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Tobacco Smoke Exposure and Impact of Smoking Legislation on Rural and Non-Rural Hospitality Venues in North Dakota

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Abstract: The purpose of this cross-sectional study in a stratified random sample of 135 bars and restaurants in North Dakota was to describe factors that influenced tobacco smoke pollution levels in the venues; to compare the quantity of tobacco smoke pollution by rurality and by presence of local ordinances; and to assess compliance with state and local laws. In data collection in 2012, we measured the indoor air quality indicator of particulate matter (2.5 microns aerodynamic diameter or smaller), calculated average smoking density and occupant density, and determined compliance with state and local smoking ordinances using observational methods. As rurality increased, tobacco smoke pollution in bars increased. A significant association was found between stringency of local laws and level of tobacco smoke pollution, but the strength of the association varied by venue type. Compliance was significantly lower in venues in communities without local ordinances. Controlling for venue type, 69.2% of smoke-free policy's impact on tobacco smoke pollution levels was mediated by observed smoking. This study advances scientific knowledge on the factors influencing tobacco smoke pollution and informs public health advocates and decision makers on policy needs, especially in rural areas.

Keywords: smoking; tobacco control; epidemiology; indoor air pollution; secondary smoke; passive smoking; public health; health policy

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Regulation of tobacco use in public places and workplaces is growing globally (Americans for Nonsmokers' Rights [ANR], 2014; World Health Organization [WHO], 2011; pp. 42, 44) due to the known negative health effects of tobacco smoke pollution exposure (Centers for Disease Control and Prevention [CDC], 2006; Institute of Medicine, 2010; US Department of Health and Human Services [USDHHS], 2013). Requiring all indoor areas to be smoke-free without exceptions is the only method that provides full protection from the negative health effects of tobacco smoke pollution (CDC, 2006).

Disparities in tobacco control exist for rural populations (American Lung Association [ALA], 2012). Smoking prevalence is higher outside of metropolitan statistical areas (USDHSS, 2010), and rural areas have fewer workplace polices restricting smoking (American Academy of Pediatrics Julius B. Richmond Center of Excellence, 2008). Although previous research teams have addressed rurality in sampling frames, or conducted studies in rural areas (Gotz et al., 2008; Hahn, Lee, Robertson, Cole, & Whitten, 2009; Hahn, Lee, Vogel, & Whitten, 2008; Hahn, Lee, Vogel, Whitten, & Robertson, 2009; Hahn, Lee, Whitten, & Robertson, 2009; Jones et al., 2006; Lee, Hahn, Riker, Head, & Seithers, 2007; Semple et al., 2007, 2010; Travers & Vogl, 2010), none compared rural to non-rural areas or analyzed results by rurality. In addition to describing smoke pollution by rurality, this study was the first statewide study on tobacco smoke pollution levels in hospitality venues (restaurants and bars), and we used stratified random sampling, rarely used in studies of indoor tobacco use, to create an accurate statewide picture.

Our objectives were to identify influences, including venue characteristics, rurality, and local ordinances, on tobacco smoke pollution levels. This study had four hypotheses as follows:

1. The quantity of tobacco smoke pollution in hospitality venues will vary depending upon: presence of any law requiring venues to be smoke-free, venue type, venue volume, occupant density (OD), active smoking density (ASD), and observed smoking.
2. In hospitality venues, the quantity of tobacco smoke pollution will increase as rurality increases.
3. The quantity of tobacco smoke pollution will be lower in hospitality venues where local ordinances require all bars to be smoke-free (more stringent than state law) than those located outside such communities.
4. Compliance with smoke-free laws will be higher in hospitality venues where local ordinances are stronger than state law than in those located outside such communities.

Method

Cross-sectional data were collected between May 11, 2012, and July 13, 2012. The North Dakota Center for Tobacco Prevention and Control Policy contracted with the investigator to conduct the study. The study protocol was deemed exempt by the University of New Mexico's Human Research Protections Office.

Settings

The study settings were restaurants and bars in North Dakota (ND) not located within American Indian reservations. Restaurants and bars are the venues, outside of private residences, where tobacco smoke pollution is most common. From 2005 until December 2012 based on ND state law (ND Century Code [NDCC], *Chapter 23–12: Public Health, Miscellaneous Provisions*, *§23-12-09 - §23-12-11, Smoking in Public Places and Places of Employment, 2015*), all restaurants, but not bars, were required to be smoke-free. Local ordinances requiring smoke-free bars were implemented in sufficient numbers to allow for analysis of tobacco smoke pollution by presence of a local smoke-free law (Buettner-Schmidt, 2013).

Bar venue exclusion criteria included (a) alcohol not consumed on-site; (b) on tribal reservation land; (c) closed for business; (d) private clubs, such as Elks Lodges, American Legions, and so forth; (e) golf courses (a seasonal venue in ND); (f) other seasonal venues, such as rodeos, county fairs, summer resorts, and so forth; (g) other, such as catering, sports stadiums, strip-clubs, and so forth.

Restaurant venue exclusion criteria included all of the above plus (1) national fast food chains, such as Burger King and McDonalds; (2) catering and event-only venues, such as city facilities; (3) cafeterias; (4) duplicate listings; (5) oilfield "man camps"; (6) drive-up only; (7) assisted living or nursing homes; (8) concessions; (9) daycare or school; (10) meat processing; (11) continental breakfast at hotels; (12) grocery stores; (13) senior citizen centers; (14) other.

Sample

State and local public health agencies provided restaurant lists (3,146). The ND Attorney General's Office provided a licensed alcohol venues list (1,485). Venues meeting exclusion criteria were removed. Local public health personnel reviewed any venue on both lists to determine whether it operated primarily as a bar or a restaurant. All venues were categorized using the US Department of Agriculture (2013) 2003 Rural Urban Continuum Codes (RUCC) as completely rural (RUCC 8–9), semi-rural/urban (RUCC 4–7), or non-rural (RUCC 1–3). Venues were also categorized as being within or outside communities with ordinances that required smoke-free bars and thus were more stringent than the ND state law.

After removing the excluded venues, the remaining population of restaurants ($N = 935$) and bars ($N = 488$) were stratified into three groups: Group 1 (restaurants), Group 2 (bars *within* communities with local ordinances stronger than the state law requiring bars to be smoke-free), and Group 3 (bars *outside* of communities with local ordinances stronger than the state law).

Using 80 computer-generated random numbers per stratum, the sample was set to include at least 30 venues per stratum to meet standard guidelines for conducting independent samples *t*-tests. Power analysis for multiple regression, assuming $\alpha = .05$, power $= .80$, up to nine predictor variables, and a medium effect size ($f^2 = .15$), indicated a required sample size of 114.

To keep sampling fractions as consistent as possible while maintaining desired minimum subsample sizes, 30 cases were included from each of Groups 1 and 2, and 54 cases were included from the substantially larger Group 3. An additional category was 16 restaurants that had co-located enclosed bars that allowed smoking. Both these restaurants and their co-located bars were included as a subsample because the state law allowed smoking in co-located bars that were separately enclosed, adding 32 more venues.

Ten of the venues in this potential total sample were out of business, did not have seating, or were misclassified, leaving a sample size of 136. Tobacco smoke pollution levels could not be obtained in one venue, so analyses that included these levels had a sample size of 135, yielding a "participation rate" of 135/146 = 92.5%.

Measures

Roswell Park Cancer Institute data collection protocols were modified slightly and used for data collection (Buettner-Schmidt, 2013; Travers, 2010). Data collection was discreet, and data collectors remained within the venue for a minimum of 30 minutes. Restaurant data were collected from 11:30 am to 1:30 pm or from 5:00 pm to 8:00 pm on all days of the week. Bar data were collected Thursday through Saturday, from 7:00 pm to midnight, peak patronage times. Data were collected for all the venues on the required days, with 94.1% of the data collected during the specified times. An average of 38 minutes ($SD = 13$ minutes, range = 30–135 minutes) was spent in the venues.

Venue characteristics assessed included type of venue, co-location status, rurality, presence of smoke-free laws, and the number of people within the venue. The number of people within the venue was counted at entry into the venue and every 15 minutes for a minimum of 30 minutes.

Tobacco smoke pollution variables included particulate matter (PM) and the air quality index (AQI). PM with a median aerodynamic diameter of $<2.5\,\mu m$ ($PM_{2.5}$) is a valid atmospheric marker of tobacco smoke pollution (International Agency for Research on Cancer [IARC], 2009). Particulate matter is composed of solid particles or liquid droplets that are suspended in the atmosphere. Most PM in tobacco smoke is less than $2.5\,\mu m$ in diameter (Klepeis, Apte, Gundel, Sextro, & Nazaroff, 2003) and is released in large quantities from burning cigarettes (Travers, 2010); therefore, $PM_{2.5}$ is the standard size measured for tobacco smoke pollution (IARC, 2009; Lee et al., 2011). Negative health outcomes occur when fine particles such as $PM_{2.5}$ are inhaled and are able to move deeply into the lungs due to their small size (Pope & Dockery, 2006; Travers, 2010). SidePak AM510 Personal Aerosol Monitors (TSI Group, Shoreview, MN) were used to collect $PM_{2.5}$. The Sidepak was set to a 1-minute logging interval and recorded for 30 minutes minimum.

The US Environmental Protection Agency (EPA, 2012) sets National Ambient Air Quality Standards for 24-hour and annual periods for outdoor air, but no standards exist for indoor air. In the EPA's AQI, $PM_{2.5}$ levels are categorized as good ($0\,\mu g/m^3$) to hazardous ($500\,\mu g/m^3$). A significant harm level (SHL) was identified for $PM_{2.5}$ levels at or above $500\,\mu g/m^3$, indicating imminent and substantial endangerment to public health (EPA, 2009a, 2009b). The AQI including the 2009 SHL was used for interpretation of $PM_{2.5}$ levels. Average $PM_{2.5}$ levels were calculated for each venue by removing the first and last minute of data and averaging the remaining data points. A calibration factor of .32, appropriate for secondhand smoke, was applied to all the $PM_{2.5}$ data (Klepeis, Ott, & Switzer, 2007).

A sonic measurement device measured room volume to enable calculation of active smoking density (ASD) and occupant density (OD), both expected to influence $PM_{2.5}$ levels. ASD was defined as the average number of burning cigarettes per $100\,m^3$. OD was defined as the average number of occupants in an area per $100\,m^3$.

Compliance was measured by observation of the venues' indoor areas. Indicators of noncompliance included observed smoking (burning cigarettes); presence of ashtrays, cigarette butts, or odor; separately enclosed areas not completely enclosed; and, in a bar that was located in the same facility as a restaurant but separately enclosed, doors in the enclosure that were open when no one was moving through the doors. Data collectors counted the number of burning cigarettes at entry into the venue and at every 15 minutes for a minimum of 30 minutes, for a total of three data collection points. The compliance indicators were collapsed into a dichotomous variable of compliant or noncompliant. Noncompliance on any one indicator resulted in the venue being categorized as noncompliant.

Analysis

Microsoft Excel, SPSS, and Stata were used for data analysis. Fisher's exact tests and χ^2 tests were used to assess statistical significance of associations between categorical variables. Independent samples *t*-tests and one-way ANOVAs were used to test statistical significance of differences in group means, and adjusted versions of these tests were used when Levene's test of homogeneity of variance was significant ($p < .05$). The ω^2 statistic was used as an effect size measure for ANOVAs, and $r_{contrast}$ was calculated as an effect size measure for follow-up contrasts. As $PM_{2.5}$ levels were strongly right-skewed, natural log-transformed values for $PM_{2.5}$ ($logPM_{2.5}$) were calculated and used as the dependent variable in linear regression analyses, which were presented with exponentiated regression coefficients. Moreover, geometric means (GM) and geometric standard deviations (*GSD*) were calculated for $PM_{2.5}$ levels. Following initial linear regressions, a mediation model was fit for factors found to significantly influence $PM_{2.5}$ levels. Statistical testing of this mediation model was conducted using the standard Baron and Kenny (1986) steps.

Results

As seen in Table 1, all venues in the "hazardous," "very hazardous," and "significant harm" AQI categories were bars in which smoking was observed and where it was allowed by local ordinance. Of the 53 venues that had "good" air quality, smoking was observed only in a single venue.

As illustrated in Figure 1 and shown in Table 2, for all venues with $PM_{2.5}$ data ($n = 135$), the arithmetic mean $PM_{2.5}$ was $87.8\,\mu g/m^3$ (range = 1.0–656.0), and the GM was $28.6\,\mu g/m^3$. The highest tobacco smoke pollution level in a single venue ($PM_{2.5} = 656\,\mu g/m^3$) was in a bar in which smoking was observed. The arithmetic mean air quality for bars not co-located with restaurants was "unhealthy" ($PM_{2.5} = 111.8\,\mu g/m^3$) and for restaurants not co-located with bars was "moderate" ($PM_{2.5} = 19.2\,\mu g/m^3$). The arithmetic mean of tobacco smoke pollution levels for venues without observed smoking was 90% lower than in venues where

Table 1. Air Quality of Restaurants and Bars by Venue Type, Presence of Local Ordinance Prohibiting Bar Smoking, and Observed Smoking: North Dakota, 2012

					Smoking Observed		Local Ordinance	
$PM_{2.5}$[a]	AQI Category	All Venues ($N = 135$)	Restaurants ($n = 40$)	Bars ($n = 95$)	Yes ($n = 57$)	No ($n = 78$)	Yes ($n = 41$)	No ($n = 94$)
.0–12.0	Good	53	18	35	1	52	32	21
12.1–35.4	Moderate	19	14	5	2	17	8	11
35.4–55.4	Unhealthy for sensitive groups	4	2	2	2	2	1	3
55.5–150.4	Unhealthy	31	5	26	25	6	0	31
150.5–250.4	Very unhealthy	15	1	14	14	1	0	15
250.5–350.4	Hazardous	7	0	7	7	0	0	7
350.5–500.0	Very hazardous	4	0	4	4	0	0	4
>500	Significant harm	2	0	2	2	0	0	2

[a]$PM_{2.5}$ ($\mu g/m^3$), micrograms of particulate matter with a median aerodynamic diameter of less than 2.5 μm^3. Ranges reflect AQI revised breakpoints.

smoking was observed. The average level for restaurants was 74% lower than in bars.

As shown in Table 3, smoking was observed in 57 (42%) of the venues, with the mean number of lit cigarettes .9. Observed smoking varied significantly by venue type ($p < .001$), rurality ($p = .003$), the presence of the state law requiring smoke-free venues ($p < .001$), the presence of local laws requiring smoke-free venues ($p < .001$), and the presence of any law requiring smoke-free venues ($p < .001$). The arithmetic mean EPA air quality category for venues where smoking was observed was "very unhealthy" ($PM_{2.5} = 182.2\ \mu g/m^3$) versus "moderate" ($PM_{2.5} = 18.8\ \mu g/m^3$) in venues where smoking was not observed.

Factors Influencing Tobacco Smoke Pollution

In Hypothesis one, we proposed that the quantity of tobacco smoke pollution in hospitality venues would vary depending upon specific factors. As expected, Pearson's correlation coefficients indicated that the quantity of tobacco smoke pollution ($logPM_{2.5}$) was positively associated with observed smoking ($r = .793$, $p < .001$), with ASD ($r = .503$, $p < .001$), and type of venue ($r = .274$, $p = .001$). The presence of a smoke-free law was negatively associated with the quantity of tobacco smoke pollution ($r = -.678$, $p < .001$).

To determine the relative impact of specific factors on tobacco smoke pollution when analyzed together, the following independent variables were included using forward selection in a linear regression, with $logPM_{2.5}$ as the dependent variable: presence of *any* law requiring venue to be smoke free, venue type (restaurant or bar), venue volume, OD, ASD, and observed smoking. The final model, $R^2 = .664$, $F(3,131) = 86.18$, $p < .001$, included only the significant independent variables: observed smoking ($\exp[b] = 10.50$, $p < .001$, 95% confidence interval (CI), 5.85–18.82), type of venue ($\exp[b] = .43$, $p < .001$, 95% CI, .27–.69), and presence of any smoke-free law ($\exp[b] = .42$, $p < .01$, 95% CI, .22–.81), using exponentiated unstandardized regression coefficients and exponentiated CIs for each independent variable.

Based on the regression results, a mediation model was tested (Fig. 2). The linear regressions for each path, controlling for the covariate of type of venue, were all significant. Moreover, a significant negative indirect effect of the presence of a smoke-free law on tobacco smoke pollution via observed smoking was found. Calculation of the percentage of mediation showed that 69.2% of the total association between a smoke-free law and tobacco smoke pollution was explained by the lack of observed smoking, and the residual unexplained portion of the association was 30.8%.

Rurality and Tobacco Smoke Exposure

The second hypothesis was: In hospitality venues, the quantity of tobacco smoke pollution will increase as rurality increases. As can be seen in Table 2, the observed overall

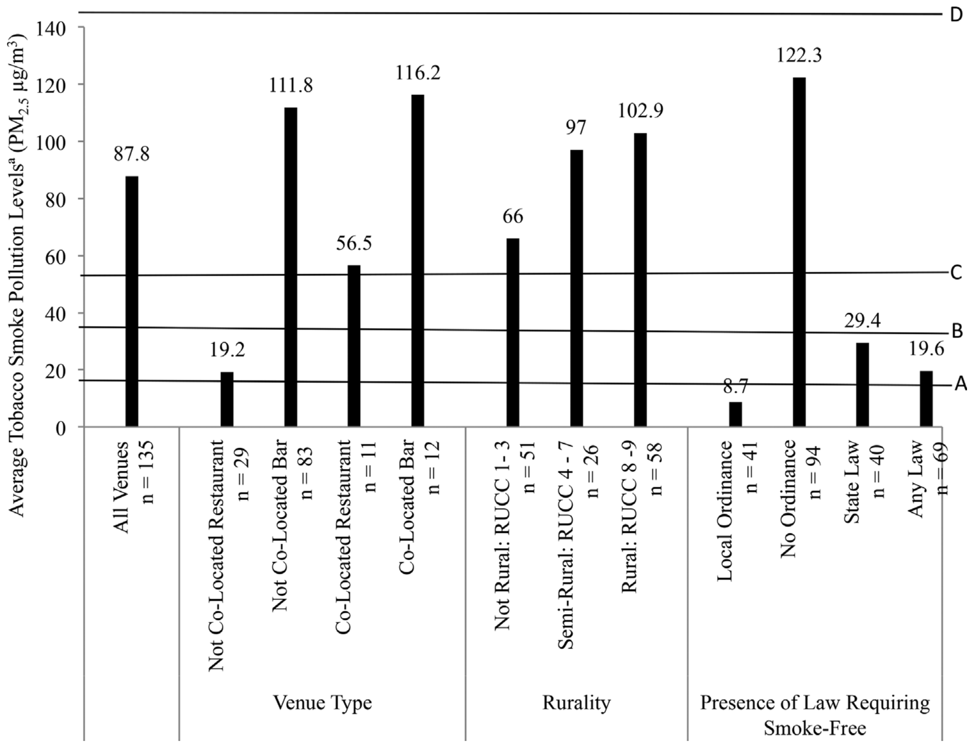

FIGURE 1. Average tobacco smoke pollution levels and air quality (based on the US Environmental Protection Agency's 2012 PM2.5 Air Quality Index) in hospitality venues: ND, 2012. Good Air Quality found in venue types below line A. Moderate Air Quality found in venue types between lines A and B, and unusually sensitive people should consider reducing prolonged or heavy exertion. Unhealthy Air for Sensitive Groups found in venue types between lines B and C, and people with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion. Unhealthy Air found in venues between lines C and D, and people with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion. PM2.5 = particulate matter with a median aerodynamic diameter of less than 2.5 µm; RUCC = Rural Urban Continuum Code; RUCC 1-3 = non-rural; RUCC 4-7 = semirural/urban; RUCC 8-9 = rural.

arithmetic mean of tobacco smoke pollution levels for restaurants and bars was 56% higher in rural (RUCC 8–9) than in non-rural (RUCC 1–3) venues. For bars alone, the arithmetic mean of tobacco smoke pollution levels was 65% higher in rural than in non-rural areas.

Planned one-way ANOVAs of $\log PM_{2.5}$ levels by rurality showed, overall, an association between rurality and tobacco smoke pollution, $F(2,132) = 7.921$, $p = .001$, $n = 135$, with a medium effect size ($\omega^2 = .09$). The contrasts revealed that tobacco smoke pollution levels were progressively higher as rurality increased, $t(132) = 3.66$, $p < .001$, with a medium effect, $r_{contrast} = .30$, but did not differ significantly between semi-rural and rural counties, $t(132) = .62$, $p = .536$, with a small effect, $r_{contrast} = .05$.

Within bars alone ($n = 95$), a follow-up one-way ANOVA of $\log PM_{2.5}$ levels by rurality showed Welch's F(2, 43.633) of 9.552, $p < .001$, with a large effect size ($\omega^2 = .15$). Follow-up contrasts revealed significantly higher tobacco smoke pollution levels between the non-rural counties and the combined semirural and rural counties ($t[62.695] = 3.481$, $p = .001$), with a medium effect, $r_{contrast} = .40$. Although the second contrast, between the semirural and rural counties, was not significant ($t[26.578] = 1.34$, $p = .193$), the effect size, $r_{contrast} = .25$, was medium. A similar follow-up ANOVA of $\log PM_{2.5}$ levels by rurality in only restaurants ($n = 40$) was not significant ($F[2,37] = 1.464$, $p = .244$), with a small effect size ($\omega^2 = .02$).

Local Smoke-free Ordinances and Tobacco Smoke Exposure

Our third hypothesis was: The quantity of tobacco smoke pollution will be lower in hospitality venues located within communities with local ordinances requiring smoke-free bars than those located outside of such communities. As can be seen in Table 2, the average tobacco smoke

Table 2. Mean Tobacco Smoke Pollution Levels and Venue Characteristics by Venue Type, Rurality, and Smoke-Free Law Type: North Dakota, 2012

		$PM_{2.5}$[a] (μg/m^3)				Room Volume (m^3)		No. of People		Occupant Density	
Characteristic	*n*	Mean	*SD*	Geometric Mean	*GSD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Total	135	87.8	122.2	28.6	5.3	494	601	18.5	16.9	5.7	5.8
Venue type[b]											
Not co-located restaurant	29	19.2	25.7	10.2	3.1	540	935	19.2	17.9	6.5	6.8
Not co-located bar	83	111.8	142.6	33.2	6.2	503	440	18.3	17.1	4.6	3.3
Co-located restaurant	11	56.5	63.5	32.1	3.1	205	195	11.6	7.4	8.2	6.3
Co-located bar	12	116.2	78.9	96.6	1.9	587	777	24.8	18.5	8.9	12.0
Rurality											
RUCC 1–3	51	66.0	130.2	14.1	5.3	646	835	23.9	22.0	5.7	4.8
RUCC 4–7	26	97.0	127.7	36.6	4.8	466	492	23.3	16.4	8.5	10.1
RUCC 8–9	58	102.9	111.3	46.3	4.6	373	311	11.6	6.6	4.4	3.0
Law requiring smoke-free[b]											
Local ordinance	41	8.7	9.1	6.4	2.1	581	544	26.9	24.1	6.2	5.2
No ordinance	94	122.3	132.3	53.9	4.8	457	624	14.9	10.8	5.5	6.0
State law	40	29.4	42.3	14.0	3.5	448	813	17.1	16.0	6.9	6.6
Any law	69	19.6	34.2	9.3	3.0	535	742	20.5	20.4	6.1	5.7

Note. *SD*, standard deviation; GSD, geometric standard deviation; Occupant density, (number of people/room volume m^3) ×100; RUCC, rural urban continuum code; RUCC 1–3, non-rural; RUCC 4–7, semirural/urban; RUCC 8–9, rural.
[a]$PM_{2.5}$ refers to particulate matter with a median aerodynamic diameter of less than 2.5 μm.
[b]Venues may be included in one or more "law requiring smoke-free" categories.

pollution level for venues within communities with local ordinances was 93% lower than for those located outside of such communities. For bars alone, a 96% lower mean tobacco smoke pollution level was seen in those within communities with local ordinances. Although not statistically significant, it may be clinically significant that tobacco smoke levels were 58% lower in restaurants with local ordinances.

Table 3. Venue Characteristics and Rates of Observed Smoking by Venue Type, Rurality, and Smoke-Free Law Type: North Dakota, 2012

		Room Volume (m^3)		No. Lit Cigarettes		ASD		Smoking Observed	
Characteristic	*n*	Mean	*SD*	Mean	*SD*	Mean	*SD*	*n*	%
Total	136	494	601	0.9	1.7	0.29	5.78	57	41.9
Venue type[a]									
Not co-located restaurant	29	540	935	0.2	0.8	0.05	0.21	2	6.9
Not co-located bar	83	503	440	1.1	1.8	0.33	0.53	44	53.0
Co-located restaurant	11	205	195	0.0	0.0	0.00	0.00	0	0.0
Co-located bar	12	587	777	2.4	2.2	0.82	1.14	11	91.7
Rurality									
RUCC 1–3	51	646	835	0.6	1.5	0.20	0.52	12	23.5
RUCC 4–7	26	466	492	1.8	2.5	0.56	0.93	1	53.9
RUCC 8–9	58	373	311	0.8	1.2	0.23	0.35	31	53.5
Law requiring smoke-free[b]									
Local ordinance	41	581	544	0.0	0.0	0.00	0.00	0	0.0
No ordinance	94	457	624	1.3	1.9	0.41	0.66	57	60.6
State law	40	448	813	0.2	0.7	0.39	0.65	2	5.0
Any law	69	535	742	0.1	0.5	0.02	0.14	2	2.9

Note. ASD, active smoker density [(average number of lit cigarettes/room volume m^3) ×100]; *SD*, standard deviation; RUCC, rural urban continuum code; RUCC 1–3, non-rural; RUCC 4–7, semirural/urban; RUCC 8–9, rural.
[a]Row percentage (example, not co-located venues = 2/29 = 6.90).
[b]Venues may be included in one or more "law requiring smoke-free" categories.

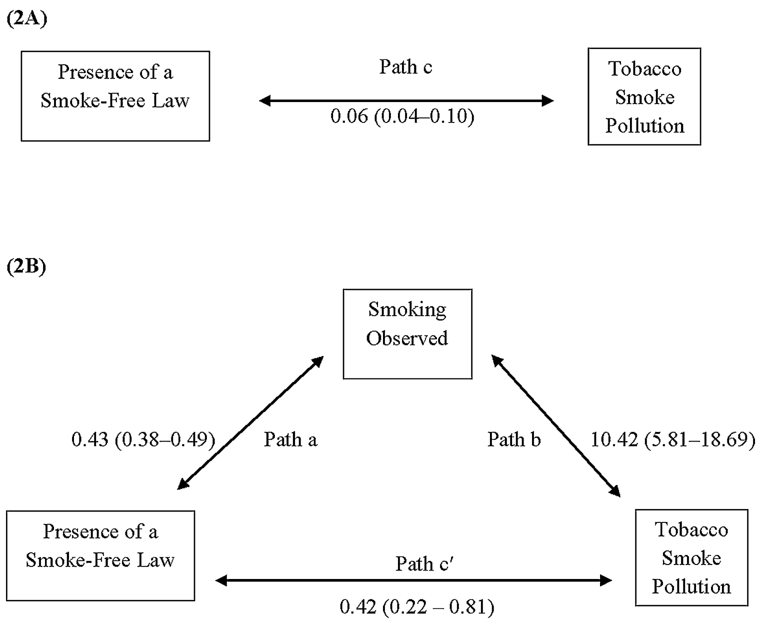

FIGURE 2. Partially mediated models of variables influencing tobacco smoke pollution: North Dakota, 2012. This model controlled for type of venue (restaurant or bar). (A) Path c values are exponentiated unstandardized regression coefficients and exponentiated 95% confidence intervals. (B) Path a, b, and c′ values are exponentiated unstandardized regression coefficients and exponentiated 95% confidence intervals.

In a two-way ANOVA (factorial ANOVA) to compare means of the $logPM_{2.5}$ levels by 1) whether a venue was required to be smoke-free by ordinance and 2) type of venue, the test for homogeneity of variance was significant, so a robust variance estimator based on heteroscedasticity-consistent covariance matrix (Long & Ervin, 2000), known as HC3 in Stata, was used. The model was significant ($N = 135$, $R^2 = .506$, $F[3,131] = 70.47$, $p < .001$). To follow up, an independent samples *t*-test assuming unequal variances, comparing the mean $logPM_{2.5}$ levels between venues required and not required to be smoke-free by ordinances, was significant ($N = 135$, $t[132.27] = 10.79$, $p < .001$), showing lower pollution in the presence of a smoke-free ordinance.

In subgroup analysis of only bars ($n = 95$), an exploratory independent samples *t*-test analysis to compare $logPM_{2.5}$ by ordinance status also was significant (equal variances not assumed, $t[91.854] = 14.61$, $p < .001$). Bar venues within communities with local ordinances requiring smoke-free bars, and thus stronger than state law, had significantly lower mean tobacco smoke pollution levels ($n = 29$, GM $PM_{2.5} = 5.4\,\mu g/m^3$, $GSD = 1.7\,\mu g/m^3$) compared to bars in communities without such ordinances ($n = 66$, GM $PM_{2.5} = 89.9\,\mu g/m^3$, $GSD = 3.9\,\mu g/m^3$). A similar analysis of only restaurants was not significant ($n = 40$, $t[38] = 1.12$, $p = .27$), and the effect size was small ($d = .41$).

Compliance and Tobacco Smoke Exposure

Our fourth hypothesis was: Compliance with smoke-free laws will be higher in hospitality venues located within communities with a local ordinance more stringent than state law than in those located outside of such communities. The ordinances more stringent than state law required bars to be smoke-free. Compliance with smoke-free laws was assessed in venues required to be smoke-free by *any* law ($n = 70$). This included all restaurants, as required by state law, and bars located within communities with an ordinance requiring bars to be smoke-free.

Noncompliance as indicated by observed smoking occurred in only two (2.9%) venues; both were restaurants that were not co-located with bars. These two restaurants also were noncompliant as indicated by smoke odor, ashtrays, and cigarette butts. Three co-located restaurants had smoke odor. Because smoke from the adjoining bars may have infiltrated their smoke-free areas, they were considered compliant. In fact, odor has been questioned as an indicator of compliance (Campaign for Tobacco-Free Kids, International Union against Tuberculosis and Lung Disease, & Johns Hopkins Bloomberg School of Public Health, 2011).

Of the 12 co-located bars and restaurants for which ordinances allowed smoking in the bar, five (41.7%) were not compliant: one had an open hallway between the restaurant and bar, and four venues had doors that were open during the entire time the data collectors were present ($n = 3$) or were propped open part of the time ($n = 1$).

In a Fisher's exact test, the presence of a local ordinance was associated with compliance ($n = 70$, $p < .01$, $\varphi = .40$), with a medium effect size. Indeed, the highest compliance rates were in venues within communities with local ordinances ($n = 41$, 100%). These venues had significantly lower mean tobacco smoke pollution levels (equal variances not assumed, $t[38.2] = 3.33$, $p = .002$), and 66.5% lower arithmetic mean tobacco smoke pollution levels than did compliant venues outside such communities. Among venues required to be smoke-free by any law, those venues within communities with local ordinances had the highest compliance rate (100%) and the lowest mean tobacco smoke pollution levels ($PM_{2.5} = 8.7\ \mu g/m^3$).

Discussion

This was the first statewide tobacco smoke pollution study reported for a US state and the first such study comparing rural and non-rural venues. Rurality was associated with the average tobacco smoke pollution levels in bars, with significantly higher tobacco smoke pollution levels in rural bars than non-rural bars. Restaurants, overall, had consistently low tobacco smoke pollution levels, reflecting compliance with the state's smoke-free restaurant law and the relatively uniform policy environment for restaurants across the state. Public health nurses may note that, as an issue of social justice, there is a need for recognition of continued disparities in exposure to tobacco smoke pollution for rural residents.

Unlike in previous studies in which ASD, defined as the average number of burning cigarettes per $100\ m^3$, was highly correlated with tobacco smoke pollution levels (King et al., 2012; Liu et al., 2010), ASD was correlated with tobacco smoke pollution but was not a significant predictor in multivariate analysis. Instead, the type of venue, observed smoking, and the presence of *any* smoke-free law were significant predictors of $PM_{2.5}$ levels.

The presence of a smoke-free law was linked to lower tobacco smoke pollution, and in mediation analysis most of the association was explained by the lack of observed smoking. Three important public health implications emerge. First, much of the difference in levels of tobacco smoke pollution in hospitality venues with smoke-free laws was explained by the lack of observed smoking. Second, when smoking was observed, it was linked to higher tobacco smoke pollution levels. While this may be intuitive, this finding reinforces that not only smoke-free laws but compliance with these laws is needed to effectively decrease tobacco smoke pollution levels. Third, simple observation of smoking may be sufficient to determine the effectiveness of smoke-free laws in decreasing exposure to tobacco smoke pollution. This would negate the necessity of expensive and time-consuming studies using equipment to assess tobacco smoke pollution.

As expected, venues in communities with local ordinances requiring bars to be smoke-free had less tobacco smoke pollution. Bars within communities with these local ordinances had significantly lower tobacco smoke pollution levels than those outside such communities. Restaurant venues in the communities with local smoke-free ordinances also had less tobacco smoke pollution than venues outside of such communities, although this difference was not significant. Because the state law required all restaurants to be smoke-free, the presence of a local ordinance did not affect the legal requirement for restaurants. Although measured pollution was not significantly lower, some restaurants with local ordinances prohibiting smoking in bars had air quality in the "good" EPA category, suggesting the clinical significance of local ordinances requiring smoke-free bars. Also as expected, compliance with smoke-free laws was significantly higher in hospitality venues located within communities with local ordinances that were more stringent than state law, and they had the lowest mean tobacco smoke pollution levels.

The influence of local ordinances is supported by previous studies. As described by Buettner-Schmidt (2013), significant reductions of exposure to $PM_{2.5}$ and other harmful substances from secondhand smoke exposure were found in studies of pre- and post-legislation of enforced comprehensive laws. Pre-legislation levels of $PM_{2.5}$ reached as high as $436\ \mu g/m^3$ in Israeli bars (Rosen, Zucker, Rosen, & Connolly, 2011), with some levels decreasing to below $3.5\ \mu g/m^3$ in hospitality venues, including bars, restaurants, and discos (Bohac et al., 2010; Marin & Diáz-Toro, 2010), after implementation. $PM_{2.5}$ decreases of up to 98.6% in drinking venues were reported (Bohac et al.). Travers et al. (2004) reported an average reduction in $PM_{2.5}$ levels of 90% (from $412\ \mu g/m^3$ to $27\ \mu g/m^3$; $p < .001$) in 14 restaurants and bars after passage of New York's smoke-free air law. Communities with only partial bans or laws lacking enforcement did not experience the same reductions (Akbar-Khanzadeh, Milz, Ames, Spino, & Tex, 2004; Johnsson et al., 2006; Nebot et al., 2009; Rosen et al.).

This report contributes evidence on tobacco smoke pollution statewide in a primarily rural state, revealing that rurality did influence tobacco smoke pollution levels. Findings supported the current literature in that smoker density was highly correlated to tobacco smoke pollution. The mediation model in which observed smoking explained much of the impact of smoke-free laws on air quality may assist in the understanding of how smoke-free laws affect public health.

Additional studies of tobacco smoke exposure and policy impact in rural areas are needed to determine whether the study findings can be replicated. As the number of venues in semi-rural areas was limited in this study, greater sampling of semi-rural venues will be important for future research. Further testing of the mediation model is needed to assure its reliability. Studies of successful policy strategies adapted to rural cultures are needed to inform public health nurses on best practices to collaborate with rural residents to increase coverage of rural areas with smoke-free laws. Longitudinal studies can test the ongoing influence of local ordinances and can assist in identifying how to increase compliance in communities without local smoke-free ordinances.

Limitations

The North American Industry Classification System (NCAIS) classifications or tax data for the individual hospitality venues were not available to classify venues as either primarily restaurants or bars, which was a limitation of the study. Second, there was a possibility of omitted variable bias, in which important predictor variables may not have been included in the analysis. Third, extensive exclusion criteria were needed to narrow the sample to venues that a) had indoor smoking, b) were commonly accessed by the public, and c) were accessible for data collection. Excluding private, seasonal, drive-through, and health care or school venues, may have affected the results. Fourth, although the specified days and times of data collection were chosen based on the assumed busiest times, results collected during different days and times could be different. Fifth, these findings should be broadly generalizable to venues in ND and, perhaps, venues in other large geographically rural areas, but generalizability is limited. Last, causality cannot be assessed by cross-sectional studies such as this. Longitudinal data collection is under way by this research team.

Conclusions

As the first reported statewide study on tobacco smoke pollution levels in hospitality venues using a random sampling procedure, this study adds to understanding of tobacco smoke pollution exposure in rural and non-rural venues. The more rural the venue, the higher the tobacco smoke pollution in bars; these findings support the theory that people living in rural communities constitute a high-risk population affected disproportionately by tobacco use (ALA, 2012). The presence of a smoke-free law was linked to lower tobacco smoke pollution in bars, and most of the association was explained by the lack of observed smoking. Venues within communities with both state and local ordinances had the highest compliance rate and the lowest mean tobacco smoke pollution levels. These results advance scientific knowledge on the factors influencing tobacco smoke pollution and inform public health advocates and decision makers on smoking policy needs, especially in rural areas.

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