus of tobacco control policies [4] and is essential to addressing ongoing disparities in tobacco use.

During the past several decades in the United States there has been a substantial increase in the population covered by smoke-free laws which restrict smoking in work-places and public spaces [5]. For example, the proportion of the US population covered by smoke-free laws in private work-places rose from 3% in 2000 [6] to more than 76% in April 2021 [7]. These laws have been shown to be associated with reductions in youth and young adult smoking in the United States [8–13] and in Europe [14, 15], but the majority of evidence has been generated from cross-sectional, rather than longitudinal, data. A prospective analysis of 1997–2007 data from the US-based National Longitudinal Survey of Youth (NLSY) found that smoke-free work-place laws, but not smoke-free bar laws, were associated with reduced odds of smoking initiation among youth and young adults [16]. An additional study using 1997–2009 NLSY data found that state-level smoke-free bar laws with exemptions (e.g. designated smoking areas) were associated with reductions in 'one-puff', daily and heavy smoking initiation [17]. A longitudinal study using data from Massachusetts (2001–06) found that restaurant smoke-free policies were associated with reduced odds of youth progressing from experimentation to established smoking [18]. While these studies suggest that smoke-free laws may lessen the likelihood of smoking initiation, they are limited to using data from the 1990s and early 2000s [16–18], the period when these policies were relatively novel. In some cases studies are further limited by examining only state-level smoke-free laws [17], which ignores exposures to local smoke-free policies, even though local jurisdictions often enact smoking restrictions prior to state governments.

Importantly, prior studies have not systematically evaluated the relationship between smoke-free laws and disparities in smoking initiation using longitudinal data. Cross-sectional studies suggest that smoke-free laws may not be uniformly associated with youth smoking outcomes among population subgroups [8, 19]. For example, a prior cross-sectional study using data on 8th-, 10th- and 12th-graders from the Monitoring the Future (MTF) study found that smoke-free laws were only significantly associated with reduced smoking prevalence among white males [19], while another found significant associations between smoke-free laws and reduced smoking among the full sample and among male and high-SES subsamples [8]. Prospective studies are needed to more clearly ascertain whether smoke-free laws have differential associations with smoking initiation.

In this study, we used data from a large survey of US 12th-graders (modal age 18) to examine the relationship between smoke-free law coverage in work-places and hospitality venues (restaurants or bars) and two smoking initiation outcomes: initiation to any past 30-day smoking among baseline never smokers and initiation to daily smoking among those who indicated that they were non-smokers or non-daily smokers at baseline. Study participants were sampled at baseline between 2000 and 2017 and were followed prospectively for up to 6 years. We explored associations between smoke-free law coverage at modal age 18 and smoking status at modal ages 19/20, 21/22 and 23/24. We further examined whether associations between smoke-free laws and smoking initiation varied by sex, race/ethnicity and parental education.

METHODS

Design and participants

We used data from the longitudinal arm of the MTF study, with baseline years from 2000 to 2017. The MTF study has collected data annually from nationally representative samples of high school seniors since 1975 [20]. From each senior year cohort (modal age 18), a subsample of approximately 2450 students is selected for longitudinal follow-up [21]. Although the baseline MTF is a probability sample of US students in the 12th grade, this subsampling involves a degree of potentially non-random selection due to the need for contact information. It is randomly split into two halves to be followed every other year. Our analyses consisted of data from follow-ups at modal ages 19/20, 21/22 and 23/24, which were collected in 2001–18. The analytical sample sizes varied by outcome variable and modal age. At modal age 19/20, the analytical sample ranged from 10 917 (any smoking initiation analysis) to 17 702 (daily smoking initiation analysis). By modal age 23/24 the analytical samples were reduced to 7314 and 12 292, respectively, due to attrition.

Smoking outcome variables

The primary outcomes at follow-up were any smoking initiation and daily smoking initiation. Any smoking initiation was defined as smoking any cigarettes in the past 30 days, assessed among baseline never smokers. Initiation to daily smoking captured whether the participant smoked at least one cigarette per day in the past 30 days versus none or non-daily smoking, assessed among a baseline sample that included all current non-smokers and non-daily smokers.

Smoke-free laws

The key independent variables were county-level smoke-free law coverage of work-places and hospitality venues (restaurants or bars) at each individual's baseline time-point (grade 12, modal age 18), matched on high school county location. We used data on smoke-free law coverage from the American Nonsmokers' Rights Foundation (ANRF) Tobacco Control Laws Database [22] and included information on laws passed at the city, county and state level. We combined smoke-free law data with Census Bureau population data [23] to calculate the percentage of the county population covered by each type of smoke-free law, following methods described in previous literature [6, 24]. Laws were considered present only if they met ANRF's standardized criteria for '100% smoke-free' definitions [25]. Because

smoke-free laws in restaurants and bars were highly collinear, we combined these laws into a single variable (hospitality law coverage) representing coverage by a restaurant or bar law.

Effect modification variables

We examined the potential for differential associations among three socio-demographic variables: sex (male, female); race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic Asian, other non-Hispanic); and highest level of parental education (high school or less, some college, college or higher). We chose these variables due to observed differences in smoking patterns by sex, race/ethnicity and SES [26]. We used parental education as a marker for household SES, following examples in prior literature [8].

State-level covariates

We included several state-level covariates to adjust for possible contextual factors that might impact the likelihood of smoke-free law coverage and smoking initiation. We included variables representing the racial/ethnic composition of each state (percentage of black and Hispanic residents) using data from the Survey of Epidemiology and End Results (SEER) program [27] and variables representing the percentage of the state population living below the poverty line, using data from the University of Kentucky's Center for Poverty Research [28]. We adjusted for the proportion of the state population with a bachelor's degree or higher using data from the United States Census Bureau (2000) [29] and from the American Community Survey (2005–17) [30], with linear interpolation between 2000 and 2005. To control for tobacco taxation, we included a variable representing the annual average cost of a cigarette pack using data from the Centers for Disease Control and Prevention (CDC) [31], with adjustment for inflation [32]. Finally, we included covariates to control for four census regions (Northeast, Midwest, South and West). All covariates were based on the state of the participant's school at baseline.

Statistical analysis

We conducted modified Poisson regression models with a sandwich variance estimator to examine the relationship between each type of baseline smoke-free measure and our two smoking outcomes at modal ages 19/20, 21/22 and 23/24. We chose Poisson models, rather than logistic models, in order to estimate relative risk [33]. We also transformed results from multiplicative models to estimate differences in the probability of each outcome using average marginal effects (AMEs) [34].

We explored differential associations by sex, race/ethnicity and parental education by including interaction terms in separate models. We examined the significance of interactions on both the multiplicative and additive scale, although we focused upon the additive scale, as it is often regarded as the most relevant scale for assessing interactions in public health [35]. Additive scale interactions were explored using AMEs. To adjust for multiple testing, we applied a Benjamini–Hochberg correction with the false discovery rate at 5% across the interaction models for each outcome and each modal age [36].

All analyses incorporated weights to account for attrition, oversampling of drug users and the complex survey design of the MTF study [37]. We performed multiple imputation for missing values via sequential regression modeling using IVEware version 0.3 [38]. A description of the attrition weights and multiple imputation process is included in the Supporting information.

In sensitivity analyses, we tested whether the inclusion of additional follow-up characteristics (highest degree earned at follow-up, employment status at follow-up and full-time student status at follow-up) impacted results. We also examined interactions between each smoke-free measure and the aforementioned follow-up covariates, and tested whether results derived from complete-case data were consistent with results using multiple-imputed data. We assessed whether results were robust when excluding respondents who reported that they lived in a different state from their high school during the follow-up period. While we hypothesized that state-level covariates would be relevant confounding variables, given that most individuals in the US are covered by state-level smoke-free laws, we conducted a separate analysis that also included adjustment for county-level covariates using 5-year estimates from the American Community Survey, as well as data from the US Census Bureau. We conducted a sensitivity analysis including a variable indicating baseline coverage by a law restricting the sale of tobacco to individuals under the age of 21 ('T21 law'). We conducted this analysis on a subset of our sample (with baseline year 2014 onwards), given that the first state T21 law (in Hawaii) became active in 2016 [39]. We also assessed the impact of adjusting for baseline year in regression analyses. Baseline year was not included in the primary model specification due to high levels of collinearity between time and smoke-free law measures. Finally, we examined whether there were differential associations between smoke-free policies and the outcome variables over time using interactions between baseline year and smoke-free laws.

All analyses were conducted using Stata version 16.0 and accounted for clustered observations at the county level. This analysis was not pre-registered on a publicly available platform and results should be considered exploratory.

RESULTS

Descriptive statistics

Table 1 presents descriptive statistics for the analytical samples for any smoking initiation and daily smoking initiation. Statistics are presented at each follow-up to capture the impact of attrition on the composition of the sample. Past 30-day cigarette use was 4.4% at modal age 19/20, 7.1% at modal age 21/22 and 8.1% at modal age 23/24

TABLE 1 Weighted descriptive statistics for any smoking initiation and daily smoking initiation analytical samples at follow-ups, Monitoring the Future longitudinal sample, baseline year 2000–17; results shown are using imputed data (mean = 10).

	Any past 30-day smoking initiation			Daily smoking initiation		
Variables	Follow-up 1 Wt %	Follow-up 2 Wt %	Follow-up 3 Wt %	Follow-up 1 Wt %	Follow-up 2 Wt %	Follow-up 3 Wt %
Any past 30-day smoking						
Yes	4.4%	7.1%	8.1%	–	–	–
No	95.6%	92.9%	91.9%	–	–	–
Daily smoking						
Yes	–	–	–	5.2%	6.8%	8.3%
No	–	–	–	94.8%	93.2%	91.7%
Sex						
Female	54.0%	54.3%	54.4%	53.0%	53.4%	53.5%
Male	46.0%	45.7%	45.6%	47.0%	46.6%	46.5%
Race/ethnicity						
Non-Hispanic white	61.3%	61.6%	62.2%	62.7%	62.8%	63.1%
Non-Hispanic black	15.7%	15.9%	15.6%	14.1%	14.1%	13.8%
Hispanic	15.4%	14.6%	13.9%	16.3%	15.7%	15.4%
Non-Hispanic Asian	5.5%	5.7%	5.9%	4.6%	4.8%	4.9%
Non-Hispanic other	1.9%	2.2%	2.4%	2.3%	2.6%	2.7%
Education, parents' highest						
Less than high school	25.6%	25.2%	25.2%	27.3%	26.5%	26.7%
Some college	19.6%	20.0%	19.7%	20.3%	20.9%	20.8%
College +	54.8%	57.8%	55.1%	52.4%	52.6%	52.5%
Census region						
Northeast	18.2%	19.1%	19.1%	17.9%	18.6%	18.8%
Midwest	23.5%	23.7%	23.6%	23.9%	24.1%	24.4%
South	36.4%	35.2%	35.4%	36.6%	35.6%	35.1%
West	21.9%	22.1%	21.9%	21.5%	21.6%	21.8%
% Living in same state as high school	83.5%	84.6%	81.5%	82.5%	79.5%	80.9%
% Covered by smoke-free work-place laws [mean % (SE), range]	44.7 (47.0), 0–100	41.1 (46.5), 0–100	36.4 (45.6), 0–100	40.8 (46.6), 0–100	37.3 (45.8), 0–100	32.8 (44.5), 0–100
% Covered by smoke-free hospitality laws [mean % (SE), range]	55.1 (48.1), 0–100	52.1 (48.5), 0–100	46.6 (48.5), 0–100	51.1 (48.5), 0–100	48.0 (48.6), 0–100	43.2 (48.2), 0–100
Cigarette price [mean % (SE), range]	5.8 (1.5), 3.5–10.6	5.7 (1.4), 3.5–10.6	5.5 (1.3), 3.5–10.6	5.7 (1.4), 3.5–10.6	5.5 (1.4), 3.5–10.6	5.4 (1.3), 3.5–10.6
% Of state below poverty level [mean % (SE), range]	13.4 (2.9), 4.6–23.1	13.5 (2.9), 5.4–23.1	13.3 (2.9), 5.4–23.1	13.4 (2.9), 4.6–23.1	13.4 (2.9), 5.4–23.1	13.3 (2.9), 5.4–23.1
% Of state college graduates (age 25+) [mean % (SE), range]	28.2 (4.8), 16.9–56.7	27.8 (4.7), 16.9–56.7	27.3 (4.5), 16.9–48.2	27.9 (4.8), 16.9–56.7	27.5 (4.7), 16.9–56.7	27.1 (4.5), 16.9–48.2
% Of state black [mean % (SE), range]	13.1 (8.2), 0.5–58.5	13.0 (8.2), 0.5–59.5	13.0 (8.3), 0.5–59.5	13.1 (8.3), 0.5–59.5	13.0 (8.3), 0.5–59.5	12.9 (8.3), 0.5–59.5
% Of state Hispanic [mean % (SE), range]	15.5 (12.6), 0.7–48.2	15.1 (12.4), 0.7–48.2	14.6 (12.2), 0.7—47.5	15.2 (12.6), 0.7–48.9	14.9 (12.5), 0.7–48.2	14.5 (12.4), 0.7–47.5
n	10 917	9037	7314	17 702	14 834	12 292

SE = standard error; Wt = weighted.

for the any smoking initiation sample. Daily smoking prevalence was 5.2% at modal age 19/20, 6.8% at modal age 21/22 and 8.3% at modal age 23/24 for the daily smoking initiation sample. The majority of respondents were female, non-Hispanic white and had at least one parent with a college degree or more. The average baseline smoke-free work-place law coverage varied between 32.8 and 44.7% among

follow-up time-points, and average smoke-free hospitality law coverage varied between 43.2 and 55.1%. Because we prospectively examined associations with baseline smoke-free law coverage, we also assessed whether individuals in our sample moved across state lines during the course of the follow-up period. At all follow-up points, approximately 80% of the sample reported living in the same state as the state of their high school.

Main effects

The main associations of each policy exposure on smoking outcomes are reported in Table 2. Estimates represent the change in probability of each smoking outcome associated with a smoke-free law covering 100% of the county population, compared to no smoke-free law coverage. There were no statistically significant associations between either type of smoke-free law coverage at baseline and any past 30-day smoking initiation at any modal ages.

Among baseline never, former and current non-daily smokers, coverage by a work-place law was associated with a 2.4 percentage point lower probability of daily smoking initiation at modal age 21/22 [AME = −0.024; 95% confidence interval (CI) = −0.039, −0.009] and a 2.0 percentage point lower probability of daily smoking initiation at modal age 23/24 (AME = −0.020; 95% CI = −0.039, −0.002). Coverage by a hospitality law was associated with a 1.6 percentage point lower probability of daily smoking initiation at modal age 19/20 (AME = −0.016; 95% CI = −0.028, −0.004), a 2.3 percentage point lower probability of daily smoking initiation at modal age 21/22 (AME = −0.023; 95% CI = −0.037, −0.009) and a 1.8 percentage point lower probability of daily smoking initiation at modal age 23/24 (AME = −0.018; 95% CI = −0.036, −0.000).

The main effects of the policy exposures on the relative risk (RR) scale matched the marginal effects in terms of sign and significance across all modal ages. Regression model results for all covariates on the RR scale are included in the Supporting information, Tables S1 and S2.

Differential associations of smoke-free measures by socio-demographic factors

Additive *P*-values from models including interactions between each policy and sex, race/ethnicity and parental education are summarized in Table 3. Before adjustment for multiple testing, we observed a

TABLE 2 Average marginal effects and relative risks of work-place and hospitality smoke-free policies on any past 30-day smoking initiation and daily initiation at follow-up, Monitoring the Future longitudinal sample, baseline year 2000–17; results shown are using imputed data (mean = 10).

		Follow-up 1 (age 19/20)		Follow-up 2 (age 21/22)		Follow-up 3 (age 23/24)	
			P-value		*P*-value		*P*-value
Any past 30-day smoking initiation							
Work-place laws	[a]AME (95% CI)	−0.006 (−0.017, 0.006)	0.313	−0.014 (−0.032, 0.005)	0.141	−0.004 (−0.028, 0.019)	0.716
	[a]RR (95% CI)	0.876 (0.677, 1.133)	0.313	0.825 (0.636, 1.070)	0.147	0.948 (0.707, 1.269)	0.716
Hospitality laws	[a]AME (95% CI)	−0.005 (−0.017, 0.006)	0.363	−0.008 (−0.026, 0.010)	0.363	−0.003 (−0.026, 0.019)	0.756
	[a]RR (95% CI)	0.885 (0.681, 1.150)	0.361	0.890 (0.690, 1.148)	0.368	0.957 (0.727, 1.261)	0.756
n		10 917		9037		7314	
Daily smoking initiation							
Work-place laws	[a]AME (95% CI)	−0.011 (−0.023, 0.002)	0.105	−0.024 (−0.039, −0.009)	**0.002**	−0.020 (−0.039, −0.002)	**0.030**
	[a]RR (95% CI)	0.815 (0.636, 1.045)	0.106	0.708 (0.569, 0.880)	**0.002**	0.782 (0.625, 0.978)	**0.032**
Hospitality laws	[a]AME (95% CI)	−0.016 (−0.028, −0.004)	**0.011**	−0.023 (−0.037, −0.009)	**0.002**	−0.018 (−0.036, −0.000)	**0.046**
	[a]RR (95% CI)	0.734 (0.577, 0.933)	**0.012**	0.715 (0.581, 0.879)	**0.002**	0.801 (0.645, 0.995)	**0.045**
n		17 702		14 834		12 292	

AME = average marginal effects; CI = confidence interval; RR = relative risk.
[a]Each average marginal effect or relative risk is estimated from a single model with either work-place laws or hospitality laws as the independent variable. All models control for baseline covariates shown in Table 1.
Bold-type *P*-values indicate statistically significant AMEs or RRs ($P < 0.05$).

TABLE 3 Additive *P*-values associated with interaction terms between smoke-free policies and gender, race/ethnicity and parental education for any past 30-day smoking initiation and daily smoking initiation at follow-up, Monitoring the Future longitudinal sample, baseline year 2000–17; results shown are using imputed data (mean = 10).

	Follow-up 1 (age 19/20) [a]*P*-value	Follow-up 2 (age 19/20) [a]*P*-value	Follow-up 3 (age 19/20) [a]*P*-value
Any past 30-day smoking initiation			
Work-place law interactions			
Gender	0.727	0.211	0.546
Race/ethnicity	0.702	0.906	0.352
Parental education	0.779	0.637	0.295
Hospitality law interactions			
Gender	0.158	0.880	0.115
Race/ethnicity	0.432	0.629	0.857
Parental education	0.137	0.197	0.133
n	10 917	9037	7314
Daily smoking initiation			
Work-place law interactions			
Gender	0.188	0.454	0.969
Race/ethnicity	0.587	0.757	0.570
Parental education	0.283	0.884	0.459
Hospitality law interactions			
Gender	0.140	0.931	0.454
Race/ethnicity	0.273	0.635	0.841
Parental education	**0.035**[b]	0.689	0.212
n	17 702	14 834	12 292

[a]Each *P*-value represents a separate model. All models controlled for baseline covariates shown in Table 1.
[b]Bold-type *P*-value indicates statistical significance before adjusting for multiple comparisons among the interaction models for each outcome and each wave.

statistically significant additive interaction between hospitality law coverage and parental education for daily smoking initiation at modal age 19/20, which implies that the association between smoke-free law coverage and the absolute change in daily smoking initiation probability varied across levels of parental education (Supporting information, Fig. S1). For young adults with parental education levels of high school or less, 100% county coverage by a smoke-free law was associated with a nearly 4 percentage point reduction in the probability of daily smoking initiation compared to no smoke-free law coverage. Conversely, the change in the probability of daily smoking initiation for higher levels of parental education was less than 2 percentage points. However, after adjusting for multiple testing, there were no statistically significant associations between smoke-free laws and any socio-demographic variable. Multiplicative *P*-values are provided in the Supporting information, Table S3. Prior to the multiple testing correction, statistically significant multiplicative scale interactions were observed for both gender and parental education with regard to the relationship between hospitality laws and daily smoking initiation at modal age 19/20. Neither interaction was significant after the multiple testing adjustment.

Sensitivity analyses

We estimated main effects models using only complete case data and found that associations were similar in magnitude and direction (Supporting information, Table S4). When models included follow-up characteristics (highest degree earned at follow-up, employment status at follow-up and full-time student status at follow-up), the association between hospitality smoke-free laws and daily smoking initiation at modal age 23/24 changed from significance to non-significance, although the magnitude of the AME was only slightly attenuated (Supporting information, Table S5). We also investigated effect modification by the follow-up characteristics and did not find any statistically significant interactions (Supporting information, Table S6). Results were similar in directionality and significance when the sample was limited to individuals who remained in the same state as their high school during follow-up (Supporting information, Table S7). Results from models including county-level covariates were similar to main analysis results; however, associations with daily smoking initiation at modal age 23/24 became marginally non-significant (Supporting information, Table S8). There were no significant

associations between smoke-free law coverage and smoking outcomes when baseline T21 law coverage was included in regression models, although the sample size for this analysis was limited (Supporting information, Table S9). The inclusion of a baseline year variable attenuated several associations (Supporting information, Table S10). While point estimates remained directionally consistent, only associations with daily smoking initiation at follow-up 2 remained statistically significant. Finally, we tested interactions between each smoke-free measure and baseline year. We found a significant association between work-place smoke-free law coverage and year at follow-up 1 with regard to daily smoking initiation. While the predicted change in the probability of smoking initiation varied across years, a clear temporal trend was not apparent (Supporting information, Fig. S2).

DISCUSSION

We found that smoke-free policies experienced in high school were consistently associated with lower levels of daily smoking initiation in young adulthood. Work-place laws were associated with reduced daily smoking initiation at modal ages 21/22 and 23/24, while hospitality smoke-free laws were associated with reduced daily initiation at all three follow-up points. Significant reductions in daily smoking initiation ranged from 1.6 percentage points (hospitality smoke-free laws at modal age 19/20) to 2.4 percentage points (work-place smoke-free laws at modal age 21/22). We did not find significant associations between smoke-free laws and any past 30-day smoking initiation.

Previous cross-sectional studies have similarly reported that smoke-free laws are associated with lower levels of smoking among youth [8–10,12,13,15], while longitudinal analyses have yielded more inconsistent results [40]. An analysis of state-level smoke-free laws in bars using a nationally representative sample found that laws with exemptions, including provisions regarding ventilation or smoking areas, were prospectively associated with reduced smoking initiation, including daily, any and heavy initiation [17], while smoke-free bar laws without exemptions were associated with reduced relapse [17]. A prior longitudinal analysis of youth using NLSY data found that smoke-free work-place laws were associated with reduced initiation, whereas smoke-free bar laws were associated with other smoking participation outcomes, but not initiation [16]. Finally, a longitudinal assessment of smoke-free restaurant laws in Massachusetts found that smoking restrictions reduced the likelihood of progressing to established smoking, specifically by lowering the probability of progression from experimentation to regular smoking [18]. Unlike some prior research [16], we found relatively consistent results for both work-place and hospitality smoke-free law coverage, in that both types of policies were associated with a lower likelihood of daily smoking initiation during the follow-up period. While we did not explicitly examine transitions between experimentation and established smoking, we found the strongest links between smoke-free laws and initiation to daily smoking, rather than any smoking. The divergence in findings between any smoking initiation and daily smoking initiation suggests that associations with smoke-free laws may be sensitive to the initiation measure used, and that these associations may be strongest with regard to the uptake of regular daily smoking, as opposed to patterns of light or intermittent smoking.

We are not aware of other longitudinal studies that have systematically explored effect modification of smoke-free laws, although a small number of cross-sectional analyses have stratified by sociodemographic characteristics [8, 19]. These studies suggested that associations between smoke-free laws and reduced probability of smoking may be seen most clearly among subpopulations of white, male and high-SES adolescents [8, 19]. In our study, we found only one example of effect modification on the additive scale prior to adjustment for multiple testing. Specifically, the relationship between hospitality smoke-free laws and reduced daily smoking initiation at modal age 19/20 was most pronounced among young adults from households with parental education levels of high school or less. There was no evidence of differential associations after incorporating a multiple testing adjustment. Differences between our findings and previous research may be due to the study design (longitudinal versus cross-sectional), the time-period of data collection (recent years versus the late 1990s/early 2000s) or the age of the participants (young adults versus school-age students), among other factors. Our study findings suggest that smoke-free policies do not exacerbate tobacco-related health disparities, but also probably do not contribute to decreasing disparities.

Strengths of this study include its longitudinal design and its focus upon smoking initiation within a critical window for establishing smoking behavior: late adolescence and young adulthood [41]. Other strengths include the substantial heterogeneity in smoke-free law coverage throughout our study period, and the incorporation of information on smoke-free laws passed at all jurisdictional levels.

This study was limited, in that we did not consider whether associations with smoke-free laws were impacted by the timing of the law's passage, relative to the measurement of smoking behavior [42, 43]. For example, a prior longitudinal study of youth in Massachusetts found that associations with reduced smoking progression were strengthened as time since the law's passage increased [42]. We limited our analysis to assessing smoke-free law coverage at baseline, and it is possible that individuals may have lived in areas with different levels of coverage during the follow-up period. However, we found that most young adults in our sample (~80%) lived in the same state at follow-up as the state of their high school at baseline. Moreover, while we had information on state of residence at follow-up, we did not have information about substate-level geographic locations, so we could not conduct a repeated-measures analysis without risking significant exposure misclassification. We were not able to adjust for parental smoking or substance use, as this information was not consistently collected for our sample. This may be an important source of unmeasured confounding. While our findings were robust to a number of sensitivity analyses, the inclusion of a variable representing baseline year attenuated estimates, which suggests that secular trends may have impacted our study's results, although an alternative explanation is that high exogenous correlation between time and the

passage of smoke-free laws may make the independent effects of each difficult to disentangle. However, associations between smoke-free laws and daily smoking initiation remained significant at modal age 21/22, even with the inclusion of baseline year variables.

In this study, we prospectively analyzed associations between exposure to smoke-free laws in work-places and hospitality venues at modal age 18 and subsequent smoking initiation during a 1–6-year follow-up period. We did not find significant associations between smoke-free laws and initiation to any past 30-day smoking; however, there were consistent associations between both types of smoke-free laws and a reduced probability of daily smoking initiation. When examining the potential for effect modification by socio-demographic characteristics we found little evidence of differential associations, and no interactions were significant after multiple testing adjustments. This analysis provides additional evidence regarding the relationship between smoke-free laws and smoking initiation using longitudinal data, and suggests that smoking restrictions may have a neutral impact upon health equity.

DECLARATION OF INTERESTS

None.

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AUTHOR CONTRIBUTIONS

Andrea Titus: Data curation; methodology; writing-original draft; writing-review & editing. **Yanmei Xie:** Formal analysis; methodology; writing-original draft; writing-review & editing. **James Thrasher:** Conceptualization; methodology; writing-review & editing. **David Levy:** Conceptualization; methodology; writing-review & editing. **Michael Elliott:** Methodology; writing-review & editing. **Megan Patrick:** Conceptualization; methodology; writing-review & editing. **Nancy Fleischer:** Conceptualization; funding acquisition; methodology; project administration; resources; supervision; writing-review & editing.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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