



## Effectiveness of Bans and Laws in Reducing Traffic Deaths

### Legalized Sunday Packaged Alcohol Sales and Alcohol-Related Traffic Crashes and Crash Fatalities in New Mexico

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We determined the relative risk of alcohol-related motor vehicle accidents and fatalities after New Mexico lifted its ban on Sunday packaged alcohol sales.

We extracted all alcohol-related crashes from New Mexico police reports for 3652 days between July 1, 1990, and June 30, 2000, and found a 29% increase in alcohol-related crashes and a 42% increase in alcohol-related crash fatalities on Sundays after the ban on Sunday packaged alcohol sales was lifted. There was an estimated excess of 543.1 alcohol-related crashes and 41.6 alcohol-related crash fatalities on Sundays after the ban was lifted.

Repealing the ban on Sunday packaged alcohol sales introduced a public health and safety hazard in New Mexico. (*Am J Public Health*. 2006;96:1944–1948. doi:10.2105/AJPH.2005.069153)

Alcohol availability policy has been the subject of many legislative sessions at all levels of government. Laws have modified the legal minimum drinking age, hours and days of on- and off-premise liquor sales, and types of liquor licenses.<sup>1–3</sup> Under pressure

from the alcohol industry, and in need of increasing tax revenue in the face of budget shortfalls, many state legislatures have repealed, or are considering repealing, bans on Sunday alcohol sales. Eighteen states currently have some form of ban on Sunday alcohol sales, and several states have lifted bans since 1998.<sup>4</sup> Sunday packaged alcohol sales have been legalized despite little formal evaluation of the public health and public safety impacts of increased alcohol availability on Sundays.

It was illegal to sell packaged alcohol on Sundays in New Mexico until July 1, 1995. Up to that time, alcohol could be purchased only by the drink for consumption in bars and restaurants. House Bill 176, which allowed special licenses to be issued for selling packaged alcohol between noon and midnight on Sundays, was introduced during New Mexico's first legislative session of 1995. Political leaders recognized that there was strong public support for reducing rates of alcohol-related crashes and alcohol-related crash fatalities. To help promote House Bill 176 to legislators, advocates for the bill argued that legalizing Sunday

packaged alcohol sales would actually reduce alcohol-related crash and alcohol-related crash fatality rates by diverting alcohol consumption from bars to homes. The rationale for this argument was that this would eliminate the need for people to drive home impaired, because the ban on packaged sales forced them to buy alcohol by the drink at bars on Sunday for on-site consumption rather than buying packaged alcohol for consumption at home. House Bill 176 narrowly passed House (37 to 25) and Senate (18 to 11) votes and was signed by then-governor Gary Johnson. Starting on July 1, 1995, licensed stores in New Mexico began selling packaged alcohol between noon and midnight on Sundays.

Previous studies suggested that extending the hours and days of alcohol sales is associated with increased alcohol-related problems, including alcohol intoxication among both casual and heavy users, driving while impaired, alcohol-related crashes, and alcohol-related crash fatalities.<sup>2,5–11</sup> However, in New Mexico the purported goal was to reduce the frequency of driving while impaired by diverting

alcohol users away from bars. Whether legalized Sunday packaged alcohol sales were associated with a change in alcohol-related crashes or alcohol-related crash fatalities was unknown. To our knowledge, no formal evaluation of the consequences of repealing the Sunday sales ban in New Mexico, or any other state, has been published. The 1995 repeal of the Sunday packaged alcohol ban in New Mexico provided a “natural experiment” for evaluating the public health and public safety impact of legislation that increases alcohol availability on Sundays.

#### METHODS

##### Study Sample

All alcohol-related motor vehicle crashes that occurred in New Mexico between July 1, 1990, and June 30, 2000, equivalent to 3652 days of observation, were included in the analysis. All crash data were extracted from the accident-level analysis files maintained by the University of New Mexico Division of Government Research. The information found in the accident-level analysis file was derived from uniform accident reports, which police



officers completed for reported crashes on public roadways that resulted in death, personal injury, or \$500 or more in property damage, according to the investigating officer's judgment. No account was kept of unreported crashes or crashes on private property.

The reporting officer noted the estimated time of the crash and the cross-street, address, or mile marker where the incident occurred. The reporting officer also recorded the number of deaths occurring at the scene of the accident. Nonfatal crashes were classified as alcohol related according to the evaluation of the reporting police officer. Fatal crashes were classified as alcohol related if the blood alcohol concentration of any involved driver was greater than 0.0%. A small number of crashes involved intoxicated bicyclists, who were not distinguished from drunk drivers in this data set. All information used in this analysis was available as public record.

The uniform crash report data are used by the National Highway and Traffic Safety Administration fatality analysis reporting system. These data incorporate a sophisticated multiple-imputation algorithm for estimating alcohol involvement in each crash, which improves comparability across states. Because we were interested in nonfatal crashes, which were not reported in the fatality analysis reporting system, as well as fatal crashes, we used the New Mexico data for this analysis.

All crashes were classified according to occurrence before or after the legalization of Sunday

packaged alcohol sales on July 1, 1995. *Prerepeal* denotes all crashes that occurred between July 1, 1990, and June 30, 1995. *Postrepeal* denotes all crashes that occurred between July 1, 1995, and June 30, 2000. Crashes also were classified according to the day of the week on which they occurred. Because the effect of alcohol availability on any given day may affect drinking and driving behavior on the following morning, each day of the week was defined from noon on the day in question until 11:59 AM the following day. For example, all crashes that occurred between noon on Saturday until 11:59 AM on Sunday morning were defined as Saturday crashes. The noon cutoff is appropriate for this study because the New Mexico legislation allows Sunday packaged alcohol sales to begin after noon on Sundays. This definition of the day of the week allows us to explicitly test the effects of Sunday sales legislation on Sunday daytime, Sunday nighttime, and early Monday morning alcohol-related motor vehicle crashes, as well as on other days of the week.

### Data Analysis

The alcohol-related crash and alcohol-related crash fatality data were modeled using the classic decomposition of the time series into trend and seasonal components and testing for temporal autocorrelation in the residuals.<sup>12</sup> The approach naturally fits the analysis into the framework of generalized linear models.<sup>13</sup>

Poisson regression models were fit to the observed daily alcohol-related crash and

alcohol-related crash fatality counts to test the effects of legalizing Sunday packaged alcohol sales on alcohol-related crash and alcohol-related crash fatality rates, after adjustment for secular and seasonal trends in crash rates and high-risk alcohol-related crash-associated holidays. Alcohol-related crash and alcohol-related crash fatality counts were modeled separately.

Independent variables included a 7-level day-of-the-week factor, a binary pre- and postrepeal indicator, and day-of-the-week by pre- and postrepeal interaction terms. The interaction term estimates the day-of-the-week-specific effects of repealing the ban on Sunday packaged alcohol sales on alcohol-related crash and alcohol-related crash fatality rates. A binary indicator for each of the following holidays identified as high-risk crash dates<sup>14–16</sup> was added to the model: New Year's Eve, Independence Day, Memorial Day, Labor Day, Thanksgiving, Christmas, Super Bowl Sunday, and Cinco de Mayo. Binary indicators for the Eve of Thanksgiving Day, the Eve of Independence Day, St. Patrick's Day, and Halloween also were added because they were associated with large positive residuals in the regression analyses.

Secular trends in alcohol-related crash or alcohol-related crash fatality rates were modeled with an unpenalized quadratic spline function, and the number of knots and knot spacing were chosen according to an algorithm previously described.<sup>17</sup> Between 1 and 35 knots were placed at

quantiles of the observation period so that there was a constant number of days between each knot. The final number of knots for the alcohol-related crash and alcohol-related crash fatality models was chosen to minimize Akaike's information criterion.

Annual and biannual seasonal fluctuations in alcohol-related crash and alcohol-related crash fatality rates were modeled with a mixture of Fourier series with 12-month (annual) and 6-month (biannual) periods.<sup>18</sup> The dispersion parameter in the Poisson model was estimated as the ratio of the model deviance to the model degrees of freedom. Model fit was evaluated by examining plots of the likelihood residuals against each predictor, plots of the leverages against the likelihood residuals, and plots of predicted and observed alcohol-related crash and alcohol-related crash fatality counts.

The modeling framework described so far assumes that the daily alcohol-related crash or alcohol-related crash fatality counts were independent Poisson random variables, which may not be appropriate if there is temporal autocorrelation in the residuals. Although it was not expected that alcohol-related crash and alcohol-related crash fatality counts were physically dependent on one another over time, we evaluated the possibility that the detrended alcohol-related crash and alcohol-related crash fatality residuals did not conform to white noise. Autocorrelation and partial autocorrelation functions of the likelihood residuals from the Poisson regression models



were plotted against lag time and examined for any autoregressive patterning. We also computed the Ljung–Box Q statistic to test the null hypothesis that none of the autocorrelations up to a lag of 30 days was significantly different from zero. Finally, we fit a first-order Markov model to the alcohol-related crash and alcohol-related crash fatality counts, with the same predictors described previously, and tested the statistical significance of the autoregressive parameter.<sup>19</sup>

Because of a database error that occurred after the New Mexico Motor Vehicles Division converted to a new computer system, approximately 15% of 1999 nonfatal motor vehicle crashes were randomly deleted from the New Mexico crash database.<sup>20</sup> Crash rates thus appeared artificially reduced during 1999. A data correction factor for crash rates in 1999 was introduced into the regression analyses as a binary 1999 indicator to control for this database error on crash rates. This indicator proved to be superfluous in the final analyses, because the regression spline accounted for the drop in crash frequencies during 1999.

The results of the Poisson regression analysis were used to estimate the excess (or reduction) in alcohol-related crash and alcohol-related crash fatality frequency that occurred after the ban on Sunday packaged alcohol sales was repealed. This was accomplished by computing the sum of the Poisson model—predicted alcohol-related crash and alcohol-related crash fatality counts from July 1, 1995, to

June 30, 2000, without the legislative change variables, and subtracting this from the sum of the Poisson model predictions with the legislative change variables included.

Differences greater than zero indicate an excess number of alcohol-related crashes or alcohol-related crash fatalities between July 1, 1995, and June 30, 2000, compared with what might have occurred had the Sunday sales ban not been lifted. Differences less than zero indicate a reduction in alcohol-related crashes or alcohol-related crash fatalities. The 95% confidence interval for the excess/reduction statistic was computed from the covariance matrix of the parameter estimates with use of the delta method.<sup>21</sup> Model reduction was performed to reduce the standard error of the excess/reduction statistic caused by having superfluous independent variables in the model. This was accomplished by removing confounding effects for which the drop in deviance after omission was not significant at the .1 level.

Poisson regression models also were fit to the non-alcohol-related crash rates with use of the modeling framework described previously. This analysis was performed to ensure that changes in alcohol-related crash rates were not simply attributable to background patterns of motor vehicle crash risks.

### Computation

All database management and analysis were performed with SAS software.<sup>22</sup> Poisson models were fit with PROC GENMOD,

and Markov models were fit with PROC NLMIXED. Autocorrelation function and partial autocorrelation function plots and the white noise test statistic were generated with PROC ARIMA. SAS/IML was used to compute point estimates and 95% confidence intervals for the excess/reduction statistics.

## RESULTS

There were 492 396 motor vehicle crashes during the observation period, and 45 596 of these were classified as alcohol involved. The average daily alcohol-related crash rate for the study period was 12.9 crashes per day (SD=6.78). The following variables were retained in the Poisson model of alcohol-related crash counts after backward elimination: a 29-knot quadratic spline for trend, biannual seasonal cycle, New Year's Eve, In-

dependence Day, St. Patrick's Day, Halloween, Cinco de Mayo, Super Bowl Sunday, Christmas, Thanksgiving Eve, and Independence Day Eve. The 29-knot spline was chosen using Akaike's information criterion, although spline functions with at least 18 knots gave similar results. There was a 29% pre- to postrepeal increase in alcohol-related crash rates on Sundays (95% confidence interval [CI]=1.05, 1.58), after adjustment for these confounding effects (Table 1). All other days of the week showed relative alcohol-related crash risks near unity.

Likelihood residual analyses indicated no gross deviations in model fit. The Ljung–Box test on the likelihood residuals was not statistically significant ( $P=.11$ ). There was no patterning in the autocorrelation function or partial autocorrelation function plots, and none of the lagged

**TABLE 1—Relative Risks of Alcohol-Related Crash and Alcohol-Related Crash Fatality After the Ban on Sunday Packaged Alcohol Sales Was Lifted: New Mexico, 1990–2000**

	Relative Risk* (95% Confidence Interval)	
	Alcohol-Related Crash	Alcohol-Related Crash Fatality
Sunday	1.29 (1.05, 1.58)	1.42 (1.05, 1.93)
Monday	1.00 (0.81, 1.22)	1.03 (0.75, 1.42)
Tuesday	1.10 (0.90, 1.35)	1.17 (0.83, 1.65)
Wednesday	0.97 (0.79, 1.19)	1.05 (0.76, 1.44)
Thursday	1.05 (0.86, 1.29)	1.08 (0.80, 1.47)
Friday	0.97 (0.80, 1.19)	1.04 (0.81, 1.33)
Saturday	1.02 (0.84, 1.24)	1.07 (0.84, 1.36)

\*Adjusted for a 29-knot quadratic spline for trend, biannual seasonal cycle, New Year's Eve, Independence day, St. Patrick's day, Halloween, Cinco de Mayo, Super Bowl Sunday, Christmas, Thanksgiving Eve, and Independence Day Eve.

<sup>b</sup>Adjusted for linear trend effect, annual seasonal cycle, New Year's Eve, Halloween, Independence Day, Thanksgiving Eve, Independence Day Eve, and Thanksgiving.



correlations exceeded 0.05. The autoregressive parameter for the first-order Markov model was 0.01 ( $P=.42$ ), indicating no significant autoregressive effect.

During the study period, there were 4620 motor vehicle crash fatalities, of which 2341 were from crashes that involved alcohol. The overall average daily alcohol-related crash fatality rate during the study period was 0.65 deaths per day ( $SD=0.98$ ). The following variables were retained in the Poisson model of alcohol-related-crash fatality counts after backward elimination: linear trend effect, annual seasonal cycle, New Year's Eve, Halloween, Independence Day, Thanksgiving Eve, Independence Day Eve, and Thanksgiving. Sunday was the only day of the week on which a statistically significant change in alcohol-related crash fatality rates occurred (Table 1) after adjustment for trend, seasonal, and holiday effects. Alcohol-related crash fatality rates on Sunday increased by 42% (95% CI=1.05, 1.93). Likelihood residual analysis showed no systematic lack of fit of the Poisson model. The Ljung-Box test was not statistically significant ( $P=.18$ ), and the autocorrelation function and partial autocorrelation plots indicated no patterning or autocorrelations greater than 0.05. The autoregressive parameter for the first-order Markov model was 0.09 ( $P=.53$ ), indicating no statistically significant autoregressive effect at the 0.05 level.

Poisson regression models fit to the non-alcohol-related crash frequencies yielded relative crash rates between 0.90 on Saturday

**TABLE 2—Estimated Excess or Reduction in Rates of Alcohol-Related Crashes and Alcohol-Related Crash Fatalities Between July 1, 1995, and June 30, 2000: New Mexico**

	Excess or Reduction (95% Confidence Interval)	
	Alcohol-Related Crash	Alcohol-Related Crash Fatality
Sunday	543.1 (158.9, 927.4)	41.6 (6.6, 76.6)
Monday	-5.8 (-392.1, 380.5)	3.1 (-29.7, 35.9)
Tuesday	184.5 (-199.2, 568.2)	13.9 (-15.6, 43.3)
Wednesday	-67.1 (-514.2, 380.0)	4.5 (-28.2, 37.2)
Thursday	121.7 (-355.7, 599.1)	9.9 (-26.4, 46.1)
Friday	-117.9 (-1003.2, 767.3)	8.0 (-46.6, 62.6)
Saturday	89.9 (-764.6, 944.5)	17.2 (-41.4, 75.8)

and 0.98 on Thursday. No relative risks of non-alcohol-related crashes were statistically significant at the .05 level for any day of the week, including Sunday.

The Poisson regression model was used to estimate the mean daily excess or reduction in alcohol-related crashes associated with repealing the ban on Sunday packaged alcohol sales (Table 2). The highest excess occurred on Sundays, with an estimated 543.1 (95% CI=158.9, 927.4) additional alcohol-related crashes between July 1, 1995, and June 30, 2000. The largest reduction in alcohol-related crashes was on Friday (-117.9), but this was not significantly different from zero (95% CI=-1003.2, 767.3). No day of the week other than Sunday showed a statistically significant excess or reduction in alcohol-related crash frequency.

Table 2 also shows the estimated difference in the number of alcohol-related crash fatalities associated with lifting the ban on Sunday packaged alcohol sales. All days of the week had excess

alcohol-related crash fatality counts, but none of these except Sunday were statistically significant. There were an extra 41.6 alcohol-related crash fatalities on Sundays (95% CI=6.6, 76.6) between July 1, 1995, and June 30, 2000.

## DISCUSSION

The analysis of alcohol-related crash rates clearly demonstrates a rise in both alcohol-related crashes and alcohol-related crash fatalities occurring between noon on Sunday and noon on Monday, after the ban on Sunday packaged alcohol sales was lifted. The 29% increase in Sunday alcohol-related crash rates resulted in an estimated excess of 543.1 alcohol-related motor vehicle crashes between July 1, 1995, and June 30, 2000, over what would have been observed had the ban not been repealed. There was a 42% pre- to postrepeal increase in the Sunday alcohol-related crash fatality rate, resulting in an excess of 41.6 fatalities attributable to repealing the ban on Sunday

packaged alcohol sales (95% CI=6.6, 76.6). No other day of the week showed any statistically significant change in alcohol-related crashes or alcohol-related crash fatalities. Furthermore, the analysis of non-alcohol-related crash rates indicates that relative crash rates on Sundays cannot be attributed to background trends in crash risks.

Some limitations are apparent. The reporting police officer classified nonfatal crashes as alcohol involved or not alcohol involved. There has been some debate about the accuracy of such reporting<sup>23,24</sup> because the designation often relies on the subjective judgment of the reporting police officer. Some researchers have suggested that investigators use single-vehicle nighttime crashes as a proxy measure of alcohol-related crashes and alcohol-related crash fatalities.<sup>25</sup> This tactic, however, did not allow us to estimate the true impact of repealing the ban on the number of alcohol-related crashes and alcohol-related crash fatalities (Table 2), which is of primary concern to state legislators. The issue is of less concern, however, because it has been shown that police-reported rates of alcohol involvement and rates of single-vehicle nighttime crashes tend to be highly correlated.<sup>26</sup> Furthermore, a recent study using the New Mexico crash data to investigate drive-up liquor window closure on crash rates in New Mexico found no difference in any results whether one considered single-vehicle nighttime or all alcohol-related



crashes.<sup>20</sup> Analyses of driving-while-impaired citation data would help corroborate our findings. Moreover, there is no reason to believe that an error in police officer reporting would be biased only on Sundays and only after the ban on Sunday packaged alcohol sales was lifted. Even so, this limitation does not apply to fatal crash results for which alcohol involvement was determined by blood alcohol concentration.

Our results strongly suggest that increasing alcohol availability on Sunday was associated with increases in alcohol-related motor vehicle crashes and fatalities. Legalizing Sunday packaged alcohol sales may increase state tax revenues, but at the same time it exacts a significant price that is paid by crash victims and their loved ones, health care providers, insurers, and law enforcement and judicial systems. State legislators should consider these consequences when deciding on policy that is intended to serve the public well-being. ■

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### Contributors

G.P. McMillan was principle investigator for this study and was responsible for all database management, data analysis, and preparation for publication. S. Lapham was co-investigator of this study and assisted in preparation of the article.

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### Human Participant Protection

This study was approved by the Behavioral Health Research Center of the Southwest institutional review board.

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