Effectiveness of Crime Prevention Through Environmental Design in Reducing Criminal Activity in Liquor Stores: A Pilot Study

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Liquor store employees experience disproportionately higher rates of workplace injury death than employees in any other retail setting. However, efforts to introduce workplace violence prevention programs into liquor stores have been minimal. This study examines the effectiveness of a Crime Prevention Through Environmental Design intervention in reducing criminal activity in Santa Monica, California liquor stores. Nine stores enrolling in the study received an individualized intervention safety plan; the remaining 13 served as a comparison group. Mixed-effects Poisson regression was used to examine intervention effectiveness. The largest reductions in criminal activity occurred for robbery and shoplifting outcomes. We conclude that the Crime Prevention Through Environmental Design program reduced crime and injury in liquor stores and educated small businesses about the risks associated with retail violence and the countermeasures that can be taken. (J Occup Environ Med. *2004;46:450–458*)

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Workplace homicide rates are disproportionately higher in liquor stores than in other retail settings.[1] Violence accounted for 99% of all deaths among liquor store employees in the United States between 1992 and 1996.[1] Despite a decline in homicides in the retail industry between 1994 and 1998, liquor store homicides remained the same.[2] The number and characteristics of nonfatal assaults to liquor store employees leading to injury but not death is largely unknown.

Risk factors associated with liquor store violence have not been studied. However, risk factors hypothesized to reduce a retail establishment's risk of robbery have been examined in convenience stores. Liquor stores share situational characteristics that place them at similar risk for robbery as convenience stores.[3] Factors such as good cash handling, restricted access and getaway, good visibility and lighting, and employee training have been identified in the literature as decreasing the risk of robberies in convenience stores.[4–9] In contrast, the installation of security devices, such as video cameras and alarms, have not shown the same level of robbery protection.[7,10–13]

Few studies have examined robbery-related prevention measures as risk factors for employee injury,[14–18] specifically nonfatal injury in nonconvenience store environments.[15] Bright exterior lighting,[15] restricted access into the business,[15] good cash handling procedures,[15] restricted hours of operation,[14,18] and having

more than one worker on duty[14,15] are shown to decrease the chances of violence-related employee injury.

The prevention model most widely used to reduce robbery and violence risk is Crime Prevention Through Environmental Design (CPTED),[19] which theorizes that criminal activity can be reduced by modifying the business environment.[19,20] Two decades of research reveal the success of using CPTED-based robbery and violence prevention programs in convenience stores,[21] but little effort has been made to introduce CPTED programs into other retail settings.

Unless state-owned, most liquor stores are small, family-run businesses with no organizational or corporate backing. Thus, liquor stores have traditionally lacked the resources to introduce prevention strategies. In this study, a CPTED intervention program was offered to all liquor stores in Santa Monica, California, and the effectiveness of the program in reducing robbery and other criminal activity was evaluated. This study was a pilot for a large-scale intervention in workplace violence.

Methods

Study Population and Enrollment

Twenty-two liquor stores in Santa Monica, California, were approached to participate in the study. Stores were selected from a census-based, computerized telephone directory by Standard Industrial Classification code 592102. The city of Santa Monica was chosen because it has a high nonfatal workplace assault injury rate among Southern California cities of comparable size.[22,23] It also has varying levels of crime and a diverse environment for testing the intervention. Santa Monica ranges from high- to low-income areas, and also has many impoverished and homeless residents. The city has a high tourist population, especially in the beach areas. Together, these features create a community that is economically and socially diverse. Additionally, the Santa Monica Police Department provided access to crime data for all liquor stores, as well as the entire city of Santa Monica.

Nine stores agreed to enroll in the study and received the CPTED intervention; 13 stores declined participation and were analyzed as the comparison group. Common obstacles to intervention enrollment included language barriers, skepticism about providing informed consent, owners claiming they were too busy, owner's disbelief that something could be done to prevent workplace violence, and distrust of outside agencies. An interview and environmental assessment was conducted with each intervention store owner and/or manager to identify risk factors for criminal activity and preventive measures already in place.

Intervention Program

The intervention program was based on CPTED concepts implemented in convenience stores by the Western Behavioral Sciences Institute.[4] The "Basic" elements of the program focused on keeping a minimal amount of cash in the register, ensuring good visibility into and outside of the business, maintaining bright interior and exterior lighting, limiting access and escape routes, and training employees in how to respond to robbery and shoplifting events. The CPTED program was successful in reducing robberies nearly 20% during an 8-month period in 60 Southland Corporation convenience stores in Southern California compared with 60 matched control stores.[4]

California Occupational Safety and Health Administration (Cal/OSHA) safety consultants implemented the intervention. From the baseline assessment, an individualized safety plan was designed, and consultants reviewed this plan with owners and/or managers. Stores also received a packet that contained their business's safety plan, a management manual outlining and describing intervention program components, an employee manual, a prevention kit containing cash handling and educational materials, and a certificate of participation. Researchers conducted a follow-up interview with each store operator three months after the consultation to document changes in the work environment as a result of the safety plan recommendations.

Outcome Surveillance

Incidents of crime occurring in Santa Monica liquor stores were obtained from the Crime Analysis Unit of the Santa Monica Police Department (SMPD).[24] The SMPD generated a report of police activity by store address for the time period January 1992 to August 1998. Criminal activity, employee injury and total reports filed with the SMPD were tracked over a preintervention time period of 4.5 years (January 1992 to July 1996) and a postintervention period of 2 years (August 1996 to August 1998).

Crime data for the city of Santa Monica were obtained from the SMPD for the years 1993 to 1998.[24] These data were used to quantify the crime trend in Santa Monica over the study period. To control for trend, a background crime rate was calculated for each SMPD reporting district. Background crime used crime categories from the Federal Bureau of Investigation's Uniform Crime Reporting System[25] and included homicide, robbery, aggravated assault, simple assault, shoplifting, and property crimes. Background crime rates were calculated for each reporting district containing a liquor store for the pre- and postintervention time periods. Since the districts varied in size, rates were calculated per total reporting district acreage per year.

Compliance

Compliance with safety plan recommendations and prevention kit items were calculated for each liquor store. To account for varying levels of program implementation and dif-

ferences in baseline risk of criminal activity and injury across stores, a weighted compliance measure was derived as the function of a 3-month follow-up score and baseline score.[26] The follow-up score was defined as the total number of implementation points received at the three-month follow-up interview based on the intervention recommendations being: 0 = unchanged, 1 = upgraded, 2 = completely implemented. The baseline score was defined as the total number of recommendations in the store's individual safety plan at baseline. The compliance index ranged from 0 to 2, where 0 indicates complete noncompliance and 2 indicates complete compliance to the intervention recommendations.

Analysis

Program effectiveness was examined using three methods. First, the percentage change in the rate of crimes, employee injuries, and reports filed with the SMPD were calculated over the pre- and postintervention time periods, comparing intervention with comparison stores. The Wilcoxon signed-rank test was used to compare crime rates between the pre- and postintervention time periods for the intervention and comparison groups. Second, the Wilcoxon rank-sum test (W) was used to compare the distributions of criminal activity between intervention and comparison stores over the pre- and postintervention time periods. Third, a semi-Bayes, mixed-effects Poisson model was selected for examining changes in the mean log rates of robbery, assault, shoplifting, injury, and SMPD reports between intervention and comparison stores over the pre- and postintervention time periods, controlling for background crime. Because this regression methodology has not been published in workplace violence research, a detailed description of the model and modeling
procedures are provided in the Appendix. Explanatory variables used in the model included enrollment status (intervention/comparison), time period (preintervention/postintervention), the product of liquor store enrollment status and study time period, and background crime rate. Mixed-effects modeling was programmed using the SAS macro GLIMMIX.[27]

Two contrasts were made in the Poisson model to measure effectiveness. The first compared the comparison with the intervention stores during the postintervention period to determine whether crime rates were lower in intervention stores. The second compared the postintervention to the preintervention period in the intervention stores to determine if there was a decrease in business crime over time. Both methods controlled for the decrease in background crime in the city of Santa Monica over the study period. Incidence rate ratios (IRR) with 95% confidence intervals (CI), adjusted for background crime, are presented. Unadjusted rate ratio estimates were very similar to adjusted estimates and are therefore not presented in this report.

Stores exhibiting an outlying number of criminal events were excluded from analyses following an influence analysis that showed their removal did not affect final results. However, environmental, administrative, and behavioral factors were not collected on comparison stores. Thus, any store-level differences in factors between intervention and comparison stores could not be accounted for in examining program effectiveness.

Results

Intervention Liquor Store Characteristics: Baseline

Intervention liquor stores in Santa Monica had been in business an average of 39.6 years with owners/managers running the stores an average of 9.1 years. The median number of employees per store was four (range = 2–12), including management. Nearly all of the stores were family-run businesses or operated by members of a particular racial/ethnic community. Almost 80% of the stores had single-employee shifts, over one-third of which were during late-night hours. Most stores (77.8%) were located in mixed business/residential areas, and nearly 70% were located on a street corner.

Approximately 89% of the store operators reported training their employees in how to respond to robberies (Table 1); however, the content of the training was informal and generally lasted no more than 10 minutes. All stores "stripped" large bills regularly from the cash registers, but safes were not used for immediate cash drops. Seventy-eight percent of the stores owned at least one safe, but only two stores had the safe located in the cash/counter area.

All of the liquor stores had very bright to normal lighting in the cash/counter and merchandise areas of the stores (Table 1). Backroom areas in 44.4% of the stores were dimly lit or dark. Clerks could not see outdoor areas while standing at the cash registers in only one of the stores, but visibility was partially obscured in the remaining eight stores. Noncustomer doors were present in 55.6% of the stores, and all but one of the stores kept their doors locked to control access. Backroom areas in 77.8% of the intervention stores were easily accessible to the public.

All of the intervention liquor stores had hardware systems: eight had alarms and seven had video cameras (Table 1). Over 70% of the stores with video cameras also had monitors, but the majority of these monitors were kept in back offices and not in public view.

Liquor stores in Santa Monica averaged 1.3 robberies (range = 0–5), 0.9 assaults (range = 0–3), and 0.4 injuries (range = 0–2) over the 4.5-year baseline period. Over one-third of the stores did not experience a robbery over the baseline period, and 55% of the stores did not experience a simple or aggravated assault. On

TABLE 1
Situational Characteristics of Intervention Stores at Baseline

Characteristic	Frequency (percentage)
Employee robbery training	
Yes	8 (88.9)
No	1 (11.1)
Cash handling	
Cash stripped from registers	
Yes	9 (100.0)
No	0 (0.0)
Presence of safes	
Cash counter area	2 (22.2)
Back room	5 (55.6)
No safes	2 (22.2)
Indoor lighting	
Cash Counter and Merchandise Areas	
Very bright	1 (11.1)
Normal	8 (88.9)
Dim/dark	0 (0.0)
Backrooms	
Very bright	0 (0.0)
Normal	5 (55.6)
Dim/dark	4 (44.4)
Visibility	
Unobscured	0 (0.0)
Partially visible	8 (88.9)
Obscured	1 (11.1)
Non-customer entrances*	
Always locked	4 (80.0)
Never locked	1 (20.0)
Back room public accessibility	
Accessible	7 (77.8)
Not accessible	2 (22.2)
Hardware	
Alarms	
Yes	8 (88.9)
No	1 (11.1)
Video Cameras	
Yes	7 (77.8)
No	2 (22.2)
Monitors†	
Yes	2 (28.6)
No	5 (71.4)

* Percentage based on the number of businesses with non-customer entrances ($n = 9$).

† Percentage based on the number of businesses with video camera systems.

average, nine reports per liquor store were filed with the Santa Monica Police Department over the baseline period.

Intervention Compliance

The mean number of intervention recommendations made at baseline per liquor store was 4 (range = 3–5). Training employees in robbery and violence prevention, implementing cash handling policies and posting decals were recommended in all of the stores, followed by recommendations to make safe changes which were recommended in four of the nine stores. Recommendations were made according to feasibility for change and the severity of risk in the presence of existing countermeasures. Per intervention component, the highest mean follow-up scores (on a scale from 0 to 2) were for training employees (score = 1), posting decals (score = 0.9), and reducing available cash in the registers (score = 0.7). The exception was the change in interior lighting that was made in the only business in which it was recommended (score = 2). None of the businesses made safe changes. Mean compliance across all intervention stores was 0.7 (range = 0–1.4).

Program Effectiveness

Rates of crime and injury decreased in intervention stores between the pre- and postintervention time periods (Table 2). In contrast, comparison stores experienced increased rates of crime and injury over the same periods. Intervention stores experienced the largest decreases for robbery (−82.2%) and shoplifting (−87.1%) events, both decreases of which were significant at the 0.05 level (robbery: $P = 0.02$; shoplifting: $P = 0.01$). Although the rate of reports filed with the Santa Monica Police Department increased 65.3% in intervention stores between the pre- and postintervention periods, the rate increased only 19.1% in comparison stores. The increase in intervention stores is likely the result of business owners complying with Cal/OSHA consultant recommendations to report all incidents of criminal activity to the Santa Monica Police.

Background crime in Santa Monica decreased 62.0% in intervention store reporting districts and 66.1% in comparison store reporting districts over the pre- and postintervention time periods (Table 2). Although background crime decreased over the study period, the percentage decease is similar for both intervention and comparison stores, suggesting that background crime may confound program effectiveness only minimally.

Program effectiveness was further examined by comparing the crude rates of criminal activity between intervention and comparison stores for the pre- and postintervention time periods. During the preintervention period, intervention and comparison stores had similar rates of overall crime (Wilcoxon test statistic [W] = 219.0, $P = 0.47$; Fig. 1). After the intervention was implemented, intervention and comparison stores had significantly different rates of crime ($W = 25.0$, $P = 0.02$). In particular, crime rates decreased in intervention stores, while in the comparison stores, crime rates increased.

Although expected that the background crime in Santa Monica would modestly impact program effectiveness (if at all) (Table 2), regression analyses were performed to control for any potential effect. As seen in Table 3, background crime was not a strong risk factor for liquor store crime, injury or reports filed with the SMPD. Rate ratios were close to the null for all outcomes examined.

Over the postintervention time period, comparison stores had higher rates of robbery, assault, shoplifting, injury, and total reports filed with the SMPD compared with intervention stores, after adjustment for background crime (Table 3). Intervention effectiveness was greatest for robbery (IRR = 5.4; 95% CI = 0.7–43) and shoplifting (IRR = 5.6; 95% CI = 0.9–36) outcomes. Specifically, comparison stores were over five times more likely to experience a robbery or shoplifting event

TABLE 2
Rate of Liquor Store Crime and Santa Monica Background Crime Over the Pre- and PostIntervention Time Periods for Intervention and Comparison Stores

	Intervention Stores (n = 9)				Comparison Stores (n = 13)			
	Rate*				Rate*			
Type of Crime	Pre	Post	*P*-value†	% Change‡	Pre	Post	*P*-value†	% Change‡
Liquor store								
Crime‖								
Robbery	2.68	0.46	0.02	−82.2	2.20	3.06	0.76	+39.1
Assault	1.39	0.93	0.64	−33.1	1.79	3.40	0.76	+89.9
Shoplifting	3.57	0.46	0.01	−87.1	2.34	2.72	1.00	+16.2
All crime¶	7.54	1.85	0.02	−75.5	6.32	9.18	0.32	+45.3
Injury	0.99	0.49	0.23	−53.5	0.41	0.68	0.90	+65.9
SMPD Reports	4.76	7.87	0.03	+65.3	18.8	22.4	0.53	+19.1
Background								
Crime in Santa Monica**	65.63	24.94	<0.01	−62.0	291.84	99.0	<0.01	−66.1

* Rate of crime per 100 businesses per year.
† p-value generated from the Wilcoxon rank sum statistic, comparing crime rates between the pre- and post-intervention time periods.
‡ Percentage change in crime rates between the pre- and postintervention time periods.
‖ Crime specifically occurring in the liquor stores.
¶ "All Crime" is the total number of robbery, assault, and shoplifting events.
** Background crime is measured for the reporting districts in which intervention or comparison stores were located.

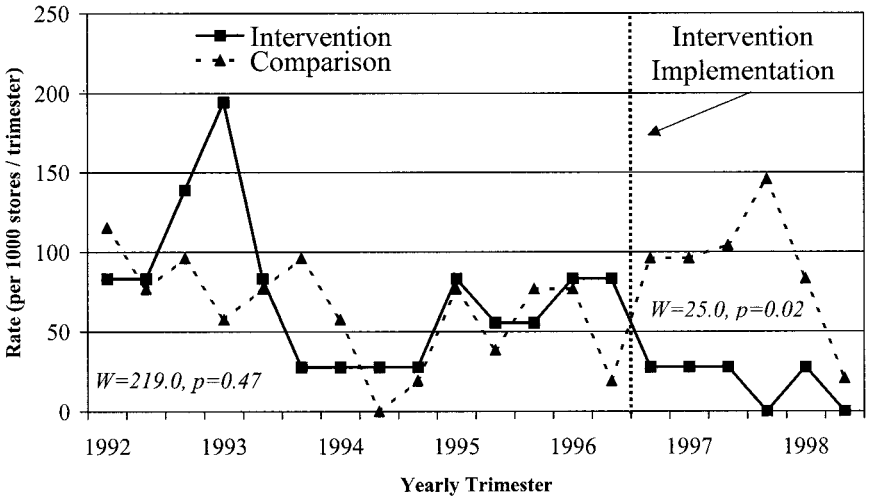

Fig. 1. Store-level crime rates for intervention and control stores, by yearly trimester.

postintervention, compared with intervention stores.

Among the intervention store population, rates of robbery, assault, shoplifting, injury, and SMPD reports were larger during the preintervention, compared with the postintervention, time period after adjustment for background crime (Table 3). The greatest change again was observed for robbery (IRR = 4.7; 95% CI = 0.7–34) and shoplifting (IRR = 6.9; 95% CI = 1.3–39) outcomes (Table 3), with robbery rates nearly five times greater and shoplifting rates nearly seven times greater preintervention than postintervention.

Discussion

Three approaches were used to examine the effectiveness of the CPTED-based intervention program in reducing crime and injury in Santa Monica liquor stores. All three approaches provide evidence that the program was effective in reducing criminal activity. Rates of all types of crime decreased between 33.1% and 87.1% between the pre- and postintervention time periods for intervention stores, while increasing between 16.2% and 89.9% for comparison stores. The decreasing trend for intervention stores and the increasing trend for comparison stores over the pre- and postintervention time periods is further seen in Fig. 1. Even after controlling for background crime in Santa Monica, rates of criminal activity continued to decrease in intervention stores postintervention. The largest reductions occurred for robbery and shoplifting events, which is consistent with the primary objectives of the intervention program as defined by the Western Behavioral Sciences Institute.[4] Similar CPTED-based programs have been effective in reducing robberies in convenience store settings,[21] and the results of this study suggest that liquor stores can also benefit from such a program.

Liquor stores and grocery stores share factors that put them at high risk for robbery, such as dealing with the public, the exchange of money, and the delivery of goods and services.[3] These similarities allow for countermeasures demonstrated in convenience stores to be tested in

TABLE 3
Adjusted Rate Ratio Estimates (with 95% CI) for the PostIntervention and Intervention Store Sub-Populations

	Post Intervention Period Control vs Intervention Stores		Intervention Store Population Pre- vs Postintervention		Background Crime	
Outcome	Rate Ratio* (95% CI)	*P*-value	Rate Ratio† (95% CI)	*P*-value	Rate Ratio (95% CI)	*P*-value
Robbery	5.4 (0.7, 43)	0.11	4.7 (0.7, 34)	0.12	1.03 (1.00, 1.07)	0.04
Assault	3.4 (0.7, 18)	0.13	1.4 (0.3, 7.0)	0.64	1.01 (0.97, 1.05)	0.57
Shoplifting	5.6 (0.9, 36)	0.07	6.9 (1.3, 39)	0.03	1.02 (0.99, 1.05)	0.16
Crime‡	4.6 (1.7, 12)	0.01	3.6 (1.6, 8.1)	<0.01	1.03 (1.00, 1.05)	0.03
Injury	1.1 (0.1, 10)	0.93	1.6 (0.2, 11)	0.63	1.06 (1.01, 1.12)	0.02
SMPD Reports	2.7 (1.3, 5.4)	0.01	2.0 (1.3, 3.0)	<0.01	1.02 (1.00, 1.04)	0.06

* Incidence rate ratio, comparing comparison with intervention stores, over the postintervention time period. Rate ratios adjusted for reporting district crime.

† Incidence rate ratio, comparing pre-intervention with postintervention time periods, for intervention stores. Rate ratios adjusted for reporting district crime.

‡ Crimes = total number of robbery, assault and shoplifting events.

liquor store settings. However, as the development of interventions become more individualized for the different retail settings, it is important to also understand how risk factors for robbery and violence differ across business types. Little research examining these factors exist. Of the research available, liquor stores and grocery stores did not vary by the median number of years in business, median number of employees, percentage of stores providing robbery training to employees, or average amount of cash maintained in the registers.[28] Liquor stores, however, did have a higher percentage of single-employee shifts and single-employee late-night shifts, and a higher percentage of stores with video cameras and alarm systems.[28] Grocery stores had a smaller percentage of safes located in the cash counter areas, a higher percentage of stores with dark or dim interior lighting, and a higher percentage of stores with significantly obscured interior visibility.[28]

Intervention liquor stores in Santa Monica, California, were longstanding, well-established businesses. However, none of the liquor stores had all elements of the CPTED "basic" program, and some had no elements in place. The majority of stores, however, had installed expensive equipment systems, which are less effective in deterring crime than basic program components.[21] Most of the liquor stores were family-run operations with no organizational affiliation. This limited their resources to find and implement a workplace violence prevention program, which was problematic in the Santa Monica liquor stores because of their high level of crime.

An individualized CPTED-based program was developed for each liquor store to meet the specific needs of the store and was administered face-to-face to ensure that store operators understood the preventive theory behind each program component. As a result, compliance with the intervention program was encouraging. The level of compliance suggests that many store operators upgraded security measures from baseline status. The study team was pleased with the upgrade, especially since store operators were difficult to influence. They had been in business for so many years that they were comfortable with their business practices.

A primary study limitation was the manner in which the liquor stores were enrolled into the study. Randomly allocating Santa Monica liquor stores into intervention and comparison groups could not be performed due in part to practical constraints of conducting field research. Even if randomization had been done, it would be unreliable for distributing determinants of criminal activity comparably between intervention and comparison groups because of the few stores available in Santa Monica. The result of nonrandomization was that comparison stores were located in higher crime areas than the intervention stores. However, the effectiveness of the intervention program was not strongly influenced by the distributional differences in district crime between intervention and comparison groups (Table 3).

Because the comparison group consisted of liquor stores that declined participation into the study, it is expected that the intervention and comparison groups will vary by situational and neighborhood factors that could influence program effectiveness. Because of the pilot nature of the project, many of these factors went unmeasured. To account for unmeasured differences, Bayesian methods were used to analytically adjust for unexplained variability of rates across liquor stores (see Appendix). This method does not correct for validity concerns but attempts to control the amount of extra variation potentially exhibited by each store. The Bayesian methods were also used in an attempt to obtain more stable estimates of program effec-

tiveness, compared with results that would be obtained from conventional maximum-likelihood methods (see Appendix).

The small number of stores in the study group likely contributed to the instability of outcome estimates. This current study was a pilot for a large-scale intervention of workplace violence in Los Angeles City and resources for recruiting businesses and providing on-site consultations were severely limited. The pilot study served to determine the most effective methods of working with small business owners, which could be accomplished in a small number of stores. One of the most valuable lessons learned was that continuity of the person interacting with the business was important. Since store operators were skeptical about outside agencies influencing their business practices, trust established at the first visit was critical.

Working with a community-oriented police department suggested that the intervention program could potentially serve as a community-based model of workplace violence prevention and that police departments could be valuable in distributing it. Law enforcement officers, however, tend not to have the tools, training or personnel to appropriately institute a comprehensive workplace violence prevention program, so security professionals become an important factor in program distribution and implementation.[29] Responding to rising trends in robberies, particularly armed robberies, the Oxnard Police Department in Ventura County, California is in the planning stages of developing the program for its business community. The Oxnard Police Department is collaborating with security consultants to distribute the program in their city and with academia to evaluate the effectiveness of the program.

OSHA Consultation would also be an important dissemination resource. Cal/OSHA consultants developed and implemented the CPTED-based program in the liquor stores and were very successful in convincing the store operators to modify their business environment and practices. In addition, offering the program, especially to businesses that would ordinarily not have alternative resources, is consistent with the overall mission of OSHA, which is to promote worker safety by providing information and consultative assistance to employers.

The CPTED-based intervention program evaluated in this study reduced the incidence of criminal activity and injury in Santa Monica liquor stores, and also served to educate small business owners about the risks associated with retail violence and the protective measures that can be taken. It also served to raise awareness among liquor store operators that prevention strategies are necessary for the successful operation of a safe working environment. Employees and the public will feel safer in stores taking precautions, which can consequently benefit the store financially. Furthermore, with the increasing threat of litigation, liquor store operators who use a robbery and violence prevention program may benefit from showing that actions were taken to protect their workers and property.

The need for workplace violence intervention research was recently communicated in an intervention research workshop attended by persons in academia, government, industry and organized labor.[30] Of particular note was the need for improved evaluations of workplace violence interventions.[31] This study contributes to evaluation research as a pilot for a large-scale intervention of workplace violence, and introduces multilevel modeling as an analytic tool for evaluating workplace violence intervention programs.

APPENDIX

Bayesian methods were used to obtain more stable estimates of program effectiveness, compared with results obtained from conventional maximum-likelihood methods. The modeling process began with the following fixed-effects Poisson regression model:

$$ln(\mu_i)=\beta_0+\beta_1(\text{status})_i+\beta_2(\text{period})_i+\beta_3(\text{status*period})_i+\beta_4(\text{district})_i, \quad (1)$$

where status = liquor store enrollment status (intervention/comparison), period = study time period (preintervention/postintervention), status*period = product term of enrollment status and study time period, district = reporting district crime (rescaled and recentered), and i = liquor store categories of enrollment status and study time period = 1, 2,. . . , 44. Since there were 22 liquor stores (9 intervention and 13 comparison) followed over two time periods (preintervention and postintervention), the number of i liquor store categories was (22)(2) = 44.

To handle unexplained variability of rates across liquor stores caused by situational factors that went unmeasured over the study period, a random-intercept term was added to the fixed-effects model (Model 1). The augmentation of the fixed-effects model with a random-intercept term was also used to handle the dependence of outcome events, which were summed over the pre- and postintervention periods for each liquor store.[32,33] Adding a random-intercept term allows the researcher to control the amount of extra variation exhibited by each store.

Let Model 1 be the first-level of a multilevel Poisson regression model:[34–36]

$$ln(\mu_i)=\beta_{0i}+\beta_1(\text{status})_i+\beta_2(\text{period})_i+\beta_3(\text{status*period})_i+\beta_4(\text{district})_i, \quad (2)$$

where the intercept is subscripted with an "i." That is, each liquor store over the pre- and postintervention time period has the unique intercept:

$$\beta_{0i}=\gamma_{00}+\delta_{0i}, \quad (3)$$

where β_{0i} = mean rate of robbery, assault, shoplifting, injury, or total SMPD reports for each liquor store over the pre-post time period, γ_{00} = mean rate of robbery, assault, shoplifting, injury or total reports for all liquor stores over the pre-post time period, and δ_{0i} = random-effects term.[27,35,36]

The random effects term, $\delta_{0i,}$ in Model 3 is assumed normally distributed with mean zero and variance τ_{0i}^2, where τ_{0i}^2 represents the degree of individual heterogeneity between liquor stores over the pre-post time periods.[34,35] Model 3 is the second level of the multi-level model.[34–36] Substituting Model 3 into Model 2 yields the following mixed-effects Poisson regression model:

$$ln(\mu_i)=(\gamma_{00}+\delta_{0i})+\beta_1(\text{status})_i+\beta_2(\text{period})_i+\beta_3(\text{status*period})_i+\beta_4(\text{district})_i \quad (4)$$

The semi-Bayes method was used to specify the variance for each i unit of stores (τ_{0i}^2). This approach allows the researcher to specify a value for each τ_{0i}^2 based on a priori knowledge about the residual effects of covariate relative risks produced by factors not included in the model.[36–38]

In setting each τ_{0i}, the number of covariates potentially contributing to crime risk that were not included in the mixed-effects model were considered.[36] Because this number is relatively high due to store-level situational factors not measured during the study period, the potential for heterogeneity across stores increases, and therefore the ranges set for τ_{0i} increase.[36] Some stores had higher rates of criminal activity, compared with others located in the same reporting district, and therefore are expected to have higher residual rates. The degree of intervention compliance was also used to set τ_{0i} values for the intervention stores. To account for these circumstances, the τ_{0i} were assigned based on a 95% certainty that the residual rates fell within a pre-specified z-fold range of outcome rates [$\exp(3.92\ \tau_{0i}) = z$].[36] Penalized quasi-likelihoods were used to fit the mixed-effects models.[27,39]

Because the study population of liquor stores was small, the precision using all estimation procedures was low. Thus, using the semi-Bayes approach did not change the precision of the estimates to a notable degree. However, use of the semi-Bayes approach was more methodologically sound than using conventional regression methods.

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