The Effect of the Smoke-Free Workplace Policy in the Exposure to Secondhand Smoke in Restaurants, Pubs, and Discos in San Juan, Puerto Rico

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Background: Tobacco use and the involuntary exposition to secondhand smoke (SHS) is one of the leading causes of all cancers in the world. The objective of this study was to assess the effect of the smoke-free workplace policy implemented in March of 2007 in Puerto Rico on the exposition to secondhand smoke in restaurants, pubs, and discos of the metropolitan area of San Juan, Puerto Rico.

Methods: The study used a pre-post comparison design on a random sample of 55 establishments (32 restaurants and 23 pubs and discos) in the metropolitan area of San Juan, Puerto Rico. Measurements of indoor concentrations of fine particulate matter (PM) (2.5 mm diameter, $PM_{2.5}$) were taken before and after the introduction of the law banning smoking using a SidePak AM510 Personal Aerosol Monitor (TSI Company). Also, data on the number of smokers, number of customers, and establishment area was collected. Paired t-tests and linear regression analyses were used to test any statistically significant effect of the law.

Results: After the smoking ban was implemented, restaurants experienced an 83.6% (p=0.013) reduction in the mean of PM 2.5 levels, from 0.169 to 0.028 mg/m3, and pubs and discos experienced a 95.6% (p=0.004) reduction, from 0.626 to .028 mg/m^3.

Conclusion: The implementation of the smoke-free workplace policy considerably reduced the exposition to SHS of workers and customers in the restaurants, pubs, and discos of the metropolitan area of San Juan, Puerto Rico. [*P R Health Sci J 2010;3:279-285*]

Key words: Smoke-free workplace policy, Secondhand smoke, Indoor air quality, Puerto Rico

The negative health consequences of tobacco use are well established (1). Smoking is the leading cause of preventable death and disability among adults in the US and almost one-third of all cancers are directly attributable to tobacco use (2). Although the prevalence of smoking for the year 2008 in Puerto Rico (PR) is lower (11.6%) than in the continental US (18.3%) (3), the five leading causes of death in PR are associated with smoking (i.e., heart disease, malignant neoplasms, stroke, hypertension and chronic pulmonary disease) (4). Moreover, 11.5% of all deaths and 10% of all health care costs in PR are attributable to smoking (5). Thus, even with a lower prevalence of smoking than that found in the US, tobacco exerts a tremendous public health burden on PR. Also, in the last four decades, public health authorities around the world, like the United States Surgeon General (6), Office of Safety and Health Administration (OSHA) (7), and the World Health Organization (WHO) (8-9) have been warning the general population about how the exposure to secondhand smoke (SHS) is dangerous for nonsmokers.

On March 2 of 2007, with the implementation of Law 66, Puerto Rico became a smoke-free island by completely banning indoor smoking in public places such as bars, pubs, casinos, hotels, work places with more than one employee, and cars with any passenger under the age of 13 . According to the literature, the immediate impact of smoke-free workplace policies has been to dramatically reduce the exposition to SHS for customers and workers (10-17). Many studies have used the level of respirable particulate matter ($PM_{2.5}$) as the main indicator of exposure to

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SHS because it has been demonstrated that smoking is one of the main sources of indoor levels of $PM_{2.5}$ (10). For example, bars in the state of New York experienced an average reduction of 84% in their $PM_{2.5}$ levels after the Clean Indoor Air Act was implemented in July of 2003 (11). In the case of Austin, Texas, bars experienced a reduction from 71% to 99% in their $PM_{2.5}$ levels after a smoking ban was implemented (12). In another study (13), Irish-theme pubs around the globe located in countries or cities with smoke-free legislation were compared with similar pubs in places without smoke-free ordinances. In this case, the results showed an average 91% reduction in $PM_{2.5}$ levels. In March of 2006, a smoking ban was implemented in Scotland, which substantially covered enclosed places including pubs. Evidence shows that, as a result, Scottish pubs experienced an average of 86% reduction in $PM_{2.5}$ levels (14). In Italy, a year after the implementation of an all smoke-free workplace policy in January of 2005, there was an average of 68% reduction in $PM_{2.5}$ levels across bars, restaurants, game rooms, and pubs (15).

The main claim of this study is that the smoke-free workplace policy implemented in March of 2007 was effective in reducing the exposure to SHS in restaurants, pubs, and discos in the metropolitan area of San Juan, Puerto Rico. The specific research objectives of the study were three. First, to measure and compare the restaurants, pubs, and discos in the metropolitan area of San Juan at baseline (before the smoke-free workplace policy was implemented) in terms of the levels of respirable particulate matter (PM), the number of smokers, the number of customers, and establishment area. Second, to measure the change in levels of PM, the number of smokers, and the number of customers before and after March 2007. And third, to measure the effect of the smoke-free workplace policy on the level of PM controlling for the number of customers and establishment area.

Methods

Design and Sampling

This study used a pre-post design in where pre-law measurements were taken on January and February 2007 and post-law measurements were taken from September to December 2007. The establishments were divided in two groups, restaurants and pubs/disco and a separate simple random sample was taken for each group. The sampling process started by preparing a computer file containing two worksheets, one with a complete list of restaurants and the other with a complete list of pubs and discos located in the metropolitan area of San Juan. The metropolitan area of San Juan was defined as the geographical area covering the following municipalities: Bayamon, Carolina, Cataño, Dorado, Guaynabo, San Juan, Toa Baja, and Trujillo Alto. Fast food and restaurant chains that already were known to have non-smoking policies in place were excluded from the list. In the case of pubs and discos, there was no need of exclusions because all of these establishments allowed indoor smoking. The final list of establishments gathered for each group consisted of 985 restaurants and 60 pubs and discos. This study received final IRB approval from the Medical Sciences Campus of the University of Puerto Rico in February of 2007.

In the second step, the minimum sample size needed for each type of establishment was estimated. The main outcome variable in this study was the level of respirable particulate matter (PM) measure in terms of micrograms per cubic meter (mg/m^3). Since the formula to estimate the minimum size of a simple random sample requires an estimate of the variance and precision of the outcome variable, data from a previous study that evaluated a smoke-free workplace ban law in Massachusetts 8 was used as reference. Based on a probability of Type I error of 0.05 and after adjusting for population size, the minimum sample size needed for each type of establishment was 27 for restaurants and 19 for pubs and discos. An attrition rate of 30% was assumed, therefore the sample sizes were inflated to compensate for this and, as a result, the final sample sizes were 39 for restaurants and 27 for pubs and discos.

For the third step, each establishment was assigned a random number and then, each list was sorted in ascending order according to the random number field. Then, the first 39 restaurants and 27 pubs and discos were selected and copied in separate lists. The fourth step was the recruitment of the establishments. As part of this process the research team attempted to make telephone contact with the management or owners of all the establishments selected in the sample to explain them the purpose of the study and to ask for their collaboration. If they accepted to participate in the study, they were informed that in a few days, personnel from the research team would visit their facilities. However, some establishments were excluded from the sample due to the following reasons: if the establishment already had in place an indoor non-smoking policy before the law was implemented in march of 2007, if the establishment decided not to participate in the study, if the research team was not able to find the physical location of the establishment, and, if as a result of an assessment by the research team the establishment was identified a high risk place due to conditions of the neighborhood, or physical facilities, or activities taking place inside the establishment. Excluded establishments were substituted with establishments in the alternate lists that were located around the area of the establishment which was originally selected. This process continued either until the target of the final sample size was reached or time ran out because the law was about to come in effect.

As result of this process, the first day of March of 2007, the day before the law became effective, a total of 38 restaurants and 27 pubs and discos were contacted and/or visited. However, due to exclusions and attrition, the final number of restaurants for which pre and post measurements were available was 32 and for pubs and discos the final sample was 23.

Data and Measurements

The SidePak AM510 Personal Aerosol Monitor equipment manufactured by the TSI Company was used to obtain the air samples and measure the level of respirable particulate matter levels within each establishment. The monitor measures the concentration of particles that are less than 2.5μm in diameter which is referred in the literature as concentration of $PM_{2.5}$. After the authorization by the owner of the establishment was received, the aerosol monitor was put in a specific location and for 20 minutes; it took an air sample every 15 seconds. The same location within each establishment was used for pre and post measurements. In addition to the $PM_{2.5}$ measurements, information and data of the establishment about the facility area in square feet, number of customers at the moment of the visit, and number of customers smoking was collected. The $PM_{2.5}$ was measured in terms of micro grams per cubic meter of air (mg/m^3), the area of the establishment in terms of square feet, and simple counts for customers and smokers present in the establishment at the moment of the visits.

Statistical Analysis

To achieve the objectives of the study, first, the descriptive characteristics of the variables by type of establishment, but only for pre-law measurements are described. Due to the highly right skewed distribution of the variables, the variables were transformed into their natural logs which tend to decrease the skewness of the variables and make it closer to a normal distribution. Thus, descriptive statistics are shown for PM, number of customers, number of smokers, and establishment area measured in their original metrics and also in their natural logs. In the second step a series of bivariate statistical tests were performed to examine if there were any significant differences between the different types of establishments at baseline.

Second, a series of bivariate statistical tests were performed to examine if there were significant differences within each type of establishment before and after the implementation of the smoking ban. Differences between groups at baseline were tested using a student's t-tests and paired t-tests were performed to examine pre and post-ban differences on the level of $PM_{2.5}$, in the number of smokers, and the number of customers in the establishment, for each type of establishment. We used Student's t-test and paired-t tests with the original values of the variables and their natural logs.

A third stage of analysis was performed by estimating a group of linear regression equations for each type of establishment in where the dependent variables was the natural log of $PM_{2.5}$. The independent variables were the following: a binary dummy variable representing the implementation of the smoking ban (1=post-ban, 0=pre-ban), the natural log of the number of customers, and the natural log of the establishment area. After estimating the first regression, if any of the variables were at least statistically marginally significant ($p \leq 0.10$), a second regression was run which included an interaction term between the dummy for the smoking ban and the natural logs of customers and area. If these interactions were at least statistically marginally significant, the final regression model reported including the interaction terms, if there were not significant, the first model, without interactions, was reported.

Since there were two observations for each establishment (pre and post-ban measurements) the data file structure is what is known as panel data or longitudinal data, in where there are multiple time periods of observations for the same unit. Due to the potential correlation of observations within each unit of observation (the establishment), a simple pooled ordinary least square (OLS) regression estimation is unlikely to be adequate. Instead, a random effects regression was used to capture, not only the correlation of observations within each establishment, but also to capture the fact that most observation units were drawn from a random sample. A generalized least square (GLS) approach was used to estimate the random effects regressions (18).

Results

Descriptive Statistics and Bivariate Analysis

In table 1, the descriptive statistics for the $PM_{2.5}$ levels, number of customers, number of smokers, and establishment area are shown together with their natural logs. The first fact that stands out is that all of these variables tend to be skewed with a long right tail which indicates the existence of outliers with large values. This is obvious from the differences between the mean and the median and the magnitude of the skewness coefficient for each variable. By transforming the variables from their original scale to their natural log, a new variable is obtained which preserves the original order of the values, but also tends to be less skewed and more similar to a normal distribution. This is advantageous, since most of the statistical tests used with quantitative and continuous variables assumed that their distribution behaves similar to a normal distribution.

In the case of $PM_{2.5}$, the level is considerably larger for the pubs/discos with a mean of .626 (mg/m^3) compared to .169 for restaurants. The same occurs with the mean number of customers present during the time where the pre-ban measurement was taken with a mean of 73.2 for pubs and discos and 23.2 for restaurants. Also, there is a large difference in the average number of smokers observed during the pre-ban measurements. There were 14.5 for pubs and discos and 3.7 for restaurants. The Student's t-test results showed that these differences are at least marginally significant ($p \leq 0.10$) for variables in their original scale and natural logs. The only exception is for the natural log of the number of smokers where the test is not statistically significant. However, restaurants and pubs/discos are similar in terms of establishment area with means of 4,173 and 4,520 square feet, correspondingly. This is confirmed by the fact that the Student's t-test was not statistically significant.

Table 1. Descriptive statistics of the variables at baseline (pre-ban), by type of establishment

	Restaurants (n=32)		Pubs and Discos (n=23)	
Particulate Matter ($PM_{2.5}$)	**mg/m^3**	**natural log of mg/m^3**	**mg/m^3**	**natural log of mg/m^3**
Mean**	0.169	-3.057	0.626	-1.715
SE	0.060	0.298	0.202	0.387
Median	0.050	-2.996	0.197	-1.625
Skewness	3.555	0.060	2.422	-0.236
Minimum	0.001	-6.908	0.007	-4.962
Maximum	1.697	0.529	4.050	1.399
Customers	**count**	**natural log of count**	**count**	**natural log of count**
Mean**	23.2	2.9	71.3	3.4
SE	3.46	0.14	23.50	0.27
Median	15.0	2.8	22.0	3.1
Skewness	1.403	0.004	2.420	0.515
Minimum	2.0	1.1	3.0	1.4
Maximum	82.0	4.4	436.0	6.1
Smokers	**count**	**natural log of count**	**count**	**natural log of count**
Mean*	3.7	1.0	14.5	1.6
SE	1.03	0.17	5.79	0.31
Median	1.5	0.9	4.0	1.6
Skewness	2.346	0.743	2.575	0.664
Minimum	0.0	0.0	0.0	0.0
Maximum	24.0	3.2	110.0	4.7
Area	**ft^2**	**natural log of ft^2**	**ft^2**	**natural log of ft^2**
Mean	4,173.0	7.9	4,520.9	7.7
SE	1,040.5	0.2	1,690.0	0.2
Median	1,925.0	7.6	1,845.0	7.5
Skewness	3.553	1.100	3.863	0.398
Minimum	1,000.0	6.9	150.0	5.0
Maximum	3,0000.0	10.3	3,9000.0	10.6

Note: SE is the standard error of the coefficient. One asterisk (*) implies that the means between restaurants and pubs/discos are different when the student-t tests (adjusted for unequal variance) were applied to the variables in their original scales. Two asterisks (**) implies that the means are different when the student-t tests (adjusted for unequal variance) were applied to the variables in their original scales and also on their natural log. The significance level was set at p≤0.10.

As was mentioned previously, to compare the means of the variables between pre and post-ban measurements within each type of establishment, a series of paired-t tests were performed. The results of theses analysis are shown in Table 2. As can be seen, the implementation of the smoking ban was associated with an important reduction in the mean level of $PM_{2.5}$ for each type of establishment. In the case of restaurants, the $PM_{2.5}$ levels decreased from 0.169 to 0.028 mg/m^3 and for pubs and discos the levels decreased from 0.626 to .028 mg/m^3. These numbers translate into an 83.6% reduction in the mean $PM_{2.5}$ levels for restaurants and 95.6% reduction for pubs and discos. The paired-t tests show that these reductions in restaurants and pubs/discos are statistically significant (p≤0.05). In addition, it turns out that after the implementation of the smoking ban, the average $PM_{2.5}$ levels for both restaurants and pubs/discos were exactly the same at 0.028 mg/m^3.

Table 2. Paired t-test for differences in means for pre and post-ban measurements of particulate matter, customers, and smokers, by type of establishment

Variables	Restaurants (n=32)		Pubs and Discos (n=23)	
Particulate Matter ($PM_{2.5}$)	**mg/m^3**	**natural log of mg/m^3**	**mg/m^3**	**natural log of mg/m^3**
Mean Pre-ban	0.169	-3.057	0.626	-1.715
Mean Post-ban	0.028	-4.204	0.028	-4.056
Difference	-0.141	-1.147	-0.598	-2.342
Difference (%)	-83.6%	-	-95.6%	-
t stat	2.332	3.454	2.956	5.848
P value(one-tail)	0.013	<0.001	0.004	<0.001
t critical (one-tail)	1.696	1.696	1.717	1.717
Customers	**count**	**natural log of count**	**count**	**natural log of count**
Mean Pre-ban	23.2	2.9	71.3	3.4
Mean Post-ban	25.5	3.1	37.4	2.9
Difference	2.3	0.2	-33.9	-0.6
Difference (%)	10.0%	-	-47.5%	-
t stat	-0.523	-1.046	2.080	1.896
P value (two-tail)	0.605	0.304	0.049	0.071
t critical (two-tail)	2.040	2.040	2.074	2.074
Smokers	**count**	**natural log of count**	**count**	**natural log of count**
Mean Pre-ban	3.7	1.0	14.5	1.6
Mean Post-ban	0.0	0.0	0.3	0.1
Difference	-3.7	-1.0	-14.1	-1.5
Difference (%)	-100.0%	-	-97.6%	-
t stat	3.542	6.012	2.421	4.247
P value(one-tail)	<0.001	<0.001	0.012	<0.001
t critical (one-tail)	1.696	1.696	1.717	1.717

The mean number of customers remains almost the same before and after the implementation of the smoking ban for the restaurants, but for pubs and discos there was a reduction from an average of 71.3 customers before the smoking ban to 37.4 after its implementation. This reduction of 33.9 in the mean number of customers represents a 47.5 % reduction. According to the paired-t tests, this reduction was marginally significant (p≤0.10) either when looking at the mean number of customers or to its natural log. In the case of the mean number of smokers, there were important and statistically significant reductions for all type of establishments after the implementation of the smoking ban. For restaurants, the decrease was from 3.4 to 0.0 mean numbers of smokers and for pubs and discos the reduction was from 14.5 to 0.3 smokers. According to the paired-t tests,

these reductions were statistically significant ($p \leq 0.05$) either when looking at the mean number of smokers or the mean of its natural log.

Regression Analysis

In Table 3, the results of the regressions for the natural log of particulate matter, by type of establishment, are shown. The smoking ban had a negative and statistically significant effect ($p \leq 0.05$) on the natural log of $PM_{2.5}$ for both restaurants and pubs/discos, even after controlling for the number of customers and the establishment area. Interestingly, the negative coefficient of the smoking ban was larger for pubs/discos (-2.14) than for restaurants (-1.12), which is consistent with the bivariate analysis. For the restaurants, the regressions coefficients for the natural log of the number of customers and the establishment were statistically significant ($p \leq 0.05$). These coefficients suggest that the number of customers has a positive effect on the level of $PM_{2.5}$ (0.526) while the area of the establishment has a negative effect (-.484). In the case of pubs and discos, the regression coefficient for the natural log of customers was statistically significant ($p \leq 0.05$) but the coefficient for the establishment area was not significant. As in the case of restaurants the association between the level of $PM_{2.5}$ and the number of customers was also positive (0.428) for pubs and discos. Interactions between the smoking ban dummy variable with the natural log of customer and area were tested for both types of establishments, but were not statistically significant; therefore, the final models do not include these interactions terms. This implies that the negative effect of the smoking ban on $PM_{2.5}$ is the same within each type of establishment, no matter how many customers were in the establishment or the establishment's area.

Table 3. Generalized least squares (GLS) coefficient estimates for the random-effects and linear regression models on the natural log of particulate matter ($PM_{2.5}$), by type of establishment.

	Linear regression for restaurants (n=32)		Linear regression for pubs and discos (n=23)	
Independent variables	**Beta**	**SE**	**Beta**	**SE**
Dummy binary variable for the smoking ban	-1.119**	0.333	-2.144**	0.405
Natural log of the count of customers	0.526**	0.244	0.428*	0.235
Natural log of the establishment area	-0.484**	0.215	0.136	0.252

Notes: a) SE is the standard error of the coefficient. b) Regression coefficients with an asterisk (*) indicates a marginal statistical significance of $p \leq 0.10$. Coefficients with two asterisks (**) indicates a statistical significance of $p \leq 0.05$.

Discussion

The statistical analysis shows that the implementation of the workplace smoking ban in Puerto Rico in March of 2007 significantly decreased the level of exposition to secondary hand smoke in the restaurants, pubs, and discos of the metropolitan area of San Juan. This reduction came about through a significant reduction in $PM_{2.5}$ levels which was a product of a large reduction in the number of smokers within each type of establishment after the implementation of the smoking ban. The law was able to reduce the number of smokers by 100% in restaurants and 97.6% in pubs/discos. These reductions in smokers, however, were not a consequence of reductions in the numbers of customers as the statistical analysis shows. As a consequence of the drastic reduction in the number of smokers, the average level of $PM_{2.5}$ decreased by 83.6% in restaurants and 95.6% in pubs/discos. The regression analysis shows that, after controlling for the number of customers and the size of the establishment area, the effect of the smoking ban was relatively larger for the pubs/discos compared to the restaurants.

The results of this study are very similar to the results of other studies done in countries, states, or cities where workplace smoking bans have also been implemented in the hospitality industry. As was mentioned in the literature review (10-17), bars in the state of New York and Austin, Texas experienced an average reduction of 84% and 99% in their $PM_{2.5}$ levels, Irish-theme pubs around the globe and Scottish pubs experienced a corresponding average reduction of 91% and 86% in $PM_{2.5}$ levels and, in Italy, there was an average of 68% reduction in $PM_{2.5}$ levels across bars, restaurants, game rooms, and pubs. Thus, the smoke-free workplace policy in the restaurants, pubs, and discos of the metropolitan area of San Juan has been as effective as any other smoke-free workplace policy implemented elsewhere in the world in terms of reducing exposition to SHS for workers and customers.

Limitations

One of the limitations of this study, however, is that its findings are limited to the metropolitan area of San Juan which covers one fourth of all the population of the island of Puerto Rico. Due to the lack of resources, this study was not able to include any restaurant, pub, or disco located in any of the cities and small towns outside the metropolitan area of San Juan. Therefore, the results of this study are not necessarily applicable to similar establishments in the rest of the island.

Conclusion

This study provides evidence that the implementation of indoor and workplace smoking bans in Puerto Rico has been successful in reducing the risk of exposition to secondhand smoke (SHS) to the general population who lives and works in the metropolitan area of San Juan. Together with the results of other studies around the world, the evidence continues to encourage the promotion of smoke free legislation as one of the most important public health interventions against

tobacco use. Despite this success, it is important to expand the geographical cover of the research and study how the smoking ban has been implemented in other areas of the island. Also, further research must include the evaluation of the medium and long term effects of the smoking ban on the behavior and health status of the general population and of smokers. Particularly, it is very important to look at the potential effect of the smoking ban on the prevalence of smoking, smoking quitting attempts, utilization of tobacco cessation services (as Quitlines) (19-22), expenditures on tobacco products, and, as recent research has reported, beneficial effects of the smoking ban in the health status of the population through the reduction in the incidence of myocardial events, for example (23-26).

Another important issue which has been raised is the importance of monitoring the implementation of the law by the owners, employees, and local authorities' years after the law has been implemented. In this sense, one of the objectives of future research is to provide policymakers and public health advocates with information and data that could help them in improving the implementation of the smoking ban through laws and rules that govern its implementation or by amending the law if it's needed.

Resumen

Trasfondo: El objetivo de este estudio fue el de evaluar el efecto de la prohibición del fumar en lugares de trabajo, implementada en marzo del 2007, sobre la exposición al humo secundario del cigarrillo en restaurantes, pubs, y discotecas del área metropolitana de San Juan, Puerto Rico. Métodos: Se utilizo un diseño pre-post comparativo y una muestra aleatoria de 55 establecimientos (32 restaurantes y 23 pubs y discotecas) del área metropolitana de San Juan para evaluar el efecto de la prohibición de fumar en la calidad del aire. Medidas del nivel de concentración de particulado en el aire (2.5 mm de diámetro, $PM_{2.5}$) se tomaron antes y después de la prohibición, utilizando un monitor personal de aire (SidePak AM510 Personal Aerosol Monitor de TSI Company). También se midieron y observaron el número de fumadores, clientes y el área del establecimiento. Pruebas de t pareada y análisis de regresión lineal se utilizaron para probar la significancia estadística del efecto de la prohibición. Resultados: Después de la implementación de la prohibición del fumar, los restaurantes experimentaron una reducción de 83.6% (p=0.013) en el promedio de niveles de $PM_{2.5}$, de 0.169 a 0.028 mg/m^3, y los pubs y discotecas experimentaron una reducción de 95.6% (p=0.004), de 0.626 a 0.028 mg/m^3. Conclusión: La implementación de la prohibición del fumar en lugares de trabajo demostró ser muy efectiva en reducir la exposición al humo secundario del cigarrillo en los restaurantes, pubs, y discotecas del área metropolitana de San Juan, Puerto Rico.

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