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ORIGINAL REPORT

A 14-year longitudinal study of the impact of clean indoor air legislation on state smoking prevalence, USA, 1997-2010

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What This Paper Adds
*Clean indoor air policies were negatively associated with smoking prevalence.
*The time policies were in place was negatively associated with smoking prevalence.
*Taxes and clean indoor air policies have effects on smoking prevalence.

ABSTRACT

While clean indoor air legislation at the state level is an evidence-based recommendation, only limited evidence exists regarding the impact of clean indoor air policies on state smoking prevalence. Using state smoking prevalence data from 1997-2010, a repeated measures observational analysis assessed the association between clean indoor air policies (i.e., workplace, restaurant, and bar) and state smoking prevalence while controlling for state cigarette taxes and year. The impacts from the number of previous years with any clean indoor air policy, the number of policies newly in effect during the current year, and the number of policies in effect the previous year were analyzed. Findings indicate a smoking prevalence predicted decrease of 0.13 percentage points (p=0.03) for each additional year one or more clean indoor air policies were in effect, a predicted decrease of 0.12 percentage points (p=0.09) for each policy newly in effect in the current year, and a predicted decrease of 0.22 percentage points (p=0.01) for each policy in effect in the previous year on the subsequent year. Clean indoor air policies show measurable associations with reductions in smoking prevalence within a year of implementation above and beyond taxes and time trends. Further efforts are needed to diffuse clean indoor air policies across states and provinces that have not yet adopted such policies.

INTRODUCTION

In the 1970s, U.S. states began adopting limits on smoking in public places.[1] Today, just under half of the U.S. population is covered by comprehensive clean indoor air policies that limit use of combustible tobacco products to protect non-hospitality workplaces, restaurants, and bars.[2] Evidence shows smoke-free environments improve health[3] and are associated with immediate and substantial reductions in heart attacks.[4] Exposure to involuntary smoking increases, among other things, cognitive impairment in older adults,[5] asthma in children,[1] and premature death.[6] The evidence for these policies is compelling with multiple Surgeon Generals' reports,[1,7] Cochrane reviews,[3,8] and other systematic reviews[9] showing that reductions in involuntary smoking improve health.

There is also strong evidence that workplace smoke-free policies improve indoor air quality and decrease smoking prevalence at that workplace.[9-15] On average, workplace smoke-free policies are associated with a 3.8% decrease in smoking prevalence among employees.[9]

While compelling evidence shows clean indoor air policies effectively reduce involuntary smoking at workplaces, less attention has been paid to the role of state clean indoor air legislation at bars, restaurants, and workplaces in reducing smoking prevalence.[3,16] Workplace policies may not operate in the same way as clean indoor air legislation that limits combustible tobacco use in public spaces such as bars and restaurants. Non-employee customers frequent these spaces, and these policy changes may change social norms about tobacco use.[17] Media coverage of state legislation may influence both norms and quit attempts.

The Community Guide is a collection of the evidence-based recommendations from an independent task force convened by the Centers for Disease Control and Prevention. The Community Guide offered a strong assessment of the available evidence for adoption of state clean air policies.[16] However, it found limited to no evidence that directly examined overall state smoking prevalence in relation to state clean indoor air legislation.[16] Only a single cross-sectional study of 2002 data assessing the association between state clean indoor air policies and state smoking prevalence was noted.[18] A 2009 International Agency for Research on Cancer (IARC) review concluded that laws restricting smoking have positive benefits on health, but shows that a relatively small amount of literature directly assesses the association between clean indoor air legislation and smoking prevalence.[19] In a 2016 Cochrane review, the authors noted, "inconsistent evidence emerged on the impact of smoking bans on reducing smoking prevalence rates."[3(p20)]

While the benefits from clean indoor air policies are likely substantial, the impact has mainly been demonstrated in studies conducted in workplaces or municipalities or assessing reductions in involuntary smoking.[9,16] While there are important exceptions that examine this at the individual level[20] or with fewer states,[15,18,21-22] the reviews above show less direct evidence of the effects of clean indoor air policies on smoking rates above and beyond the effects of taxes and trends over time at the state level.

There is a need to address this gap in evidence given the already compelling rationale for adoption of clean indoor air legislation in states and the slowing

progress of adoption.[23] The purpose of this study was to investigate the relationship between state clean indoor air policies and state smoking prevalence in the United States over a 14-year time period taking into account state cigarette taxes and time trends.

We hypothesized that the length of time clean indoor air policies had been in effect and the number of these policies in effect during both the current and previous year would all have a negative association with smoking prevalence in a state above and beyond the effects of taxes and trends over time.

METHODS

Data Sources

Data on clean indoor air legislation, state cigarette taxes, and adult smoking prevalence for all 50 states and the District of Columbia (DC) over 14 years were obtained from the CDC State Tobacco Activities Tracking and Evaluation database (http://www.cdc.gov/statesystem/). Smoking prevalence reflects results from the 1997-2010 Behavioral Risk Factor Surveillance System.[24] Recent data were not included in the analyses because in 2011 the CDC changed the methodology it used for estimating state-specific adult smoking.

Measures

We define clean indoor air policies as those prohibiting the use of combustible tobacco products in indoor spaces with no exceptions (e.g., no designated areas). Clean indoor legislation was operationalized as a count of three separate variables calculated for each year and each state, (a) the presence of a statewide clean indoor

air policy for bars, (b) the presence of a statewide clean indoor air policy for restaurants, and (c) the presence of a statewide clean indoor air policy for private worksites. Thus, states with comprehensive clean indoor air that covered bars, restaurants, and workplaces were scored 3, while states with no clean indoor air policy for these locations were scored 0. While comprehensive clean indoor air policies (i.e., clean indoor air policies at *all* hospitality and non-hospitality worksites and public places) are recommended, the use of a count allowed us to assess a potential "dose-response" of policy strength. For each year and each state, we also calculated the number of prior years in which one or more of these policies were in effect. Our measure of clean indoor air did not include any assessment of policies regarding electronic nicotine delivery systems (ENDS, e.g., e-cigarettes) or non-combustible tobacco products.

Analysis Strategy

We used an observational longitudinal cross-sectional design with 14 years of data and conducted a repeated measures analyses using the SPSS® version 20 Linear Mixed Model procedure. States were the subjects and year was the repeated effects variable. Hence state was a random effect. The dependent variable was adult smoking prevalence. The explanatory variables were year, state cigarette tax (dollars and cents per pack) and three state clean indoor air policy variables: (1) Number of previous years in which the state had one or more of the three statewide clean indoor air policies (i.e., workplace, restaurant, and/or bar considered separately) in effect as reported by the CDC STATE System (variable range: 0 to 15 years), (2) number of clean indoor air policies for workplaces, restaurants, and bars

newly in effect in the current year (variable range: 0 to 3), and (3) number of clean indoor air policies in effect in the previous year (variable range: 0 to 3). To help account for the observed non-linear decrease of smoking prevalence over time, a centered year squared (square of year – 2003.5) variable was included as an explanatory variable. The year was centered before squaring to reduce the correlation of this quadratic term with year. The explanatory variables were treated as fixed effects.

To fully answer the research questions, three separate models are reported. These models were selected to understand policy relevance and its association between smoking prevalence in a given year and the number of years any clean air policy had been in place (Model 1), policy implementation in that same year (Model 2), and the strength of the policy in place in the prior year (Model 3). Based on the Akaike information criterion, the model with the best "fit" had the explanatory variables year, centered year squared, state cigarette tax (in dollars), and number of clean indoor air policies in effect in the previous year. We used two-tailed tests and set alpha = 0.05.

RESULTS

We report three models in Table 1. Each model controls for the effect of state cigarette taxes and time trends. Model 1 examines the relationship between the length of time in years in which one or more clean indoor air policies was in effect in the state and state smoking prevalence. There is a significant negative association with adult smoking prevalence (an estimated decrease of 0.13 percentage points for each additional year where one or more policy was in place, p=0.03). Model 2

examines the association between the number of clean indoor air policies newly in effect and state smoking prevalence in that same year. The coefficient showed no significant association (p=0.09) between the number of new clean indoor air policies in effect and state smoking prevalence in that same year. Model 3 examines the relationship between the number of clean indoor air policies in effect in the previous year and smoking prevalence in the subsequent year. For each state clean indoor air policy in effect the previous year, the smoking prevalence decreases by an estimated 0.22 percentage points (p=0.01). This suggests that the effect of newly enacted clean air policies on smoking prevalence do not take place immediately but have more of an effect the longer the policy is in place.

In each of our models, adjusting for clean air policy variables and time trends, each additional dollar of state tax is associated with just over a one-half percentage point decrease in state smoking prevalence. Additionally, we confirm a time trend of declining smoking prevalence over time: The passing of each additional year was associated with a decline of just under a one-third percentage point decrease in state smoking prevalence. These findings suggest that, in adjusted models, the association between taxes and reductions in state smoking prevalence are larger than for either time trends or clean indoor air policies. This is consistent with the existing evidence that per-unit price increases are among the strongest tobacco control interventions.[25]

Table 1. Results for the final repeated measures model predicting state smoking prevalence, 1997-2010, U.S. states

	Model 1	Model 2	Model 3
	Coefficient (95% CI)		
Year	**-0.36 (-0.41 – -0.30)**	**-0.37 (-0.42 – -0.32)**	**-0.36 (-0.41 – -0.31)**
State cigarette tax (per pack)	**-0.54 (-0.88 – -0.20)**	**-0.54 (-0.88 – -0.19)**	**-0.53 (-0.87 – -0.19)**
Number of previous years with any clean air policies	**-0.13 (-0.26 – -0.01)**	-	-
Number of clean air policies newly in effect in current year	-	-0.12 (-0.27 – 0.02)	-
Number of clean air policies in effect in the previous year	-	-	**-0.22 (-0.37 – -0.07)**
Akaike information criterion	2362.33	2363.64	2358.41

Note: All models control for centered year squared to account for non-linearity. CI = confidence interval. Bolded text signifies significance at 0.05 level.

DISCUSSION

Our findings, using observational, longitudinal data and repeated measures analysis, add to the limited evidence about the relationship between state-level clean indoor air policies and state-level smoking prevalence. These results have multiple implications. First, as assumed but largely untested,[3] *statewide* clean indoor air policies show evidence of a negative association with smoking prevalence on a *state* level. Second, the analysis indicates the cumulative benefits associated with multiple clean indoor air policies (*i.e.*, taxes and clean air policies in bars, restaurants,

workplaces). More comprehensive policies are recommended. Additionally, state clean indoor air policies are associated with reduced smoking prevalence above and beyond the impact of state cigarette taxes and vice versa. Tax increases and non-tax approaches[26] to increase the per-unit cost of tobacco products should be considered by policymakers.[27] For example, cities can consider adding cigarette butt litter mitigation fees to pay for cleanup.[28] Clean indoor air policies denormalize smoking. Third, there are likely to be cumulative benefits for the number of years clean indoor air policies have been in place.

The non-significant finding for the association between smoking prevalence and clean indoor air policies newly in effect *in the same year* may be explained by two factors. One, variability of state policy implementation and, two, a time lag of the policy's effect. Many states implemented new clean indoor air policies in the latter half of the year leaving only a small window of time for it to affect smokers in that year.

Our findings add to very strong evidence on the importance of clean air legislation for improving population health. Extensive evidence has already shown that state clean indoor air legislation has impacts on health through reductions in involuntary smoking.[1,3,16,28] Extensive evidence also shows that smoke-free policies in worksites reduce employee involuntary smoking and promote quitting.[9,10,16]

Health promotion approaches are compatible with clean indoor air policies. All health promotion efforts relate to the concept of salutogenesis.[29] Salutogenesis focuses on the causes, creation and/or origins of health rather than the just prevention of disease or other problems. Comprehensive health promotion policies

should include clean indoor air policies because they are a necessary part of a health promoting environment for all occupants, the smoker and the nonsmoker.[30,31] Adoption and implementation of clean indoor air policies can promote societal, economic, health, and social benefits, and highlighting these benefits may help minimize unlikely but potentially concerning undesirable behaviors from clean indoor air policies.[32,33]

Limitations

Our results should be interpreted in light of several limitations. First, our modeling strategy treated different types of clean indoor air policies as having the same impact. Second, this research did not examine policies regarding ENDS products and/or non-combustible tobacco. Future work should examine the differential impact of types of clean indoor air policies. Third, we do not control for all other possible policies that could impact changes in smoking prevalence over time. Fourth, we do not differentiate between policies in effect in January versus a policy in effect in December. Fifth, we do not account for non-tax policy approaches to increase the cost of tobacco products or the role of municipal cigarette taxes that may vary across a state. Sixth, this is an observational study and while we are able to establish temporality, the role of confounding variables cannot be ruled out in assessing causality between policy adoption and subsequent state smoking prevalence.

Conclusion

Our findings should send a strong message and provide clear guidance to state legislatures: Clean indoor air policies and efforts to increase the per-unit cost

tobacco products are an important part of creating a health-promoting environment. Evidence demonstrates that clean indoor air promotes health and reduces the harms of involuntary smoking while simultaneously reducing smoking prevalence.

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DECLARATION OF INTERESTS

No conflicts of interest are reported by the authors.

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Highlights:

- Clean indoor air policies were negatively associated with smoking prevalence.
- The time policies were in place was negatively associated with smoking prevalence.
- Taxes and clean indoor air policies have effects on prevalence.