

# UC Berkeley

## UC Berkeley Electronic Theses and Dissertations

### Title

Dosage of Policy Enforcement Interventions and Community Alcohol Problems

### Permalink

<https://escholarship.org/uc/item/6vk9g340>

### Author

O'HARA, SHARON E

### Publication Date

2018

Peer reviewed|Thesis/dissertation

Dosage of Policy Enforcement Interventions and Community Alcohol Problems

by

Sharon Elizabeth O'Hara

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Public Health

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Denise Herd, Chair

Professor Jodi Halpern

Professor Valerie Shapiro

Mallie J. Paschall, PhD

Spring 2018



## ABSTRACT

### Dosage of Policy Enforcement Interventions and Community Alcohol Problems

by

Sharon Elizabeth O'Hara

Doctor of Public Health

University of California, Berkeley

Professor Denise Herd, Chair

Problems associated with alcohol affect individuals, families and communities. Alcohol-related community problems include underage and excessive drinking, driving under the influence (DUI) crashes and injuries, violence, crime and negative effects on quality of life. Policy interventions to reduce and prevent community-level alcohol-related problems have been the focus of much research, resulting in the recognition of effective and promising prevention practices. Alcohol policies include laws: establishing a maximum blood alcohol concentration (BAC) allowed for driving, a minimum age for purchase and consumption of alcohol; and limiting sales to underage or intoxicated persons. Policy enforcement can deter DUI, sales of alcohol to underage or intoxicated persons, underage and excessive drinking, especially if the enforcement is highly visible to the public. A growing body of literature examines the amount and frequency, or "dosage" of interventions that is associated with improved health or reductions in problems. Much of the dosage research involves educational or treatment interventions that focus on individual or group behavior change, rather than on policy interventions designed to make change at the community level. The overarching goals of this dissertation research are to: 1) examine the existing alcohol policy enforcement literature; 2) explore certain community factors that may be associated with higher levels of dosage; and 3) compare how varying levels of alcohol policy enforcement dosage affect community alcohol-related outcomes.

Paper 1 examines research literature regarding the association between dosage of high-visibility alcohol policy enforcement and alcohol-related problems at the community level. A systematic review found support for consistent enforcement to achieve desired alcohol-related outcomes, and for "high" versus "low" levels of enforcement. However, there was no consensus found among the studies for a necessary threshold of enforcement dosage, due in part to the differences in problems addressed, existing policies in study communities, types of enforcement interventions used, and the designs and sizes of the studies. Findings support the need for additional research with rigorous study designs to determine effective levels of dosage of high-visibility alcohol policy enforcement.

Paper 2 investigates the association between dosage of high-visibility alcohol enforcement interventions and: level of alcohol problems at baseline, interagency collaboration, and additional grant funding from two state agencies, in 12 intervention cities funded by the California Strategic Prevention Framework State Incentive Grant (SPF SIG). Multi-level modeling is used to study the effects of these three community characteristics on levels of dosage over 12 months. Findings indicate that funding may lead to more high-visibility enforcement to reduce crashes, injury, and mortality associated with driving under the influence (DUI). Interagency collaboration may lead to more enforcement and visibility to reduce retail availability of alcohol (e.g., at convenience stores) to underage persons. Baseline levels of alcohol-related problems were not found to be significantly associated with higher levels of enforcement. None of the community characteristics studied here was significantly associated with higher levels of enforcement to reduce social availability of alcohol (e.g., at parties). Future studies that include larger samples of cities are needed to help explain how these and other community factors may influence implementation of high-visibility alcohol enforcement interventions.

Paper 3 focuses on the effects of four levels of dosage (zero, low, medium, and high) of a high-visibility DUI enforcement intervention on changes over 58 months in the proportion of DUI crashes and DUI injury crashes in the 24 cities of the California SPF SIG project. Multi-level modeling is used to examine the moderating effect of dosage level on the relationship between time and DUI crash and injury rates. Findings reveal a statistically significant moderating effect of medium dosage level (i.e., approximately 1 intervention per month) on the negative relationship between time and DUI crashes. Although not statistically significant, a high level of dosage is associated with an increase in the proportion of DUI crashes, while a low dosage level results in no change in the proportion of DUI crashes. Statistically significant moderating effects of both medium and high dosage levels are found on the negative relationship between time and injury DUI crashes. These findings suggest that implementing approximately 1 DUI enforcement intervention per month may be best for reducing both DUI crashes and DUI injury crashes, and that a higher number of interventions per month does not lead to better outcomes. Replication can help strengthen these findings, and may lead to practical policy enforcement recommendations for communities to reduce DUI injuries and related crashes.

## DEDICATION

This dissertation is dedicated to my beloved husband, Daniel, for his remarkable intelligence, patience and unwavering love and support.

## TABLE OF CONTENTS

List of Tables.....	iii
List of Figures.....	iv
List of Abbreviations.....	vi
Acknowledgements.....	vii
INTRODUCTION.....	viii
PAPER 1: Measuring Dosage of Alcohol Policy Enforcement Operations: A Systematic Review.....	1
PAPER 2: Do Certain Community Characteristics Predict Dosage of Alcohol Policy Enforcement Interventions?.....	30
PAPER 3: Do Higher Levels of Dosage of Enforcement and Visibility Lead to Reductions in Alcohol-related Problems at the Community Level in the California SPF SIG project?.....	52
CONCLUSION.....	68
REFERENCES.....	70

## List of Tables

Table 1.1. Electronic Sources for Literature Searches

Table 1.2. Summary of study characteristics and findings: dosage of interventions to reduce DUI

Table 1.3. Summary of study characteristics and findings: dosage of interventions to reduce underage drinking

Table 1.4. Summary of study characteristics and findings: dosage of interventions to reduce intoxication/excessive drinking

Table 2.1: Descriptive statistics for outcome and main predictor variables

Table 2.2. Pearson correlation of all variables

Table 2.3. Results of retail availability intervention dosage models, regression coefficient (standard error)

Table 2.4. Results of social availability intervention dosage models, regression coefficient (standard error)

Table 2.5. Results of DUI intervention models, regression coefficient (standard error)

Table 3.1. Descriptive Statistics – 12 intervention cities only with continuous measure of dosage

Table 3.2. Rank of time-invariant dosage variables for intervention cities

Table 3.3. Descriptive Statistics – 24 cities

Table 3.4. Results of multilevel analyses, regression coefficient (standard error)



## List of Figures

- Figure 1.1. Flowchart of study selection process
- Figure 2.1. Retail alcohol availability intervention dosage across quarters by city
- Figure 2.2. Social alcohol availability intervention dosage across quarters by city
- Figure 2.3. DUI intervention dosage across quarters by city
- Figure 2.4. Residual diagnostics, model 1, level 1
- Figure 2.5. Residual diagnostics, model 1, level 2
- Figure 2.6. Residual diagnostics, model 2, level 1
- Figure 2.7. Residual diagnostics, model 2, level 2
- Figure 2.8. Residual diagnostics, model 3, level 1
- Figure 2.9. Residual diagnostics, model 3, level 2
- Figure 2.10. Residual diagnostics, model 4, level 1
- Figure 2.11. Residual diagnostics, model 4, level 2
- Figure 2.12. Residual diagnostics, model 5, level 1
- Figure 2.13. Residual diagnostics, model 5, level 2
- Figure 2.14. Residual diagnostics, model 6, level 1
- Figure 2.15. Residual diagnostics, model 6, level 2
- Figure 2.16. Residual diagnostics, model 7, level 1
- Figure 2.17. Residual diagnostics, model 7, level 2
- Figure 2.18. Residual diagnostics, model 8, level 1
- Figure 2.19. Residual diagnostics, model 8, level 2
- Figure 2.20. Residual diagnostics, model 9, level 1
- Figure 2.21. Residual diagnostics, model 9, level 2
- Figure 2.22. Residual diagnostics, model 10, level 1

## List of Figures (cont'd)

Figure 2.23. Residual diagnostics, model 10, level 2

Figure 2.24. Residual diagnostics, model 11, level 1

Figure 2.25. Residual diagnostics, model 11, level 2

Figure 2.26. Residual diagnostics, model 12, level 1

Figure 2.27. Residual diagnostics, model 12, level 2

Figure 3.1. Proportion of DUI Crashes/All Crashes - Model Predictions by Dosage Rank

Figure 3.2. Proportion of Injury DUI Crashes/All Injury Crashes - Model Predictions by Dosage Rank

Figure 3.3. Level 1 residuals diagnostics: proportion of DUI crashes out of all crashes

Figure 3.4. Level 2 random intercepts diagnostics: proportion of DUI crashes out of all crashes

Figure 3.5. Level 2 random slopes diagnostics: proportion of DUI crashes out of all crashes

Figure 3.6. Level 1 residuals diagnostics: proportion of injury DUI crashes out of all injury crashes

Figure 3.7. Level 2 random intercepts diagnostics: proportion of injury DUI crashes out of all injury crashes

Figure 3.8. Level 2 random slopes diagnostics: proportion of injury DUI crashes out of all injury crashes

## List of Abbreviations

ABC	California Department of Alcoholic Beverage Control
CDC	United States Centers for Disease Control and Prevention
DALYs	Disability-Adjusted Life Years
DUI	Driving Under the Influence
DWI	Driving While Intoxicated
OTS	California Office of Traffic Safety
PRC	Prevention Research Center
SPF SIG	California Strategic Prevention Framework State Incentive Grant
YPLL	Years of Potential Life Lost

## Acknowledgements

I want to express my deep gratitude to those who helped make this dream become a reality for me. First, I would like to thank my committee members for their guidance throughout the DrPH program. Dr. Denise Herd, my advisor and dissertation committee chair, contributed her extensive knowledge about models of community alcohol problems and theory to my work. Dr. Jodi Halpern, my qualifying exam chair and dissertation committee member, posed incisive ethical questions that helped me think even more deeply through the differential impacts of policies and enforcement on diverse communities. Dr. Valerie Shapiro offered a fresh perspective about prevention, implementation science, intervention dosage, and research methods from her vantage point with the Center for Prevention Research at the School of Social Welfare. Finally, I want to express my deep appreciation for my “outside” committee member, friend and mentor Dr. Mallie J. Paschall of the Prevention Research Center (PRC) in Oakland. Dr. Paschall was tireless in supporting me through every stage of the dissertation process, including idea generation, model-building, data analysis, interpretation of results and writing.

I also want to acknowledge my long-time mentor Dr. Bob Saltz from PRC, who provided me the opportunity to work with data collected from the California Strategic Prevention Framework State Incentive Grant (SPF SIG), which formed the basis of my dissertation research.

A sincere thanks to all the U.C. Berkeley faculty and School of Public Health staff, who taught me so much and helped me stay on track to finish the DrPH program in 3 years. I was fortunate to have Dr. Amani Nuru-Jeter, who set the tone in the first semester by consistently challenging me to be a scholar, not just a student. Special thanks to Dr. Cheri Pies and Dr. Norm Constantine, without whose support and encouragement I would not have been able to complete my prospectus and take my qualifying exam in my second year. The incredible SPH staff, especially Dr. Marques Redd and Judy Smithson, deserve thanks for administrative support, for answering questions with a smile, and for unending patience.

I am so grateful for the community of fellow Berkeley students who provided academic and moral support, and who I count among the most intelligent, accomplished, and inspirational people I know. Thanks to Bina, Carly, Erika, May Lynn, Rachel; my original cohort - Annie, Anoop, David and Erica; the Donnas - Annie, Brinda, Chris, Katie, and Lisa; and the Social Welfare Graduate Research Group - Brita, Emily, Joe, Juyeon and Kelly. In particular, I am thankful to Annie, for being a treasured friend, sounding board, and writing partner throughout this process, and for her generous spirit and great sense of humor.

Finally, I want to thank my family: Jessica, Caitlin, Connor, Tom, Joselyn, Denise and especially Dan, on whom I can rely for support, love and inspiration every day.

## INTRODUCTION

### *Community alcohol problems*

Excessive alcohol consumption is associated with a high disease burden worldwide, and is the third leading cause of death in the United States.<sup>1</sup> As defined by the United States Centers for Disease Control and Prevention (CDC), excessive alcohol consumption includes binge drinking (four or more drinks per occasion for women; five or more drinks per occasion for men); heavy drinking (more than eight drinks per week for women; and 15 or more drinks per week for men); and any alcohol consumption by persons under 21 years of age or by pregnant women.<sup>2</sup> In the U.S., between 2006-2010, approximately 88,000 deaths and 2.5 million years of potential life lost (YPLL) were the result of excessive alcohol consumption; this cost an estimated \$223.5 billion in 2006,<sup>3</sup> and \$249.0 billion in 2010.<sup>2</sup> Furthermore, excessive drinking among underage youth (<21 years of age) is responsible for at least 4,300 deaths each year, and cost the U.S. \$24 billion in 2010.<sup>2</sup> Costs include those associated with health care, lost productivity, motor vehicle crashes, crime and violence, and are borne by federal, state and local governments, communities and individuals.<sup>2</sup> Worldwide, 3.3 million deaths were attributable to alcohol consumption in 2012 alone. That year, alcohol consumption was associated with more than 5% of the global burden of disease and injury, or 139 million DALYs (disability-adjusted life years).<sup>4</sup> Poor populations have a greater disease burden attributable to alcohol consumption than high-income populations.<sup>4</sup> Extending beyond the problems of individuals and families, the harms and costs associated with excessive alcohol consumption include social and community consequences such as automobile crashes, increased crime and nuisance behaviors.<sup>4</sup>

### *Environmental factors*

Certain community environmental factors are associated with higher rates of alcohol consumption and related harm.<sup>4</sup> One environmental factor that contributes to alcohol consumption and related harm is the level of alcohol availability in a community.<sup>5</sup> For example, a greater density of businesses that sell alcohol is associated with higher rates of consumption among youth and adults, and with higher levels of crime, blight and violence.<sup>6,7</sup> Accessibility, or the ease with which alcohol can be obtained, is also associated with excessive and underage drinking.<sup>8</sup> Whether it is from social sources such as gatherings of friends at parties or retail settings such as grocery stores or mini-marts, underage youth are more likely to consume alcohol if it is easy for them to obtain.<sup>9</sup> Among adults, retail alcohol sales to intoxicated patrons of bars and restaurants are associated with assaults, injuries and motor vehicle crashes.<sup>10</sup>

### *Alcohol policy interventions*

According to the World Health Organization (WHO), "... a critical factor in determining the level of vulnerability to harmful use of alcohol and alcohol-related harm across countries is the level and effectiveness of alcohol control and regulations in each country, and within countries, in each jurisdiction with the ability to set alcohol policies."<sup>4</sup>

Policy interventions to reduce and prevent community level alcohol-related problems have been the focus of much research, resulting in the recognition of effective and promising prevention practices.<sup>11–17</sup> Examples of alcohol policies include, but are not limited to, “per se” laws that limit the level of blood alcohol concentration (BAC) allowed for operating a motor vehicle, minimum age for purchase and consumption of alcohol, and prohibitions against sales to underage persons and to intoxicated persons.

### *High-visibility policy enforcement*

These policies are most effective in preventing alcohol-related community problems when they are properly implemented and enforced.<sup>18,19</sup> Deterrence theory, which holds that the certainty and swiftness of consequences are key to reducing policy violations,<sup>20</sup> focuses on prevention, rather than on making more arrests.<sup>21</sup> Thus, enforcement activities that are highly visible to the general public are expected to have a greater deterrent effect than those that are not highly visible.<sup>18,22</sup> Examples of alcohol policy enforcement operations include: alcohol outlet compliance checks for sales to underage youth or intoxicated patrons; roadside sobriety checkpoints; dedicated driving under the influence (DUI) patrols; and party patrols focused on nuisance parties and events where a social host provides alcohol to minors, or an opportunity for underage drinking. “High visibility” includes publicity campaigns about enforcement operations before they occur, as well as publicity about the results of operations after they are completed. A well-publicized enforcement operation is intended to act as a deterrent to policy violations, and does not necessarily result in more arrests or citations.<sup>23</sup> In this sense, the goal of enforcement is to create a credible threat of apprehension and consequences that prevents people from violating a policy or law.

### *Dosage of interventions*

What is not well-understood is the dosage of high-visibility enforcement intervention that is necessary to be effective in reducing alcohol-related problems at the community level. The dosage of a community intervention has been referred to as its strength,<sup>24</sup> the level to which it is implemented,<sup>25</sup> and the amount and frequency needed to have an effect.<sup>26</sup> Much of the public health literature about dosage has focused on treatment or educational interventions that target individual behavior change,<sup>25,27</sup> rather than policy-focused interventions intended to change environmental factors associated with poor health outcomes. However, current public health practice reflects a trend in the implementation and enforcement of policies that modify community environments, including smoke-free environments, increased availability of healthy foods, and walkable communities. It is therefore, important to understand how much enforcement is necessary for policies to be effective so that community decision-makers can make appropriate resource allocations toward this purpose.

It is also not clear what leads communities to implement a higher dosage of alcohol policy enforcement interventions. Implementation science has been defined as “...the study of factors that influence the full and effective use of innovations in practice.”<sup>28</sup>

Most of the emphasis of implementation science has been on the dissemination and implementation of evidence-based programs focused on individual, family or group behavior change. Research on translating policy innovation, including enforcement, is perhaps the least developed in the implementation and dissemination literature.<sup>29</sup> However, there are some clues in the implementation literature that can help with forming hypotheses about whether certain community characteristics may predict better implementation. In one review of implementation research, funding, perceived need for the intervention, and coordination between agencies were found to be factors, among others, that positively affect the implementation process.<sup>30</sup> Another review concluded that necessary conditions for implementation to be successful were: community readiness, which included recognition that problems exist; the development of effective community partnerships; solutions that fit the problems; fidelity to the interventions; and adequate resources.<sup>31</sup> Furthermore, in Rosenbaum's analysis of anti-crime partnerships, he theorizes that the availability of resources from multiple agencies likely increases the dosage of interventions.<sup>32</sup>

### *Dissertation goals and research questions*

The goals of this dissertation were to 1) increase the scientific understanding about how the dosage of high-visibility policy enforcement is associated with alcohol-related outcomes at the community level, and 2) contribute practical recommendations about dosage levels necessary to affect outcomes. The following research questions were answered:

- 1) How does dosage of community-level alcohol policy enforcement and visibility of enforcement contribute to reductions in excessive alcohol use and other alcohol-related problems?
- 2) Do certain community characteristics predict dosage of alcohol policy enforcement interventions?
- 3) Did higher levels of dosage of enforcement and visibility lead to reductions in alcohol-related problems at the community level in a randomized community trial?

### *Significance of dissertation research*

The current research contributes to the understanding of how varying levels of high-visibility policy enforcement interventions affect alcohol-related outcomes at the community level. The contribution includes, in part, a systematic review of the existing literature regarding how dosage of alcohol policy enforcement, including high-visibility enforcement, is associated with reductions in excessive drinking and related community problems. As of this writing, this is the first systematic review to examine the dosage effects of a variety of alcohol policy enforcement interventions on various outcomes.

In addition, the dissertation research identified some of the community characteristics associated with alcohol policy enforcement and visibility dosage levels in 12 intervention cities of a randomized community trial study. For researchers and practitioners, these

results can provide important insights into the processes and tools necessary to assist communities with increasing these types of interventions to effective levels.

Finally, this dissertation research is significant because it can help lead to recommendations with practical value for communities to replicate a specified number of enforcement operations and visibility activities to reduce problems associated with excessive drinking.



## PAPER 1

### Measuring Dosage of Alcohol Policy Enforcement Operations: A Systematic Review

#### **Abstract**

**Background.** A growing body of research examines the required “dosage,” or amount of an intervention that is sufficient to be associated with a hypothesized effect. Much of the public health dosage literature is focused on treatment or educational interventions that target individual behavior change. Less is known about the level of dosage of the enforcement of policies needed to modify environments that are associated with poor health outcomes.

**Objective.** The purpose of this systematic literature review is to examine what is known about the dosage of alcohol policy enforcement and visibility of enforcement that is associated with reductions in underage drinking, excessive drinking, driving under the influence (DUI), DUI crashes, other alcohol-related community problems, like crime and violence, and provision of alcohol to underage or intoxicated persons.

**Methods.** Research was selected that examined the association between the frequency and/or amount of alcohol policy enforcement and/or publicity about the enforcement, and reductions in underage drinking, binge drinking and alcohol-related harm at the community level. 12 health, safety and social sciences databases were searched. Database searches were supplemented by searches of websites focused on alcohol policy research. The reference lists of retrieved articles were searched to locate additional research relevant to this review. A collection of published and unpublished literature was compiled in Zotero from systematic searches of electronic sources, and through searching for additional relevant literature from references of retrieved articles. Title and abstract screening was conducted on 482 references, and 55 references were retrieved as full text articles and screened for inclusion. 16 studies were identified that met the criteria for inclusion in this review.

**Results.** The 16 studies differed in measures of dosage and outcomes, existing policies in study communities, types of enforcement interventions used, study designs and sizes of the samples. Although all included studies found that consistent enforcement was associated with desired outcomes, this review found no consensus among the studies for an effective level, or threshold of enforcement dosage.

**Conclusion.** Future research can add to the literature by using rigorous study designs, and testing measures of dosage of enforcement and visibility suggested by the results of the studies in this review. Further study is needed to support communities in making realistic decisions about allocating resources for high visibility enforcement to address alcohol related problems.

## 1. Introduction

An essential body of public health research examines the relationship between the implementation of evidence-based interventions and improvements in community health and safety. One area of focus within this niche is examining the required “dosage” of an intervention that is sufficient to be associated with a hypothesized effect. Dose of an intervention has been described as its strength,<sup>24</sup> the level to which it is implemented,<sup>25</sup> and the amount and frequency needed to have an effect.<sup>26</sup> Increasing the dosage of interventions is expected to be associated with improved health or with greater reductions in health-related problems.<sup>33</sup>

Much of the literature about dosage in public health is focused on treatment or educational interventions that target individual behavior change, rather than policy-focused interventions intended to change environmental factors associated with poor health outcomes. For example, Warren et al defined dose as number of “teaching episodes” in an intervention session.<sup>27</sup> Legrand et al developed a framework that calculated an intervention dose for a health promotion program that included two major domains: the delivery of the intervention and the extent of participation of those involved, each of which was defined in terms of quantity and quality. They conceded that the terminology in this area is not yet consolidated and that research is ongoing.<sup>25</sup> In some cases, environmental factors are considered in a dosage analysis, as in the dose-response relationship formula used in community obesity prevention efforts, for example. However, the dosage calculation involves individual measures: multiplying reach (e.g., per cent of a community population exposed to the intervention) by strength (e.g., the increase in desired behavior by those exposed).<sup>34</sup>

Current public health practice reflects a trend in the implementation and enforcement of policies that modify community environments, including smoke-free environments, increased availability of healthy foods, and walkable communities. In this same tradition, community environmental factors have been identified that are associated with higher rates of alcohol consumption and related harm.<sup>4</sup> The evidence base for alcohol policy interventions to reduce alcohol availability and related harm is well established.<sup>5–8,11,16–18,35–41</sup> However, less is known about the required dosage of the enforcement of policies to modify environments that are associated with poor health outcomes.

Enforcement of policies is a fundamental part of implementing interventions to reduce excessive and underage alcohol use and related harms.<sup>18,19</sup> A systematic review of population-level interventions to reduce alcohol-related harm found “...more consistent support for the effectiveness of interventions targeting alcohol consumption or harm if they involve regulatory or statutory enforcement.”<sup>42</sup> The deterrent effect of alcohol-impaired driving enforcement has been found to be enhanced when combined with publicity activities that make the enforcement highly visible. Numerous studies have shown beneficial effects of enforcement of alcohol policies,<sup>43–52</sup> and high-visibility enforcement in particular.<sup>22,23,46,53–56</sup> In contrast, a Tennessee study using 2001-2003 data found no significant relationship between enforcement and reductions in alcohol impaired crashes.<sup>57</sup> However, increased enforcement is a common goal in policy implementation. What is not clear is the amount or frequency of enforcement that is

necessary to lead to intended outcomes. It has been theorized that, at least in traffic crash morbidity and mortality, there is an eventual “diminishing return” effect of increased enforcement.<sup>58</sup>

Raising visibility through well-publicized enforcement operations is intended to act as a deterrent to violations, and does not necessarily result in more citations or arrests. The goal of high-visibility enforcement is to create a credible threat of apprehension and punishment that deters or prevents people from violating the law. Deterrence efforts may be specific or general, depending on whether they focus on individuals or the public at large. Laws dealing with driving while intoxicated (DWI) or driving under the influence (DUI) and the enforcement of these laws serve as both general and specific deterrents to drinking and driving.<sup>59</sup> High visibility enforcement works as general deterrence, communicating the likelihood of enforcement and arrest to the general public, therefore deterring drinking and driving. The visibility of enforcement has been described as “key” to the relationship between enforcement and reductions in alcohol-impaired driving crashes.<sup>22</sup>

The purpose of this systematic literature review is to examine what is known about the intensity or “dosage” of alcohol policy enforcement and visibility of enforcement that is associated with reductions in a range of outcomes, such as: underage drinking, excessive drinking, drinking and driving, impaired driving crashes, other alcohol-related community problems, like crime and violence, and provision of alcohol to underage or intoxicated persons. Alcohol policies include the: blood alcohol concentration (BAC) limits for driving (.08 g/dL in the United States); prohibition against sales or furnishing alcohol to persons under 21; and, prohibition against sales to intoxicated persons.

## **2. Methods**

### *Search Strategy*

Twelve health, safety and social sciences databases were searched. No limitations on the start search date, geographical settings or type of study were applied. A broad search strategy was used that included a combination of appropriate keywords, subject headings, and free text terms, adapted for each database. Search terms included:

(((intensity) OR dosage) OR frequency) AND alcohol policy) AND enforcement

Database searches were supplemented by searches of websites related to alcohol policy research. All electronic sources used in the searches are listed in Table 1.1. Finally, the reference lists of retrieved articles were searched to locate additional research relevant to this review. A collection of published and unpublished literature was compiled in Zotero from systematic searches of electronic sources, and through searching for additional relevant literature from references of retrieved articles.

Overall, a total of 482 non-duplicate references were identified from the literature searches. After title and abstract screening, 428 references were excluded (see Figure 1.1 for exclusion criteria). 55 references were retrieved as full text articles, and screened for inclusion.

### *Study selection*

Studies were included in this review if they examined the association between the frequency and/or amount of alcohol policy enforcement and/or publicity about the enforcement, and reductions in underage drinking, binge drinking and alcohol-related harm at the community level. Alcohol policies include the: blood alcohol concentration (BAC) limits for driving (e.g., .08 g/dL in the United States), laws prohibiting sales or furnishing alcohol to persons under 21, and laws prohibiting sales to intoxicated persons. Enforcement includes sobriety checkpoints, driving under the influence (DUI) patrols, random or selective breath testing, compliance checks at retail alcohol establishments, undercover operations to observe alcohol serving behavior in retail alcohol establishments, or holding adults accountable when underage drinking or nuisance parties occur on their property. Community level alcohol-related harm includes a wide range of problems, including alcohol-impaired driving (DUI) crashes, violence, crime, and injuries.

Studies that examined regulating the physical availability of alcohol (for example, zoning limits or limiting hours and days of sale) or price (for example, tax initiatives) were excluded. In addition, studies that included multi-component interventions were excluded if they did not identify the specific contribution, or lack of contribution of enforcement dosage to study outcomes.

### *Data extraction and synthesis*

A spreadsheet was created to compile and synthesize key information from each of the included articles. This began with a citation that identified the author(s), title, journal and publication year. Other categories included the study method, location, and measures used. Finally, the study results and/or conclusions made by the authors, as well as other comments that helped to elucidate key learning were noted. The results of data extraction for each included study are presented in structured tables (see Tables 1.2-1.4) and as a narrative summary. Studies are grouped according to alcohol policy area. Results of statistical tests are cited if they were reported by study authors.

## **3. Results**

### *Summary of studies identified*

A total of sixteen studies were identified that met the criteria for inclusion in this review. Tables 1.2-1.4 summarize the characteristics and findings of the included studies. Studies varied as to the kinds of alcohol policies that were enforced. Seven studies focused exclusively on enforcement efforts and/or visibility of enforcement to reduce

alcohol-impaired driving. These examined interventions such as random breath tests (RBTs), sobriety checkpoints, DUI arrests, or a combination of these. An additional five studies were concerned only with enforcement efforts and/or visibility of enforcement related to alcohol sales to underage persons. These examined interventions such as compliance check operations at retail alcohol establishments. One study focused solely on enforcement and/or visibility of enforcement of sales to intoxicated persons through unannounced or undercover observations of server activity at bars and restaurants. The remaining three studies examined enforcement and/or visibility of enforcement of multiple policies using a combination of enforcement interventions. One of the studies focused on sales or furnishing of alcohol to underage persons and DUI. Another study focused on sales to intoxicated persons and DUI. A third study focused on sales or furnishing alcohol to underage persons, DUI, and alcohol parties that disturb the peace (by using enforcement patrols and responding to complaints).

### *Study designs and locations*

Two studies were randomized community trials (RCT), and six were quasi-experimental trials in which groups were non-randomly assigned to an intervention or comparison condition. One of these quasi-experimental studies was a multiple time-series trial, with a cohort design nested within the time-series quasi-experiment. The remaining eight studies used cross-sectional designs.

Thirteen studies were conducted in the United States, one in The Netherlands, one in Australia, and one involved multiple European countries, including Belgium, Cyprus, Germany, Estonia, Finland, France, Hungary, Ireland, Israel, Italy, Netherlands, Norway, Poland, Serbia, Slovenia, Spain, Sweden and the Czech Republic.

### *Dosage of enforcement interventions to reduce driving under the influence of alcohol (DUI/DWI)*

Eight studies<sup>45,50,52,60-64</sup> evaluated dosage of enforcement operations to reduce alcohol impaired driving. These studies varied in the types of enforcement used, including sobriety checkpoints, random breath testing (RBT), dedicated DUI/DWI patrols, and/or number of traffic stops per population. The studies also differed in the way enforcement dosage was measured, for example, number of DUI/DWI arrests,<sup>50,52,60</sup> frequency<sup>52,60,62</sup> or number<sup>45</sup> of sobriety checkpoints, number of random breath tests per population,<sup>61</sup> number of saturation patrols,<sup>45,60</sup> frequency of alcohol checks in the past three years<sup>63</sup> or traffic stops per 10,000 population,<sup>60</sup> total number of sworn officers per 10,000 in the community population,<sup>52</sup> and amount of funding used for enforcement activities.<sup>50</sup>

Outcome measures also varied among the studies. Three of the studies used alcohol-impaired driving crashes as the primary outcome measure.<sup>50,52,61</sup> Another three used self-reported drinking and driving.<sup>45,62,63</sup> One study used the prevalence of nighttime drivers in the 2007 National Roadside Survey (NRS) who were alcohol positive (BAC > 0), who were at BACs  $\geq 0.05$ , and who were above the legal limit (BAC  $\geq 0.08$ ).<sup>60</sup> One study used blood alcohol concentration (BAC) levels of drivers arrested for DUI and DUI

arrestees naming retail alcohol establishments exposed to the program as their place of last drink.<sup>64</sup> Two additional studies employed DUI enforcement interventions, but they did not include alcohol-impaired driving outcome measures. One of these found that person-hours and citations related to DUI enforcement were not tracked consistently and did not always focus on the target population of underage drivers.<sup>65</sup> The other study included DUI enforcement in combination with other alcohol enforcement activities, but did not use DUI-related outcome measures in the results.<sup>66</sup>

### Driving under the influence (DUI) arrests

Some studies found associations between DUI arrests and alcohol impaired driving, crashes, and fatalities. For example, a 10% increase in the DUI arrest rate was associated with a 1% reduction in the alcohol-impaired-driving crash rate in one study. Similar results were obtained for an increase in the number of sworn officers per 10,000 driving-age population.<sup>52</sup> In a separate study, it was found that the number of traffic stops per population had the most significant effect on alcohol-impaired driving, and that arrest rates at or higher than 38 per 10,000 population resulted in significantly lower odds of driving at or above the .08 legal limit. However, the authors acknowledge that they did not find a “threshold” for arrests per capita.<sup>60</sup> Elsewhere it was reported that, in an “average” state, an increase of 0.001 in DUI arrest rate (approximately 6000 more arrests) per capita was associated with a 1.87% reduction in the fatal crash ratio of drivers involved in fatal crashes with BACs  $\geq 0.08$  g/dl to drivers involved in fatal crashes with BACs = 0.00 g/dl. This reduction translated into saving approximately five lives per year. The association was found to be stronger in states with a greater number of African Americans, people living in urban areas, and college graduates, although the authors deemed this finding “exploratory” and emphasized the need for further research.<sup>50</sup>

### Sobriety checkpoints

Several studies focused on the use of sobriety checkpoints to reduce driving under the influence, even though only 36 states have laws permitting enforcement agencies to conduct them. One study found that states that conducted sobriety checkpoints at least monthly had approximately 40.1% less self-reported drinking and driving, compared to states who did not conduct sobriety checkpoints, regardless of having a law allowing them. In addition, states that conducted sobriety checks less than monthly were found to have approximately 36.2% less self-reported drinking-driving than states who did not conduct sobriety checks, regardless of having a law permitting them. The difference in the effect on self-reported drinking and driving between conducting checkpoints at least monthly compared to less than monthly was not found to be statistically significant.<sup>62</sup> While another study found no significant associations of alcohol-impaired-driving crash rates with the use of sobriety checkpoints, the authors suggest that this finding is not surprising, given that very few law enforcement agencies reported conducting this type of intervention.<sup>52</sup> In a subsequent article, the authors posited that weekly sobriety checkpoints may very likely be the key threshold for checkpoint effectiveness.<sup>60</sup>

## Combination of sobriety checkpoints, saturation patrols, open container laws and media campaigns

The effects of enforcement by U.S. state patrol agencies and local police agencies were explored in a study that drew upon a latent class analysis developed in previous research<sup>67</sup> to rank agencies into “high” and “low” categories according to their annual frequency of conducting sobriety checkpoints, saturation patrols, open container enforcement, and media campaigns to raise the visibility of enforcement efforts. The included study<sup>45</sup> found that the prevalence of self-reported alcohol-impaired driving was lower in states where state patrol agencies conducted sobriety checkpoints, conducted saturation patrols, and enforced open container laws. Results from the state agencies showed that saturation patrols had the strongest association with reductions in self-reported alcohol-impaired driving. Similarly, the prevalence of self-reported alcohol-impaired driving was found to be lower in states where a large proportion of local law enforcement agencies conducted sobriety checkpoints, conducted saturation patrols, and enforced open container laws. Results from local agencies showed that sobriety checkpoints and open containers laws had the strongest associations with reductions in self-reported alcohol-impaired driving rates. Contrary to previous research, the prevalence of self-reported alcohol-impaired driving was higher in states where state patrol agencies reported media campaigns related to enforcement efforts. States with all local agencies in the high enforcement class had an estimated 84% lower prevalence of alcohol-impaired driving, compared to states that had no local agencies in the high class. Relatedly, states with all local agencies in the low enforcement class had an estimated 71% higher prevalence of alcohol-impaired driving than states with no local agencies in the low class.

The study concluded that the effects of combined enforcement on alcohol-impaired driving were larger than those associated with any of the individual enforcement activities. Extremely high levels of saturation patrols and media contact and fairly high levels of sobriety checkpoints were found to be associated with a greater decrease in alcohol-impaired driving than any of the individual enforcement interventions on its own. However, other than the designation of “high” and “low” classes based on aggregate measures of each agency’s combined enforcement activities, no specific frequency or dosage of enforcement was reported to be associated with reductions in alcohol-impaired driving.<sup>45</sup>

## Random breath testing (RBT)

The association between monthly random breath testing (RBT) per 1000 licensed drivers and alcohol-related crashes in Australian states and territories was the focus of a study that used January 2000 – December 2012 data (where available).<sup>61</sup> Random breath testing differs from saturation patrol programs in the U.S., where drivers may be stopped and tested only if they show signs of impaired driving. RBT allows police to randomly stop any driver and test for being over the legal limit to drive (BAC  $\geq$  0.05). While Australian law allows RBT, it does not specify a certain number of tests to conduct each year. Therefore, individual states and territories determine their own annual dosage, based on a percentage of the number of licensed drivers under their

jurisdictions. The study found that, in general, jurisdictions with 1:1 ratios of RBT to licensed drivers annually reported declining trends of alcohol-related crashes and lower percentages of self-reported drinking and driving (8.38% - 12.49%), compared to jurisdictions with a ratio of 1:2 or 1:3 annually, which also had declining trends but higher prevalence rates of self-reported drinking and driving (13% - 14.56%). While overall, a higher ratio of RBTs to licensed drivers was associated with fewer alcohol-related crashes, this effect was not found in all jurisdictions, suggesting that other factors may influence the number of RBTs, crashes, and the relationship between the two. Such factors may include: the levels of publicity and educational interventions that accompany the enforcement operations; varying penalties for impaired drivers; and geographical variation.<sup>61</sup>

### Alcohol checks

Responses to a survey conducted in 19 European countries in 2010 were used to investigate the association between alcohol checks and self-reported driving under the influence (DUI) above the legal limit. In this study, alcohol checks included a variety of interventions, including sobriety checkpoints, DUI patrols and random breath tests (RBTs). Analysis was conducted on data collected from 12,507 drivers (approximately 600 drivers per country) about having experienced an alcohol check in the past three years, and having driven under the influence of alcohol within the past month. Effects were investigated at the individual driver level and at the national level. Despite variation in age and national BAC limits across the respondents, individual level results showed that those who experienced alcohol checks at least once in the past three years were 1.8 times more likely to drive under the influence of alcohol than drivers who had not been checked within the past three years. This result was found after controlling for other significant predictors of DUI. However, on the national level, the relationship between alcohol checks and self-reported driving under the influence was negative. Countries with a higher number of alcohol checks had a lower prevalence of self-reported DUI than countries with fewer alcohol checks (OR=0.985). The authors concluded that the paradoxical results confirm the preventive effect of alcohol checks, intended to increase the perceived likelihood of being caught for driving under the influence, but not the repressive effect, which increases the actual likelihood of being caught.<sup>63</sup>

### Reducing alcohol sales to intoxicated persons to reduce DUI arrests and crashes

Mixed results were found in a quasi-experimental study that had a long-term goal of reducing DUI arrests and alcohol-related crashes by reducing sales of alcohol to intoxicated patrons at bars and restaurants associated with the highest numbers of DUI arrests, or highest BAC levels among DUI arrestees. In each of two regions of Washington State, bars and restaurants were randomly assigned to intervention or comparison condition. Enforcement consisted primarily of unannounced premise inspections at selected bars and restaurants to check for alcohol service to intoxicated patrons. 102 checks were conducted during the intensive enforcement period in intervention sites, compared with 48 in comparison sites during the same period. 23 checks were conducted in intervention sites during the regular enforcement period,



compared to 12 at comparison sites. Although no tests of significance were conducted due to small sample size, at intervention sites, the rate of sales to intoxicated patrons *increased* from 50% to 88.9%, compared to a decrease from 80% to 77.9% in comparison sites. However, the average number of DUI arrests in which intervention establishments were identified as place of last drink, decreased 36% from the three-month period before the intensive enforcement activities to the three-month period after, a statistically significant result compared to the seven percent reduction of comparison establishments over the same period. Also found was a statistically significant reduction in the average BAC level for arrestees coming from intervention sites from the three-month period before the intensive enforcement activities to the three-month period after, from .135 g/dL to .127 g/dL, compared to a non-significant increase of .135 g/dL to .149 g/dL in arrestees coming from comparison sites. The authors note that the level of enforcement in comparison sites was greater than anticipated, so study results do not reflect the strength of an intensive enforcement intervention weighed against little or no enforcement.<sup>64</sup>

#### *Dosage of enforcement interventions to reduce underage drinking –compliance checks*

Six studies<sup>9,65,68–71</sup> evaluated dosage of enforcement interventions intended to reduce underage drinking. One of these was a randomized community trial (RCT);<sup>65</sup> four of the studies were quasi-experimental;<sup>9,68,70,71</sup> and one was a secondary analysis of a quasi-experimental study.<sup>69</sup> All six studies examined the use of compliance operations conducted at retail alcohol establishments to check for alcohol sales to underage persons. Three of the six studies incorporated additional enforcement activities, such as: mandatory fines for noncompliance,<sup>68</sup> increased enforcement of underage drinking and third-party purchase laws,<sup>65</sup> and increased party enforcement to prevent furnishing alcohol to minors or disturbing the peace.<sup>65</sup> Three of the six studies involved the strategic use of media to increase the visibility of the enforcement activities.<sup>65,68,71</sup> All but one of the studies<sup>70</sup> were conducted in the United States.

In the RCT,<sup>65</sup> compliance checks were conducted at all off-premise alcohol establishments (i.e., stores) once per year for two years in intervention communities. However, the frequency and intensity (i.e., dosage) of other enforcement activities varied across the intervention communities. Measures of dosage included the number of citations/warnings issued and the number of person-hours spent conducting enforcement activities. Enforcement intensity was analyzed post hoc, with high intensity defined as values of one standard deviation above the mean, and low intensity as values one standard deviation below the mean. Because DUI enforcement was inconsistently tracked and did not always specifically focus on underage drivers, the number of citations and person-hours spent on this type of activity were not included in intensity measures or in outcomes. Combined intervention effects demonstrated a statistically significant reduction in alcohol sales to persons under 21 ( $p < 0.01$ ), but not in past 30-day use of alcohol or binge drinking among underage persons, in intervention communities compared to comparison communities. However, post-hoc analysis revealed additional effects of the interaction between high vs. low enforcement intensity and time on outcomes. Statistically significant ( $p < 0.01$ ) effects were found by high levels of citations, on reductions in self-reported past 30-day use (beta = -0.0017; C.I. -0.0025,

-0.0009) and binge drinking (beta =-0.0018; C.I. -0.0028, -0.0008). Similarly, significant effects were found by high levels of person hours engaged in enforcing underage drinking laws on self-reported past 30-day use (beta =-0.0011; C.I. -0.0021, -0.0001;  $p < 0.05$ ) and binge drinking (beta =-0.0018; C.I. -0.0030, -0.0006;  $p < 0.01$ ).<sup>65</sup>

The effects of more frequent use of underage sales compliance checks were examined in the city of Concord, New Hampshire, using the rest of the state for comparison.<sup>68</sup> During the study period, the Concord Police Department conducted quarterly compliance checks of all off-premise alcohol establishments, compared to the routine one or two checks per year conducted in the rest of the state of New Hampshire. Results showed a 64% reduction in alcohol sales to underage persons in Concord, while the rate of underage sales in the rest of the state remained unchanged. In addition, statistically significant declines in self-reported drinking and binge drinking occurred from 2001 to 2003 among Concord youth. No statistically significant declines occurred in self-reported drinking or binge drinking from 1995 to 2003 among students statewide. Study authors acknowledge that other enforcement efforts to reduce alcohol access to underage persons were conducted in Concord during the study period, thereby reducing the likelihood that the reduction in sales to minors was only associated with enhanced compliance checks. In addition, mandatory penalties were instituted for a shorter time than compliance checks, therefore it was difficult to assess the separate contribution of each intervention to the reductions in alcohol sales to minors.

Reductions in underage alcohol sales were also found in another study, where each intervention community determined the schedule and numbers of compliance checks, but were encouraged to conduct at least two checks per year for all alcohol establishments over the two-year intervention period.<sup>9</sup> Results showed that, in “on-sale” alcohol establishments (i.e., bars and restaurants), the likelihood of selling alcohol to a person under 21 years of age was reduced immediately after an enforcement compliance check by 17%, and that over two months, the effect changed to an 8.5% reduction. In “off-sale” premises (i.e., stores), the immediate effect was also a 17% reduction, but this went down to 0% over 3 months, with no long-term effect. Any effects found were for the specific establishments that were checked, with no significant general deterrent effect or “diffusion” to other establishments. However, a follow up study conducted a secondary analysis of diffusion effects by examining sales to pseudo-underage buyers at establishments within a 500 m area around each establishment that had experienced a compliance check.<sup>69</sup> Results indicated that the odds of alcohol sales to minors at establishments within 125 m of an establishment that had been checked in the past 90 days were reduced by more than 30%, with the strongest effects in neighborhoods with high density of alcohol outlets. Results also confirmed the earlier study’s finding of decayed effect of the intervention over time, noting, however, that effects were still significant for up to 90 days after compliance checks in low-density neighborhoods.

Deterioration of effects was also found in an earlier study where three waves of compliance checks were conducted over a twelve-month period at a random sample of 143 off-sale alcohol establishments in New Orleans.<sup>71</sup> Overall compliance increased from 11.3% at Time 0 to 21% at Time 2, with stronger effects for establishments that

had been cited for violating the law (from 6.7% to 28.9%) compared to establishments that had not been cited (from 13.3% to 17.3%). However, between Time 1 (two months after enforcement began) and Time 2 (eight months after Time 1), compliance decreased from 40% overall to 21%, indicating a decaying effect of the enforcement over time.

Unlike in the United States, where laws allow the use of minor decoys in law enforcement operations for compliance checks as described above, in the Netherlands, the Food and Consumer Product Safety Authority (FCPSA) conducts inspections to observe sales to underage persons (<16 years of age).<sup>70</sup> A study examining the association between this practice and reductions in underage alcohol sales and underage drinking selected 25 on-sale and off-sale establishments considered to be attractive to underage persons in each of one intervention and one comparison community. Over the two-year study period, such “hotspots” were inspected approximately nine times in the intervention communities, and not at all in the comparison communities. In addition, establishments in the intervention community were subject to losing their alcohol licenses if they were found to be in violation and fined twice in a year. Sales to underage persons were observed in 25 out of a total of 248 inspections, and only seven of these incidents resulted in fines or warnings. No alcohol licenses were forfeited because none of the establishments were fined twice in one year. Underage persons in the intervention community were found to be *more* likely to initiate weekly drinking than those in the comparison community, however, those who did initiate drinking had lower odds of drinking to intoxication. The authors conclude that the enforcement conducted in the intervention community was effective in protecting the health among the highest risk adolescent drinkers, those who are likely to initiate weekly use, especially considering the small likelihood of sanctions for establishments from the inspections (28%).

#### *Dosage of interventions to reduce excessive drinking/intoxication*

Studies examining the dosage of interventions to reduce excessive drinking or intoxication included one randomized community trial,<sup>66</sup> and one quasi-experimental study.<sup>72</sup> The two studies were distinct from one another according to the types of interventions employed, measures of dosage of enforcement, outcome measures used, populations of interest, and locations. In both studies, media strategies were used to publicize enforcement operations.

The RCT involved fourteen California public universities, half of which were assigned randomly to the intervention condition, with the other half designated as comparison sites. The enforcement combined sobriety checkpoints, underage alcohol sales compliance checks, and “party patrols” to enforce local and state laws regarding provision of alcohol to minors or disturbing the peace. The suggested dosage was any combination of nine enforcement activities within the first eight - ten weeks of school, but actual enforcement varied across the intervention sites. In communities with relatively high enforcement levels, there were approximately 900 fewer students per university drinking to intoxication at off-campus parties and approximately 600 fewer students per university getting drunk at bars/restaurants during the fall semester relative

to communities with low levels of enforcement.<sup>66</sup>

Although sales to intoxicated patrons (SIP) is illegal in all but two of the United States (Florida and Nevada), enforcement of these policies is relatively rare.<sup>73</sup> A quasi-experimental study included in this review focused on SIP enforcement in on-sale alcohol establishments in one county in Michigan, using another Michigan county as a comparison site. Dosage consisted of conducting ten hours of SIP enforcement a week in each of the two participating agencies, and publicity both before and after to make establishments aware of the enforcement over a one-year period. In the intervention county, the percentage of observations of refusing service to pseudo-intoxicated patrons increased significantly from 17.5% before the enforcement began to 54.3% after the first three months of enforcement. Over the next three months, the percentage decreased to 47.4%, and after one year to 41.0%. In the comparison community, SIP refusal rates to pseudo-intoxicated patrons were consistently lower than those in the intervention community during each of the observation periods. A statistically significant difference in DWI rates was found between intervention and comparison communities. Intervention communities saw a 25% decrease in DWI rates and comparison communities had no statistically significant change.<sup>72</sup>

#### *Dosage of visibility activities to publicize enforcement interventions*

Six studies included specific measures of enforcement visibility,<sup>9,52,60,66,71,72</sup> while four other studies mention the importance of high levels of visibility to enhance the effects of enforcement activities, but do not provide specific measures.<sup>45,61,65,68</sup> Only two of these studies<sup>9,71</sup> analyzed the effect of visibility separately, while the other four studies combined the effect of visibility with enforcement activities.

Both studies focused on compliance checks to reduce sales to underage persons, and found significant results. In one study, a significant increase in compliance was found even among the alcohol establishments that were not cited, but were only exposed to the news coverage about the enforcement activities that was covered by the three major (at the time) television networks on one evening, and appeared on the front page of the main daily New Orleans newspaper. At Time 0, 13.3% of the 98 non-cited establishments visited were compliant, compared to 34.7% of those same outlets at Time 1, after the press coverage.<sup>71</sup> The other study found that an increase in TV broadcasts that specifically mentioned the compliance checks significantly decreased the likelihood of underage alcohol sales at licensed establishment by approximately 5%, with this effect decreasing to zero within two weeks after the compliance checks. However, an increase in broadcast media that included alcohol prevention messages, but not enforcement was only marginally significant, with a 0.4% decrease in sales following each broadcast.<sup>9</sup> These results reveal a greater effect of media that incorporates an enforcement message compared to that which does not.

## **4. Discussion**

Sixteen studies were identified that examined the association between dosage of enforcement operations and reductions in a variety of alcohol-related problems. Dosage

was variously referred to as frequency, number and intensity of enforcement operations, and was measured differently among the studies. Meta-analysis was not conducted in this review because of differences in dosage measures, outcome measures and types of alcohol-related problems addressed across the studies, as well as variation in study designs and very few randomized controlled trials. All sixteen studies emphasized the need for consistent enforcement to achieve desired outcomes. However, there was no consensus among the studies for a necessary level, or threshold of enforcement dosage. This is due, in part, to the differences in problems addressed, existing policies in study communities, types of enforcement interventions used, and the designs and sizes of the studies.

Alcohol policies in different U.S. states and across different countries sometimes dictated what types of interventions could be studied. For example, in Australia and some countries in Europe, it is permissible to conduct random breath testing (RBT) to check for driving under the influence. In the United States and other European countries studied, it is only permissible to conduct selective breath testing, based on police observation of obvious indicators of impaired driving. Therefore, while a study in Australia may recommend conducting a ratio of one random breath test per licensed driver per year,<sup>61</sup> this would not apply to countries where RBTs are not legal. Similarly, a U.S. study showing significant effects of conducting sobriety checkpoints monthly<sup>62</sup> could only apply to states where sobriety checkpoints are allowed by law.

Four studies discussed a “decaying” effect of enforcement over time, suggesting the need for ongoing enforcement to maintain beneficial effects. Three of these focused on underage alcohol sales,<sup>9,69,71</sup> suggesting that compliance checks of alcohol establishments be conducted at least every three months. The fourth study focused on alcohol service to intoxicated persons, showing an increase in refusal rates within three months after the enforcement checks, followed by a decline from the three month period to a year after enforcement.<sup>72</sup> An additional study also found a significant reduction in underage alcohol sales after quarterly compliance checks, but did not specifically examine decaying effects.<sup>68</sup> In a randomized community trial, however, compliance checks conducted only once per year were found to be associated with a significant decrease in underage alcohol sales, although these checks were part of a larger strategy that included other interventions, including a non-enforcement reward and reminder program with young pseudo-patrons attempting to purchase alcohol at off-premise outlets.<sup>65</sup>

Three studies found effects of a higher number of DUI arrests, using a variety of outcome measures, including alcohol-involvement in crashes,<sup>52</sup> alcohol-involved crash fatalities,<sup>50</sup> and prevalence of nighttime drivers who were alcohol positive, or alcohol-impaired according to a 2007 U.S. survey.<sup>60</sup> A higher number of arrests was found to be associated with reductions in the outcome measures in each study. While these findings reinforce the hypothesis that higher levels of enforcement lead to reductions in problems, they do not offer a specific dosage or threshold needed for this to occur.

While one study found no significant difference in drinking and driving between conducting sobriety checkpoints less than monthly versus at least monthly,<sup>62</sup> another cited previous studies to assert that weekly checkpoints may be the key threshold for checkpoint effectiveness.<sup>52</sup>

Three studies reported challenges with obtaining accurate levels of enforcement activity. One study found that person-hours and citations related to DUI enforcement were not tracked consistently, consequently no DUI outcome measures were reported.<sup>65</sup> Two other studies noted that some police agencies did not supply data about the number of sobriety checkpoints they conducted, which limited analysis and the applicability of study results to the wider population.<sup>52,60</sup> Thus, obtaining reliable data from enforcement agencies is one of the challenges for estimating a minimum threshold for enforcement dosage.

Several studies incorporated a combination of enforcement activities with various measures of dosage, making it difficult to attribute results to any one type.<sup>45,65,66</sup> In addition, visibility of enforcement was mentioned in ten studies, but was only analyzed in six studies, and was only analyzed separately from enforcement in two studies, with no consensus about necessary dosage.

The applicability of the results found by studies in this review is limited by the dearth of high quality study designs. Eight studies used cross-sectional designs,<sup>45,50,52,60–63,69</sup> which are useful for examining associations between interventions and outcomes, and for developing hypotheses. However, a cross-sectional study does not provide evidence of causation, nor even temporality in many cases. Six studies used quasi-experimental designs,<sup>9,64,68,70–72</sup> which have advantages over cross-sectional designs in that they include comparison groups and can track changes over time, for instance. However, because groups are not randomly assigned to intervention or comparison condition, these studies are subject to internal threats to validity including selection bias. This makes it difficult to know whether observed changes are due to actual intervention effects, or to differences between the groups before the intervention occurred. This concern is addressed by randomizing groups to intervention or comparison, which was employed in only two studies in this review.<sup>65,66</sup> However, the results of the two RCTs are not comparable because there were different measures of dosages, types of enforcement interventions, and outcome measures used in their analyses.

## **5. Conclusion**

The findings of this review indicate that regular, consistent enforcement of alcohol policies may reduce underage drinking, drinking to intoxication, alcohol impaired driving, crashes, and related harm. However, the results reveal that there is no consensus in the literature about a threshold or recommended intensity of enforcement that is associated with reductions in these problems. Similarly, this review did not identify an agreed-upon dosage for publicizing enforcement operations to raise visibility. While some studies defined “high” and “low” levels of enforcement intensity, these are mainly post-hoc analyses based on comparisons between actual levels of enforcement that were

implemented in study communities, and are not based on a “standard” that can be used generally. Therefore, the reported levels may not have practical value for communities hoping to replicate a specified number of enforcement operations to reduce alcohol-related problems. Future research should build on these findings by using rigorous study designs, and focusing on testing measures of dosage of enforcement and visibility suggested by the results of the studies in this review. Further study is needed to support communities in making realistic decisions about allocating resources for high visibility enforcement to address alcohol related problems.

## 6. Tables and Figures

Table 1.5. Electronic Sources for Literature Searches

<b>Databases</b>	<b>Websites</b>
<ul style="list-style-type: none"> <li>• Alcohol Studies Database</li> <li>• Cochrane Library</li> <li>• Google Scholar</li> <li>• PsychInfo</li> <li>• PubMed</li> <li>• SafetyLit</li> <li>• Science Direct</li> <li>• Scopus</li> <li>• Social Work Abstracts</li> <li>• Sociological Abstracts</li> <li>• Trials Register of Promoting Health Interventions (TRoPHI)</li> <li>• Web of Science</li> </ul>	<ul style="list-style-type: none"> <li>• Alcohol Policy Information System (APIS)</li> <li>• Centers for Disease Control and Prevention</li> <li>• Centre for Alcohol Policy Research</li> <li>• European Institute of Studies on Prevention</li> <li>• Monash University Accident Research Centre</li> <li>• Mothers Against Drunk Driving (MADD)</li> <li>• National Highway Traffic Safety Administration</li> <li>• National Institute of Alcoholism and Alcohol Abuse (NIAAA)</li> <li>• World Health Organization (WHO) – Global Health Observatory (GHO) Data</li> </ul>



Table 1.6. Summary of study characteristics and findings: dosage of interventions to reduce DUI

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Fell et al. (2014)	USA	Cross-sectional	(1) DUI arrests per 10,000 populations; (2) frequency with which sobriety checkpoints are conducted (weekly, monthly, less than monthly, never); (3) traffic stops per 10,000 population as a measure of overall intensity and visibility (4) sworn officers per 10,000 population; (5) other enforcement activities (warnings, seat belt citations, speeding citations, and other moving violations) per 10,000 people in the community.	Alcohol-impaired-driving (BAC $\geq$ 0.5) involvement in crashes.	10% increase in the DUI arrest rate associated with a 1% reduction in the alcohol-impaired-driving crash rate. Similar results were obtained for an increase in the number of sworn officers per 10,000 driving-age population. No significant associations of alcohol-impaired-driving crash rates with other types of enforcement actions, or with the use of sobriety checkpoints.
Fell et al. (2015)	USA	Cross-sectional	1) DUI arrests and 2) DUI saturation patrols per 10,000 population, 3) traffic stops per 10,000 population, 4) sworn officers per 10,000 population, 5) other traffic enforcement activities per 10,000 population, and 6) the frequency of sobriety checkpoints (weekly, monthly, less than monthly, never)	Prevalence of nighttime drivers in the 2007 National Roadside Survey (NRS) who were alcohol positive (i.e., BAC > 0), who were at BACs $\geq$ 0.05, and who were driving with BACs over the illegal limit (i.e., with a BAC $\geq$ 0.08) in each of the 30 communities in the study.	Drivers who were exposed to fewer than 228 traffic stops per 10,000 population aged 18 and older had 2.4 times the odds of being BAC positive, 3.6 times the odds of driving with a BAC $\geq$ 0.05, and 3.8 times the odds of driving with a BAC $\geq$ 0.08 compared to those drivers on the roads in communities with more than 1,275 traffic stops per 10,000 population. Drivers in communities with fewer than 3.7 driving under the influence (DUI) arrests per 10,000 population had 2.7 times the odds of BAC-positive drivers on the roads compared to communities with the highest intensity of DUI arrest activity (>38 DUI arrests per 10,000 population).

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Ferris et al. (2015)	Australia	Cross-sectional	Ratio of RBTs to alcohol-related crashes.		Jurisdictions with 1:1 ratios of RBT to licensed drivers annually reported declining trends of alcohol-related crashes and lower percentages of self-reported drinking and driving (8.38% - 12.49%), compared to jurisdictions with a ratio of 1:2 or 1:3 annually, who also report declining trends but higher percentages of self-reported drinking and driving (13% - 14.56%).
Lenk et al. (2016)	USA	Cross-sectional	3-level variable for conducting sobriety checkpoints: no; yes, less than monthly; yes, at least monthly	Self-reported drinking and driving	States that conducted checks at least monthly (vs. not conducting checks), regardless of having a law, tended to have 40.1% less self-reported drinking-driving; states that conducted checks less than monthly (vs. not conducting checks), regardless of having a law, tended to have 36.2% less self-reported drinking-driving. No significant difference found in drinking and driving between conducting checkpoints less than monthly versus at least monthly.

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Meesmann et al. (2015)	Belgium, Cyprus, Germany, Estonia, Finland, France, Hungary, Ireland, Israel, Italy, Netherlands, Norway, Poland, Serbia, Slovenia, Spain, Sweden, the Czech Republic.	Cross-sectional	Frequency of self-reported alcohol checks in the past 3 years.	Frequency of self-reported driving under the influence of alcohol above the legal limit in the past month.	At the individual level of the model, drivers who had been checked within the last 3 years were 1.8 times more likely to DUI compared to those who have not been checked for alcohol within this period. Though the effect varied, results showed that in all countries personal experience with alcohol checks was positively associated with self-reported DUI. At the national level, an increase of 1 percentage point of the national level of alcohol checks is associated with national decrease of the odds for DUI by 1.5%.

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Sanem et al. (2015)	USA	Cross-sectional	<p>3 enforcement classes:</p> <p>(1) uniformly low enforcement class characterized by very low levels of all four strategies (sobriety checkpoints, saturation patrols, open-container enforcement, media re: enforcement efforts);</p> <p>(2) uniformly high enforcement class characterized by high levels of saturation patrols, high levels of media campaigns, and fairly high levels of sobriety checkpoints; (3) enforcement class characterized by high levels of saturation patrols, high levels of media campaigns, and low levels of sobriety checkpoints</p>	<p>1) Alcohol-impaired driving, defined as responding “one or more times” to the following Behavioral Risk Factor Surveillance System (BRFSS) question: “During the past 30 days, how many times have you driven when you have had perhaps too much to drink?”</p> <p>Controlling for binge drinking, defined as responding “one or more times” to the following BRFSS question: “Considering all types of alcoholic beverages, how many times during the past 30 days did you have X (X=5 for men; X=4 for women) or more drinks on an occasion?”</p>	<p>Compared to a state with no local agencies in the high enforcement class, a state with all local agencies in the high enforcement class had a model-estimated 84% lower prevalence of alcohol-impaired driving. Conversely, compared to a state with no local agencies in the low enforcement class, a state with all local agencies in the low enforcement class had a model-estimated 71% higher prevalence of alcohol-impaired driving. The uniformly high enforcement class (which includes extremely high levels of saturation patrols and media contact and fairly high levels of sobriety checkpoints) in fact is associated with a greater decrease in alcohol-impaired driving than any individual enforcement-related activity. Alcohol-impaired driving enforcement-related strategies are associated with decreased alcohol-impaired driving above and beyond their association with decreased binge drinking.</p>

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Yao et al. (2015)	USA	Cross-sectional	1) numbers of DUI arrests per capita; 2) as a proxy for enforcement, each state's annual per capita receipt of Section 402 State and Community Highway Safety Grants (used to fund traffic safety enforcement).	Alcohol-impaired crash fatality score (ratio of the number of drivers involved in fatal crashes with BACs $\geq$ 0.08g/dl over the number of drivers involved in fatal crashes without any measurable alcohol (BACs=0.00g/dl).	In 'typical' state, increase in arrest rate of 0.001 (approximately 6000 more arrests) associated with annual reduction of 5 fewer alcohol-impaired driver fatalities. [An increase of 0.001 in arrest rate per capita associated with 1.87% reduction in fatal crash ratio outcome. Model predicts increase in DUI arrest rate of 0.001 will be associated with reduction in alcohol-impaired fatalities from 261 to 255.8 in 'average' state—saving roughly five lives per year.] [when the proportion of population living in rural areas was low (defined as 28%), increase in arrest rate of 0.001 associated with decrease in crash ratio of 4.6%, but decrease only 1.2% when proportion of population living in rural areas high (62%). When low proportion identified as African American (2.5%), 0.001 increase in arrest-rate associated with reduction in crash ratio of only 0.5%, but reduction was 3.0% when high proportion of African Americans (15%). Similarly, a 0.001 increase in arrest rate associated with larger reduction in crash ratio (2.9 versus 1.9%) when higher proportion of college graduates (28 versus 24%)]

Table 1.7. Summary of study characteristics and findings: dosage of interventions to reduce underage drinking

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Barry et al. (2004)	USA	Quasi-experimental	Quarterly compliance checks of all off-premise alcohol licensees in Concord, N.H., compared to the routine 1 or 2 checks per year in the rest of the state of New Hampshire	*Reduction in retail sales of alcohol to minors *Declines in alcohol use among high school students in Concord, NH	1) 64% reduction in retail alcohol sales to underage youths; and 2) statistically significant declines in proportion of Concord students who reported current alcohol use (from 49.8% in 2001 to 39.9% in 2003; RR = 0.8; 95% CI = 0.7–0.9) and binge drinking (from 32.0% in 2001 to 25.0% in 2003; RR = 0.8; 95% CI = 0.7–0.9).
Erickson et al. (2013)	USA	Secondary analysis of a 4-year, quasi-experimental, community trial with both a time-series component and a cohort component	959 compliance checks at alcohol establishments in intervention communities, over a 2-year period, ranging from 0 to 6 per establishment, with a mean of 2.1.	Sale of alcohol to a pseudo-underage buyer without the need for age identification.	Compliance checks reduced odds of sales to a young-looking patron without age identification by more than 60% in the month following the check. Effects decayed quickly over time, although there was still a significant effect for up to 90 days for establishments in lower density areas. Among all establishments, having a close neighbor (within 125 m) checked in the past 90 days reduced the odds of sales by more than 30%. This reduction is in addition to or on top of the direct effect of an establishment itself being checked.

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Flewelling et al. (2013)	USA	Randomized community trial	Compliance checks once per year for 2 years in each off-premise alcohol establishment in intervention communities. Dosage of project-related enforcement activities other than compliance checks varied across the intervention communities, including: 1) total number of citations and warnings issued for underage drinking-related violations by the local police department over the two-year intervention period ; 2) number of person- hours worked by local police officers in conducting these activities.	4 primary outcome measures were identified. Three of these were derived from the student survey data and include self-reported use of any alcohol in the past 30 days and self-reported drinking five or more drinks on one occasion in the past 30 days (i.e., "binge" drinking). The third was a general measure of perceived availability of alcohol, which was defined as whether students reported that alcohol was "very easy" to get. The fourth primary outcome measure was a direct measure of retail availability, based on whether alcohol was successfully purchased in each of the underage alcohol purchase attempts conducted for the retail alcohol purchase survey.	Combined intervention effects showed statistically significant reduction in alcohol sales to persons under 21 ( $p<0.01$ ), but not in past 30-day use of alcohol or binge drinking among underage persons, in intervention communities compared to comparison communities. However, post-hoc analysis showed statistically significant ( $p<0.01$ ) effects by high levels of citations, on reductions in self-reported past 30-day use (-0.0017; C.I. -0.0025, -0.0009) and binge drinking (-0.0018; C.I. -0.0028, -0.0008). Similarly, significant effects found by high levels of person hours engaged in enforcing underage drinking laws on self-reported past 30-day use (-0.0011; C.I. -0.0021, -0.0001; $p<0.05$ ) and binge drinking (-0.0018; C.I. -0.0030, -0.0006; $p<0.01$ ).

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Schelleman-Offermans et al. (2012)	The Netherlands	Longitudinal quasi-experimental	1) Number of inspections per "hotspot" establishment within the 2-year intervention period in the intervention community compared to the comparison community [248 inspections (approximately 9 inspections per hotspot; 4–5 times yearly) versus 0]. 2) Number of establishments fined twice by the regulation authority per year of the intervention ["Two-strikes-out" policy was implemented, such that if a retailer was fined by the FCPSA twice per annum, the local authority would start proceedings to withdraw the retailer's liquor license]. 3) All establishments (except supermarkets, which are exempted) received information about the policy.	Based on survey responses from 688 adolescents in the intervention and 639 adolescents in the comparison community re: 1) Initiation of weekly alcohol consumption; 2) Initiation of drunkenness among weekly adolescent drinkers; 3) Frequency of alcohol purchases from commercialized resources (on and off premises) in the past month; 4) Perceived ease of purchasing alcohol (response options ranged from 1=very difficult to 5=very easy).	Adolescents in intervention community had a .12 significant increased hazard to start weekly drinking compared with adolescents in the comparison community. Adolescents in intervention community were at reduced risk (hazard ratio = .81) to initiate drunkenness when already drinking compared with adolescents in the comparison community. No significant mediation effects found for adolescents' perceived ease of purchasing alcohol or frequencies of alcohol purchases.
Scribner and Cohen (2001)	USA	Quasi-experimental	3 compliance checks over 12 months.	Compliance by alcohol retailers with the minimum legal alcohol sales age law.	Among those that did not receive a citation, 17/98 (17.3%) were compliant, which does not represent a significant difference between Time 0 and Time 2. Among those that did receive a citation, 13/45 (28.9%) were compliant, a significant difference between Time 0 and Time 2. Over the 8-month period between



Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
					Time 1 and Time 2, rate of compliance deteriorated from 40% - 21% overall, indicating short-lived deterrent effect of enforcement on compliance.
Wagenaar et al (2005)	USA	Multiple time-series quasi-experimental community trial, with a cohort design nested within the time-series quasi-experiment.	Enforcement - Number of underage sales compliance checks conducted by law enforcement agencies (each intervention community decided the number conducted each year but were encouraged to conduct at least two rounds of checks at all establishments each year). Visibility - 2 measures each of alcohol-related print/broadcast media coverage: number of articles/stories with alcohol enforcement checks as main theme, and number of articles on alcohol in general.	Establishment-level effects: propensity of each of 942 alcohol retail establishments (602 on-premise, 340 off-premise) to sell alcohol to underage youths, measured using pseudo-underage purchase attempts conducted repeatedly over a 4-year period. Community-level effects: effects of each intervention on the aggregate of all alcohol establishments in a community, not just the subset of individual establishments directly experiencing enforcement.	Establishments effects, off-premise: 17% decrease in likelihood of selling alcohol to youth immediately following law enforcement check, decaying to 11% decrease in likelihood of selling at 2 weeks, and to 3% decrease at 2 months, with eventual decay to 0, no residual long-term permanent effect. Increase in TV broadcasts regarding enforcement checks conducted in community was significant: it initially decreased likelihood of underage sales approximately 5%, with effect decreasing to 0 within 2 weeks after check. Establishment effects, on-premise: 17% decrease in likelihood of selling immediately following enforcement check, decaying to 14% decrease at 2 weeks, and 10% decrease at 2 months. Long term decrease in likelihood was 8.2%. Increase in general

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
					<p>alcohol broadcast media was only marginally significant, with a 0.4% decrease in sales following each broadcast.</p> <p>Community level effects: no observed community-level general deterrent effects in either on-premise or off-premise establishments (no diffusion of effects).</p>

Table 1.8. Summary of study characteristics and findings: dosage of interventions to reduce intoxication/excessive drinking

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
McKnight and Streff (1994)	USA	Quasi-experimental	1) Enforcement: approx. 10 personnel hours of SIP enforcement per week over one year by each of two participating enforcement agencies, compared to almost zero enforcement before intervention; and 2) Visibility: enforcement presentation to 105 alcohol establishments; after-visit report to establishments who were visited by officers but not cited; and media coverage of enforcement efforts and effects on establishments. Visibility focused on those that would be a part of enforcement effort; not intended to form special information program.	1) Number of establishments named as source of the last drink consumed by DWIs prior to their arrest; and 2) % of refusals to pseudopatrons.	Statistically significant increases in refusals of service to pseudo-patrons: from 17.5% before intervention to 54.3% after first 3 months. After 3 months, it dropped to 47.4%, and after 1 year to 41.0%. Statistically significant decrease in DWI drivers coming from alcohol establishments in intervention county, from 31.7% - 23.3%.
Ramirez et al. (2008)	USA	Quasi-experimental pre-post evaluation design	Number of unannounced premise checks, with 102 conducted during the intensive enforcement phase (6 mos.), and 23 conducted during the regular enforcement phase (3 subsequent mos.).	1) retailer willingness to sell alcohol to apparently intoxicated people, 2) blood alcohol concentration (BAC) levels of drivers arrested for DUI, and 3) DUI arrestees naming establishments exposed to the program as their place of last drink.	1) Sales rates for intervention sites increased from 50 percent to 88.9 percent, while sales rates for comparison sites decreased slightly from 80 percent to 77.9 percent. (Due to small sample size, tests of statistical significance were not included in this portion of results analysis). 2) Average number of DUI arrests in which intervention establishments were identified as place of last drink, decreased 36 % between 3-month period before intensive enforcement period and 3 months following, while average number of DUI arrests naming comparison establishments

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
					<p>decrease was 7%. Neither decrease was statistically significant.</p> <p>3) Statistically significant decrease in average BAC for people arrested for DUI in 3 mo. period before intensive enforcement began and 3 mos. after in the intervention communities from .135 g/dL (n = 105) to .127 g/dL (n = 19), while average BAC for arrestees increased from .135 (n = 67) to .149 (n = 16) for comparison sites (increase not statistically significant).</p>

Study	Country	Study Design	Dosage Measures	Outcome Measures	Outcomes
Saltz et al. (2010)	USA	Randomized community trial	<p>Objective was to implement any combination of 9 enforcement activities within the first 8–10 weeks of school. [In Year 1, range of DUI enforcement operations was 0-3 with a mean of 1.4; range of compliance checks was 0-5 and 2.4; range of party patrols was 0 -10 and 3.7. In Year 2, range of 0-3 DUI enforcement operations with a mean of 2; range of compliance checks was 0-5 and 2.1; and range of party patrols was 0-28 and 9.3.]</p> <p>Visibility: average number of campus news items for the 2 intervention years was 7.5 and 7.2, and dedicated websites grew from 3 to 5 campuses over the 2 years.</p>	<p>1) Proportion of drinking occasions in which students drank to intoxication at six different settings during the fall semester (residence hall party, campus event, fraternity or sorority party, party at off-campus apartment or house, bar/restaurant, outdoor setting); 2) any intoxication at each setting during the semester; and 3) whether students drank to intoxication the last time they went to each setting.</p>	<p>Relative reductions in risk of intoxication the last time at each setting: 9% for an off-campus party, 15% for a bar/restaurant, 6% for any setting. Approximately 900 fewer students per university drank to intoxication at off-campus parties and 600 fewer students per university drank to intoxication at bars/restaurants during the fall semester at intervention schools relative to comparison schools. Highest levels of enforcement were associated with reductions in problems like intoxication levels in college students: approximately 6000 fewer incidents of intoxication per university at off-campus parties and 4000 fewer incidents of intoxication per university at bars/restaurants during fall semester at intervention schools relative to comparison schools. At lowest level, (no enforcement) no difference from comparison sites.</p>

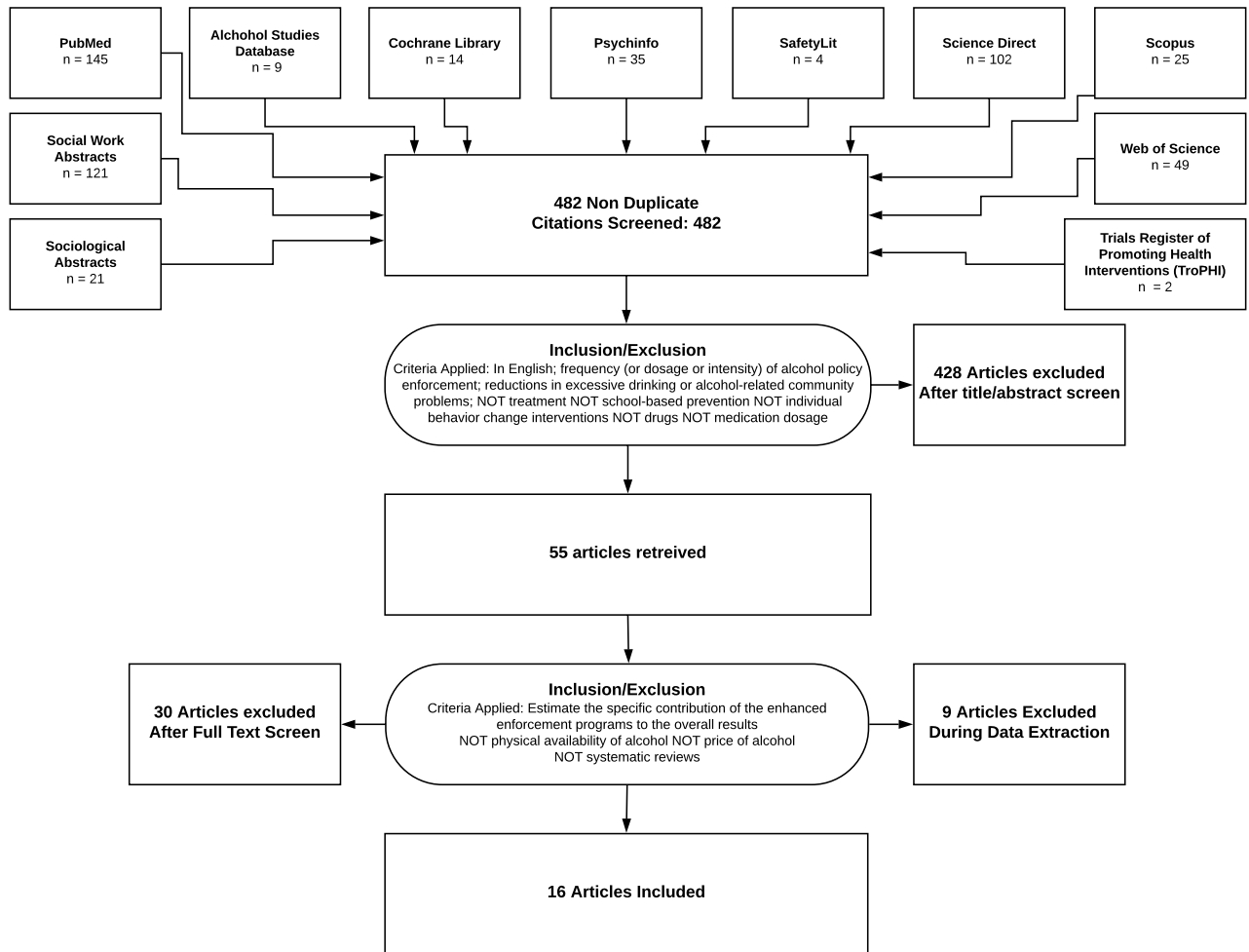


Figure 2.1: Flowchart of study selection process

PAPER 2  
Do Certain Community Characteristics Predict Dosage of  
Alcohol Policy Enforcement Interventions?

**Abstract**

**Background.** Highly visible policy enforcement has been found to be effective in reducing alcohol-related community problems, but is often underutilized. However, few studies have explored what community characteristics predict the level of dosage of such enforcement.

**Objective.** This study investigated the association between dosage of alcohol enforcement and accompanying publicity and level of alcohol problems at baseline, interagency collaboration and additional grant funding from two state agencies, in 12 California cities.

**Design.** Secondary analysis of data collected from intervention cities of the California Strategic Prevention Framework State Incentive Grant (SPF SIG) project, a randomized community trial.

**Sample.** 24 matched California cities were randomly assigned to intervention or treatment condition. Dosage data was collected through a monthly reporting system for the 12 intervention cities from April 2013 to March 2016.

**Main outcome measures.** Dosage of quarterly enforcement and related publicity targeting: retail alcohol availability, social availability, and driving under the influence (DUI) in 12 SPF SIG intervention cities.

**Methods.** Multilevel modeling was used to estimate the effects of baseline levels of alcohol problems, collaboration, and funding on intervention dosage data collected from the 12 cities at 12 quarterly time points.

**Results.** Funding from the California Office of Traffic Safety (OTS) was significantly associated with a greater frequency of DUI enforcement and publicity ( $p < 0.05$ ). Better interagency collaboration was associated with a greater frequency of enforcement and publicity to reduce retail alcohol availability to underage persons ( $p < 0.05$ ). None of the three community characteristics was significantly associated with a greater number of interventions to reduce social availability. A higher level of alcohol problems at baseline was not found to be significantly associated with a greater number of any of the interventions.

**Conclusions.** Funding may lead to more enforcement and publicity to reduce DUI crashes, injury and mortality. Interagency collaboration may lead to more enforcement and visibility to reduce retail availability of alcohol to underage persons. Future research with a larger sample of cities can help elucidate how these and other community factors may influence implementation of high visibility alcohol enforcement interventions.

## 1. Introduction

Excessive alcohol consumption is associated with a high disease burden worldwide, and is the third leading cause of preventable death in the United States.<sup>1</sup> As defined by the Centers for Disease Control and Prevention (CDC), excessive alcohol consumption includes binge drinking ( $\geq 4$  drinks per 2-3 hours for women;  $\geq 5$  drinks per 2-3 hours for men); heavy drinking ( $> 8$  drinks per week for women; and  $\geq 15$  drinks per week for men); and any alcohol consumption by persons under 21 years of age or by pregnant women. Costs due to excessive alcohol use include those associated with health care, lost productivity, motor vehicle crashes, crime and violence, and are borne by federal, state and local governments, communities and individuals. The cost due to excessive drinking by youth and adults in 2010 was an estimated \$249.0 billion in the U.S.,<sup>2</sup> and \$35.0 billion in California alone.<sup>3</sup>

Higher alcohol availability in communities has been associated with higher rates of alcohol consumption and related harm.<sup>5</sup> Policy interventions that address alcohol availability, when enforced, have been shown to be effective in reducing alcohol consumption and related harm at the community, or population level.<sup>5,6,8,11,16-18,35,38,39,41,44,74-78</sup> The effectiveness of policy enforcement interventions<sup>44-52,79</sup> is enhanced when they are combined with publicity that makes the enforcement highly visible to the public.<sup>14,22,23,46,54-56</sup> Publicity may include radio or television announcements, billboards or press releases that inform the public or intended audience that enforcement is occurring.

Various studies emphasize the importance of high “dosage” of enforcement to achieve reductions in excessive and underage drinking, and alcohol-related community problems. One way that the dosage of a policy enforcement intervention has been defined is the amount and frequency of the implementation of the intervention.<sup>26,80</sup> Increasing the frequency of evidence-based interventions is expected to be associated with improved population health or with greater reductions in health-related problems on a population level.<sup>33</sup>

A review of the literature reveals that it is not clear what leads communities to implement a higher dosage of alcohol policy enforcement interventions. However, there are some clues in the implementation science literature that can help with forming hypotheses about whether certain community characteristics may predict better implementation. In one review of implementation research, funding, perceived need for the intervention, and coordination between agencies were found to be among the factors that positively affect the implementation process.<sup>30</sup> Another review concluded that necessary conditions for implementation to be successful were: community readiness, which included recognition that problems exist; the development of effective community partnerships; solutions that fit the problems; fidelity to the interventions; and adequate resources.<sup>31</sup>

Studies have indicated that community activism that calls for implementation and enforcement of alcohol policies is driven by a recognition of the connection between excessive alcohol use and alcohol availability in neighborhood disruption, violence and



crime.<sup>81-83</sup> Further, trends in effective law enforcement methods over the past 30 years focus less on reacting to individual incidents of crime and more on analyzing and proactively responding to identified problems and their underlying causes. Such problem-oriented policing is intended to be highly localized, incorporating criminal law, but also municipal and civil statutes and local resources to focus on specific problems.<sup>84,85</sup>

Interagency collaboration has long been considered an essential part of solving multifaceted problems in fields as varied as business, social work, and healthcare. Interorganizational Relations Theory (IOR) emerged in the 1960's to address the need for collaboration between businesses in order to respond to an uncertain and volatile environment. The basis of IOR is that by collaborating, organizations can problem-solve in more coordinated and innovative ways than an organization can do by itself.<sup>86</sup> Interagency collaboration has been called "imperative"<sup>87</sup> for solving complex community issues, especially if the partnerships are diverse, allowing for comprehensive and reinforcing strategies that build organizational and community capacity.<sup>88</sup> By working collaboratively, organizations "achieve higher levels of performance in complex, uncertain, and fragmented policy contexts."<sup>89</sup>

Finally, Resource Mobilization (RM) theory posits that awareness and frustration with the level of problems are precursors, but not necessarily sufficient ones to spur community action. According to RM, this may only occur when resources become available to address the problems.<sup>83</sup> Indeed, funding has been used as a surrogate measure of alcohol policy enforcement in previous studies.<sup>37,44</sup> Moreover, an analysis of anti-crime partnerships theorizes that the availability of resources from multiple agencies likely increases the dosage of interventions.<sup>32</sup>

The current study focused on high-visibility policy enforcement interventions intended to reduce alcohol availability from retail sources, like bars and stores and social sources like parties, and reduce driving under the influence (DUI). The objective was to investigate whether three community characteristics predicted dosage of alcohol enforcement interventions and accompanying publicity: level of alcohol problems at baseline, interagency collaboration and funding. It was hypothesized that results would indicate that: acknowledgement of a high number of alcohol-related community problems results in more effort to address them; better interagency collaboration is predictive of a higher dosage of interventions to reduce alcohol-related community problems; and additional dollars from two California state agencies for enhanced enforcement was associated with higher dosage of interventions for cities who received such funding.

This study is multilevel and longitudinal, with the 12 SPF SIG intervention cities as the level 2 clusters and 12 repeated observations over time as the level 1 units. Covariates that have been shown to be linked with community alcohol problems, and are therefore controlled for, are total population size, socioeconomic status (SES), and percent minority population. More alcohol-related problems are likely to occur in communities with larger populations, and those cities are likely to have higher levels of enforcement

because of the higher tax base. Persons with lower SES have been found to bear a disproportionate burden of the consequences of alcohol consumption.<sup>90</sup> Research has also indicated that fatal consequences of excessive alcohol consumption are higher for blacks and Hispanics than for whites, and that Native Americans are at higher risk of many alcohol-related injury deaths than individuals of other racial/ethnic groups.<sup>91</sup>

The research question for this study was: Do 1) community alcohol problems, 2) agency collaboration and 3) funding predict frequency of alcohol enforcement and visibility activities in the 12 intervention cities of the California Strategic Prevention Framework State Incentive Grant (SPF SIG) Project over 12 time points, controlling for socioeconomic status, population size and percent minority population? The specific aim of this question was to explore whether these three community variables predicted the frequency of interventions in the study cities of the California SPF SIG project. The California SPF SIG Project was a randomized community trial with 12 intervention cities and 12 comparison cities whose goal was to reduce excessive drinking among 12-25 year olds, and related community problems. This study focused on the intervention communities only. Government agencies, including police and public health, and community-based organizations received SPF SIG funding to deliver two coordinated interventions: 1) alcohol policy enforcement operations, and 2) publicity to raise the visibility of the enforcement. Cities were instructed to conduct specific types of interventions twice per quarter over 3 years.

## **2. Methods**

### ***Sample***

This study is a secondary quantitative analysis of a dataset from a randomized community intervention trial called the California Strategic Prevention Framework State Incentive Grant (SPF SIG). SPF SIG was conducted by the Prevention Research Center (PRC) in 2013 - 2016 to reduce excessive alcohol consumption and related problems among youth and young adults aged 12-25. The study was funded by the National Institute on Alcohol Abuse and Alcoholism.

Twelve intervention cities and twelve comparison cities were chosen from a list of 50 California cities distributed throughout the state with populations between 50,000 and 500,000. Demographic, survey, and archival records for the 50 communities were consolidated to determine which would be candidates for selection based on need, with the prevalence of alcohol-related problems in the upper-half of the sample. Twelve pairs of cities were created from the original set in order to use an experimental design for the evaluation. Cities were paired via a combination of demographic characteristics (population size; ethnic composition) and the alcohol problem indicators, such as high rates of excessive drinking, DUI crashes, and injuries. The final set of intervention communities was determined via random selection of one from each pair, leaving the other city to become a comparison community. This study will involve the 12 intervention communities only: Antioch, Folsom, Huntington Beach, Livermore, Merced, Redlands, San Rafael, Santa Barbara, Santa Monica, Santa Rosa, Ventura and Walnut Creek. In each city, interventions were conducted by the local law enforcement agency,

which collaborated with a local prevention agency to plan and conduct visibility activities.

### **Data Collection**

*Alcohol enforcement and visibility activities.* Local enforcement and public health agencies in intervention cities were required to submit monthly activity reports for the SPF SIG project. These reports documented the dates and types of enforcement activities such as: driving under the influence (DUI) sobriety checkpoints or patrols, minor decoy operations to check for alcohol sales to persons under 21, and party patrols. The reports included activities conducted to make these enforcement operations highly visible to the public, such as billboards, social and traditional media reports indicating that enforcement is occurring.

*Community alcohol problems.* Outcomes of interest included alcohol-related motor vehicle crashes and violent assaults. These outcomes were measured at the city level, and 2012 baseline levels were used in the current study. Alcohol-related motor vehicle crash data were obtained from the California Highway Patrol Statewide Integrated Traffic Reporting System (SWITRS). Violent assault data were obtained through local police incident reports and California Monthly Arrest and Citation Register.

*Underage drinking.* Annual prevalence rates of past-30-day alcohol use and heavy drinking (5+ consecutive drinks) were obtained for school districts in the cities using data from the California Healthy Kids Survey (CHKS) from 2012 through 2016 (i.e., 5 observations per city for each outcome). The CHKS is a statewide self-administered survey for 5<sup>th</sup>, 7<sup>th</sup>, 9<sup>th</sup> and 11<sup>th</sup> graders with supervision by teachers who have received instructions from the California Department of Education (CDE). Passive or active parental consent is required. CHKS response rates are typically greater than 60%. De-identified student-level data was obtained from CDE for multi-level analyses.

*Alcohol use and heavy drinking.* Telephone interviews were conducted by a subcontractor with a panel of 2,400 18 to 30-year-olds (100 per city) in 2012 and early 2013. The interview questions included measures of past-year and past-28-day alcohol use, heavy drinking, alcohol-related problems, drinking locations, sources of alcohol, alcohol expectancies, and demographic characteristics.

### **Hypotheses**

*Hypothesis 1:* Cities with a higher number of alcohol problems at baseline will have a greater frequency of enforcement and visibility than cities with a lower level of alcohol problems at baseline.

*Hypothesis 2:* Cities with better multi-agency collaboration will have a greater frequency of enforcement and visibility than cities with a lower level of collaboration.

*Hypothesis 3:* Cities with additional funding from the California Department of Alcoholic Beverage Control (CA-ABC) and/or the California Office of Traffic Safety (CA-OTS) will

have a greater frequency of enforcement and visibility than cities without additional funding.

### **Measures**

*Dosage of interventions.* The total number of enforcement and visibility activities conducted by each of the twelve intervention communities in each of the twelve quarters from April 2013 - March 2016. These data were collected from the twelve cities through monthly activity reports, as described in *Alcohol enforcement and visibility activities*. Types of interventions included in the measure included the following:

#### Interventions to reduce retail availability of alcohol

- Minor decoy operation - checking compliance with laws disallowing sales to minors at alcohol licensed establishments / or
- Recognition and reminder - checking compliance with laws disallowing sales to minors at alcohol licensed establishments;
- Responsible Beverage Service Enforcement (RBSE) – checking compliance with laws disallowing sales to obviously intoxicated patrons at alcohol licensed establishments;
- Responsible Beverage Service Training (RBST) – training for employees of licensed alcohol establishments about how to identify and refuse service to persons under the age of 21 and persons who are obviously intoxicated;
- Visibility / publicity activities for each of the operations above.

#### Interventions to reduce social availability of alcohol

- Nuisance party patrols – dedicated enforcement patrols for parties that create a public nuisance, or
- Social Host Ordinance (SHO) enforcement – fines for hosting a gathering where underage drinking occurs;
- Visibility / publicity activities for each of the operations above.

#### Interventions to reduce driving under the influence (DUI)

- Roadside driving under the influence (DUI) checkpoints
- DUI saturation patrols - dedicated enforcement patrols for DUI
- Visibility / publicity activities for each of the operations above

First, for each type of intervention, any activity in a month counted as a “1”. Then, totaling the number of interventions and visibility activities conducted each quarter in each of the communities by intervention type yielded the outcome variables, dosage of: retail availability of alcohol (rados), social availability of alcohol (sados), and DUI (dddos).

*Community collaboration.* Two level 2 continuous predictor variables were computed as mean scores across raters and items of the responses to 2 three-item subscales of questions developed from a survey given at the end of the SPF SIG project.

Forty-three project participants completed the survey. Although the number of respondents varied by city, at least one survey was returned from each of the 12 intervention cities. The number of respondents per city ranged from one to seven. The average number of respondents per city was 3.7. One respondent, from a county organization, included information about two cities within the county. The greatest number of respondents were county staff or administrators (13), followed closely by municipal or county law enforcement (12) and prevention or social service agency staff (11). Five people identified as being from another non-profit organization and 1 as a local education agency nurse. Most respondents worked on the SPF SIG project more than 2 years (70%), while almost one-third were with the project between 1 and 2 years. Only one person worked on the project one year or less. Response choices, on a Likert-type scale, were: 1) strongly agree; 2) agree; 3) disagree; and 4) strongly disagree

Exploratory factor analysis (EFA) was conducted to determine whether survey items represented one or more underlying factors. A two-factor solution resulted from EFA (3 survey items each) with orthogonal rotation.

The first collaboration subscale came from these questions:

1. We were able to coordinate enforcement operations with "visibility" activities
2. By the end of SPF SIG, collaboration was working smoothly
3. Most of those early difficulties were solved or reduced by the end of SPF SIG

These three questions were reverse coded so that a higher score represents better collaboration. The average interitem Pearson's correlation for these three items is 0.55 ( $p < 0.01$ ). The scale reliability coefficient is a Cronbach's alpha of 0.78. Since Cronbach's alpha  $> 0.7$ , it was decided that the variable (collab1) would be represented by the mean score of these 3 items across the participants from each city.

The second collaboration subscale came from these questions:

1. At the start, collaboration between law enforcement agencies and prevention agencies was challenging
2. Organizational cultural differences posed difficulties for us
3. It was difficult to bring everyone together for planning or coordination

The average interitem Pearson's correlation for these three items is 0.523 ( $p < 0.01$ ). The scale reliability coefficient is Cronbach's alpha: 0.74. Since Cronbach's alpha  $> 0.7$ , it was decided that the variable (collab2) would be represented by the mean score of these 3 items across the participants from each city.

*Alcohol-related problems.* A level 2 continuous predictor variable based on measures from the original California SPF SIG research was based on a total number of alcohol-related crashes per 1,000 population, number of arrests for assaults per 1,000 population, prevalence of past 30-day binge drinking by adolescents, and past 30-day binge drinking for young adults at baseline in 2012, for each city. This variable was created by standardizing each of these to create z scores, then computing the mean of these z scores to create a single variable.

*Funding.* Three level 1 dichotomous predictor variables indicated whether a community received grant(s) from the California Department of Alcoholic Beverage Control (CA-ABC) or Office of Traffic Safety (CA-OTS) to conduct specific interventions during the time of the SPF SIG project. This was in addition to the SPF SIG funding that all 12 intervention communities received. CA-ABC provides funding to local law enforcement agencies for minor decoy operations and enforcement of responsible beverage service, including sales to intoxicated patrons. CA-OTS provides funding for roadside checkpoints and saturation patrols to reduce and prevent driving under the influence. Another grant is jointly given by the OTS and the ABC to form partnerships to reduce retail availability of alcohol. These were constructed as separate dichotomous variables to represent funds through: grants from the ABC (abc: 1 = city received funds from the ABC, 0 = city did not receive funds from the ABC); from the OTS (ots: 1 = city received funds from the OTS, 0 = city did not receive funds from the OTS); or from a joint grant (abcots: 1 = city received funds from the ABC-OTS partnership grant, 0 = city did not receive funds from the ABC-OTS partnership grant). The grants described in this section do not provide funds for social availability interventions, and are therefore not included in the models for social availability intervention dosage.

*Socioeconomic status.* Socio-economic status (SES) was determined for the twenty-four study cities at baseline in 2012 for the SPF SIG study, and includes four socioeconomic characteristics: level of poverty, level of unemployment, percent of population with a college education, and median household income. A standardized SES factor score was created for each city with these four variables. This covariate was held constant in the models for both outcomes.

*Population size.* Population size represented the total population (in units of 10,000) of each study city at baseline in 2012. This covariate was held constant in the models for both outcomes.

*Minority population.* Minority population represented the percentage of minority residents in each city at baseline in 2012. This covariate was held constant in the models for both outcomes.

*Time.* Time represented the periods in which the dosage observations were collected. There were 12 time points for each cluster/city, corresponding to the annual quarters from April 2013 – March 2016.

### **Data Analysis**

Data analysis began with summary descriptive statistics to examine characteristics of the main predictor and outcome variables, including mean, standard deviation, minimum and maximum data points, and skewness of the data. Further, graphs will be presented that show the distribution of the 3 outcome variables and the trajectories of these outcomes over time. Bivariate analysis was conducted using Pearson correlation to observe the relationships between the outcome variables and the predictor variables.

Next, multi-level modeling analyses were conducted using hierarchical linear modeling (HLM) in Stata v.15<sup>92</sup> with restricted estimated maximum likelihood (reml) and unstructured covariance to test study hypotheses by examining the association between predictor variables and the 3 outcomes. HLM allows for modeling fixed and random effects, and adjusts for nesting of repeated observations within cities over time. A random intercepts model was used for all outcomes, with unstructured covariance and restricted maximum likelihood estimates.<sup>93</sup> To retain sufficient power in the models, hypotheses were modeled separately for the association between each predictor and each outcome. Residual diagnostic post-analyses were conducted to check assumptions of normality of the residuals from regression models.

### *Models*

Twelve models were built to test the three hypotheses. All the models were random intercept models that took into account linear and nonlinear changes over time, and included the following:

- $\beta_1$  - mean intercept for all cities, mean dosage of interventions of each type for all cities
- $\beta_2$  - slope of time for all cities
- $\zeta_{1j}$  - random intercept for city  $j$ , the deviation of city  $j$ 's intercept from the mean intercept  $\beta_1$
- $\zeta_j \sim N(0, \psi)$
- $\theta$  - the variance of the level 1 residual  $e_{ij}$

The models will be estimated using the mixed command in Stata, with restricted maximum likelihood estimates. Because of the limited degrees of freedom due to the small number of clusters, it was decided to use an exchangeable covariance structure and not to include random slopes in the models. In addition, the small number of degrees of freedom limited the number of covariates that could be included in each model, which meant that separate models had to be run for each predictor.

### Interventions to reduce retail availability of alcohol

Model 1 estimated the effect of funding from the CA-ABC (abc) on the dosage of interventions to reduce retail alcohol availability (rados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min). abc is a time-varying level 1 variable.

$$y(\text{rados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{abc}_{ij} + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 2 estimated the effect of joint funding from the CA-ABC and CA-OTS (abcots) on the dosage of interventions to reduce retail alcohol availability (rados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min). abcots is a time-varying level 1 variable.

$$y(\text{rados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{abcots}_{ij} + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 3 estimated the effect of interagency collaboration based on the first subscale (collab1) on the dosage of interventions to reduce retail alcohol availability (rados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(\text{rados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab1}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 4 estimated the effect of interagency collaboration based on the second subscale (collab2) on the dosage of interventions to reduce retail alcohol availability (rados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(\text{rados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab2}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 5 estimated the effect of alcohol-related problems at baseline (alcprob) on the dosage of interventions to reduce retail alcohol availability (rados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(\text{rados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{alcprob}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

#### Interventions to reduce social availability of alcohol

Model 6 estimated the effect of interagency collaboration based on the first subscale (collab1) on the dosage of interventions to reduce social availability (sados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(\text{sados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab1}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 7 estimated the effect of interagency collaboration based on the second subscale (collab2) on the dosage of interventions to reduce social availability (sados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).:

$$y(\text{sados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab2}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 8 estimated the effect of alcohol-related problems at baseline (alcprob) on the dosage of interventions to reduce social availability (sados), controlling for covariates socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(\text{sados})_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{alcprob}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$



## Interventions to reduce driving under the influence (DUI)

Model 9 estimated the effect of funding form CA-OTS (ots) on the dosage of interventions to reduce drinking and driving (dddos), controlling for socioeconomic status (ses), total population (pop) and percent nonwhite population (min). ots was a time-varying level1 variable:

$$y(dddos)_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{OTS}_{ij} + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 10 estimated the effect of interagency collaboration based on the first subscale (collab1) on the dosage of interventions to reduce drinking and driving (dddos), controlling for socioeconomic status (ses), total population (pop) and percent nonwhite population (min):

$$y(dddos)_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab1}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 11 estimated the effect of interagency collaboration based on the second subscale (collab2) on the dosage of interventions to reduce drinking and driving (dddos), controlling for socioeconomic status (ses), total population (pop) and percent nonwhite population (min):

$$y(dddos)_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{collab2}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

Model 12 estimated the effect of alcohol-related problems at baseline (alcprob) on the dosage of interventions to reduce drinking and driving (dddos), controlling for socioeconomic status (ses), total population (pop) and percent nonwhite population (min).

$$y(dddos)_{ij} = \beta_1 + \beta_2 \text{time}_{ij} + \beta_3 \text{time}_{ij}^2 + \beta_4 \text{alcprob}_j + \beta_5 \text{ses}_j + \beta_6 \text{pop}_j + \beta_7 \text{min}_j + \zeta_{1j} + e_{ij}$$

### **3. Results**

#### ***Sample characteristics***

The number of clusters was 12 (cities), with 12 units per cluster corresponding to 12 time points (quarters). The units did not vary by cluster because all cities were observed at each quarter from April 2013 - March 2016. The minimum, maximum and mean number of units was 12 for each cluster. There were no missing data. Descriptive statistics are presented in Table 2.1. The mean number of interventions to reduce retail alcohol availability was 2.96 per quarter, with a minimum of 0 and a maximum of 10 interventions, compared to the mean number of interventions to reduce social alcohol availability (1.56) and for drinking and driving (4.76).

Pearson correlations for outcome variables, predictor variables and covariates (see Table 2.2) show that social availability interventions, retail availability interventions and DUI interventions are positively correlated ( $p < .05$ ). Cities that conducted social

availability interventions, for example, were more likely to also conduct retail availability and DUI interventions. The two variables representing collaboration (collab1 and collab2) are positively correlated. Because collab1 was reverse-coded, both variables are coded in the same direction, with a higher score indicating more positive collaboration for each variable. Collaboration (both collab1 and collab2) is also positively correlated with retail availability interventions ( $p < 0.05$ ), while worse collaboration appears to be negatively correlated with DUI interventions ( $p < 0.05$ ).

Figure 2.1 displays the retail alcohol availability intervention dosage across the 12 quarters by city. Figure 2.2 displays social alcohol availability intervention dosage across the 12 quarters by city. Figure 2.3 displays DUI intervention dosage across the 12 quarters by city. Figures 2.1-2.3 show non-linear trends in intervention dosage over time, and considerable variation in intervention dosage across the 12 cities.

### ***Multilevel analysis***

Results of multilevel analyses are presented in Tables 2.3-2.5. Each model was analyzed using the Stata mixed command with restricted estimated maximum likelihoods (reml). The random intercept indicates the between city variation in each model since observations within each city are not independent of each other. The residuals represent variance that is not explained by the regression models.

Table 2.3 presents the results of the models related to the retail availability intervention outcome. Models 1 and 2 estimated the relationships of funding from the California Department of Alcoholic Beverage Control (CA-ABC) or joint funding from the CA-ABC and the California Office of Traffic Safety (CA-OTS) on the dosage of retail availability interventions, controlling for population size, percent minority population and socioeconomic status. Model 1 indicates that CA-ABC funding did not have a significant effect on the retail intervention dosage. There was significant variation in the intervention dosage level over time, as indicated by the significant coefficients for time ( $p < 0.01$ ) and time squared ( $p < 0.01$ ). Model 2 shows that joint funding from the CA-ABC and CA-OTS also did not have a significant effect on retail availability interventions.

Models 3 and 4 estimated the effects of multi-agency collaboration on the retail intervention outcome, controlling for population size, percent minority population and socioeconomic status. While the first subscale measure of collaboration (collab1) did not have a significant effect on the outcome, the second subscale (collab2) did. It is estimated that each unit increase in the score of the second collaboration measure is associated with a mean of 2.47 additional retail availability interventions ( $p < 0.05$ ), controlling for population size, percent minority population and socioeconomic status. Both time and time squared again had significant effects on the outcome ( $p < 0.01$ ). The level of alcohol related problems at baseline does not appear to have a significant effect on the outcome, according to Model 5. The effect of time and time squared on the outcome remains significant in Models 3-5 ( $p < 0.01$ ). None of the other city characteristics were significantly associated with retail intervention dosage.

Table 2.4 displays the results of the models estimating the effects of collaboration and level of alcohol problems at baseline on the social availability intervention outcome controlling for population size, percent minority population and socioeconomic status. The effect of funding is not explored here because the grants from CA-ABC and CA-OTS are not intended for social availability interventions. Neither measure of collaboration has a significant effect on the outcome, nor does the level of alcohol-related problems at baseline. These models also found a significant effect of time and time squared on the outcome.

Table 2.5 includes the models for the DUI intervention outcome, controlling for population size, percent minority population and socioeconomic status. As shown in Model 9, funding from the California Office of Traffic Safety (CA-OTS) significantly affects this outcome ( $p < 0.05$ ). For every quarter when OTS funding was received, an estimated mean of 1.44 additional DUI interventions occurred. Population size is also significantly associated with a higher dosage of DUI interventions ( $p < 0.01$ ) in Model 9, as are time ( $p < 0.01$ ) and time squared ( $p < 0.01$ ). For each additional 10,000 in population, there were an estimated .43 additional interventions. Models 10 and 11 found that neither measure of collaboration has a significant effect on the outcome, nor does the level of alcohol-related problems at baseline. These models also found a significant effect of population size ( $p < 0.05$ ) time ( $p < 0.01$ ) and time<sup>2</sup> ( $p < 0.01$ ) on the outcome.

Residual diagnostics checking the normality assumption are shown in Figures 2.4-2.27. The histograms indicate that, for most of the models, the distribution of residuals is fairly symmetric around zero, with some outliers. Skewness of some of the histograms may be due to the small number of clusters in the study (12).

#### **4. Discussion**

This study explored the effect of three community characteristics on the frequency, or dosage, of community interventions intended to reduce retail availability of alcohol, social availability of alcohol and driving under the influence (DUI). Three hypotheses were that funding, better collaboration and a higher level of alcohol problems at baseline would predict greater frequency of the community alcohol interventions.

The first hypothesis was partially supported, in that funding from the CA-OTS had a significant positive effect on the number of DUI interventions. This finding is not surprising since the OTS grant provides funding specifically for those activities, which are consistent with the requirements of the SPF SIG grant. On the other hand, the ABC and ABC-OTS funding were not significantly associated with a higher dosage of retail interventions even though both types of funding are intended to be used for interventions with licensed retail establishments. It is possible that the cities that received these grants used the funds for other activities, such as inspections of alcohol businesses or to prevent third-party purchases of alcohol for minors (“shoulder-tap”), instead of minor decoy operations or enforcement of sales to intoxicated patrons, which were included in the approved set of interventions for the SPF SIG project. Absence of

significant effect from ABC funding may be that SPF SIG dollars were available for similar intervention activities. An implication of this study is that funding may lead to more evidence-based interventions that have been shown to reduce DUI crashes and mortality.

The second hypothesis was also partially supported, as collaboration was found to have a significant positive effect on retail availability interventions. However, this association held for one, but not both collaboration measures. It is difficult to explain the exact difference between the effects of the two collaboration measures. Collaboration appeared not to be significantly associated with either social availability or DUI interventions. A limitation of this study is the measure of collaboration, which was based on a survey that was not specifically designed for this purpose. The survey was tailored to the specific project population, and is not necessarily valid for other populations. There was no independent validity assessment for the survey. Future studies may include qualitative methods like interviews to assess the level of collaboration, in addition to using a validated survey.

The current study found no support for the third hypothesis, as the level of alcohol problems at baseline appeared not to have a significant effect on any of the three outcomes. This may be due to selection bias, since the intervention cities were chosen from a list of cities with a high prevalence of alcohol-related problems at baseline. Additional studies may select cities at random to see if the level of alcohol problems at baseline influences the frequency of interventions to reduce retail or social alcohol availability or driving under the influence.

An obvious limitation of this study is the small number of clusters (cities), which did not allow for robust standard errors or maximum likelihood estimations. The small number of degrees of freedom limited the number of covariates that could be included in each model, which meant that separate models had to be run for each predictor. The study was therefore underpowered, which may explain why it was difficult to find significant effects of the predictor variables. Further research is needed with a larger sample of cities to better understand how these and other community factors may influence implementation of high visibility alcohol enforcement interventions.

## 5. Tables and Figures

Table 2.1: Descriptive statistics for outcome and main predictor variables

Variable	Mean	Std. Dev. Overall	Std. Dev. Between	Std. Dev. Within	Min	Max	Skewness
rados	2.96	2.539	1.407	2.149	0	10	0.803
sados	1.56	1.480	0.696	1.321	0	6	0.611
dddos	4.76	3.375	2.774	2.071	0	12	0.435
ots	0.35	0.478	0.344	0.345	0	1	0.642
abc	0.13	0.340	0.165	0.301	0	1	2.175
abcots	0.17	0.380	0.202	0.327	0	1	1.723
collab1	2.37	0.569	0.592	0.000	1	2.97	-1.070
collab2	1.68	0.413	0.430	0.000	1	2.39	0.092
alcprob	0.00	0.401	0.418	0.000	-0.67	0.54	-0.312
ses	0.49	0.807	0.840	0.000	-1.68	1.47	-1.375
pop10k	10.45	4.274	4.448	0	6.12	19.56	1.353
min	0.27	0.102	0.106	0.000	0.16	0.50	1.368

Table 2.2: Pearson correlation of all variables

	dddos	rados	sados	ots	abc	abcots	collab1	collab2	alcprob	time	pop10k	min	ses
dddos	1												
rados	0.1286	1											
sados	0.1245	0.2025*	0.4844*										
ots	0.0149	0	0.1965*	1									
abc	0.1351	0.0812	0.0182	0.0605	1								
abcots	0.1064	0.3333	0.4716	0.0123	-0.0162	1							
collab1	0.2906*	-0.0585	0.9588	0.4716	0.8837	0.8474	1						
collab2	0.0004	0.4864	0.9882	0.1615	0.144	0.1855*	-0.1173	1					
alcprob	-0.0377	0.0075	0.9639	0.0015	0.144	0.1855*	0.4369*	0	1				
time	0.6533	0.9285	0.1043	0.8837	0.8474	0.1244	0.0064	0.2556*	0.1204	1			
pop10k	0.1523	0.2481*	-0.1726*	-0.0012	-0.0594	0.026	-0.1173	0.002	0.1504	0	1		
min	0.0684	0.0027	0.0385	0.9882	0.4797	0.1615	0.1615	0	0.1504	0	0	1	
ses	-0.1993*	0.3024*	-0.0038	0.1465	-0.2615*	0.0064	0.4369*	1	0.1504	0	0	0	1
	0.0166	0.0002	0.9639	0.0798	0.0015	0.939	0	0.2556*	0.1204	0	0	0	0
	-0.1206	0.0661	-0.0819	0.0093	0.144	0.1855*	-0.1286	0.2556*	0.1204	0	0	0	0
	0.1498	0.4309	0.3293	0.9116	0.0851	0.026	0.1244	0.002	0.1504	0	0	0	0
	0.1534	0.2608*	0.2857*	-0.1944*	0.0089	0.3160*	0	0	0	1			
	0.0663	0.0016	0.0005	0.0196	0.9155	0.0001	1	1	1				
	0.5019*	-0.1367	-0.1517	-0.1775*	0.2512*	-0.1264	-0.0239	-0.2379*	0.1204	0	1		
	0	0.1022	0.0696	0.0333	0.0024	0.1313	0.7762	0.0041	0.1504	1			
	-0.2496*	0.0465	-0.0108	0.0992	-0.1521	0.0591	0.1238	0.4244*	0.4100*	0	-0.0527	1	
	0.0026	0.5797	0.8979	0.2368	0.0688	0.4817	0.1393	0	0	1	0.5302		
	0.0833	0.0334	0.0249	-0.2221*	0.0183	-0.2001*	-0.0137	-0.4664*	-0.6059*	0	-0.1593	-0.7376*	1
	0.321	0.6908	0.7667	0.0075	0.8274	0.0162	0.8705	0	0	1	0.0565	0	

\* p < 0.05; \*\*p < 0.01

Table 2.3: Results of retail availability intervention dosage models, regression coefficient (standard error)

Predictor	Model 1	Model 2	Model 3	Model 4	Model 5
<i>Fixed Effects</i>					
abc	-0.32 (0.53)				
abcots		-0.17 (0.51)			
collab1			1.07 (-0.77)		
collab2				2.47* (1.09)	
alcprob					0.94 (1.49)
ses	0.30 (0.88)	0.28 (0.88)	0.18 (0.85)	0.90 (0.76)	0.62 (1.04)
pop10k	-0.06 (0.11)	-0.07 (0.11)	-0.07 (0.11)	.01 (0.10)	-0.07 (0.12)
min	2.58 (6.90)	2.64 (6.85)	1.29 (6.59)	2.21 (5.58)	3.10 (7.15)
time	1.40** (0.20)	1.38** (0.20)	1.38** (0.20)	1.38** (0.20)	1.38** (0.20)
time2	-0.09** (0.02)	-0.09** (0.01)	-0.09** (0.01)	-0.09** (0.01)	-0.09** (0.01)
<i>Random Effects</i>					
Intercept	2.18 (1.24)	2.17 (1.23)	1.93 (1.19)	1.35 (0.88)	2.39 (1.43)
Residual	3.60 (0.45)	3.60 (0.45)	3.57 (0.44)	3.57 (0.44)	3.57 (0.44)

\* p < 0.05; \*\*p < 0.01

Table 2.4: Results of social availability intervention dosage models, regression coefficient (standard error)

Predictor	Model 6	Model 7	Model 8
<i>Fixed Effects</i>			
collab1	-0.46 (0.39)		
collab2		-0.20 (0.69)	
alcprob			-0.38 (0.73)
ses	-0.001 (0.42)	-0.11 (0.48)	-0.18 (0.51)
pop10k	-0.05 (0.05)	-0.06 (0.06)	-0.05 (-0.06)
min	0.04 (3.30)	-0.57 (3.55)	-0.73 (3.51)
time	0.86** (0.12)	0.86** (0.12)	0.86** (0.12)
time2	-0.06** (0.01)	-0.06** (0.01)	-0.06** (0.01)
<i>Random Effects</i>			
Intercept	0.45 (0.30)	0.55 (0.36)	0.54 (0.35)
Residual	1.32 (0.16)	1.32 (0.16)	1.32 (0.16)

\* p < 0.05; \*\*p < 0.01

Table 2.5: Results of DUI intervention models, regression coefficient (standard error)

Predictor	Model 9	Model 10	Model 11	Model 12
<b>Fixed Effects</b>				
ots	1.44* (0.48)			
collab1		1.18 (1.21)		
collab2			0.13 (2.12)	
alcpob				-1.21 (2.23)
ses	0.34 (1.21)	-0.18 (1.31)	-0.01 (1.48)	-0.43 (1.54)
pop10k	0.43** (0.15)	0.38* (0.17)	0.39* (0.19)	0.39* (0.17)
min	-6.01 (9.44)	-9.29 (10.34)	-7.65 (10.87)	-7.98 (10.66)
time	0.96** (0.20)	1.05** (0.21)	1.05** (0.21)	1.05** (0.21)
time2	-0.06** (0.02)	-0.07** (0.02)	-0.07** (0.02)	-0.07** (0.02)
<b>Random Effects</b>				
Intercept	4.40 (2.36)	5.18 (2.94)	5.91 (3.33)	5.67 (3.20)
Residual	3.64 (0.45)	3.83 (0.47)	3.83 (0.47)	3.83 (0.47)

\* p < 0.05; \*\*p < 0.01

Figure 2.1: Retail alcohol availability intervention dosage across quarters by city

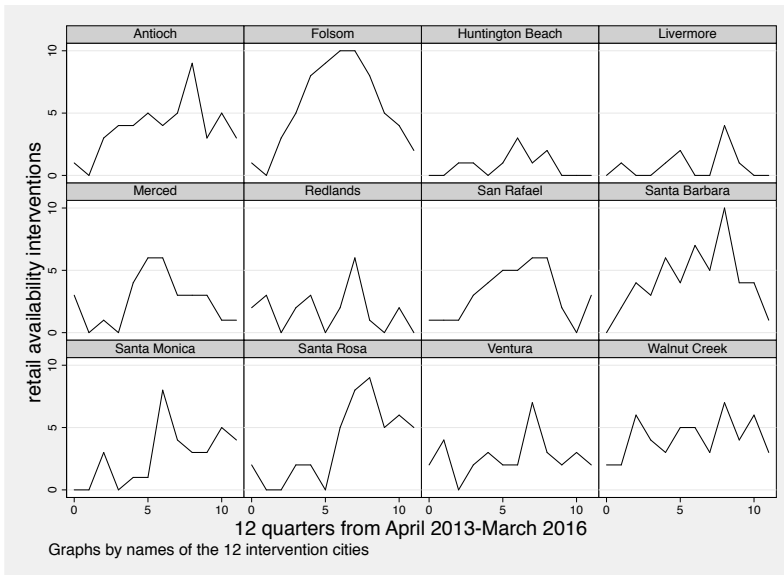


Figure 2.2: Social alcohol availability intervention dosage across quarters by city

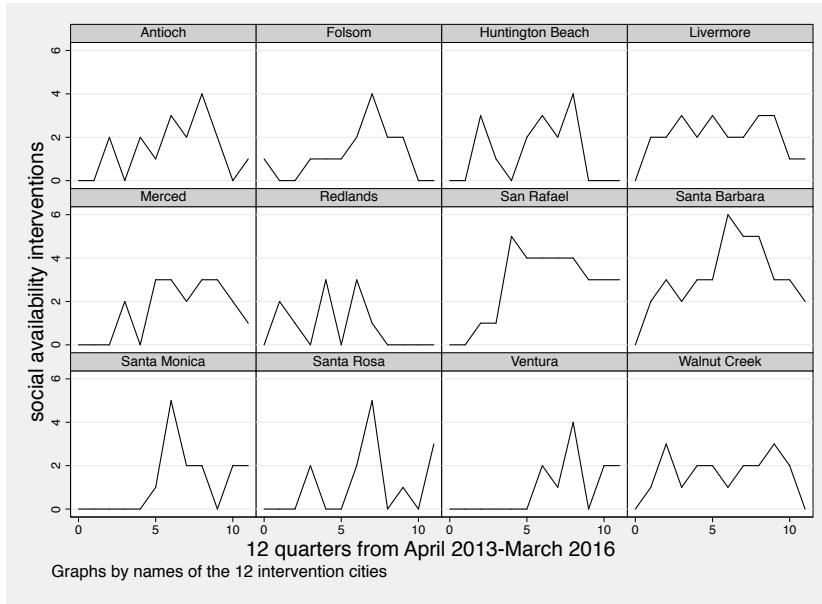


Figure 2.3: DUI intervention dosage across quarters by city

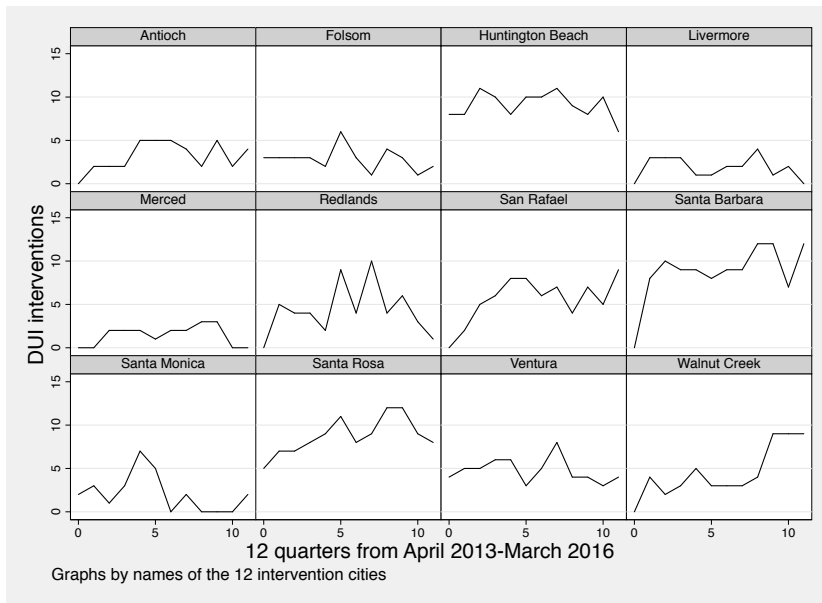




Figure 2.4: Residual diagnostics, model 1, level 1

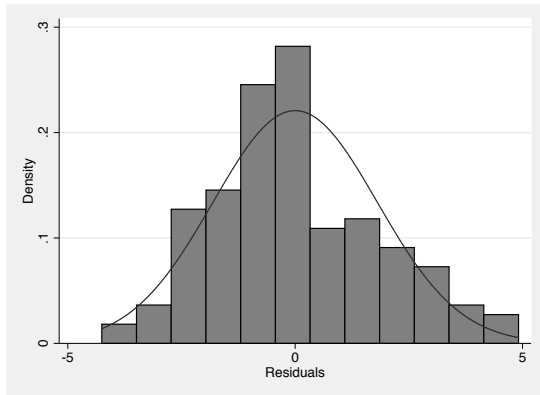


Figure 2.5: Residual diagnostics, model 1, level 2

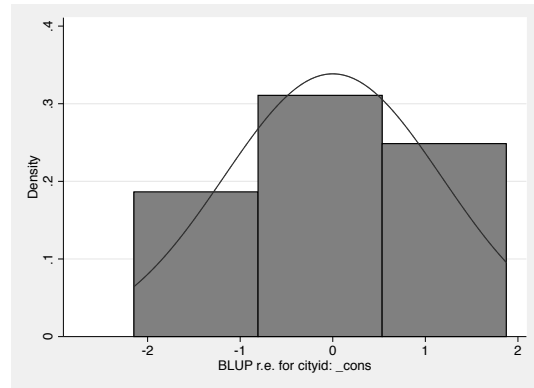


Figure 2.6: Residual diagnostics, model 2, level 1

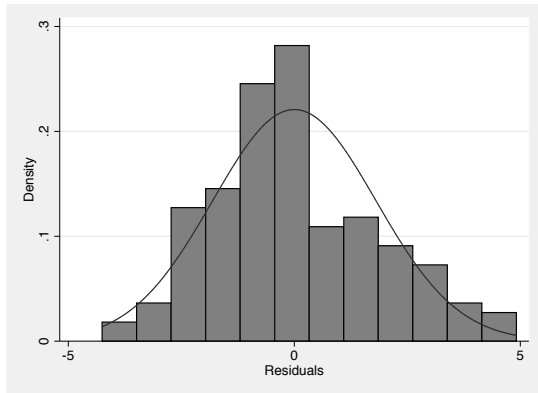


Figure 2.7: Residual diagnostics, model 2, level 2

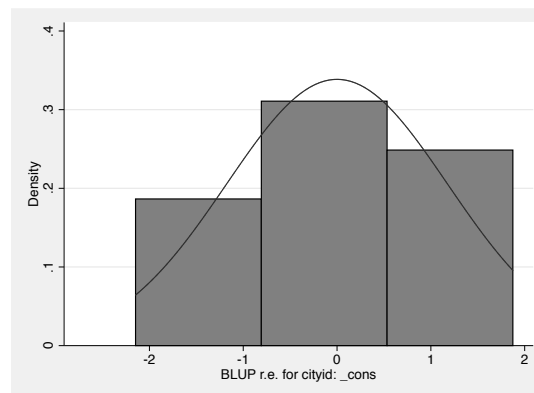


Figure 2.8: Residual diagnostics, model 3, level 1

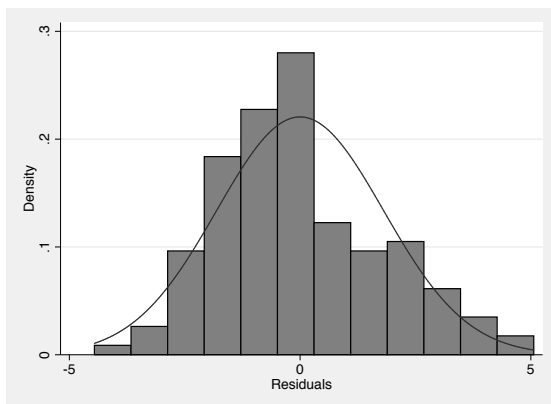


Figure 2.9: Residual diagnostics, model 3, level 2

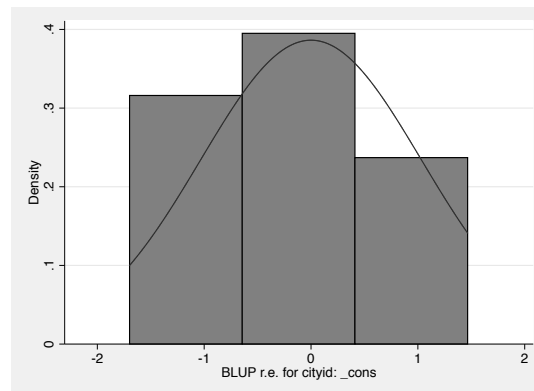


Figure 2.10: Residual diagnostics, model 4, level

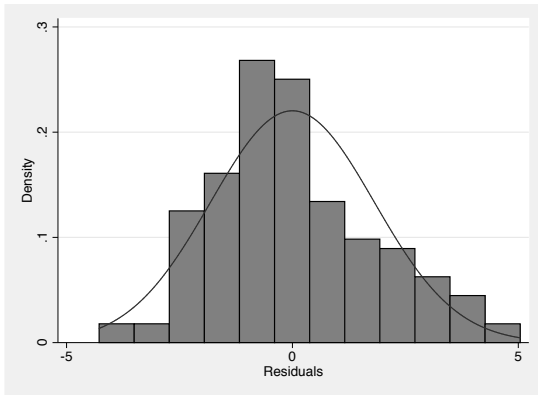


Figure 2.11: Residual diagnostics, model 4, level 2

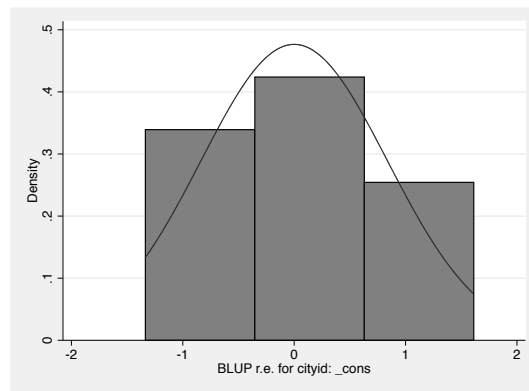


Figure 2.12: Residual diagnostics, model 5, level 1

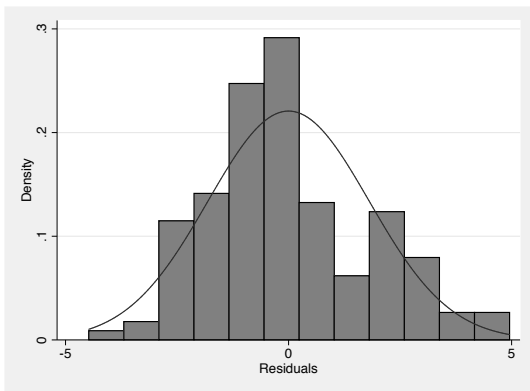


Figure 2.13: Residual diagnostics, model 5, level 2

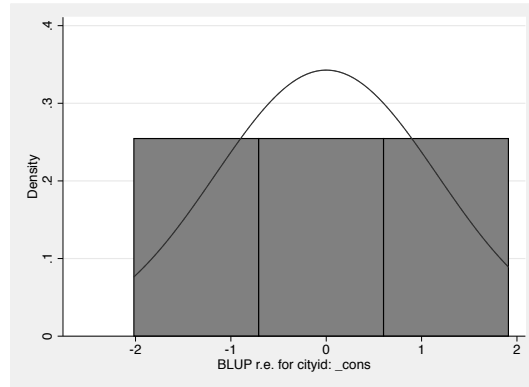


Figure 2.14: Residual diagnostics, model 6, level

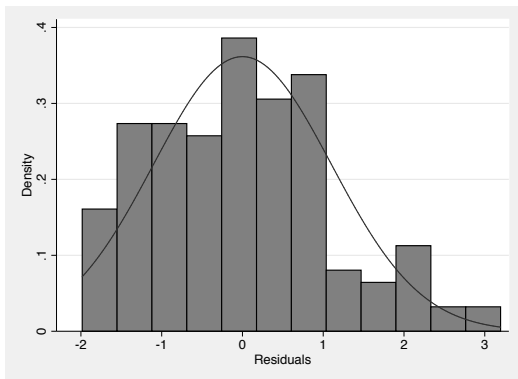


Figure 2.15: Residual diagnostics, model 6, level 1

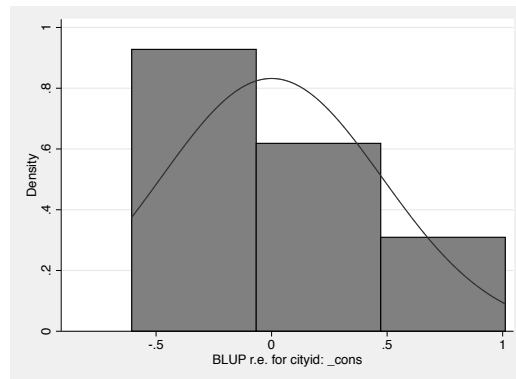


Figure 2.16: Residual diagnostics, model 7, level 1

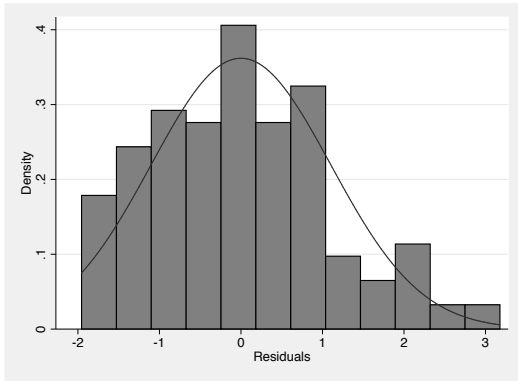


Figure 2.17: Residual diagnostics, model 7, level 2

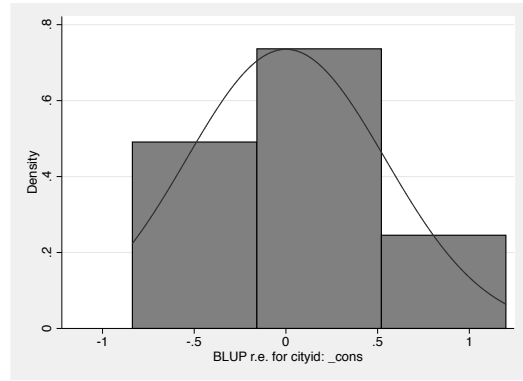


Figure 2.18: Residual diagnostics, model 8, level 1

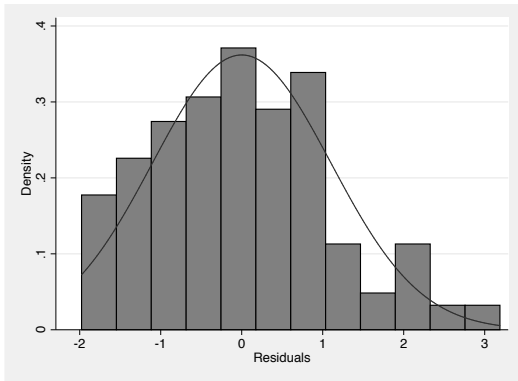


Figure 2.19: Residual diagnostics, model 8, level 2

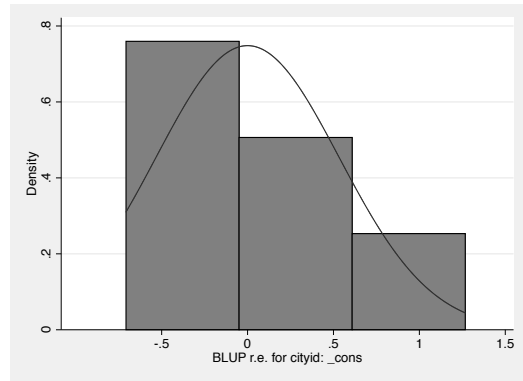


Figure 2.20: Residual diagnostics, model 9, level

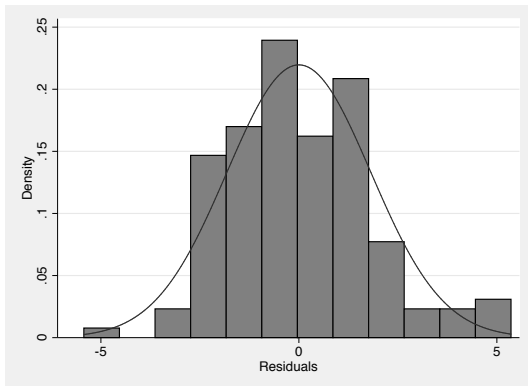


Figure 2.21: Residual diagnostics, model 9, level 2

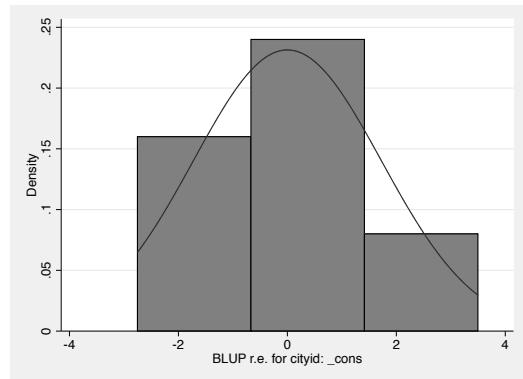


Figure 2.22: Residual diagnostics, model 10, level 1

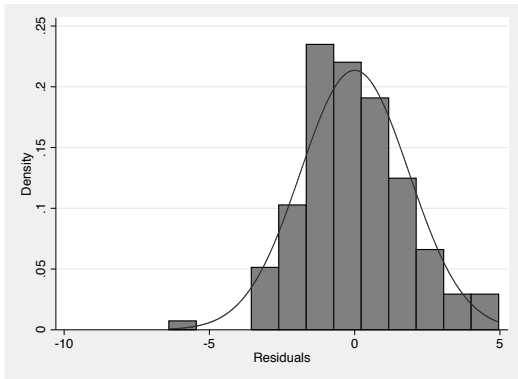


Figure 2.23: Residual diagnostics, model 10, level 2

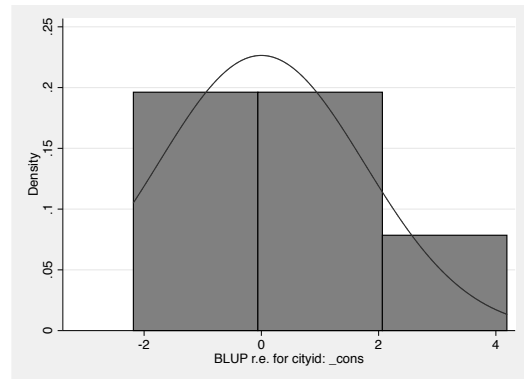


Figure 2.24: Residual diagnostics, model 11, level 1

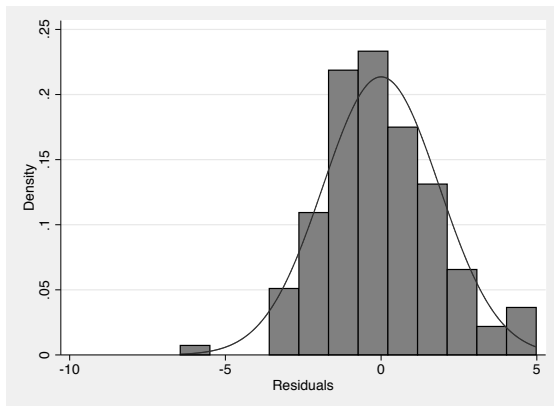


Figure 2.25: Residual diagnostics, model 11, level 2

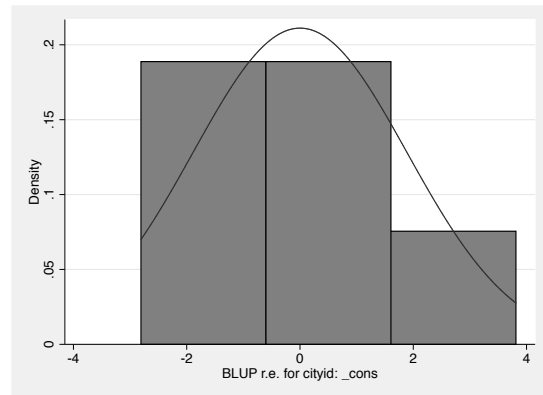


Figure 2.26: Residual diagnostics, model 12, level 1

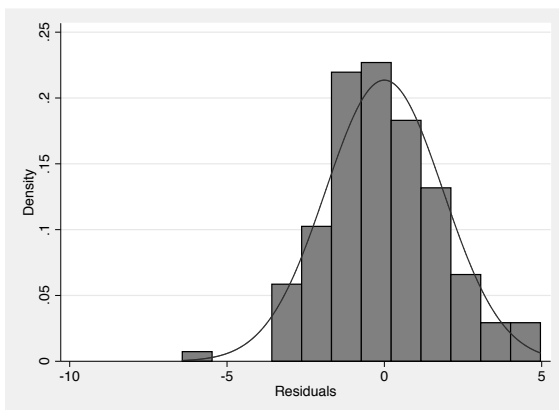
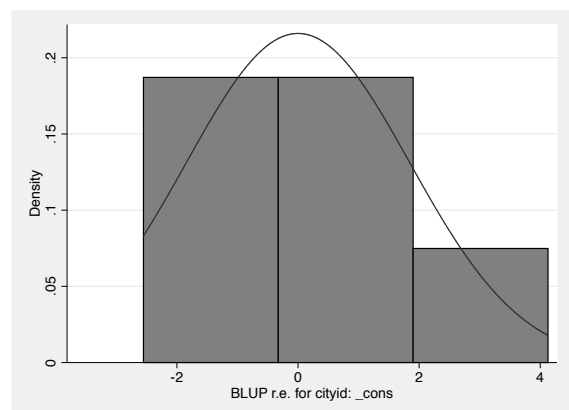


Figure 2.27: Residual diagnostics, model 12, level 2



## PAPER 3

Do higher levels of dosage of enforcement and visibility lead to reductions in alcohol-related problems at the community level in the California SPF SIG project?

### **Abstract**

**Background.** In the U.S., the annual cost of driving under the influence (DUI) is \$121.5 billion. Highly visible DUI enforcement interventions have been found to be effective in reducing DUI crashes and injuries. However, no consensus exists in the literature about what constitutes an effective level of dosage for these interventions.

**Objective.** This study investigated whether greater reductions in alcohol impaired driving (DUI) crashes and DUI injury crashes were observed over time in California cities that implemented a higher dosage of high-visibility sobriety checkpoints or DUI saturation patrols.

**Design.** Secondary analysis of data collected from the 24 cities of California Strategic Prevention Framework State Incentive Grant (SPF SIG) project, a randomized community trial, and from the California Highway Patrol Statewide Integrated Traffic Reporting System (SWITRS).

**Sample.** 24 matched California cities were randomly assigned to intervention or treatment condition in the SPF SIG study.

**Outcome measures.** The moving monthly average proportion of DUI crashes out of all crashes, and the moving monthly average proportion of injury DUI crashes over 58 time points from 2012-2016, using SWITRS data.

**Statistical analysis.** Multi-level analyses were conducted to assess moderating effects of varying city dosage levels on the relationship between time and the moving average proportion of DUI crashes out of all crashes, and the moving average proportion of injury DUI crashes out of all injury crashes in the 24 study cities from 2012-2016, controlling for socioeconomic status, total population and minority population. Comparison cities served as the referent dosage category for both outcomes.

**Results.** Statistically significant negative effects were found for the interaction between medium level of dosage (.63-1.0 interventions/month) and time on both outcomes. The interaction of time with low dosage level (0-.60 interventions/mo.) was not found to have a statistically significant effect on either outcome. Statistically significant negative effects found for the interaction between high level of dosage (1.01-4 interventions/mo.) and time on injury DUI crashes appeared to no greater than for medium dosage level.

**Conclusion.** Despite limitations, this study has promising implications for communities working to reduce DUI crashes and injuries. Although replication is necessary, these results suggest that conducting 1 high-visibility DUI enforcement intervention per month may be more effective than conducting either fewer or more than 1 per month in reducing DUI crashes and injury DUI crashes.

## 1. Introduction

The United States Centers for Disease Control and Prevention (CDC) defines excessive alcohol consumption as: binge drinking (four or more drinks per occasion for women; five or more drinks per occasion for men); heavy drinking (more than eight drinks per week for women; and 15 or more drinks per week for men); and any alcohol consumption by persons under 21 years of age or by pregnant women.<sup>2</sup> Harms associated with excessive alcohol use constitute a burden on society, generating costs in health care, lost productivity, and community level problems like motor vehicle crashes and injuries, crime and violence. The cost due to excessive drinking by youth and adults in 2010 in the U.S. was an estimated \$249.0 billion,<sup>2</sup> with \$121.5 billion attributable to alcohol-impaired driving alone.<sup>94</sup> Eighty-five per cent of alcohol-impaired driving events are associated with binge drinking.<sup>94</sup>

Policy interventions to reduce community level alcohol-related problems have been the focus of much research, resulting in the recognition of effective and promising prevention practices. For example, a systematic review found strong evidence of effectiveness for laws making it illegal “*per se*” to drive with a blood alcohol concentration (BAC) of .08g/dL or higher in reducing deaths due to alcohol-related motor vehicle crashes.<sup>15</sup> Such *per se* laws have been adopted in all 50 states in the United States. Subsequent research in some states has shown that lowering the BAC limit from .10 g/dL to .08 g/dL resulted in 5–16% reductions in alcohol-related crashes, fatalities, or injuries.<sup>95</sup> These reductions are dependent on enforcement of the *per se* laws, commonly through the use of roadside sobriety checkpoints and/or dedicated driving under the influence (DUI) saturation patrols conducted by state and local law enforcement agencies.

However, laws must be enforced in ways that increase public awareness of the enforcement efforts, otherwise their effect on preventing DUI crashes and related injuries is likely to be minimal.<sup>18</sup> This type of prevention is based on deterrence theory, which emphasizes the important role that the perception of certain and swift consequences plays in preventing crime.<sup>20,21</sup> Thus, the deterrent effect of alcohol-impaired driving enforcement has been found to be enhanced when combined with publicity activities that make the enforcement highly visible. “High visibility” includes publicity campaigns about enforcement operations before they occur, as well as publicity about the results of operations after they are completed. A well-publicized enforcement operation is intended to act as a deterrent to policy violations, and does not necessarily result in more citations or arrests. In this sense, the goal of enforcement is to create a credible threat of apprehension and consequences that prevents people from violating a policy or law. The visibility of enforcement has been called “key” to the relationship between enforcement and reductions in alcohol-impaired driving crashes.<sup>22</sup> The beneficial effects of enforcing policies<sup>42,44–48,50–52,79</sup> on reducing alcohol-related problems, and of high-visibility enforcement in particular,<sup>22,23,46,53–56</sup> has been well documented in previous studies.

What is not clear is the amount or frequency of enforcement and publicity that is necessary to lead to intended outcomes, making it difficult for municipalities to know the amount of resources to allocate for reducing specific problems. Studies of the amount and frequency of an intervention needed to have an effect, referred to here as intervention “dosage,”<sup>26</sup> have resulted in varying conclusions.<sup>9,45,50,52,60–66,68–72</sup> This variation is due, in part, to differences in dosage measures, outcome measures and types of alcohol-related problems addressed across the studies, as well as variation in study designs. While the studies cited here concluded that consistent enforcement can achieve desired outcomes, there was no consensus among the studies for a necessary level, or threshold of enforcement dosage.

The current study builds on prior research by investigating whether greater reductions in alcohol impaired driving (DUI) crashes and related injuries were observed in California cities that implemented a higher dosage of specific policy enforcement and publicity interventions (i.e., high-visibility DUI enforcement). DUI crashes are based on archival data that are publicly available and can be used by community-based organizations and government agencies to assess impacts of alcohol control policies and related enforcement and visibility activities at the local and state level. Systematic reviews of evidence show that DUI crash rates and/or DUI injury crash rates have been used as measures of alcohol-impaired driving outcomes in prior studies.<sup>15,19,42,96,97</sup> Interventions to prevent these outcomes included DUI sobriety checkpoints, DUI saturation patrols, and publicity about these enforcement operations. DUI crash outcomes associated with three levels of high-visibility DUI enforcement dosage employed by the intervention cities were contrasted with DUI crash outcomes of comparison cities. This study examined the moderating effect of dosage level on the relationship between time and DUI crash rates. Multi-level modeling was used to investigate these relationships, adjusting for city-level covariates, such as socio-economic indicators, total city population, and percent minority population.

## **2. Methods**

### ***Sample***

This study is a secondary analysis of data from a randomized community intervention trial primarily funded through the California Strategic Prevention Framework State Incentive Grant (SPF SIG). Working in collaboration with the California Department of Health Care Services, the Prevention Research Center (PRC) developed and conducted the California SPF SIG intervention trial in 2013 - 2016 to reduce excessive alcohol consumption and related problems among youth and young adults aged 12-25. The SPF SIG study was funded by the U.S. Substance Abuse and Mental Health Services Administration (SAMHSA) and the National Institute on Alcohol Abuse and Alcoholism (NIAAA).

From a pool of 50 randomly-selected California cities with populations between 50,000 and 500,000, twenty-four cities were selected to be in the study, based on power calculations and on their having above-median levels of alcohol-related problems such as DUI crashes and underage drinking. Twelve pairs of cities were then identified from

the set of 24 based on similarities in levels of alcohol problems (e.g., DUI crashes, heavy drinking) and demographic characteristics (e.g., population size, ethnic composition). The final set of 12 intervention communities was determined via random selection of one from each pair, leaving the other city to become a comparison community. Intervention cities were given SPF SIG funds for policy enforcement operations conducted by the local law enforcement agency, which, in most cases, collaborated with a local prevention agency to plan and conduct related visibility activities.

### **Data Collection**

According to requirements of the SPF SIG project, local enforcement and public health agencies in intervention cities submitted monthly activity reports. These reports documented the dates and types of enforcement activities conducted. These included: driving under the influence (DUI) sobriety checkpoints or DUI saturation patrols, minor decoy operations to check for alcohol sales to persons under 21, and party patrols. The reports also included activities conducted to make these enforcement operations highly visible to the public, such as signage, social media posts, and traditional media reports indicating that enforcement was occurring. Data from the monthly reports were used to calculate monthly dosage of interventions, including enforcement and publicity activities. Outcomes of interest included alcohol-related motor vehicle crashes and alcohol-related injury crashes. These outcomes were measured at the city level, with 2012 baseline levels used for the current study. Alcohol-related motor vehicle crash and injury data were obtained from the California Highway Patrol Statewide Integrated Traffic Reporting System (SWITRS).

### **Hypotheses**

Two hypotheses were tested in the current study:

H<sub>1</sub>: A greater reduction in the DUI crash rate over the study period will be observed in cities with higher intervention dosage levels compared to cities with lower intervention dosage levels.

H<sub>2</sub>: A greater reduction in the injury DUI crash rate over the study period will be observed in cities with higher intervention dosage levels compared to cities with lower intervention dosage levels.

Although stated in general terms, these hypotheses are based on the objective of identifying the minimum intervention dosage level that yields meaningful reductions in DUI crashes and injury DUI crashes.

### **Measures**

*Driving under the influence (DUI) crashes.* The proportion of DUI crashes out of all crashes was calculated using data from the California Highway Patrol Statewide Integrated Traffic Reporting System (SWITRS) from the baseline year of 2012 through the SPF SIG intervention period from 2013 - 2016. To smooth out monthly fluctuations (i.e., “noise”) in the data, a three-month moving average was calculated for this outcome



measure over the study period, yielding 58 outcome data points or observations per city.

*Injury driving under the influence (DUI) crashes.* The proportion of injury DUI crashes out of all injury crashes for each city was calculated using SWITRS data from the baseline year of 2012 through the SPF SIG intervention period from 2013 - 2016. To smooth out monthly fluctuations in the data, a three-month moving average was calculated for this outcome measure over the study period, yielding 58 outcome data points or observations per city.

*Intervention condition.* SPF SIG intervention condition was included as a city-level variable.

*Intervention dosage.* SPF SIG intervention cities conducted up to 4 enforcement and/or publicity activities per month to reduce DUI crashes and DUI injury crashes. These activities were: DUI sobriety checkpoints or DUI saturation patrols, and publicity activities to make the enforcement operations highly visible. Based on the total number of DUI enforcement and visibility activities conducted by each of the 12 intervention communities in each of the intervention months of the SPF SIG project from April 2013 – March 2016, intervention dosage was first calculated as a continuous variable ranging from 0-4. The monthly measure was relevant, rather than the total number of interventions conducted over the study period because this study was longitudinal, focusing on the change in outcomes over a five-year period with 58 observations per city. Trends showed that the 12 intervention cities fell into low, medium and high intervention dosage categories, based on the monthly average of intervention activities from 2013 to 2016. For analysis, a categorical measure was created that identified 3 levels of average monthly dosage based on cumulative monthly frequencies of the continuous dosage measure: “low (0 -.60 interventions/month)”, “medium (.63 – 1.0 interventions/month)” and “high (1.01-4 interventions/month).” Each of the twelve intervention communities was placed into one of the three categories based on its overall mean dosage level from 2013 to 2016. This measure was held constant for each city in the analyses. Because they implemented none of the SPF SIG visibility interventions and relatively few or none of the enforcement interventions, the twelve comparison communities were assigned to a level of “zero (0)” dosage and used as controls for the analysis.

*Socioeconomic status.* Socio-economic status (SES) was determined for the 24 study cities in 2012 for the original SPF SIG study, and includes four socioeconomic characteristics: level of poverty, level of unemployment, percent of population with a college education, and median household income. A standardized SES factor score was created for each city with these four variables. This covariate was held constant in the models for both outcomes.

*Population size.* Population size represented the total population (in units of 10,000) of each study city in 2012. This covariate was held constant in the models for both outcomes.

*Minority population.* Minority population represented the percentage of all minority residents in each city in 2012. This covariate was held constant in the models for both outcomes.

*Time.* Time represented the periods in which the dosage, proportion of DUI crashes out of all crashes, and proportion of injury DUI crashes out of all injury crashes were collected for each of the 24 cities, corresponding to the months between 2012-2016. A moving 3-month average was created to remove fluctuations in the data, resulting in 58 time-points for this level-1 variable. The baseline intervention dosage level was zero for all 24 cities in 2012.

### **Data Analysis**

First, descriptive statistics were obtained to examine characteristics of the main predictor and outcome variables, including mean, standard deviation, minimum, maximum, and skewness of the data. Next, multi-level modeling analyses were conducted using hierarchical linear modeling (HLM) in Stata v.15<sup>92</sup> with restricted estimated maximum likelihood (reml) and unstructured covariance to test study hypotheses by examining possible moderating effects of differing levels of intervention dosage on the relationship between time and the proportion of DUI crashes out of all crashes, and the proportion of injury DUI crashes out of all injury crashes, with zero dosage as the referent category. That is, whether and to what extent changes in DUI crash rates varied by intervention dosage level over the study period.

The proportion of DUI crashes out of all crashes, the proportion of injury DUI crashes out of all injury crashes, and time were modeled as level 1 variables (i.e., repeated observations within cities), while dosage level, socio-economic status, population per 10,000, and percent minority population were modeled as level 2 variables (i.e., city-level variables held constant for the study period). Possible moderating effects of dosage on the relationship between time and DUI crash outcomes were examined by including interaction terms (e.g., time x dosage) in the models. A time squared variable and time squared x dosage was also included in the models to allow for a quadratic effect of time, due to the nonlinear trends in DUI crashes and DUI injury crashes over the study period. HLM allows for modeling fixed and random effects, and adjusts for nesting of repeated observations within cities over time. A random coefficients model was used for both outcomes, with unstructured covariance and restricted maximum likelihood estimates.<sup>93</sup> Residual diagnostic post-analyses were conducted to check assumptions of normality of the residuals from regression models (i.e., differences between predicted and actual values for DUI crash rates) and to identify any obvious outliers.

### 3. Results

#### ***Sample characteristics***

The number of clusters is 24 (cities), with 60 units per cluster corresponding to 60 time points representing the months from January 2012 - December 2016. Descriptive statistics are presented in Tables 3.1 and 3.3. Table 3.1 includes the outcome and predictor variables for the twelve intervention cities, using a continuous measure of intervention dosage for the months of the SPF SIG intervention (April 2013 – March 2016).

For analysis, a time-invariant measure of dosage was created for the twelve intervention cities, based on the mean monthly dosage of the SPF SIG interventions for each city. The cities were ranked into 1) low, 2) medium, and 3) high dosage categories. The comparison cities were ranked at zero SPF SIG intervention dosage, representing “business as usual.” As shown in Table 3.2, four of the intervention cities fell into each level above zero. Table 3.3 includes the outcome and predictor variables for the twelve intervention cities and the twelve comparison cities.

#### ***Multi-level analyses***

Multi-level analyses were conducted to assess the moderating effects of overall city dosage levels on the relationship between time and the moving average proportion of DUI crashes out of all crashes, and the moving average proportion of injury DUI crashes out of all injury crashes in the 24 study cities from 2012-2016. Comparison cities served as the referent dosage category for both outcomes, as they were ranked at the zero level for SPF SIG intervention dosage. Results of multilevel analyses are presented in Table 3.4. Each model was analyzed using the Stata mixed command with restricted estimated maximum likelihood (reml) and unstructured covariance. The random intercepts and random slopes indicate the between-and within-city variation in each model, respectively, since observations within each city are not independent of each other. The residuals represent variance that is not explained by the regression models.

#### ***Effects on monthly proportion of DUI crashes out of all crashes***

Results in Table 3.4 indicate a statistically significant moderating effect of the medium dosage level on the relationship between time and the monthly proportion of DUI crashes out of all crashes ( $p < 0.01$ ), controlling for socio-economic status, population size, and percent minority population. A similar effect is shown for the interaction of time squared and medium level of dosage on this outcome. Neither the interaction of time with low dosage level nor the interaction of time with high dosage level was found to have a statistically significant effect on DUI crashes. Though not the direct focus of the current study, it was also found that socioeconomic status was inversely related to the proportion of DUI crashes out of all crashes ( $p < 0.05$ ). Neither of the other community characteristics was associated with this outcome.

Estimated marginal means were calculated to find modeled linear predictions for the average proportion of DUI crashes out of all crashes over 60 months, at every fourth month, by dosage level. Figure 3.1 illustrates the predictions for lines at each dosage level, including a line representing zero intervention dosage for comparison. According to the predictions for this model, implementing the enforcement and visibility interventions at the medium dosage level could reduce DUI crashes by about 8.0% compared to no dosage, which translates to more than 186 fewer DUI crashes per year in the 24 study cities, or about 16 fewer DUI crashes per month in the 24 study cities. Although not statistically significant, it appears that the high level of dosage would be associated with an increase in the proportion of DUI crashes out of all crashes, similar to the effect of no dosage, while a low dosage level would result in no change in the proportion of DUI crashes out of all crashes.

### ***Effects on injury DUI crashes out of all injury crashes***

A statistically significant moderating effect of a medium dosage level on the relationship between time and the monthly proportion of injury DUI crashes out of all injury crashes ( $p < 0.05$ ) was also found, controlling for socio-economic status, population size, and percent minority population. In addition, statistically significant negative effects of the interaction of time and a high dosage level on the monthly proportion of injury DUI crashes out of all injury crashes ( $p < 0.05$ ) was found, controlling for socio-economic status, population size, and percent minority population. A similar effect is shown for the interactions of time squared with the medium level of dosage and with the high level of dosage on the same outcome. The interaction of time with the low dosage level was not found to have a statistically significant effect on the proportion of injury DUI crashes. None of the other city characteristics were significantly associated with the proportion of injury DUI crashes out of all injury crashes.

Estimated marginal means were calculated to find modeled linear predictions for the average proportion of injury DUI crashes out of all injury crashes over 60 months, at every fourth month, by dosage level. Figure 3.2 illustrates the predictions for lines at each dosage level, including a line representing zero intervention dosage for comparison. According to the predictions for this model, implementing the enforcement and visibility interventions at the medium or high level of dosage could reduce injury DUI crashes by about 7.0% compared to no dosage, which translates to approximately 55 fewer injury DUI crashes per year in the 24 study cities, or approximately 5 fewer injury DUI crashes per month in the 24 study cities. Although not statistically significant, the model indicates that the low level of dosage could result in a 5% reduction in injury DUI crashes, meaning 39 fewer per year, or 3 fewer per month.

### ***Residual diagnostics for both models***

Residual diagnostics checking the normality assumption are shown in Figures 3.3-3.8. The histograms indicate that, for both outcomes, the distribution of residuals is symmetric around zero, with some outliers. Skewness of some of the histograms may be due to the relatively small number of clusters in the study (24).

#### 4. Discussion

This study explored the effects of different levels of dosage of a high-visibility DUI enforcement intervention on changes in the proportion of DUI crashes out of all crashes and injury DUI crashes out of all injury crashes in 24 California cities. The hypothesis was that a greater number and frequency of DUI-specific enforcement activities, and publicity to make the enforcement highly visible, would result in a greater reduction in DUI crashes and injury DUI crashes over the study period. The analyses presented here indicate that different levels of dosage had varying effects on these outcomes over time, and the highest level of dosage did not necessarily have the greatest effect.

Results of this study are consistent with prior research findings that high-visibility enforcement is associated with reductions in DUI crashes and injury DUI crashes.<sup>23,61,98</sup> The current study builds on previous research examining enforcement frequency and intensity required to reduce alcohol-related problems, which has resulted in varying conclusions. While prior studies suggest that “high levels” of high visibility enforcement yield greater effects on DUI crashes and DUI injury crashes, they haven’t determined the minimum number and frequency of high-visibility DUI enforcement operations to achieve meaningful reductions in DUI crashes and DUI injury crashes.

For example, it has been suggested that weekly DUI sobriety checkpoints may be the threshold for effectiveness,<sup>52</sup> however, another study found no significant difference in drinking and driving between conducting sobriety checkpoints less than monthly versus at least monthly.<sup>62</sup> The current study adds to the literature by investigating reductions in DUI crashes and DUI injury crashes over time in California cities that implemented varying dosage levels of specific interventions, i.e., DUI sobriety checkpoints, DUI saturation patrols, and publicity about these enforcement operations. This is the first study to assess the effects of four categories of DUI enforcement and visibility intervention levels to determine moderating effects on outcomes over time.

Statistically significant effects were found for the interaction between time and the medium level of dosage on the proportion of DUI crashes out of all crashes. Based on the measure of medium dosage (.63 – 1.0 interventions per month), the results suggest that conducting even one enforcement or enforcement-related visibility activity per month could lead to 186 fewer DUI crashes per year in the study cities, compared to conducting no such activities. It appears that conducting less than one enforcement or enforcement-related visibility activity per month (low dosage) will likely result in no significant change in the number of DUI crashes per year compared to zero dosage. Further, although not a statistically significant finding, conducting more than one enforcement or enforcement-related visibility activity per month (high dosage) was associated with an increase in DUI crashes, similar to the results associated with zero dosage. It is difficult to explain the positive relationship between the highest level of dosage studied here and an increase in DUI crashes. It is possible that more DUI sobriety checkpoints or saturation patrols were conducted in cities that had a higher number of DUI crashes over the study period. Nevertheless, an implication of this study

is that one enforcement or enforcement-related visibility activity per month may be sufficient, and that additional activities per month may result in diminishing returns.

A similar conclusion emerges from analyzing the effects of the interactions between dosage and time on injury DUI crashes. Here, statistically significant effects were found for the interaction between time and both the medium and high levels of dosage on the proportion of injury DUI crashes out of all injury crashes. However, the high dosage level was not found to have a larger effect than the medium level. The results suggest that implementing the enforcement and visibility interventions at the medium (.63 – 1.0 interventions per month) or high level (1.01 - 4 interventions) of dosage could lead to 55 fewer injury DUI crashes in the study city, compared to conducting no such activities. Although not statistically significant, results suggest that implementing a low dosage of interventions could result in 39 fewer injury DUI crashes per year. These findings again imply that one enforcement or enforcement-related visibility activity per month is a necessary dosage, that fewer activities will not be sufficient, and that additional activities per month may not show any better result.

The current study has promising implications for communities wishing to employ similar interventions to reduce DUI crashes and injuries. However, it is important to take caution in interpreting results of this study due to several limitations. First, because the intervention cities were not randomly assigned to dosage level, selection bias may be a threat to internal validity. This makes it difficult to know whether observed changes are due to actual intervention effects, or to unobserved differences between the intervention cities before the intervention occurred (i.e., selection bias). Another threat to internal validity may be due to some cities having a higher rate of DUI crashes and/or DUI injury crashes at baseline, where reductions in both outcomes are attributable to a regression to the mean, rather than the effects of the interventions.

As a secondary analysis of existing data, it is also possible that the analyses presented here underestimate the actual effects of the varying levels of dosage. The comparison communities were assigned “zero dosage”, but it is very likely that they conducted DUI prevention activities like sobriety checkpoints and saturation patrols to some extent during the study period. Since this information was not tracked, it was not possible to compare dosage levels in the intervention communities with actual dosage in the comparison cities. However, it was determined that some of the comparison cities received funding from the California Office of Traffic Safety for DUI enforcement operations. Future studies would benefit from improved instrumentation for tracking activities in intervention communities as well as comparison communities, as underreporting was likely in some of the monthly SPF SIG reports.

Finally, this study was conducted exclusively with California cities, making it difficult to generalize to cities in other states or countries where other types of enforcement interventions are used. For example, DUI sobriety checkpoints are not allowed in all states, and law enforcement agencies in some countries have greater latitude to employ random breath testing without reasonable suspicion of alcohol-impaired driving, as is required in the United States. Therefore, these results may only be applicable to

municipalities with policies and law enforcement practices similar to those in the study cities. For those jurisdictions, the findings of this study may help to guide realistic planning for effective practices to reduce DUI crashes and injuries.

The current study also has several strengths. First, it benefited from the randomized community trial design used in the original SPF SIG study, in which 12 pairs of communities were matched on sociodemographic factors and then randomly assigned to either the intervention or comparison condition. This design likely helped reduce bias, increase analytical precision<sup>99</sup> and offered the opportunity to evaluate high-visibility alcohol policy enforcement interventions in natural circumstances. Second, as stated above, this study examined the moderating effects of varying levels of specific enforcement and visibility activities on the DUI crash outcomes over time, an advancement over prior research. Finally, although replication in other communities is needed before determining a threshold level for the effectiveness of these interventions, results of the current study provide a step toward making this determination. It is hoped that cities, counties, states, and other jurisdictions can use the results of this and similar studies to make practical decisions about implementing high-visibility alcohol policy enforcement operations. Community leaders and policy makers, who are concerned with community health and safety as well as budget issues, are likely to be relieved to learn that fewer resources may be needed to implement an effective level of DUI enforcement and visibility activities than they had previously thought.

## 5. Tables and Figures

Table 3.1: Descriptive Statistics – 12 intervention cities only with continuous measure of dosage

Variable	Mean	Std. Dev. Overall	Std. Dev. Between	Std. Dev. Within	Min	Max	Skewness
Monthly DUI crashes/all crashes	.0928205	.0311255	.0239339	.0210463	.02562	.2049333	.5511835
Monthly injury DUI crashes/all injury crashes	.0763671	.0316541	.0186144	.0261516	0	.197619	.544235
Monthly dosage of interventions during intervention period	1.597222	1.341742	.9316197	1.001417	0	4	.3863872
Socio-economic status	.4862209	.8046405	.8398156	7.98e-16	-1.68392	1.469081	-1.37458
Population per 10,000	10.45127	4.262176	4.448498	0	6.1245	19.5572	1.352824
Proportion minority population	.2687914	.1017649	.1062136	2.55e-16	.1644545	.5042018	1.367962

Table 3.2 – Rank of time-invariant dosage variables for intervention cities

City	Rank		
	Low	Medium	High
Antioch		x	
Folsom	x		
Huntington Beach			x
Livermore	x		
Merced	x		
Redlands		x	
San Rafael			x
Santa Barbara			x
Santa Monica	x		
Santa Rosa			x
Ventura		x	
Walnut Creek		x	



Table 3.3: Descriptive Statistics – 24 cities

Variable	Mean	Std. Dev. Overall	Std. Dev. Between	Std. Dev. Within	Min	Max	Skewness
Monthly DUI crashes/all crashes	.1012761	.0385775	.0285088	.0266229	.0107533	.306	.9945154
Monthly injury DUI crashes/all injury crashes	.0802297	.0343089	.0172151	.0298812	0	.2777778	.6272213
Socio-economic status	.3612846	.7066416	.7215806	6.14e-16	-1.68392	1.469081	-.905207
Population per 10,000	10.31319	4.461202	4.555516	6.64e-15	5.8059	22.6126	1.430179
Proportion minority population	.273203	.1145594	.1169813	2.29e-16	.102088	.6193902	1.368725

Table 3.4: Results of multilevel analyses, regression coefficient (standard error)

Predictor	Outcome	
	DUI Crashes /All Crashes 2012-2016	Injury DUI Crashes/All Injury Crashes 2012-2016
<b>Fixed Effects</b>		
Low dosage	-.021847 (.0175392)	-.0011931 (.0137327)
Medium dosage	.006295 (.0176508)	.0102548 (.0137895)
High dosage	-.0026673 (.0181718)	.0120129 (.0140564)
Low dosage x time	-.0004979 (.0005438)	-.0008747 (.0005675)
Medium dosage x time	-.0014536** (.0005438)	-.0012096* (.0005675)
High dosage x time	5.95e-06 (.0005438)	-.0012357* (.0005675)
Low dosage x time <sup>2</sup>	5.63e-06 (7.82e-06)	.0000115 (9.01e-06)
Medium dosage x time <sup>2</sup>	.0000236** (7.82e-06)	.0000204* (9.01e-06)
High dosage x time <sup>2</sup>	8.95e-07 (7.82e-06)	.0000188* (9.01e-06)
Time	.0003765 (.0002719)	.0003948 (.0002838)
Time <sup>2</sup>	-6.81e-06 (3.91e-06)	-7.85e-06 (4.50e-06)
Socioeconomic status	-.0160459* (.0079936)	-.0072057 (.0050444)
Population (per 10,000)	.0004246 (.001277)	.0006822 (.0008058)
Percent minority population	-.0704705 (.0489333)	-.0090049 (.0308794)
<b>Random Effects</b>		
Slope	2.07e-07 (7.85e-08)	6.39e-08 (3.75e-08)
Intercept	.0007968 (.0002842)	.0004123 (.0001593)
Residual	.0006683 (.0000258)	.0008867 (.0000343)

\* p < 0.05; \*\*p < 0.01

Figure 3.1. Proportion of DUI Crashes/All Crashes  
Model Predictions by Dosage Rank

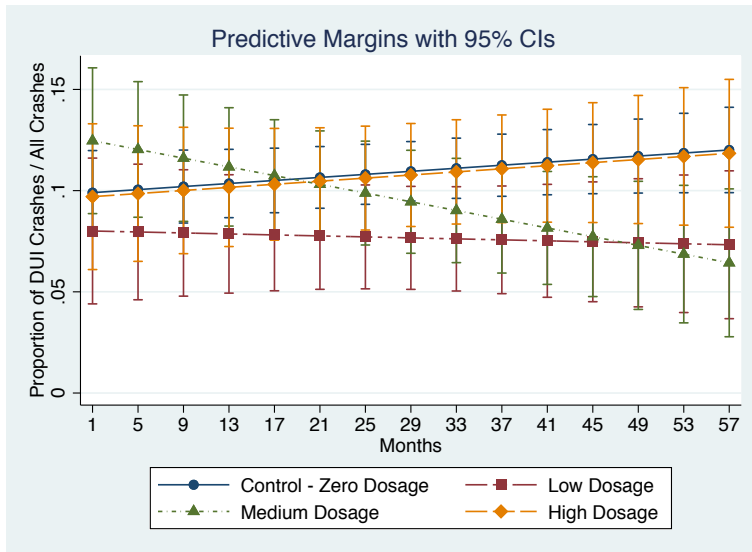
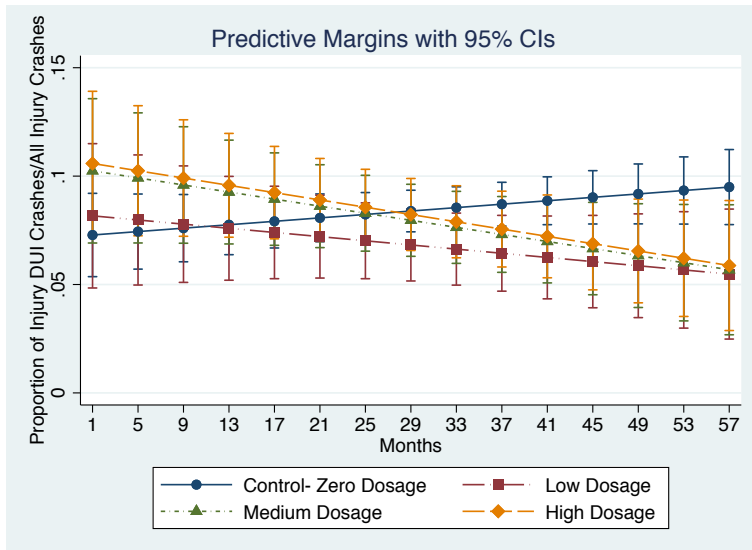


Figure 3.2. Proportion of Injury DUI Crashes/All Injury Crashes  
Model Predictions by Dosage Rank



Figures 3.3. – 3.5. Residual diagnostics: Proportion of DUI crashes out of all crashes

Figure 3.3. Level 1: residuals

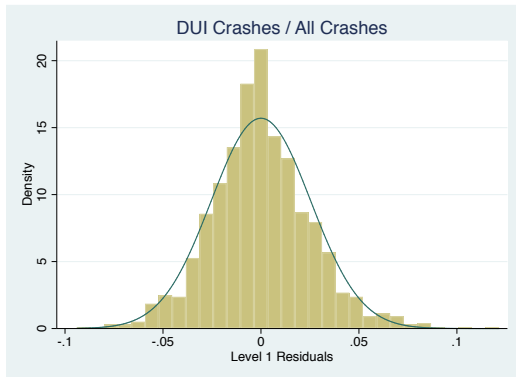


Figure 3.4. Level 2: random intercepts

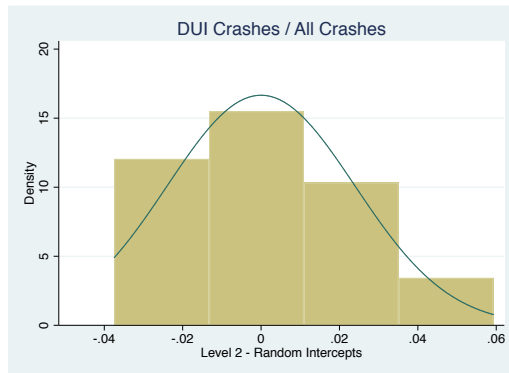
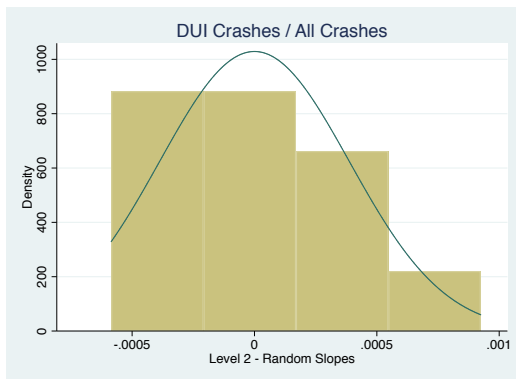


Figure 3.5. Level 2: random slopes



Figures 3.6-3.8. Residual diagnostics: Proportion of injury DUI crashes out of all injury crashes

Figure 3.6. Level 1: residuals

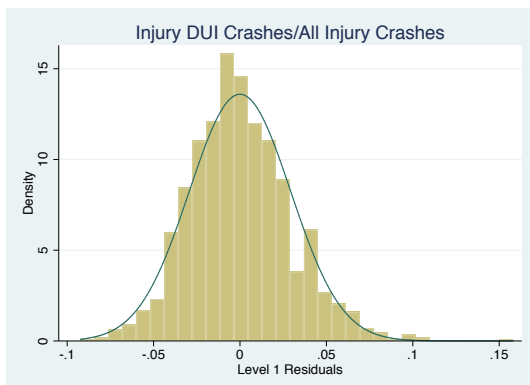


Figure 3.7. Level 2: random intercepts

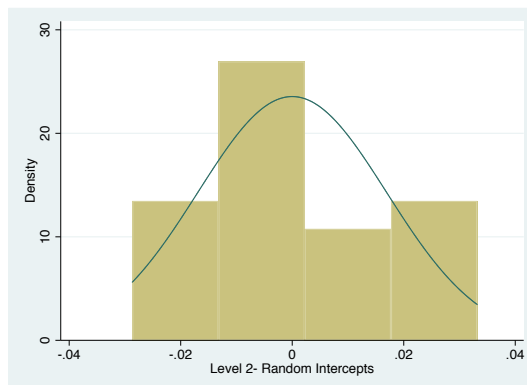
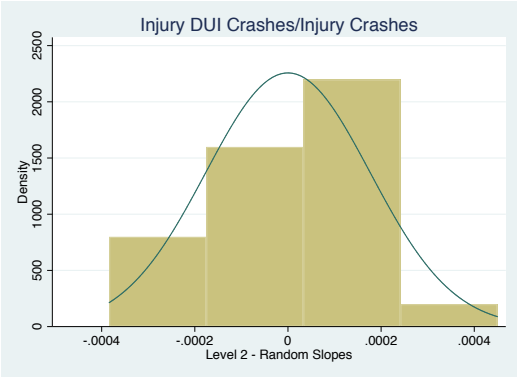


Figure 3.8. Level 2: random slopes



## CONCLUSION

### *Summary of key results*

This dissertation sought to contribute to the scientific literature about how much high-visibility alcohol policy enforcement is needed to achieve intended outcomes, and what influences communities to implement a higher dosage of these interventions. Three related papers examined crucial questions regarding what is known about needed levels of interventions, what community factors are predictive of higher levels of interventions, and whether higher levels of interventions are associated with better outcomes than low, medium or zero intervention levels.

The first paper provides a systematic review of the literature examining what is known about the association between dosage of policy enforcement and reductions in a range of alcohol-related outcomes at the community level. This review represents a contribution to the literature, in that no prior study of dosage had focused on multiple policy enforcement interventions and alcohol-related community problems. The review found support for consistent enforcement to achieve desired outcomes, and for “high” versus “low” levels of enforcement. However, there was no consensus found among the studies for a necessary level, or threshold of enforcement dosage. This was at least partly due to the differences in problems addressed, existing policies in study communities, types of enforcement interventions used, and the designs and sizes of the studies. Among the sixteen studies that met the criteria for inclusion, only two were randomized community trials. Results from this systematic review clearly point out the need for additional research with rigorous study designs to determine effective levels of dosage of high-visibility alcohol policy enforcement, underscoring the significance of the dissertation research presented here.

The second paper examines whether certain community characteristics of the 12 intervention cities of a randomized community trial were associated with higher dosage of high-visibility alcohol policy enforcement. The hypotheses were that funding, better interagency collaboration and a higher level of alcohol problems at baseline would predict greater dosage of the community alcohol interventions. Funding from the California Office of Traffic Safety (OTS) was found to be significantly associated with a greater frequency of high-visibility enforcement to reduce driving under the influence of alcohol (DUI). Better interagency collaboration between enforcement agencies and prevention organizations was associated with a greater dosage of high-visibility enforcement to reduce retail alcohol availability to underage persons (e.g., at stores). None of the three community characteristics was significantly associated with a greater number of interventions to reduce social availability (e.g., at parties). A higher level of alcohol problems at baseline was not found to be significantly associated with a greater number of any of the interventions. Although further research with a larger sample of cities is warranted, these findings provide evidence that funding can spur action, and suggest that collaboration may be an important component in some alcohol policy enforcement initiatives, perhaps especially those focused on protecting underage youth.

Finally, the third paper explores the effects of four different levels of dosage (zero, low,

medium, and high) of a high-visibility DUI enforcement intervention on changes over 58 months in two outcomes: the proportion of DUI crashes out of all crashes and injury DUI crashes out of all injury crashes, in 24 California cities. For both outcomes, medium level dosage (.63 – 1.0 intervention per month) was significantly associated with reductions in both outcomes. Low dosage (up to .60 intervention per month) was not significantly associated with either outcome, and high dosage (1.01 – 4 interventions per month) was significantly associated only with reductions in injury DUI crashes, but the effect size was approximately the same as for the medium level of dosage. In other words, the results of this study indicate that implementing as few as 1 high-visibility enforcement intervention per month could reduce DUI crashes in the study cities by approximately 186 per year, or 16 per month. Implementing 1 high-visibility enforcement intervention per month could mean a reduction in injury DUI crashes in study cities by approximately 55 per year, or 5 per month. Although replication in other communities is needed before determining that a threshold level for the effectiveness of these interventions has been found, these results have promising implications for cities wishing to employ similar interventions to reduce DUI crashes and injuries. Local decision makers may find that the actual cost of increasing safety is less than they had previously assumed.

#### *Implications of study results*

This dissertation continues the discussion among researchers about how much enforcement is necessary to make policies effective in reducing alcohol-related problems. In addition, this dissertation introduces an examination of factors that predict the level of alcohol policy enforcement that a community will implement. These results point to the need for additional randomized control trials focusing on dosage of specific policy enforcement strategies and intended community alcohol outcomes. While outcomes and policy strategies vary according to community needs, consistent measures of dosage and outcomes within each category of alcohol-related problem (e.g., frequency of sobriety checkpoints, rates of DUI crashes) should be used to determine necessary levels for effectiveness of specific policy enforcement interventions. It is hoped that further exploration of community characteristics that lead to adequate levels of enforcement will also be conducted. Meta-analyses of the findings of such studies produce practical recommendations to assist community decision-making regarding allocation of resources for effective alcohol policy enforcement.

## REFERENCES

1. Sudhinaraset M, Wigglesworth C, Takeuchi DT. Social and Cultural Contexts of Alcohol Use: Influences in a Social–Ecological Framework. *Alcohol Research*. 2016;38(1):35-45.
2. Sacks JJ, Gonzales KR, Bouchery EE, Tomedi LE, Brewer RD. 2010 National and State Costs of Excessive Alcohol Consumption. *American Journal of Preventive Medicine*. 2015;49(5):e73-e79. doi:10.1016/j.amepre.2015.05.031
3. Gonzales K, Roeber J, Kanny D, et al. *Alcohol-Attributable Deaths and Years of Potential Life Lost—11 States, 2006–2010*. Centers for Disease Control and Prevention; 2014:213-216.
4. World Health Organization, & World Health Organization. Management of Substance Abuse Unit. *Global Status Report on Alcohol and Health, 2014*. Geneva: World Health Organization; 2014.
5. Ayuka F, Barnett R. Place Effects on Alcohol Consumption: A Literature Review. *Journal of Addiction Research & Therapy*. 2015;06(01). doi:10.4172/2155-6105.1000207
6. Livingston M. Alcohol outlet density and harm: comparing the impacts on violence and chronic harms. *Drug Alcohol Rev*. 2011;30(5):515-523. doi:10.1111/j.1465-3362.2010.00251.x
7. Weitzman ER, Folkman A, Folkman MKL, Wechsler H. The relationship of alcohol outlet density to heavy and frequent drinking and drinking-related problems among college students at eight universities. *Health & place*. 2003;9(1):1–6. <http://www.sciencedirect.com/science/article/pii/S135382920200014X>. Accessed November 24, 2015.
8. Gruenewald, PJ. Regulating availability: how access to alcohol affects drinking and problems in youth and adults. *Alcohol Research and Health*. 2011;34(2).
9. Wagenaar AC, Toomey TL, Erickson DJ. Preventing youth access to alcohol: Outcomes from a multi-community time-series trial. *Addiction*. 2005;100(3):335-345. doi:10.1111/j.1360-0443.2005.00973.x
10. Lenk KM, Toomey TL, Erickson DJ. Propensity of alcohol establishments to sell to obviously intoxicated patrons. *Alcoholism: Clinical and Experimental Research*. 2006;30(7):1194–1199. <http://onlinelibrary.wiley.com/doi/10.1111/j.1530-0277.2006.00142.x/full>. Accessed October 17, 2016.
11. Middleton JC, Hahn RA, Kuzara JL, et al. Effectiveness of policies maintaining or restricting days of alcohol sales on excessive alcohol consumption and related harms. *Am J Prev Med*. 2010;39(6):575-589. doi:10.1016/j.amepre.2010.09.015

12. Rammohan V, Hahn RA, Elder R, et al. Effects of Dram Shop Liability and Enhanced Overservice Law Enforcement Initiatives on Excessive Alcohol Consumption and Related Harms: Two Community Guide Systematic Reviews. *American Journal of Preventive Medicine*. 2011;41(3):334-343. doi:10.1016/j.amepre.2011.06.027
13. Elder RW, Lawrence BA, Janes G, et al. Enhanced Enforcement of Laws Prohibiting Sale of Alcohol to Minors: Systematic Review of Effectiveness for Reducing Sales and Underage Drinking. *Transportation research circular*. 2007;2007(E-C123):181-188. <http://dx.doi.org/>.
14. Bergen G, Pitan A, Qu S, et al. Publicized Sobriety Checkpoint Programs. *American Journal of Preventive Medicine*. 2014;46(5):529-539. doi:10.1016/j.amepre.2014.01.018
15. Shults RA, Elder RW, Sleet DA, et al. Reviews of evidence regarding interventions to reduce alcohol-impaired driving. *American Journal of Preventive Medicine*. 2001;21(4, Supplement 1):66-88. doi:10.1016/S0749-3797(01)00381-6
16. Campbell CA, Hahn RA, Elder R, et al. The Effectiveness of Limiting Alcohol Outlet Density As a Means of Reducing Excessive Alcohol Consumption and Alcohol-Related Harms. *American Journal of Preventive Medicine*. 2009;37(6):556-569. doi:10.1016/j.amepre.2009.09.028
17. Elder RW, Lawrence B, Ferguson A, et al. The effectiveness of tax policy interventions for reducing excessive alcohol consumption and related harms. *Am J Prev Med*. 2010;38(2):217-229. doi:10.1016/j.amepre.2009.11.005
18. Babor T, ed. *Alcohol: No Ordinary Commodity: Research and Public Policy*. Oxford ; New York: Oxford University Press; 2010.
19. Holder HD. Community prevention of alcohol problems. *Addictive behaviors*. 2000;25(6):843–859. /pii/S0306460300001210. Accessed September 18, 2016.
20. Marchese di Beccaria C. An essay on crimes and punishments. 1819. <http://www.thefederalistpapers.org/>. Accessed December 2, 2016.
21. Nagin DS. Deterrence in the twenty-first century. *Crime and Justice*. 2013;42(1):199–263. <http://www.journals.uchicago.edu/doi/abs/10.1086/670398>. Accessed April 11, 2017.
22. Voas R, Fell J. Commentary on Yao et al.(2016): Enforcement uniquely predicts reductions in alcohol-impaired crash fatalities. *Addiction*. 2016;111(3):454–455. <http://onlinelibrary.wiley.com/doi/10.1111/add.13275/full>. Accessed May 26, 2016.
23. Johnson MB. A successful high visibility enforcement intervention targeting underage drinking drivers: Underage drinking and driving intervention. *Addiction*. February 2016:n/a-n/a. doi:10.1111/add.13346



24. Holder HD. Planning for Alcohol-Problem Prevention through Complex Systems Modeling: Results from SimCom. *Substance Use & Misuse*. 1998;33(3):669-692. doi:10.3109/10826089809115890
25. Legrand K, Bonsergent E, Latache C, et al. Intervention dose estimation in health promotion programmes: a framework and a tool. Application to the diet and physical activity promotion PRALIMAP trial. *BMC medical research methodology*. 2012;12(1):146.
26. Issel LM. *Health Program Planning and Evaluation: A Practical and Systematic Approach for Community Health*. 2nd ed. Sudbury, Mass: Jones and Bartlett Publishers; 2009.
27. Warren SF, Fey ME, Yoder PJ. Differential treatment intensity research: A missing link to creating optimally effective communication interventions. *Mental Retardation and Developmental Disabilities Research Reviews*. 2007;13(1):70-77. doi:10.1002/mrdd.20139
28. Fixsen, D.L., Naoom, S.F., Friedman, K. A., Blase´, R. M., Wallace, F. *Implementation Research: A Synthesis of the Literature*. Tampa, FL: University of South Florida, Louis de la Parte Florida Mental Health Institute, The National Implementation Research Network; 2005.
29. Dodson EA, Brownson RC, Weiss SM. Policy dissemination research. In: *Dissemination and Implementation Research in Health*. Oxford University Press; 2012:437-458.
30. Durlak JA, DuPre EP. Implementation Matters: A Review of Research on the Influence of Implementation on Program Outcomes and the Factors Affecting Implementation. *American Journal of Community Psychology*. 2008;41(3-4):327-350. doi:10.1007/s10464-008-9165-0
31. Stith S, Pruitt I, Dees J, et al. Implementing Community-Based Prevention Programming: A Review of the Literature. *The Journal of Primary Prevention*. 2006;27(6):599-617. doi:10.1007/s10935-006-0062-8
32. Rosenbaum DP. Evaluating multi-agency anti-crime partnerships: Theory, design, and measurement issues. *Crime prevention studies*. 2002;14:171–225. [http://www.popcenter.org/library/crimeprevention/volume\\_14/06-Rosenbaum.pdf](http://www.popcenter.org/library/crimeprevention/volume_14/06-Rosenbaum.pdf). Accessed April 7, 2017.
33. Center for Community Health and Evaluation. Measuring and Increasing the “Dose” of Community Health Interventions. June 2012. [www.cche.org](http://www.cche.org). Accessed October 16, 2016.
34. Cheadle A, Rauzon S, Spring R, et al. Kaiser Permanente’s Community Health Initiative in Northern California: Evaluation Findings and Lessons Learned.

*American Journal of Health Promotion*. 2012;27(2):e59-e68.  
doi:10.4278/ajhp.111222-QUAN-462

35. Giesbrecht N. Reducing alcohol-related damage in populations: rethinking the roles of education and persuasion interventions. *Addiction*. 2007;102(9):1345–1349. <http://onlinelibrary.wiley.com/doi/10.1111/j.1360-0443.2007.01903.x/pdf>. Accessed November 23, 2015.
36. Holder HD, Saltz RF, Grube JW, et al. Summing up: Lessons from a comprehensive community prevention trial. *Addiction*. 1997;92(6s1):293–302. <http://onlinelibrary.wiley.com/doi/10.1046/j.1360-0443.92.6s1.11.x/full>. Accessed November 19, 2015.
37. Paschall MJ, Lipperman-Kreda S, Grube JW. Effects of the local alcohol environment on adolescents' drinking behaviors and beliefs: Local alcohol environment and youth drinking. *Addiction*. 2014;109(3):407-416. doi:10.1111/add.12397
38. Task Force on Community Preventive Services. Increasing alcoholic beverage taxes is recommended to reduce excessive alcohol consumption and related harms. *Am J Prev Med*. 2010;38(2):230-232. doi:10.1016/j.amepre.2009.11.002
39. Task Force on Community Preventive Services. Recommendations on dram shop liability and overservice law enforcement initiatives to prevent excessive alcohol consumption and related harms. *Am J Prev Med*. 2011;41(3):344-346. doi:10.1016/j.amepre.2011.05.024
40. Wechsler H, Kuo M, Lee H, Dowdall GW. Environmental correlates of underage alcohol use and related problems of college students. *American journal of preventive medicine*. 2000;19(1):24–29. <http://www.sciencedirect.com/science/article/pii/S074937970000163X>. Accessed November 24, 2015.
41. Xuan Z, Nelson TF, Heeren T, et al. Tax policy, adult binge drinking, and youth alcohol consumption in the United States. *Alcohol Clin Exp Res*. 2013;37(10):1713-1719. doi:10.1111/acer.12152
42. Martineau F, Tyner E, Lorenc T, Petticrew M, Lock K. Population-level interventions to reduce alcohol-related harm: An overview of systematic reviews. *Preventive Medicine*. 2013;57(4):278-296. doi:10.1016/j.ympmed.2013.06.019
43. Erickson DJ, Lenk KM, Toomey TL, Nelson TF, Jones-Webb R. The alcohol policy environment, enforcement and consumption in the United States: Alcohol policy, enforcement, and consumption. *Drug and Alcohol Review*. 2016;35(1):6-12. doi:10.1111/dar.12339
44. Paschall MJ, Grube JW, Thomas S, Cannon C, Treffers R. Relationships between local enforcement, alcohol availability, drinking norms, and adolescent alcohol use

- in 50 California cities. *Journal of studies on alcohol and drugs*. 2012;73(4):657–665.
45. Sanem JR, Erickson DJ, Rutledge PC, et al. Association between alcohol-impaired driving enforcement-related strategies and alcohol-impaired driving. *Accident Analysis & Prevention*. 2015;78:104-109. doi:10.1016/j.aap.2015.02.018
  46. Shinar D, McKnight AJ. The effects of enforcement and public information on compliance. In: *Human Behavior and Traffic Safety*. Springer; 1985:385–419. [http://link.springer.com/chapter/10.1007/978-1-4613-2173-6\\_17](http://link.springer.com/chapter/10.1007/978-1-4613-2173-6_17). Accessed May 18, 2016.
  47. Wagenaar AC, Toomey TL, Erickson DJ. Complying With the Minimum Drinking Age: Effects of Enforcement and Training Interventions: *Alcoholism: Clinical & Experimental Research*. 2005;29(2):255-262. doi:10.1097/01.ALC.0000153540.97325.3A
  48. Wagenaar AC, Wolfson M. Deterring sales and provision of alcohol to minors: a study of enforcement in 295 counties in four states. *Public health reports*. 1995;110(4):419. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1382151/>. Accessed May 18, 2016.
  49. Werb D, Rowell G, Guyatt G, Kerr T, Montaner J, Wood E. Effect of drug law enforcement on drug market violence: A systematic review. *International Journal of Drug Policy*. 2011;22(2):87-94. doi:10.1016/j.drugpo.2011.02.002
  50. Yao J, Johnson MB, Tippetts S. Enforcement uniquely predicts reductions in alcohol-impaired crash fatalities: Enforcement predicts reductions in fatalities. *Addiction*. 2016;111(3):448-453. doi:10.1111/add.13198
  51. Warpenius K, Holmila M, Mustonen H. Effects of a community intervention to reduce the serving of alcohol to intoxicated patrons: Community intervention on licensed premises. *Addiction*. 2010;105(6):1032-1040. doi:10.1111/j.1360-0443.2009.02873.x
  52. Fell JC, Waehrer G, Voas RB, Auld-Owens A, Carr K, Pell K. Effects of enforcement intensity on alcohol impaired driving crashes. *Accident Analysis & Prevention*. 2014;73:181-186. doi:10.1016/j.aap.2014.09.002
  53. Elder RW, Shults RA, Sleet DA, Nichols JL, Thompson RS, Rajab W. Effectiveness of mass media campaigns for reducing drinking and driving and alcohol-involved crashes. *American Journal of Preventive Medicine*. 2004;27(1):57-65. doi:10.1016/j.amepre.2004.03.002
  54. Thomas FD, Blomberg RD, Peck RC, Cosgrove LA, Salzberg PM. Evaluation of a high visibility enforcement project focused on passenger vehicles interacting with commercial vehicles. *Journal of Safety Research*. 2008;39(5):459-468. doi:10.1016/j.jsr.2008.07.004

55. Van Houten R, Malenfant L, Huitema B, Blomberg R. Effects of High-Visibility Enforcement on Driver Compliance with Pedestrian Yield Right-of-Way Laws. *Transportation Research Record: Journal of the Transportation Research Board*. 2013;2393:41-49. doi:10.3141/2393-05
56. Piontkowski SR, Peabody JS, Reede C, et al. Reducing motor vehicle-related injuries at an Arizona Indian reservation: ten years of application of evidence-based strategies. *Global Health: Science and Practice*. 2015;3(4):619–629. <http://www.ghspjournal.org/content/3/4/619.abstract>. Accessed July 11, 2016.
57. Dula CS, Dwyer WO, LeVerne G. Policing the drunk driver: Measuring law enforcement involvement in reducing alcohol-impaired driving. *Journal of Safety Research*. 2007;38(3):267-272. doi:10.1016/j.jsr.2006.10.007
58. Elvik R. *Cost-Benefit Analysis of Police Enforcement.*; 2001.
59. Tay R. General and specific deterrent effects of traffic enforcement: do we have to catch offenders to reduce crashes? *Journal of Transport Economics and Policy (JTEP)*. 2005;39(2):209–224. <http://www.ingentaconnect.com/content/lse/jtep/2005/00000039/00000002/art00005>. Accessed August 10, 2016.
60. Fell JC, Waehrer G, Voas RB, Auld-Owens A, Carr K, Pell K. Relationship of Impaired-Driving Enforcement Intensity to Drinking and Driving on the Roads. *Alcoholism: Clinical and Experimental Research*. 2015;39(1):84-92. doi:10.1111/acer.12598
61. Ferris J, Devaney M, Sparkes-Carroll M, Davis G. *A National Examination of Random Breath Testing and Alcohol-Related Traffic Crash Rates*. Canberra: Foundation for Alcohol Research and Education.; 2015.
62. Lenk KM, Nelson TF, Toomey TL, Jones-Webb R, Erickson DJ. Sobriety checkpoint and open container laws in the United States: Associations with reported drinking-driving. *Traffic Injury Prevention*. 2016;17(8):782-787. doi:10.1080/15389588.2016.1161759
63. Meesmann U, Martensen H, Dupont E. Impact of alcohol checks and social norm on driving under the influence of alcohol (DUI). *Accident Analysis & Prevention*. 2015;80:251-261. doi:10.1016/j.aap.2015.04.016
64. Ramirez R, Nguyen D, Cannon C, Carmona M, Freisthler B. *A Campaign to Reduce Impaired Driving through Retail-Oriented Enforcement in Washington State*. United States: National Highway Traffic Safety Administration.; 2008.
65. Flewelling RL, Grube JW, Paschall MJ, et al. Reducing Youth Access to Alcohol: Findings from a Community-Based Randomized Trial. *American Journal of Community Psychology*. 2013;51(1-2):264-277. doi:10.1007/s10464-012-9529-3

66. Saltz RF, Paschall MJ, McGaffigan RP, Nygaard PMO. Alcohol Risk Management in College Settings. *American Journal of Preventive Medicine*. 2010;39(6):491-499. doi:10.1016/j.amepre.2010.08.020
67. Erickson DJ, Rutledge PC, Lenk KM, Nelson TF, Jones-Webb R, Toomey TL. Patterns of alcohol policy enforcement activities among local law enforcement agencies: A latent class analysis. *The International Journal of Alcohol and Drug Research*. 2015;4(2):103. doi:10.7895/ijadr.v4i2.204
68. Barry R, Edwards E, Pelletier A, et al. Enhanced enforcement of laws to prevent alcohol sales to underage persons-New Hampshire, 1999-2004 (Reprinted from MMWR, vol 53, pg 452-454, 2004). *JAMA*. 2004;292(5):561-562. doi:10.1001/jama.292.5.561
69. Erickson DJ, Smolenski DJ, Toomey TL, Carlin BP, Wagenaar AC. Do alcohol compliance checks decrease underage sales at neighboring establishments? *Journal of studies on alcohol and drugs*. 2013;74(6):852. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3817047/>. Accessed July 10, 2016.
70. Schelleman-Offermans K, Knibbe RA, Kuntsche E, Casswell S. Effects of a Natural Community Intervention Intensifying Alcohol Law Enforcement Combined With a Restrictive Alcohol Policy on Adolescent Alcohol Use. *Journal of Adolescent Health*. 2012;51(6):580-587. doi:10.1016/j.jadohealth.2012.03.006
71. Scribner R, Cohen D. The effect of enforcement on merchant compliance with the minimum legal drinking age law. *Journal of Drug Issues*. 2001;31(4):857-866. <http://jod.sagepub.com/content/31/4/857.short>. Accessed July 11, 2016.
72. McKnight AJ, Streff FM. The effect of enforcement upon service of alcohol to intoxicated patrons of bars and restaurants. *Accident Analysis and Prevention*. 1994;26(1):79-88. doi:10.1016/0001-4575(94)90070-1
73. Mosher J, Hauck A. *Legal Research Report: Laws Prohibiting Alcohol Sales to Intoxicated Persons.*; 2009.
74. Bonnie RJ, O'Connell ME, National Research Council (U.S.), Committee on Developing a Strategy to Reduce and Prevent Underage Drinking. *Reducing Underage Drinking a Collective Responsibility*. Washington, DC: National Academies Press; 2003. <http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=102001>. Accessed November 23, 2015.
75. Rammohan V, Hahn RA, Elder R, et al. Effects of Dram Shop Liability and Enhanced Overservice Law Enforcement Initiatives on Excessive Alcohol Consumption and Related Harms. *American Journal of Preventive Medicine*. 2011;41(3):334-343. doi:10.1016/j.amepre.2011.06.027

76. Holder HD, Gruenewald PJ, Ponicki WR, et al. Effect of community-based interventions on high-risk drinking and alcohol-related injuries. *Jama*. 2000;284(18):2341–2347. <http://jama.jamanetwork.com/article.aspx?articleid=193252>. Accessed May 26, 2016.
77. Wolfson M, Champion H, McCoy TP, et al. Impact of a Randomized Campus/Community Trial to Prevent High-Risk Drinking Among College Students. *Alcoholism: Clinical and Experimental Research*. 2012;36(10):1767-1778. doi:10.1111/j.1530-0277.2012.01786.x
78. Beaglehole R, Bonita R. Alcohol: a global health priority. *The Lancet*. 2009;373(9682):2173–2174.
79. Erickson DJ, Lenk KM, Toomey TL, Nelson TF, Jones-Webb R. The alcohol policy environment, enforcement and consumption in the United States. *Drug and alcohol review*. 2016;35(1):6–12.
80. Wolfson M, Champion H, Rogers T, et al. Evaluation of Free to Grow: Head Start Partnerships to Promote Substance-Free Communities. *Evaluation Review*. 2011;35(2):153-188. doi:10.1177/0193841X11403989
81. Herd D. Voices from the field: The social construction of alcohol problems in inner-city communities. *Contemporary Drug Problems*. 2011;38(1):7–39. <http://cdx.sagepub.com/content/38/1/7.short>. Accessed April 7, 2017.
82. Herd D. Community Mobilization and the Framing of Alcohol-Related Problems. *International Journal of Environmental Research and Public Health*. 2010;7(3):1226-1247. doi:10.3390/ijerph7031226
83. Herd D, Berman J. Mobilizing for Change: Activism and Alcohol Policy Issues in Inner City Communities. *Social Movement Studies*. 2015;14(3):331-351. doi:10.1080/14742837.2014.945073
84. *Fairness and Effectiveness in Policing: The Evidence*. Washington, D.C.: National Academies Press; 2004. doi:10.17226/10419
85. Weisburd D, Eck JE. What Can Police Do to Reduce Crime, Disorder, and Fear? *The ANNALS of the American Academy of Political and Social Science*. 2004;593(1):42-65. doi:10.1177/0002716203262548
86. Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). *Health Behavior and Health Education: Theory, Research, and Practice*. John Wiley & Sons.; 2008.
87. Gajda R. Utilizing collaboration theory to evaluate strategic alliances. *American journal of evaluation*. 2004;25(1):65–77.

88. Lasker, R. D., Weiss, E. S., Miller, R. Partnership synergy: a practical framework for studying and strengthening the collaborative advantage. *The Milbank Quarterly*. 79(2):179-205.
89. Mandarano LA. Evaluating Collaborative Environmental Planning Outputs and Outcomes: Restoring and Protecting Habitat and the New York—New Jersey Harbor Estuary Program. *Journal of Planning Education and Research*. 2008;27(4):456-468. doi:10.1177/0739456X08315888
90. Collins SE. Associations between socioeconomic factors and alcohol outcomes. *Alcohol research: current reviews*. 2016;38(1):83.
91. Keyes KM, Liu XC, Cerda M. The Role of Race/Ethnicity in Alcohol-attributable Injury in the United States. *Epidemiologic Reviews*. 2012;34(1):89-102. doi:10.1093/epirev/mxr018
92. StataCorp. *Stata Statistical Software*. College Station, TX: StataCorp LLC; 2017.
93. Rabe-Hesketh S, Skrondal A. *Multilevel and Longitudinal Modeling Using Stata*. STATA press; 2008.
94. National Academies of Sciences, Engineering, and Medicine. *Getting to Zero Alcohol-Impaired Driving Fatalities: A Comprehensive Approach to a Persistent Problem*. Washington, D.C.: The National Academies Press; 2018. doi: <https://doi.org/10.17226/24951>.
95. Fell JC, Voas RB. The effectiveness of reducing illegal blood alcohol concentration (BAC) limits for driving: Evidence for lowering the limit to .05 BAC. *Journal of Safety Research*. 2006;37(3):233-243. doi:10.1016/j.jsr.2005.07.006
96. Yadav R-P, Kobayashi M. A systematic review: effectiveness of mass media campaigns for reducing alcohol-impaired driving and alcohol-related crashes. *BMC Public Health*. 2015;15(1). doi:10.1186/s12889-015-2088-4
97. Shults RA, Elder RW, Nichols JL, Sleet DA, Compton R, Chattopadhyay SK. Effectiveness of Multicomponent Programs with Community Mobilization for Reducing Alcohol-Impaired Driving. *American Journal of Preventive Medicine*. 2009;37(4):360-371. doi:10.1016/j.amepre.2009.07.005
98. Elder RW, Shults RA, Sleet DA, Nichols JL, Zaza S, Thompson RS. Effectiveness of Sobriety Checkpoints for Reducing Alcohol-Involved Crashes. *Traffic Injury Prevention*. 2002;3(4):266-274. doi:10.1080/15389580214623
99. Atienza AA. Community-based Health Intervention Trials: An Overview of Methodological Issues. *Epidemiologic Reviews*. 2002;24(1):72-79. doi:10.1093/epirev/24.1.72