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# **Synthesis of Studies That Relate Amount of Enforcement to Magnitude Of Safety Outcomes**

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16. Abstract This report covers the findings of a research project carried out by the Volpe Center on behalf of NHTSA and the Governors Highway Safety Association (GHSA) under the National Cooperative Research and Evaluation Program (NCREP), which identifies and funds research and evaluation projects for improving and expanding State highway safety countermeasures. One such topic identified is measuring the impact of various amounts of traffic enforcement on changes in safety outcomes. The project team identified 80 relevant studies for inclusion in the synthesis. Current literature only supported findings related to occupant protection enforcement. No relationship between levels of enforcement and safety outcomes could be identified for distracted driving, alcohol-impaired driving, speeding, or aggressive driving. However, for all targeted behaviors, the enforcement campaigns evaluated in the available literature were effective in improving safety outcomes even though the combination of these evaluations could not provide sufficient evidence to establish a relationship between the level of resources used and the magnitude of the safety improvement.			
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## **Introduction**

While there has been much published research showing that traffic safety enforcement reduces unsafe driving behavior and crashes, there has been very little research on the relationship between the intensity or amount of enforcement and the magnitude of observed safety impacts. This study seeks to fill that information gap by investigating the research question: What is the impact of various amounts of enforcement on safety outcomes? In other words, how much change in prohibited driving behaviors could one expect in a particular jurisdiction by increasing enforcement by a specific amount?

To examine the relationship between the amount or intensity of enforcement activities and the magnitude of changes in safety outcomes, the project endeavored to find all available studies that evaluated the impact of individual traffic safety enforcement in terms of safety outcome measures. The research team extracted information describing the amount of enforcement and the resulting changes in safety outcomes to attempt to identify a dose-response relationship between them.

This report is a summary of the main findings related to this research effort and is intended for highway safety practitioners. Additional details on the data, data collection methods, and analysis techniques used in this research can be found in the separate Technical Appendix document.

## Literature Review

The project team searched for all available studies that contained information regarding the relationship between levels of traffic enforcement and safety outcomes. Ideally, the collected observations would represent a wide range of enforcement levels for estimating the impact of different amounts of additional enforcement on safety outcomes.

### Focus on Certain Targeted Behaviors

In practice, traffic safety enforcement campaigns tend to target specific driving behaviors. This research focuses on enforcement that target occupant protection, alcohol-impaired driving, distracted driving, speeding, and aggressive driving. These driving behaviors are the among the most common focus of grant funding provided under Sections 402 and 405 of Title 23, U.S. Code. These behaviors also represent major safety issues that contribute to significant numbers of traffic fatalities. The list below provides brief descriptions of these driving behaviors:

- *Occupant protection*: Occupant protection relates to the use of seat belts by older children and adults and the proper use of car seats and booster seats by infants and younger children.
- *Distracted driving*: Distracted driving refers to any activity that diverts attention from the driving task; however, in practice, enforcement targets observable forms of distraction, such as texting and handheld cell phone use.
- *Alcohol-impaired driving*: Alcohol-impaired driving is distinct from generally impaired driving which can include other types of prescription or illegal drugs. Targeting of alcohol-impaired driving seeks to reduce the number of alcohol-related crashes and the number of drivers with alcohol in their systems above certain thresholds (for adults, during the time of the research, a blood alcohol concentration of .08 g/dL; for younger drivers, the limits vary by State).
- *Speeding*: Speeding is a type of aggressive driving behavior characterized by driving faster than the posted speed limit, or driving at or below the speed limit, but traveling too fast for roadway conditions (NCSA, 2018).
- *Aggressive driving*: Aggressive driving is defined as operating a motor vehicle in a selfish, pushy, or impatient manner that directly affects other drivers, often unsafely (Neuman et al., 2003).

### Literature Search

The team developed an extensive list of search terms to focus on the targeted behaviors. The purpose of the search was to identify studies that provided evaluations of specific enforcement that included quantitative information on the safety outcomes as well as the level of enforcement used in the effort. Through an iterative process, the list of search terms was determined to return *all* available potentially relevant literature on these topics to avoid potential bias in the data collection effort. A total of 15,254 studies were identified. After several levels of screening, based first on the title and key words, then abstracts, and last the entire text of the study, 80 studies were deemed relevant for inclusion in this synthesis.

## **Data Extraction**

The research team extracted relevant data from each study including the levels of enforcement activities, the measurement of the change in safety outcomes, the context of the enforcement effort (the time frame, the strategy employed, the jurisdiction), and the evaluation methodology.

The topic of traffic safety enforcement covers a variety of enforcement activities such as patrols, spotters, checkpoints, and publicity of those activities. High-visibility enforcement (HVE) is a strategy uses a variety of enforcement. It emphasizes publicity of the enforcement effort to deter the public from the prohibited (illegal) behavior. In the literature various measures of these enforcement activities were used, including simple counts (such as number of checkpoints), officer enforcement hours, and/or dollars spent for either officer wages or paid media.

## **Study Challenges**

The available evaluations of enforcement varied in measures and metrics to describe both the safety outcomes and the intensity of the enforcement (see Elvik, 2001). This variety of measures presented a challenge because it is not possible to compare the results of one study to the results of other studies if they are not expressed in the same units.

Additionally, even after screening studies and keeping only ones that appeared to report information on the levels of enforcement and measurements of safety outcomes, the study team found that several studies failed to report key pieces of information. To evaluate the effectiveness of an enforcement effort focused on a specific behavior, at a specific place, and for a specific length of time, it is typical for a study to report metrics describing a baseline safety outcome that was measured prior to the enforcement and compare it to the same metric as measured during and/or after the effort. However, information on the baseline level of enforcement was often missing in the available studies. Without this information to compare to baseline safety levels, it is difficult to develop a complete understanding of the relationship between safety outcomes and levels of enforcement.

Finally, studies used different research methods. For example, some studies only reported safety outcomes before and after enforcement, while others used large amounts of data to model the relationship using different control variables or different model specifications. Therefore, the results may not be directly comparable across studies. Challenges more specifically related to the targeted behaviors are discussed in the next sections.



## Results

The following sections present the results of the synthesis for each of the targeted behaviors described previously. The available literature only supported findings for occupant protection enforcement and safety impacts. The synthesis could not identify a relationship between levels of enforcement and safety outcomes for distracted driving, alcohol-impaired driving, speeding, or aggressive driving. However, for all targeted behaviors, the enforcement campaigns evaluated in the available literature are generally effective in improving safety outcomes, even though this synthesis could not link the level of resources used in enforcement to the magnitude of the safety improvement. The list below summarizes all the findings in the synthesis by behavior. These results are discussed in more detail below.

### Occupant protection

- HVE improved seat belt use.
- One additional checkpoint per 100,000 people per week in an HVE occupant protection campaign is expected to increase seat belt use by 0.76 percentage points.
- For enforcement conducted from 1993 to 2008, increasing media spending by \$1 per 1,000 residents in HVE campaigns increased seat belt use by 0.011 percentage points.
- No statistically significant relationship between number of officer enforcement hours and changes in seat belt use or between increased media spending after 2008 and changes in seat belt use.

### Distracted driving

- HVE is effective at reducing handheld phone use.
- No relationship between magnitude of safety outcomes and level of enforcement could be identified.

### Alcohol-impaired driving

- Enforcement targeting alcohol-impaired driving produced positive outcomes.
- Due to lack of comparable data across studies, no relationship between magnitude of safety outcomes and level of enforcement could be identified.

### Speeding

- Speeding enforcement focused on work zones produced average decreases in speed of approximately 4 mph.
- Across studies, it was not possible to investigate a possible relationship between levels or intensity of enforcement and the magnitude of change in speeding behavior.

### Aggressive driving

- Overall, the available studies indicate that the TACT program, “Ticketing Aggressive Cars and Trucks” is effective.
- It was not possible to investigate a possible relationship between levels or intensity of enforcement to the magnitude of change in aggressive driving behavior.

## Occupant Protection

Of the 80 studies identified as relevant to this research, 38 studies focused on the effect of police enforcement strategies on occupant protection. Some studies evaluated enforcement in different locations, and some evaluated waves of the same enforcement campaign at one location. This means that a single study might have relevant data points.

The following highlights the key findings related to occupant protection, including the impact of additional checkpoints, additional officer enforcement hours, and higher levels of media spending.

- **Overall, the HVE evaluated in the available literature improved seat belt use.**

HVE campaigns were generally successful, producing on average a 3.5-percentage-point improvement in seat belt use rates. Thus, the average pre-enforcement seat belt use rate of 77.9 percent would be expected to increase to 81.4 percent post-enforcement. Note that these pre- and post-enforcement seat belt use rates were estimated based on observations typically a week or two prior to the enforcement campaign and a week or two following the enforcement campaign. Accordingly, this finding only applies to the same time frame, and longer-lasting or sustained effects on seat belt use cannot be inferred based on the available literature.

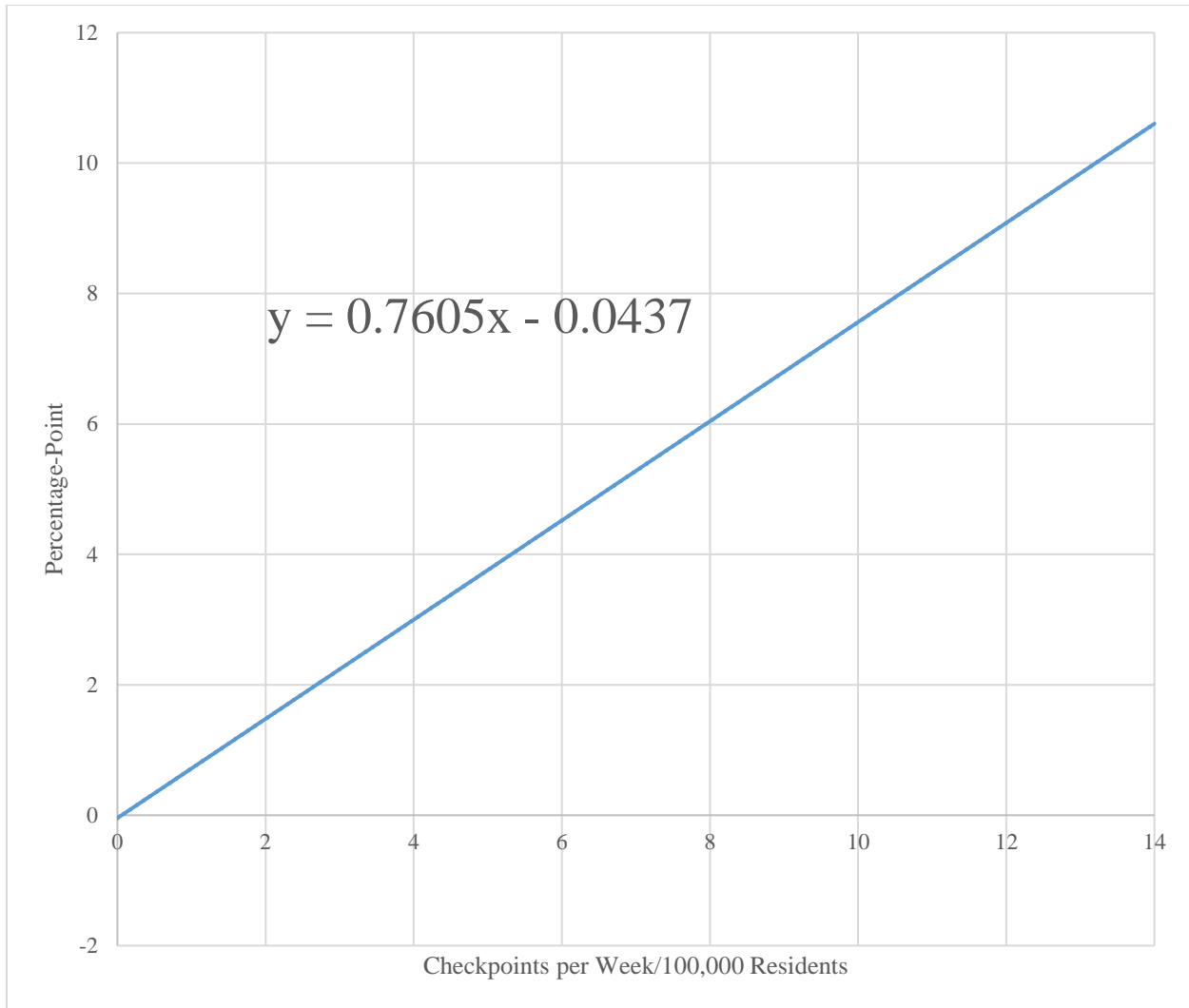
- **One additional checkpoint per 100,000 people per week in an HVE occupant protection campaign is expected to increase seat belt use by 0.76 percentage points.**

A linear regression based on 23 data points from 6 studies was used to explore whether the magnitude of the change in seat belt use rates could be linked to the number of checkpoints used in the enforcement. The regression identified a positive and statistically significant relationship between number of checkpoints and percentage-point changes in seat belt use rates, while controlling for amount of paid media, baseline levels of seat belt use, and a time trend.<sup>1</sup> Figure 1 shows the relationship between expected changes in seat belt use and number of checkpoints per week.

These results should only be considered valid within the range present in the analysis dataset. In the dataset the average value for checkpoints per 100,000 residents per week was 2.9, although most enforcement had fewer than 2 checkpoints per 100,000 residents per week. The impact of changing from 0.4 checkpoints per 100,000 residents per week (the 25th percentile value in the analysis dataset) to 2.4 checkpoints per 100,000 residents per week (the 75th percentile value) is expected to be a 1.5-percentage-point increase in seat belt use. Note that these studies tended to omit information on whether any checkpoints were conducted under baseline conditions prior to the enforcement campaign being evaluated. Thus, these results apply specifically to the impact of special enforcement and do not apply when considering on-going levels of enforcement. In addition, this result describes the impact on seat belt use rates *while* the enforcement campaign is underway or shortly after. The available literature did not explore the lasting impact of the campaigns after they had concluded.

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<sup>1</sup> In this and other regressions estimated as part of this research, a time trend is used to control for general changes in the effectiveness of enforcement campaigns over time.



*Note:* The model controls for other variables, including a time trend, media spending, and the baseline level of seat belt use although these control variables are not statistically significant.

*Figure 1. Relationship between checkpoints per week per 100,000 residents and the estimated percentage-point change in seat belt use, holding other variables from the regression analysis constant at their average values*

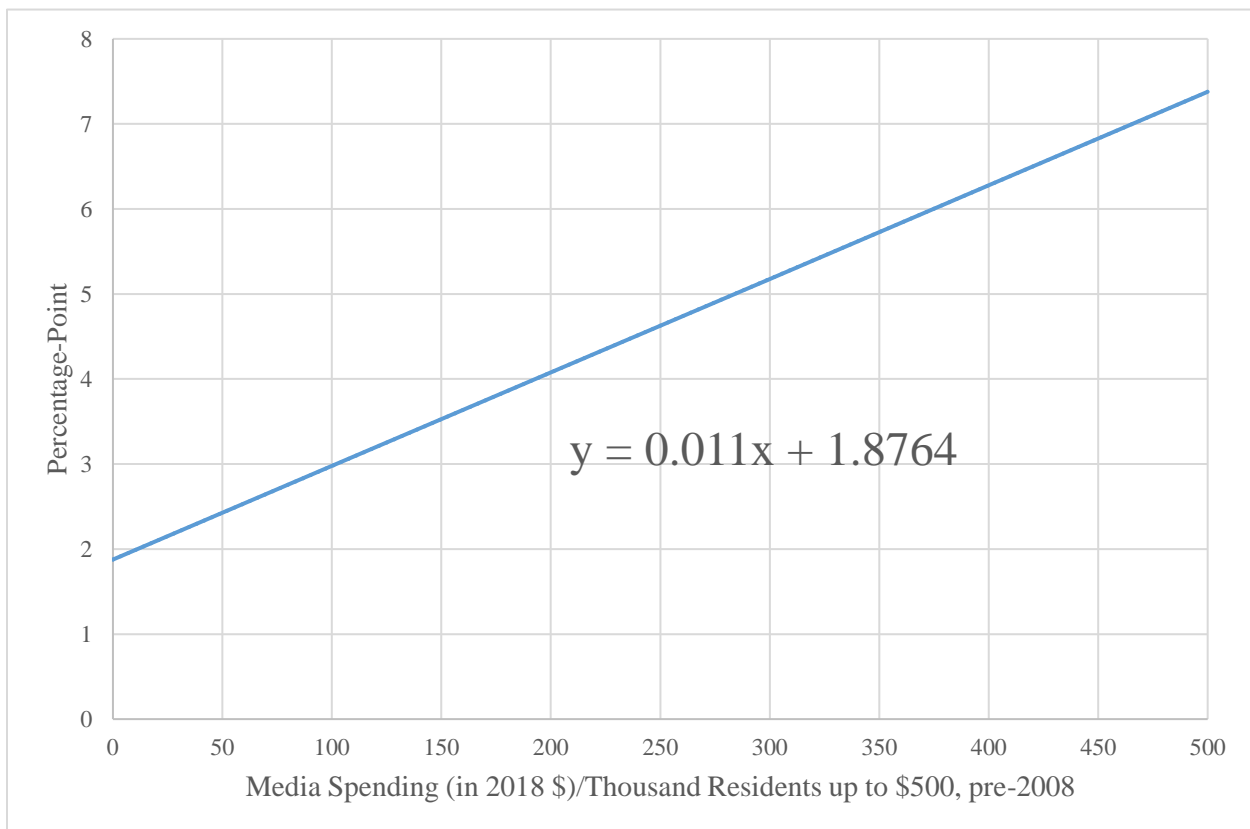
- **A statistically significant relationship between number of officer enforcement hours and changes in seat belt use could not be identified with the available data.**

The synthesis attempted to identify a relationship between the number of officer enforcement hours used during the effort and the change in seat belt use based on the 10 studies that reported the necessary information. These officer hours of enforcement only cover the additional hours used specifically for this enforcement program; these hours do not account for the baseline level of hours used during routine law enforcement activities. The study team used a linear regression to explore whether the magnitude of the change in seat belt use rates could be linked to the size or intensity of the enforcement effort. The linear regression found no statistically significant relationship between hours of enforcement and percentage-point changes in seat belt use rates, in part because of the variation in outcomes. However, overall, these studies resulted in positive

increases in seat belt use, indicating that these campaigns were effective in increasing seat belt use.

- **For enforcement conducted from 1993 to 2008, increasing media spending by \$1 per 1,000 residents in an HVE campaign increased seat belt use by 0.011 percentage points.**

A linear regression tested the effect of media spending across 89 wave-level results (several studies examined programs in several locations and over several waves). The analysis found that each additional cent (\$0.01) per resident spent on media up to 50 cents (\$0.50) increased seat belt use by an additional 0.11 percentage points. The statistically significant impact of increasing media was only detected for the period 1993 to 2008 and only for spending amounts less than \$0.50 per resident. Extrapolating to a fictional town of 100,000 people, for each additional \$9,091 (or \$0.09 per person) spent in an enforcement effort, seat belt use rates would increase by 1 percentage point. Note that the amount of money spent above \$500 per thousand people was not found to increase seat belt use, suggesting that spending more than 50 cents per resident produces no additional impact on safety outcomes beyond the first 50 cents per resident. Figure 2 shows the relationship between expected changes in seat belt use and levels of media spending up to \$500 per thousand people for efforts conducted prior to 2008.



*Note:* The model controls for other variables, including a time trend, the baseline level of seat belt use, and the type of enforcement. These control variables are statistically significant. Other control variables of media spending over \$500 per 1,000 residents and media spending post-2008 are not statistically significant.

*Figure 2. Relationship between media dollars spent (in 2018 dollars) per thousand residents up to \$500 prior to 2008 and the estimated percentage-point change in seat belt use, holding other variables in the regression analysis constant at their average value.*

It is difficult to know why an impact from increased media spending was not observed after 2008. The nature of the available data is one factor that may explain the result. After 2008 in the literature examined in this study, the amounts spent on media were confined to a small range and were on the lower end of amounts spent prior to 2008. Thus, there is not much variation among studies related to media spending from which to determine a relationship with safety outcomes. Another possibility is that the impact of currently used safety messages spread through paid media has diminished over time. Some research suggests that no one message can appeal to all audiences (Schmid et al., 2008). Therefore, the next generation of safety messages may need to be tailored to specific audiences (see Thomas et al., 2016). The estimated dose-response curve controlled for the category of enforcement effort (checkpoints only; patrols only; checkpoints and patrols; and safety zones), pre-enforcement level of seat belt use, and a time trend to control for external factors that could be changing over time and influencing the results of these studies.

This finding is based on 27 studies that provided a dollar value for paid media, producing the 89 wave-level results. These estimates are based on study locations where the baseline seat belt use typically ranged between 66 percent and 87 percent. In using these results they should likewise be applied only in contexts with similar baseline levels of use.

- **Occupant protection enforcement campaigns are *more effective* in places with *lower* rates of seat belt use.**

The analysis of the impact of paid media supporting occupant protection enforcement campaigns found that, controlling for the amount of media, the category of enforcement effort (checkpoints only; patrols only; checkpoints and patrols; and safety zones), and a time trend, locations that had a lower baseline level of seat belt use experienced larger improvements in seat belt use than those with a higher baseline. For example, a typical occupant protection program in a town where the baseline use is 70 percent would produce a 0.88-percentage-point larger increase than a town where the baseline use is 80 percent.

## **Distracted Driving**

There is limited literature available on the impact of distracted driving enforcement. Five distracted driving studies analyzing 6 enforcement locations were available for inclusion in the synthesis. The enforcement included statewide initiatives and efforts aimed at a single town, complicating the attempt to compare results across studies.

- **Overall, HVE efforts are effective at reducing handheld phone use.**

The literature summarized in Table 1 shows that HVE efforts reduce drivers' handheld phone use rates by amounts ranging from 18 to 56 percent. Baseline handheld phone use rates averaged 4.9 percent across the available study locations, and HVE reduced drivers' handheld phone use an average of 1.7 percentage points. Note that 1.7 percentage points, while perhaps seemingly small, is a decrease of 35 percent in the baseline rate, from 4.9 percent to 3.2 percent.

Table 1. Dedicated Hours of Distracted-Driving Enforcement

Location	Dedicated Hours of Enforcement per 1,000 Residents	Total Paid Media per 1,000 Residents (2018\$)	Handheld Phone Use Pre-Wave 1	Handheld Phone Use Post-Final Wave	Change Pre-to-Post-Final Wave
Towns in Connecticut	21.21	\$0.00	2.7%	1.6%	-41%
Delaware	8.05	\$172.82	4.5%	3.0%	-33%
Hartford	39.93	\$3,213.68	6.6%	2.9%	-56%
Towns in Massachusetts	6.81	\$0.00	7.7%	6.3%	-18%
Greater Sacramento Region	2.34	\$238.99	4.1%	2.7%	-34%
Syracuse	36.89	\$1,282.78	3.7%	2.5%	-32%

- **No relationship between magnitude of safety outcomes and level of enforcement could be identified for distracted driving enforcement.**

Although all the enforcement evaluated were effective at decreasing handheld phone use, the magnitude of the observed safety impact did not appear related to the intensity of the enforcement effort. Figure 3 shows the results from the 6 data points from Table 1 with the hours of enforcement on the x-axis and the percentage-point change in handheld phone use on the y-axis. As the graph shows, five of the 6 results had very similar changes in handheld phone use, despite the variation in additional hours of enforcement. Generally, this graph indicates that these campaigns all achieved similar outcomes, regardless of the amount of additional hours dedicated to enforcement, with one exception. Hartford, Connecticut, as reported by Chaudhary et al. (2012) had a large impact and a high level of officer enforcement hours.



Figure 3. Hours of enforcement versus change in handheld phone use.

### Alcohol-Impaired Driving

Nineteen impaired driving studies were found to be appropriate for inclusion in this analysis. The studies explored various sizes of treatment locations, including specific intersections, towns, counties, States, and the nation. In the case of impaired driving the synthesis was constrained by the large variety of ways safety outcomes were measured in the available literature. Only a limited number of studies shared the same safety outcome measure to allow for cross-study comparisons, and those that did tended not to report information that could be used to quantify the level of enforcement that generated the observed safety outcomes.

- **Overall, enforcement targeting alcohol-impaired driving produce positive outcomes.**

Table 2 shows the results over all enforcement studied in the available literature. With respect to HVE, the table indicates that 58 percent of the 90 study locations resulted in reductions in either crashes or prohibited behavior while 40 percent showed an increase. The remaining 2 percent of enforcement locations showed mixed results. Other types of enforcement (non-HVE) resulted in reductions in either crashes or prohibited behavior, exclusively. Looking across all enforcement, a simple sign test can test the odds of getting at least 57 positive increases out of 95 results due to random chance. Testing the hypothesis that the result is due to random chance results in a very small p-value of less than 0.02, meaning that one can reject that hypothesis of no real effect. This finding indicates that it is very likely that alcohol-impaired driving enforcement is effective at improving safety outcomes.

Table 2. Summary of Alcohol-Impaired Driving Safety Outcome Vote Counts

Enforcement	Number of study locations	Reduction in crashes or prohibited behavior	Mixed results	Increases in crashes or prohibited behavior
HVE	90	52 (58%)	2 (2%)	36 (40%)
Checkpoints	2	2 (100%)	0 (0%)	0 (0%)
Publicity	1	1 (100%)	0 (0%)	0 (0%)
Unspecified	2	2 (100%)	0 (0%)	0 (0%)
All	95	57 (60%)	2 (2%)	36 (38%)

- **Due to lack of comparable data across studies, no relationship between magnitude of safety outcomes and level of enforcement could be identified for alcohol-impaired driving enforcement in this synthesis.**

The studies used a variety of metrics to measure outcomes for alcohol-impaired-driving enforcement. Since for any one metric there were very few studies, it was not possible to identify a relationship between level of enforcement and safety outcomes for alcohol-impaired-driving enforcement campaigns.

### Speeding

The screening process resulted in 13 studies related to speeding enforcement that are in the scope of this synthesis. The 13 studies provided results on 40 enforcement efforts of which 17 were from work zones and 23 were not from work zones.

- **Speeding enforcement focused on work zones produced average decreases in speed of approximately 4 mph.**

This synthesis found an average change of -4.16 mph in work zones and an average change of -0.99 mph in non-work zones. A two-tailed t-test found that both estimates are statistically significantly different from zero at the 0.01 level. A change in speed of over 4 mph in work zones may produce significant safety benefits for highway construction workers. Not only does reducing speed allow more reaction time to potentially avoid a collision between a vehicle and worker, but non-occupants are more likely to survive a collision at slower speeds. Figure 4 shows the distribution of speeding improvements results from the relevant literature for work zones and non-work zones.



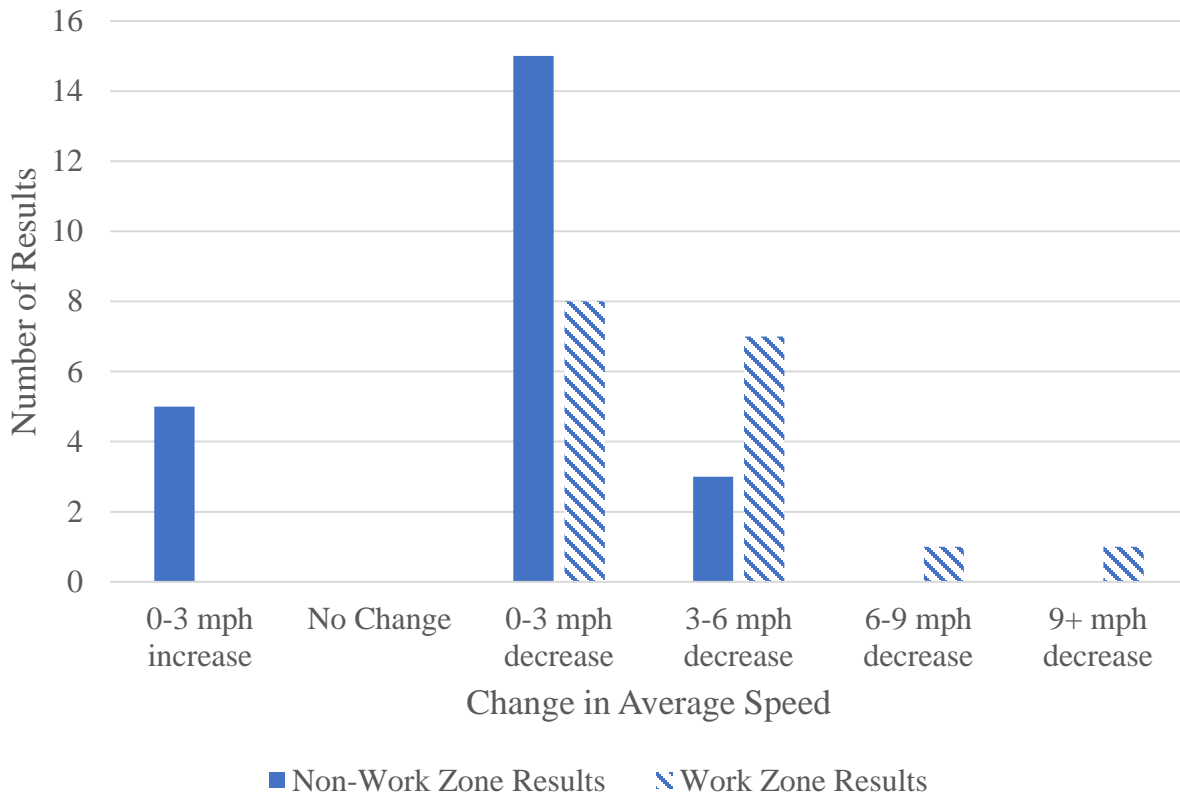


Figure 4. Impact of speeding enforcement for work zones and non-work zones.

- **Across studies it was not possible to investigate a relationship between levels or intensity of enforcement and the magnitude of change in speeding behavior.**

As with alcohol-impaired driving, the analysis was constrained by the large variety of ways safety outcomes were measured in the available literature. Additionally, speeding enforcement studied in the available literature typically involved placing some sort of visibility element (e.g., a dynamic speed feedback sign or a visible patrol car) at a certain highway site and observing the resulting speeds of passing vehicles. Thus, the impact of the enforcement was observed in relation to the presence or absence of a visibility element and did not lend itself to being measured on a continuous scale, which would allow assessment of the incremental impact of additional enforcement.

### Aggressive Driving

Each of the 5 studies reviewed on aggressive driving looked at the impact of the Ticketing Aggressive Cars and Trucks (TACT) program on aggressive driving behaviors. TACT was established specifically to try to reduce fatalities and injuries that come from cutting off, tailgating, and speeding around commercial trucks (Nerup et al., 2006).

- **Overall, the available studies indicate that TACT is an effective program.**

Out of the 5 TACT studies included in this review, 4 found that TACT reduced instances of aggressive driving, and one study found mixed results. This suggests that TACT is generally an effective program.

- **It was not possible to investigate a relationship between levels or intensity of enforcement and the magnitude of change in aggressive driving behavior.**

Each study had its own measure of safety, such as the number of crashes, the number of unsafe events, or the percentage of drivers tailgating. This variety of safety outcomes precludes comparison of results across studies.

## Conclusion

The primary research question for this synthesis was whether a relationship could be established between the amount of the change in traffic enforcement and the magnitude of the change in safety outcome for highway safety enforcement campaigns. This research identified a positive and statistically significant relationship between seat belt use and both the number of checkpoints and amount of media spending during occupant protection enforcement campaigns. However, for enforcement campaigns related to distracted driving, alcohol-impaired driving, speeding, and aggressive driving, no such relationship was identified between the size of the change in enforcement and the size of the change in safety outcomes. The reasons likely stem from the low number of studies that provided information upon which to make cross-study comparisons and a lack of variability among the levels of enforcement used across studies. Nonetheless, the synthesis concluded that for all targeted behaviors, enforcement campaigns are effective at reducing prohibited behaviors, even though the magnitude of the observed safety improvements cannot be explained by the level of enforcement used in the effort.

To address the issue of lack of consistent data reporting in the available literature, future studies that attempt to evaluate or analyze the safety impacts from enforcement should endeavor to collect and report a more complete description of the enforcement using quantitative measures such as number of enforcement hours, number of checkpoints, number of patrols, dollar amount of paid media, etc. In addition, evaluations should describe the baseline levels of enforcement that exist prior to the specific enforcement. Another suggestion for researchers is to report safety outcomes several weeks or months after an enforcement campaign has ended. An extended reporting period would provide information on the long-term effects of a campaign, whereas most of the studies in the available literature were concerned with only the immediate effects. Finally, to better explore the dose-response relationship between incremental levels of enforcement and safety outcomes, a suggestion for researchers is to adopt a research plan informed by concepts of experimental design that would randomly select test sites and assign varying levels of enforcement in a pre-determined manner.

Several findings could be relevant for practitioners. One suggestion is to conduct HVE programs that have all program elements; the available literature provides substantial evidence that combining enforcement, visibility, and publicity is an effective strategy. Practitioners should also endeavor to collect robust data on their activities, even when they are not conducting a specialized enforcement program. This would allow for greater data availability for researchers.

The implementation of these suggestions would accomplish two goals: first, they would help improve the success of enforcement programs and second, they would help increase data availability such that future research will be able to better understand the relationship between enforcement and safety. While improving safety is the goal, an important intermediate step is understanding which resource allocation strategies are the most effective for improving safety. Without more data, it is difficult to identify those strategies and estimate the resources necessary to effectively implement them.

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