

# Smoke-Free Laws, Gender, and Reduction in Hospitalizations for Acute Myocardial Infarction

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## ABSTRACT

**Objective.** We examined gender differences in the incidence of acute myocardial infarction (AMI) after the passage of a smoke-free law in Lexington, Kentucky. The initial legislation had exemptions not covering manufacturing facilities and government buildings, which may have put men at greater risk for AMI.

**Methods.** We examined the effect of Lexington's smoke-free public places law on hospitalizations for AMI (i.e., heart attack) among men and women 40 months prior to and 32 months after enactment of the law. We used the statewide administrative database (Comp Data) for all hospital billing records for the four health-care systems in Lexington-Fayette County. Cases were included in the analysis if (1) the patient was  $\geq 35$  years of age; (2) the patient had a primary discharge diagnosis of AMI, with an International Classification of Diseases, Ninth Revision code in the range of 410.00 to 410.99; and (3) the date of service was between January 1, 2001, and December 31, 2006.

**Results.** Among women, AMI hospitalizations declined 23% after the law took effect. The rate of AMI events among men did not change significantly. There was an overrepresentation of women in the hospitality industry and a disproportionate number of men working in manufacturing facilities and government worksites not mandated by the law.

**Conclusions.** We found gender differences in the reduction of AMI hospitalizations following implementation of a smoke-free law that covered only some sectors of the workforce. Enacting smoke-free laws that cover all places of employment and strengthening existing partial laws may extend protection against AMIs to female and male workers.

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Despite the U.S. trend to enact state and local smoke-free legislation, exposure to secondhand smoke (SHS) continues to present a significant public health and occupational hazard. As of April 1, 2011, only 48% of Americans were protected by 100% smoke-free legislation covering all workplaces, restaurants, and bars.<sup>1</sup> Lexington-Fayette (Kentucky) Urban County Government implemented a smoke-free enclosed public places law on April 27, 2004, prohibiting smoking in most enclosed public places, including, but not limited to, restaurants, bars, bowling alleys, bingo halls, convenience stores, laundry facilities, and other businesses open to the public.<sup>2</sup> Workers in buildings not open to the public—including facilities operated by private organizations, rooms used for private social functions and those in retail tobacco stores, government office buildings or workplaces (pursuant to Kentucky Revised Statute 61.165), and tobacco warehouses—remained exposed to SHS. The ordinance did not cover manufacturing facilities or government worksites, which have a preponderance of male workers,<sup>3,4</sup> thus putting men at greater risk for poor health outcomes related to SHS exposure. Kentucky has a rich tobacco-growing tradition and weak tobacco-control policies,<sup>5,6</sup> and its adult smoking rates for men and women are among the highest in the nation.<sup>7</sup> Tobacco-producing states such as Kentucky fall behind other states in enacting progressive tobacco-control policies,<sup>6</sup> in part due to a long tradition of pro-tobacco influence.<sup>8</sup>

Exposure to SHS has immediate, substantial, and sustained adverse effects on the cardiovascular system and is a cause of coronary heart disease among adults,<sup>9–15</sup> resulting in an estimated 46,000 coronary heart disease deaths annually among nonsmokers.<sup>13</sup> Nonsmokers exposed to SHS have a 25%–30% higher risk of coronary heart disease compared with those who are not exposed to SHS. Exposure to SHS alters both platelet and endothelial function, increasing the risk for acute myocardial infarction (AMI).<sup>9</sup> Even brief exposure to SHS affects both the number and function of endothelial progenitor cells and leads to sustained vascular injury.<sup>16</sup>

An estimated 1.2 million Americans are diagnosed with a new or recurrent AMI every year. Gender disparities in the incidence and mortality from AMI and in the influence of modifiable risk factors and medical therapies exist. Men are more likely than women to be diagnosed and hospitalized for AMI.<sup>17</sup> Further, in a study by Berger et al., 30-day crude mortality rates were higher among women than men; however, gender differences disappeared after controlling for relevant clinical factors.<sup>18</sup> Gender disparities have also been found in response to medical therapies designed to reduce

the risk of AMI (e.g., women may be less responsive to aspirin therapy than men).<sup>19</sup> Modifiable risk factors such as cigarette smoking, SHS exposure, high blood lipid levels, and obesity account for more than 90% of the risk for an initial AMI.<sup>20</sup> Young male current smokers have the highest population-attributable risk for AMI, and they are at particular risk as a result of exposure to SHS.<sup>21</sup> However, middle-aged women who smoke cigarettes are more likely to have AMIs than their male counterparts.<sup>22</sup> Women may be more sensitive than men to the harmful effects of smoking and more likely to develop ischemic heart disease due to exposure to tobacco smoke.<sup>23</sup>

While there is a preponderance of scientific evidence supporting the protective effect of smoke-free legislation on the heart,<sup>24–27</sup> there is emerging literature to suggest that gender may be an important consideration in studying the outcomes of this legislation. A study of New York City's comprehensive tobacco-control efforts reported a differential effect on smoking prevalence by gender.<sup>28</sup> Young adult women were more likely to quit smoking compared with young adult men following smoke-free legislation and smoking cessation assistance. One study in Rome found that a smoke-free public places law was associated with reductions in acute coronary events among middle-aged men but not women.<sup>29</sup> Indeed, studies suggest that smoke-free legislation may have greater effects on AMIs experienced by men, regardless of smoking status.<sup>30</sup> Low-income women may remain exposed to SHS at work in smoke-free communities.<sup>31</sup> Greaves and Hensing called for a framework that is sensitive to gender when developing and evaluating smoke-free policies.<sup>32</sup>

We examined the effects of a non-comprehensive smoke-free law in Lexington, Kentucky, on hospitalizations for AMI among men and women. Given that a substantial number of men, who comprise the majority of the manufacturing and government workforce, were not protected by the smoke-free law, we hypothesized that females would be more likely than males to experience a decline in AMIs after the law took effect (hereafter, “post-law”).

## METHODS

We measured AMI events 40 months prior to and 32 months after the enforcement of Lexington-Fayette County's smoke-free law on April 27, 2004. The statewide administrative database (Comp Data) was the data source for all Lexington-Fayette County hospital billing records for the four health-care systems serving the area. Records included hospital discharge diagnosis by International Classification of Diseases, Ninth

Revision (ICD-9) billing code, dates of service, gender, age, and county of residence. Tobacco use information was not available. While some residents of Fayette work outside the county, most who live in the county also work there.<sup>33</sup> We excluded from the analysis patients treated in Fayette County who lived outside the area.

Cases were included in the analysis if (1) the patient was  $\geq 35$  years of age; (2) the patient had a primary discharge diagnosis of AMI, with an ICD-9 code in the range of 410.00 to 410.99; and (3) the date of service was between January 1, 2001, and December 31, 2006. We omitted patients younger than 35 years of age because approximately 10% of the cases were younger than this cutoff, which would have led to very small cell sizes after further considering the 10 relevant age-by-gender categories; omitting patients younger than this cutoff is consistent with a prior study by Juster et al.<sup>34</sup> We chose discharge diagnosis as the criterion for inclusion, as it is a more accurate reflection of the true condition than the diagnosis at admission (e.g., chest pain due to gall bladder disease vs. heart attack).<sup>35</sup>

### Data analysis

We summarized the pre- and post-law demographic characteristics of patient populations using descriptive statistics; we compared pre- and post-law events using a two-sample t-test or the Chi-square test of association. We combined the yearly number of cases for residents of Lexington-Fayette County with the corresponding population estimate to obtain crude annual rates.<sup>36</sup> We then age-adjusted these crude rates, with standardization to the 2000 U.S. Census population estimates for each corresponding age cohort. We determined annual age-adjusted rates for the entire group of patients, as well as for women and men separately. While we recognize the gender gap in smoking prevalence, especially among Latinos in the U.S.,<sup>37</sup> we were unable to control for race/ethnicity in this study due to relatively few minority cases in the state (and county), whose population is predominantly non-Hispanic white.

We modeled the monthly rates for AMI hospitalizations during the six-year period using Poisson regression; we specified the negative binomial distribution to allow for over- or under-dispersion. We based the model on crude (unadjusted) rates, given that age was included as a covariate in the model. The initial regression model included the effects of law status (pre-law vs. post-law), gender, age (with seven categories corresponding to Census data cohorts  $\geq 35$  years of age), and the two- and three-way interactions of these effects. We used the log of the estimated population size as an offset variable in the model, with population estimates specific to the year, gender, and age category of the

cases. The regression model also contained annual Fayette County weighted estimates for adult smoking rates, obtained from the Behavioral Risk Factor Surveillance System; an indicator for time (month of event, ranging from one to 72) to assess secular trends unrelated to law implementation; a law status by time interaction term to estimate whether AMI hospitalization rates continued to change over time; and first- and second-order harmonics to account for seasonal variation. We sequentially removed the interaction terms not significant in the initial model for ease of interpretation, with little change in model fit. We determined goodness of fit of the models using Pearson's Chi-square statistic and corresponding degrees of freedom.

In addition to Poisson regression, we considered a first-order autoregressive time-series model. Consistent with a study comparing these two strategies when quantifying time trends for relatively rare outcomes<sup>38</sup> (e.g., hospitalizations for AMI), there were no appreciable differences for the present study in the level of significance between these two methods for any of the predictors. We reported the Poisson regression results in this article, as this method estimates the relative risk (RR) of an event post-law compared with pre-law, adjusting for county-level smoking rate and demographic, time-trend series, and seasonal main effects and significant interactions in the model.

Due to the significant interaction between law status and gender in the Poisson model, we plotted the actual monthly gender-specific rates per 100,000 population, weighted by age distribution, on a graph of the predicted rates based on the Poisson regression model, with separate curves for men and women. We conducted data analyses and graphing using SAS<sup>®</sup> version 9.1,<sup>39</sup> with  $\alpha=0.05$ .

### RESULTS

During the six-year study period, there were a total of 2,692 AMI hospitalizations among Lexington-Fayette County residents, including 1,564 before the smoke-free law (i.e., through April 2004) and 1,128 post-law. The average age for pre-law AMI cases (67.3 years) was older than the average age for the post-law period (65.5 years) ( $t=3.2$ ,  $p=0.001$ ). The percentage of female AMI cases was lower in the post-law period (38%) than in the pre-law period (47%) ( $\chi^2=24.0$ ,  $p<0.0001$ ).

As shown in Table 1, the age-adjusted rates for men did not exhibit a directional trend over time, but there was a decrease in these rates for females from 2003 to 2004 (the year when the smoke-free law was implemented), which was maintained during the subsequent two years. As there was no systematic change

**Table 1. Size of the population aged ≥35 years at risk for AMI hospitalization, with number of cases and age-adjusted rates, by gender and overall: Lexington-Fayette County, Kentucky, 2001–2006**

Year	At-risk population N	AMI hospitalizations					
		Women ≥35 years of age		Men ≥35 years of age		All patients ≥35 years of age	
		N	Rate <sup>a</sup>	N	Rate <sup>a</sup>	N	Rate <sup>a</sup>
2001	123,702	230	174.7	243	244.9	473	209.4
2002	124,121	234	178.3	256	260.2	490	216.1
2003	125,272	213	159.2	237	225.4	450	195.0
2004	125,988	162	121.1	266	257.9	428	182.0
2005	126,952	168	122.3	258	251.0	426	180.3
2006	128,305	153	112.5	272	247.0	425	174.3

<sup>a</sup>Age-adjusted rate per 100,000 at-risk population, adjusted to the 2000 U.S. Census

AMI = acute myocardial infarction

in age-adjusted rates for men, the decline over time was less pronounced in the combined group of men and women.

The final Poisson regression model fit the data well; the ratio of Pearson's Chi-square statistic to the degrees of freedom was 0.98, close to the null value of 1.0. In addition to the main effects of law, gender, and age, as well as the time-trend series and harmonic terms, the final model contained the two-way interactions of gender with law and age. Other interaction terms, including the interaction between law status and time, were not significant and were removed from the final model. We used the main effect of law and the gender-by-law interaction effect to determine the post- and pre-law RRs for women and men within the Poisson model, adjusting for county-level adult smoking rate, demographics, time trends, and seasonality.

As displayed in Table 2, the rate of AMI hospitalizations declined by 97.1 per 100,000 person-years from pre- to post-law for women, but men demonstrated an increase of 13.8 per 100,000 person-years for this

pre- to post-law comparison. Considering only the number of cases for each gender pre- and post-law, along with the corresponding size of the at-risk population for each gender and time frame, the RR of an AMI hospitalization was 0.71 for women and 1.03 for men; the decline in AMI hospitalizations was significant for women ( $p < 0.05$ ) but not for men.

The results of the Poisson regression adjusting for county-level smoking rate, demographic factors, time trends, and seasonality were similar to the unadjusted RRs. For women, the RR of post- to pre-law AMI hospitalizations was 0.77 ( $p = 0.02$ ), while the RR for men was 1.11 ( $p = 0.3$ ); these adjusted comparisons also demonstrated a significant decline for women and a nonsignificant change for men (Table 2). Among women, AMI hospitalizations declined 23% post-law, while the rate of these AMI events among men did not change significantly between the two time periods.

The Figure shows the actual rates of AMI hospitalizations per month for women and men relative to the size of the population at risk, weighted by age

**Table 2. Rate of AMI hospitalizations among people ≥35 years of age before and after implementation of a public places smoke-free law in 2004, by gender: Lexington-Fayette County, Kentucky, 2001–2006**

Gender	AMI hospitalizations		AMI hospitalizations post-law to pre-law RR (95% CI)	AMI hospitalizations post-law to pre-law, determined from Poisson regression <sup>b</sup> RR (95% CI)
	Pre-law rate <sup>a</sup>	Post-law rate <sup>a</sup>		
Female	334.4	237.3	0.71 (0.58, 0.87)	0.77 (0.62, 0.96)
Male	424.6	438.4	1.03 (0.87, 1.23)	1.11 (0.91, 1.36)

<sup>a</sup>Per 100,000 person-years

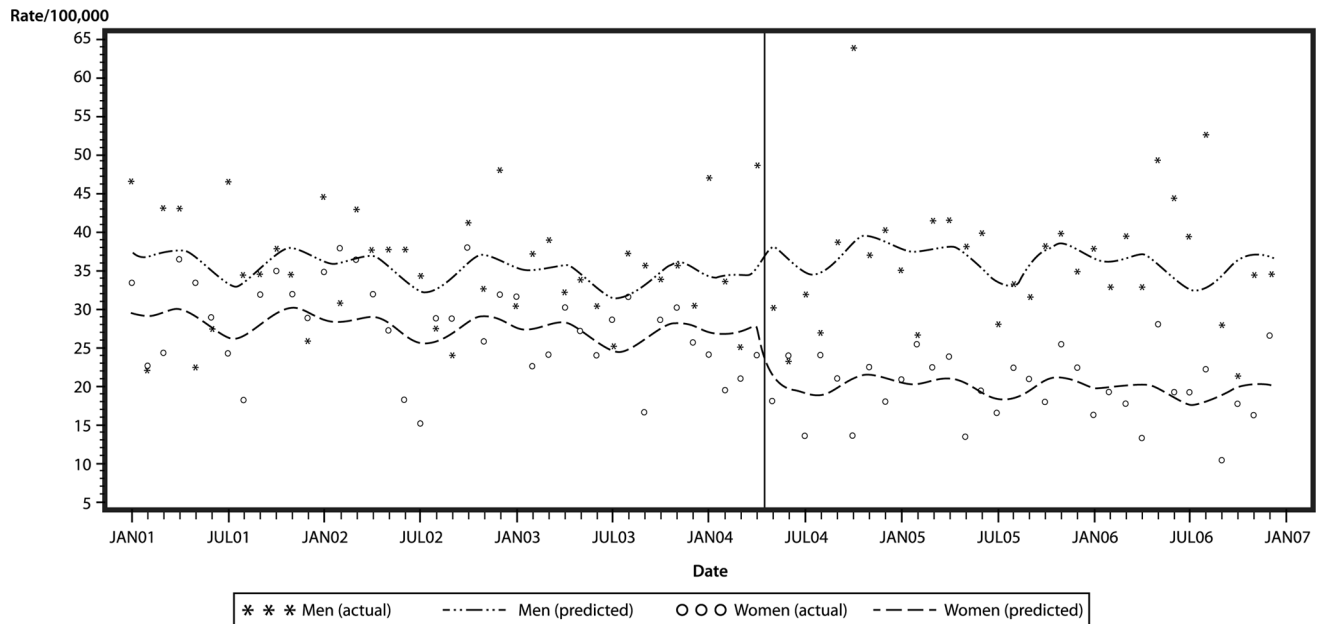
<sup>b</sup>Adjusted for county-level adult smoking rate, demographics, time, and seasonality. The two significant interaction terms retained in the regression were law status by gender and gender by age.

AMI = acute myocardial infarction

RR = relative risk

CI = confidence interval

**Figure. Actual and predicted monthly rates of AMI hospitalizations per 100,000 population before and after implementation of a smoke-free public places law in 2004: Lexington-Fayette County, Kentucky, 2001–2006<sup>a</sup>**



<sup>a</sup>The vertical line represents the date the smoke-free law went into effect (April 2004). The Poisson regression model used to determine the predicted rates demonstrated a 23% decrease in AMI hospitalizations for women after the law went into effect, while the change in rates for men was not significant.

AMI = acute myocardial infarction

distribution. The Poisson regression pre- and post-law curves predicted from the model described previously are also shown with separate curves by gender. Consistent with the age-adjusted rates presented in Table 1 and the significant decline among women in RR post-law (Table 2), the Figure illustrates that while the pre- and post-law curves for men were relatively stable over time, there was a notable post-law decline for women that was maintained during the 32-month post-law period.

## DISCUSSION

Following implementation of a smoke-free enclosed public places law in Lexington-Fayette County, there was a 23% decline in AMIs among women, adjusting for time trends, county-level smoking rate, seasonality, and the demographics of the at-risk population. The post-law rates for women were relatively stable during the 32-month post-law period, indicating that the protective effect of the smoke-free law was maintained for women. This 23% decline in AMIs was slightly higher than the estimate from one meta-analysis that reported a decline of 15% for each year after implementation.<sup>26,40</sup>

The fact that we did not see a beneficial effect of the law on AMIs among men may have been because the smoke-free legislation did not cover all workplaces at the time. Our findings are inconsistent with two studies of smoke-free legislation and AMI in Italy. One study in Piedmont found a significant decline in admissions for AMIs among both men and women younger than 60 years of age following implementation of a smoke-free law that covered all indoor public places but not all workplaces.<sup>41</sup> Another study in Rome showed a significant reduction in acute coronary events (including, but not limited to, AMI) among Roman men but not women following implementation of the smoke-free public places law.<sup>29</sup> Our dissimilar findings may have been due to Kentucky's pro-tobacco heritage, coupled with higher-than-average adult smoking<sup>7</sup> and cardiovascular disease<sup>42</sup> rates.

Both AMI prevalence and rate of hospitalizations for cardiovascular disease showed a steady upward trend from 2001 to 2006 in Kentucky. The prevalence of AMIs increased from 5.0% to 6.6% from 2003 to 2006 (prevalence data not available for 2001–2002).<sup>43</sup> Among men, AMI prevalence during this time period changed from 6.6% to 8.3%, representing a 26% increase; among

women, there was a 39% increase in AMI hospitalizations, from 3.6% to 5.0%. The rate of cardiovascular hospitalizations among Kentuckians also increased from 210.3 per 10,000 population to 232.9 per 10,000 population during the six-year period;<sup>42</sup> gender-specific rates were not available. While AMI prevalence and cardiovascular disease were trending upward in the state during the study period, AMI events for women in Lexington, the second-largest metropolitan area of Kentucky, showed a decline during this time period that coincided with implementation of the smoke-free law. Further research is needed to determine the differential effects of smoke-free legislation on AMIs among men and women.

This is the first study to report an association between smoke-free laws and AMIs among women but not men. At the time of this study, Lexington's law covered all venues open to the public; however, not all workers were protected. Lexington's ordinance at the time was not a 100% smoke-free workplace law; rather, it covered all buildings open to the public. Manufacturing facilities that were not open to the public were not mandated to be smoke-free. Of the civilian employed population aged 16 years and older in Fayette County, 9.5% work in manufacturing. While men comprise 53.7% of the civilian workforce in Fayette County, 77.5% of manufacturing workers are male.<sup>3</sup> Further, government office buildings or workplaces were not covered by the ordinance. Of the civilian employed population aged 16 years and older in Fayette County, 18.1% work for the government (including local, state, and federal). While men comprise 53.7% of the civilian workforce in Fayette County, 48.5% of government workers are male.<sup>4</sup> Combining these two work sectors, 27.5% of the civilian workforce  $\geq 16$  years of age work in manufacturing and government. While men comprise 53.7% of the workforce in the county, they comprise 58.5% of workers in these two sectors not protected by the smoke-free ordinance. The gender distribution of workers in other workplaces not covered by the smoke-free policy, including workers in tobacco retail stores, is not known.

A plausible explanation for the lack of effect of the legislation on AMIs among men, and one possible contributing factor to our findings, was that men are overrepresented in the manufacturing and government sectors and that those workers were not covered by Lexington's smoke-free ordinance. Another factor that could have contributed to the decrease in AMI hospitalizations was the decline in adult smoking prevalence in Fayette County after the law went into effect.<sup>44</sup> However, the rate of decrease did not differ by gender.

One possible explanation for the protective effect of the smoke-free law among women was that women are overrepresented in the food service/hospitality industry in Fayette County. Although 54.4% of food preparation and serving-related workers in Fayette County are female, women comprise only 46.3% of the civilian workforce.<sup>3</sup> It is well-known that workers in the food service industry are disproportionately affected by SHS on the job.<sup>45</sup> The protective effect of the smoke-free law for hospitality workers is evident from other studies in Lexington. There was a dramatic improvement in air quality in hospitality venues<sup>46</sup> and an immediate reduction in hair nicotine among bar and restaurant workers following implementation of Lexington's smoke-free law.<sup>47</sup> While more research is needed, at least two studies suggest that women may be more sensitive to tobacco smoke,<sup>22,23</sup> perhaps putting them at higher risk for AMIs when exposed to SHS. The exact mechanism is unclear, but there is speculation that tobacco smoke may have an anti-estrogenic effect, particularly in young, premenopausal women who would otherwise benefit from estrogen's cardioprotective role.<sup>22</sup> Smoke-free laws may be more protective for women, given the possibility that they may be more sensitive than men to tobacco smoke.

#### Limitations

This study had several limitations. One limitation was the absence of a control or comparison group. We cannot infer causation, but we can say that there was an association between smoke-free laws and AMIs based on the pre-post, no-control-group design. We also were unable to examine differences by race/ethnicity, given the small subgroup sizes for racial/ethnic minority group categories in Lexington-Fayette County. Another limitation was the potential for underestimation of AMI cases, given the migration of workers both in and out of Lexington. Lexington-Fayette County is a growing metropolitan area in which some residents commute outside the county to work. Similarly, there are people who live in surrounding counties who commute to Lexington-Fayette County to work. Health outcomes of those who work in the county but live elsewhere were not investigated because their place of work was unavailable. Likewise, Fayette County residents who work elsewhere may have been hospitalized in a non-county hospital during work hours, and they were not included in the analysis. The limited number of personal characteristics for each case was another limitation, as data on tobacco use and SHS exposure were not available. Many in our sample may have been current smokers, but we did not have access to these data.

## CONCLUSIONS

There was a 23% decline in AMIs among women after implementation of Lexington's smoke-free public places ordinance in 2004. We found this decline despite the fact that AMI prevalence and hospitalizations for cardiovascular disease were on an upward trend in Kentucky during the study period. We did not find an effect of the law on AMIs among men. The overrepresentation of women in the hospitality industry in Fayette County, combined with the disproportionate number of men working in manufacturing facilities and government worksites not mandated by the smoke-free law, may partially explain why women may have been more protected by this law than men. Another explanation is that women may be more sensitive to tobacco smoke and, thus, more likely to be protected by smoke-free legislation. Further research is needed to examine the differential effects of smoke-free laws by strength of law, gender, and worker subgroup.

To date, most of the published smoke-free law and AMI studies have evaluated the impact of comprehensive 100% smoke-free workplace and public places legislation.<sup>34,48-50</sup> While 23 U.S. states and 454 communities have adopted laws requiring all workplaces, restaurants, and bars to be smoke-free, the majority of states and municipalities in the U.S. have been slow to protect all workers from exposure to SHS.<sup>51</sup> We found gender differences in the reduction of AMI hospitalizations following implementation of a smoke-free law that covered only some sectors of the workforce. Enacting comprehensive smoke-free laws that cover all places of employment and strengthening existing partial laws may extend protection against AMIs to both male and female workers. However, smoke-free legislation is greatly influenced by the corporate tobacco lobby and anti-government groups, and progress toward protecting all workers from SHS requires adequate resources and commitment to pro-health advocacy.<sup>8</sup>

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