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Universal Motorcycle Helmet Laws to Reduce Injuries: A Community Guide Systematic Review

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Abstract

Context—Motorcycle crashes account for a disproportionate number of motor vehicle deaths and injuries in the U.S. Motorcycle helmet use can lead to an estimated 42% reduction in risk for fatal injuries and a 69% reduction in risk for head injuries. However, helmet use in the U.S. has been declining and was at 60% in 2013. The current review examines the effectiveness of motorcycle helmet laws in increasing helmet use and reducing motorcycle-related deaths and injuries.

Evidence acquisition—Databases relevant to health or transportation were searched from database inception to August 2012. Reference lists of reviews, reports, and gray literature were also searched. Analysis of the data was completed in 2014.

Evidence synthesis—A total of 60 U.S. studies qualified for inclusion in the review. Implementing universal helmet laws increased helmet use (median, 47 percentage points); reduced total deaths (median, −32%) and deaths per registered motorcycle (median, −29%); and reduced total injuries (median, −32%) and injuries per registered motorcycle (median, −24%). Repealing universal helmet laws decreased helmet use (median, −39 percentage points); increased total deaths (median, 42%) and deaths per registered motorcycle (median, 24%); and increased total injuries (median, 41%) and injuries per registered motorcycle (median, 8%).

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Names and affiliations of the Community Preventive Services Task Force members can be found at: www.thecommunityguide.org/about/task-force-members.html.

SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://www.thecommunityguide.org/sites/default/files/assets/mvoi-ajpm-app-universalhelmets.pdf.

Conclusions—Universal helmet laws are effective in increasing motorcycle helmet use and reducing deaths and injuries. These laws are effective for motorcyclists of all ages, including younger operators and passengers who would have already been covered by partial helmet laws. Repealing universal helmet laws decreased helmet use and increased deaths and injuries.

CONTEXT

Motorcycle crashes contribute considerably to preventable fatal and non-fatal injuries in the U.S. Although motorcycles only account for about 3% of registered vehicles and 0.7% of traveled vehicle miles, a disproportionate 15% of all motor vehicle crash fatalities were due to motorcycle crashes in 2013.[1] The U.S. Government Accountability Office estimated that the total direct measurable costs from motorcycle-related crashes were approximately $16 billion in 2010.[2] A Cochrane systematic review found that motorcycle helmet use can lead to an estimated 42% reduction in risk for fatal injuries and a 69% reduction in risk for head injuries.[3] Helmet use in the U.S., however, remained around 60% in 2013.[4]

Motorcycle helmet laws require motorcycle riders to wear a helmet while riding on public roads. In the U.S., these laws are implemented at the state level with varying provisions and fall into two categories: universal helmet laws (UHLs), which apply to all motorcycle operators and passengers; and partial helmet laws (PHLs), which apply only to certain motorcycle operators such as those under a specified age (usually 18 years), novices (most often defined as having <1 year of experience), or those who do not meet the state's requirement for medical insurance coverage. Further, motorcycle passengers are not consistently covered under PHLs.

According to the National Occupant Protection Use Survey conducted by the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration, helmet use is seen to be "significantly higher in states that require all motorcyclists to be helmeted," that is, states with UHLs.[5] The number of states implementing UHLs peaked in 1975, with 47 states requiring all motorcyclists to wear helmets. Since then, many states have repealed UHLs.[6] Currently, 19 states and the District of Columbia have UHLs.[6] Among the other states, 28 states have PHLs and three states (Illinois, Iowa, and New Hampshire) have no motorcycle helmet laws.[6]

The current review aims to evaluate the effectiveness of UHLs in increasing helmet use and decreasing fatal and non-fatal injuries. This review was a collaborative effort between researchers from the U.S. (Community Guide Branch and National Center for Injury Prevention and Control, both at the Centers for Disease Control and Prevention [CDC]) and Australia (The George Institute for Global Health at the University of Sydney). Researchers from the George Institute will prepare a companion review with a global focus, including evidence from low- and middle-income countries. This paper is based solely on evidence from the U.S.

The research questions for this review are:

How effective are motorcycle helmet laws in achieving the following outcomes?

- Increasing helmet use
- Reducing fatal and non-fatal injuries

Does helmet law effectiveness vary by the following factors?

- Universal helmet law versus partial helmet law
- Setting characteristics, such as rural versus urban
- Population characteristics, such as age, gender, race/ethnicity, or SES

EVIDENCE ACQUISITION

Detailed systematic review methods used for the Community Guide have been published previously.[7,8] For this review, a coordination team was formed, composed of motor vehicle injury prevention subject matter experts from various agencies, organizations, and academic institutions, together with systematic review methodologists from the Community Guide Branch at CDC. The team worked under the oversight of the independent, unpaid, nonfederal Community Preventive Services Task Force whose members are appointed to 5-year terms by the director of CDC.

Conceptual Approach and Analytic Framework

The analytic framework (Appendix Figure 1, available online) shows the postulated mechanism through which motorcycle helmet laws affect incidence and severity of non-fatal and fatal injuries. UHLs can lead to increased helmet use, resulting both in reduced incidence and severity of non-fatal injuries and in reduced fatal injuries. If motorcycle helmet laws affect overall motorcycle use, as some have speculated,[9] that could also contribute to observed decreases in fatal and non-fatal injuries. Other factors that may influence helmet use or injury include strength of the law (UHLs versus PHLs); intensity of enforcement efforts; type of helmet used (U.S. Department of Transportation approved or non-approved); and individual attitudes such as the desire not to wear a helmet.

Search for Evidence

Reviewers from the George Institute in Sydney, Australia, conducted the search for evidence, and the detailed search strategy can be found at: www.thecommunityguide.org/mvoi/motorcyclehelmets/supportingmaterials/SShelmetlaws.html. Briefly, databases relevant to health or transportation were searched from database inception to August 2012. Reference lists of reviews and reports relevant to the current review were also searched. Two reviewers from the George Institute performed the initial screening and eliminated publications not evaluating motorcycle helmet laws. Reviewers from CDC's Community Guide Branch further screened the publications using the predetermined inclusion criteria listed below.

Inclusion Criteria

Studies were included in the current review if they evaluated motorcycle helmet laws and also met the following criteria:

- published in English;

- published journal article or government report; and
- reported at least one outcome of interest.

Assessing and Summarizing the Body of Evidence on Effectiveness

Study abstraction—Each study meeting the inclusion criteria was independently abstracted by two reviewers. Reviewers from the George Institute developed abstraction forms by adapting guidelines from the Cochrane Effective Practice and Organization of Care group.[10] Information on intervention components, population demographics, and outcomes was gathered using these forms. Uncertainties and disagreements were reconciled by consensus among review team members.

Risk of bias assessment—The team evaluated each study's risk of bias using templates adapted from the Cochrane Effective Practice and Organization of Care group[10]: Were data analyzed properly? Was the intervention independent of other changes? Were sufficient data points used for reliable statistical inference? Was the intervention unlikely to affect data collection? Was primary outcome assessment blinded? Was the data set complete? Were primary outcome measures reliable?

Studies could be of high, low, or unclear risk for each of these criteria. Quality of each included study was assessed by two reviewers independently, and uncertainties and disagreements were resolved by consensus.

Outcomes of interest—Outcomes commonly used to evaluate the impact of helmet laws were identified and abstracted for this review, including helmet use, total fatal and non-fatal injuries, and fatal and non-fatal injury rates. The included studies used data sources such as the Fatality Analysis Reporting System from the National Highway Traffic Safety Administration, state highway safety departments' databases, and hospitals that admitted motorcyclists injured in motorcycle-related crashes. Total fatal or non-fatal injuries (with or without hospital admission) are direct measures of helmet law impact on a population and were commonly reported by the included studies. Total injury counts, however, are affected by the amount of motorcycle use ("riding exposure"), which could change in response to the presence or absence of UHLs. To account for this potential change, injury rates were collected or calculated from the included studies, including fatal and non-fatal injuries per registered motorcycle, traveled vehicle miles, or crashes. Outcomes that were less commonly reported but useful for answering the research questions were also collected, including injury severity and neck injuries.

Analysis—Helmet use was reported using percentage point (pct pt) changes; for example, helmet use rate post-law change - helmet use rate pre-law change or helmet use rate in states with UHLs - helmet use rate in states without UHLs. All other outcomes were reported using relative percentage changes. Some studies (studies using panel design or the autoregressive integrated moving average model) provided calculated effect estimates as relative changes and no further calculation was needed. Effect estimates were calculated for all other studies. For studies examining impact of a law change, only the data points

immediately before and after the law change were used to calculate effect estimates to minimize the effect of secular changes on the outcomes of interest.

For overall summary measures, the median of effect estimates from individual studies and the interquartile interval, which is the interval between the first and third quartiles, were calculated for each outcome. Strength of evidence on effectiveness was based on the number of studies, the quality of available evidence, consistency of results, and magnitude of effect estimates, per Community Guide standards.[7,8] Analyses of the data were completed in 2014.

EVIDENCE SYNTHESIS

Search Yield

A total of 262 potentially relevant articles were identified in the search for evidence, and 125 were candidates for inclusion. Forty-nine articles were excluded as they did not meet the inclusion criteria: Three papers[11–13] were not published in English, 11 papers[14–24] evaluated helmet laws in low- or middle-income countries, 20 papers[25–44] were not primary evaluations, and 15 papers[45–59] did not report on the outcomes of interest. Overall, 71 studies[60–130] with 78 study arms were included in the current review (Figure 1), with five studies[131–135] providing additional information on already included studies. Of the 71 included studies, 60 studies[60–66,68–72,74,76–79,81–90,92–106,108–116,120–122,125–130] with 67 study arms evaluated helmet laws in the U.S. As mentioned above, this paper is solely focused on the U.S., and only U.S. data are reported in the following sections.

Risk of Bias Assessment

Detailed assessment results can be found on the Community Guide website (www.thecommunityguide.org/mvoi/motorcyclehelmets/supportingmaterials/ROB-helmetlaws.pdf). All included studies were observational studies and no study performed blinded assessment of primary outcomes. Included studies obtained data from routine government and hospital reports, which were unlikely to be affected by helmet laws or law changes. Most included studies examined helmet laws or law changes that were independent of other traffic safety interventions.[60–66,68–71,74,76–79,81–90,92–97,99–106,108–116,120–122,125–130] Some studies did not provide sufficient data points for reliable statistical inference,[92,113,114,130] had missing data,[62,72,92] or did not describe statistical methods.[72,87,88,92,94,95,98,111,120,122,125,126,130] Three studies[99,122,126] reported observed helmet use without describing study methods; outcome reliability could not be assessed.

Study and Intervention Characteristics

Sixty studies[60–66,68–72,74,76–79,81–90,92–106,108–116,120–122,125–130] with 67 study arms evaluated motorcycle helmet laws in the U.S. These studies either evaluated law changes such as helmet law implementations (from no or partial laws to UHLs)[60,71,74,78,88,89,94,95,99,101,103,104,109,116] or repeals (from UHLs to partial or no laws),[61,63,66,70–72,81–83,85,87,90,92,93,96,98,100,105,106,108,111,116,121,122,125–128] or compared the impact of UHLs to partial or no helmet laws.[62,64,65,68,69,76,77,79,84–86,96,97,102,106,110,112–115,120,129,130] Study designs included in the

review were panel,[64,70,71,76,77,79,81,84–86,102,112,115,128] time series or before–after with concurrent comparison groups,[62,65,66,96,97,110,114,120,126,129] interrupted time series,[61,74,78,103,105,121] uncontrolled before–after,[60,63,72,82,83,87–90,92–96,98–101,104,106,108,109,111,116,122,125,127] and cross-sectional.[68,69,106,113,114,130] More detailed information can be found at: www.thecommunityguide.org/mvoi/motorcyclehelmets/supportingmaterials/SET-helmetlaws.pdf.

Demographic Characteristics From Included Studies

Twenty-two studies[60,63,65,68,69,78,82,83,87,89,90,95,96,99,101,104,108,110,113,125,127,129] of the 60 from the U.S. reported population characteristics. The study population consisted of motorcycle riders and passengers observed for helmet use[125] or who sustained fatal or non-fatal injuries during motorcycle crashes.[60,63,65,68,69,78,82,83,87,89,90,95,96,99,101,104,108,110,113,127,129] Mean age of the study population was 36.5 years[60,63,65,68,69,78,82,83,87,89,95,96,101,104,108,113,127] and a median of 91% were male.[60,63,65,68,69,78,82,83,87,89,90,95,96,99,101,104,108,110,113,125,127,129]

Outcomes

Impact of helmet laws was assessed through the following outcomes: helmet use, motorcycle crash-related fatal and non-fatal injuries, and injury rates. These outcomes were assessed and reported in three categories:

- law implementing: study arms evaluating the change in outcomes when states with no or partial helmet laws implemented UHLs;
- law repealing: study arms evaluating the change in outcomes when states repeal UHLs, changing to no or partial helmet laws; and
- law comparison: study arms comparing outcomes from states with UHLs to states with partial or no helmet laws.

The included studies reported many outcomes, almost all indicating substantial benefits associated with UHLs when compared to partial or no helmet law (Table 1). In the presence of UHL, there was higher prevalence of helmet use (Appendix Figure 2, available online); fewer fatal (Figure 2) and non-fatal injuries (Appendix Figure 3, available online); and lower injury rates. In the absence of UHL, there was lower prevalence of helmet use (Appendix Figure 4, available online); greater fatal (Figure 3) and non-fatal injuries (Appendix Figure 5, available online); and higher injury rates. Head-related fatal (Figures 2 and 3) or non-fatal injuries (Appendix Figures 3 and 5, available online) were especially affected by presence or absence of UHLs.

As of 2016, a total of 47 states in the U.S. had either UHLs or PHLs. The team performed additional analyses specifically to compare the laws' effectiveness; results are summarized in Appendix Table 1 (available online). Results are similar to the overall findings that compared UHL to partial or no helmet laws (Table 1); states with UHLs, when compared with states with PHLs, have much higher helmet use and fewer fatal and non-fatal injuries.

The PHLs apply only to certain motorcycle operators. As of 2015, all 28 PHL states covered motorcyclists under a certain age (usually ≤21 years).[6] The team summarized youth-specific data (Table 1) to determine if PHLs protect this population; the results are described below.

Impact of Universal Helmet Laws on Young Motorcyclists

Helmet use—Implementing UHLs[99] increased helmet use among young motorcyclists (aged <21 years) by an estimated 31 pct pts in one study, and repealing UHLs[82,90,111,125,127] decreased helmet use by a median of 17 pct pts (interquartile interval, −19 to −3 pct pts). Two[96,106] law comparison study arms with four effect estimates found that youth helmet use was a median of 42 pct pts (range, 31–59 pct pts) higher in states with UHLs when compared with states with partial or no laws.

Fatal injuries—Implementing UHLs[95] decreased fatalities among youth involved in motorcycle crashes by an estimated 48% in one study, and three others found that repealing UHLs[90,125,127] increased fatalities by a median of 125% (range, 116%−189%). One[84] law comparison study arm found that total fatal injuries were 31% lower in states with UHLs versus states with no laws.

Fatality rates—One study found that repealing UHLs[90] led to an increase of 97% in fatalities per traveled vehicle mile. One[65] study arm compared the impact of PHLs to no helmet law, and found no difference in fatalities per registered motorcycle between states with PHLs and states with no helmet law.

Non-fatal injuries—Compared with states with partial or no laws, young motorcyclists (aged <21 years) in states with UHLs experienced 8% higher motorcycle crash-related hospitalization[68] but 12% lower motorcycle crash-related hospitalization due to non-fatal head injuries.[129]

DISCUSSION

In 2013, an estimated 1,630 lives were saved by motorcycle helmets in the U.S., and an additional 715 lives could have been saved if all motorcyclists were wearing helmets.[136] Over the past few decades, however, the trend in the U.S. has been to repeal UHLs. The arguments made by opponents of UHLs include that helmet use should be a personal choice instead of state policy, helmet effectiveness is not certain, and data on helmet law effectiveness are inconclusive. Individual rights are an important consideration for policymakers, but are beyond the scope of the current review. Evidence from the present review complements the Cochrane systematic review and demonstrates the effectiveness of UHLs.

Michigan was the latest state to repeal its UHL in April 2012, and evaluations of this law change were published recently. Two reports found that the repeal resulted in decreased helmet use,[137] increased fatalities and fatalities per crash,[137] and increased medical care costs to the state,[138] consistent with the findings from the current review.

In addition to being more effective than PHLs, UHLs are easier to enforce. The characteristics specified in PHLs (e.g., age, experience, level of medical insurance) are not easily evaluated by law enforcement officers monitoring traffic. By contrast, UHLs apply to all motorcycle operators and passengers, making anyone riding without a helmet easily identifiable.

Currently, all PHLs in the U.S. cover young motorcyclists, usually aged <18 years.[6] Evidence from the present review shows that any protection provided by PHLs is small in comparison to that provided by UHLs.

In 2013, approximately 9% of U.S. motorcyclists wore unapproved helmets.[4] The U.S. Department of Transportation requires that all motorcycle helmets sold in the U.S. meet Federal Motor Vehicle Safety Standard 218. This standard defines minimum performance levels that helmets must meet to protect the head and brain in the event of a crash, including factors such as inner liner thickness, weight of helmet, and chin strap sturdiness. A recent study[139] in California reported that motorcycle riders wearing novelty helmets (defined as half-helmet not meeting the Department of Transportation standard) were almost three times more likely to suffer from head injuries when compared with riders wearing full-face helmets. As of 2015, a total of 12 states with UHLs and 16 states with PHLs require the use of Department of Transportation-approved helmets.[6] Training traffic law enforcement officers in these states to recognize unapproved helmets, and thereby enforce existing laws, may improve helmet law effectiveness.

Although UHLs increase helmet use and reduce fatal and non-fatal injuries, they do not prevent motorcycle-related crashes. Policies that are effective in reducing overall motor vehicle crashes could be relevant to motorcycle safety, such as reducing alcohol-impaired driving and reducing speeding.[140]

Limitations

This body of evidence included a wide range of study designs. Even though each design comes with unique risks of bias, effect estimates across multiple study types, population groups, and outcome measures were remarkably consistent within the context of this review, and with independent estimates of efficacy of helmet use,[3] demonstrating robustness of findings.

Total motorcycle-related fatal or non-fatal injuries are widely used measures of helmet law effectiveness. These total injury counts, however, are affected by the amount of motorcycle use (“riding exposure”), which could change in response to the presence or absence of UHLs. Many included studies attempted to account for driving exposure by dividing total counts of fatal and non-fatal injuries by the number of registered motorcycles, traveled vehicle miles, or crashes. Regardless of the specific measure used, UHLs were shown to be more effective than PHLs or no law in reducing fatal and non-fatal injuries.

Applicability

The current review focused on motorcycle helmet laws in the U.S. Some of the included studies performed stratified analyses based on certain demographic characteristics. Evidence

showed that UHLs were effective for male and female motorcyclists in increasing helmet use,[90,96,99] decreasing fatal and non-fatal injuries,[81,90,127] and decreasing fatalities per crash.[90] Compared with motorcycle operators, passengers usually had a lower prevalence of helmet use irrespective of the helmet law,[90,94,99,106] though implementing UHLs increased helmet use[94,99] and reduced fatal injuries[88,89,99] for both operators and passengers. When UHLs were repealed, passengers experienced greater decreases in helmet use[90] and greater increases in total fatal injuries and fatal injuries per crash.[90] Two studies compared helmet law effectiveness in rural versus urban areas and found that implementing UHLs reduced fatal injuries in both settings[60] and repealing UHLs increased fatal and non-fatal injuries in urban settings.[122]

The UHLs were effective across age groups in increasing helmet use[90,96,99,106,125] and decreasing overall fatal injuries[81,90,95,125] and fatal injuries per crash.[90] Young motorcyclists, when compared with their older counterparts, experienced larger decreases in fatal injuries when UHLs were implemented[95] and larger increases in total fatal injuries and fatal injuries per crash when UHLs were repealed.[90,125]

Other Benefits or Harms

No additional benefits of motorcycle helmet laws were identified in the included studies or in the broader literature.

Although one of the postulated harms associated with helmet use is increased risk of neck injuries, the ten included study arms[62,68,69,82,89,99,103,104,109,127] that assessed this outcome found that fatal and non-fatal neck injuries accounted for a very small proportion of motorcycle-related injuries (median, 1.8%; interquartile interval, 0.2%−3.2%) and the type of helmet law had no noticeable effect on neck injury prevalence. One study arm found that implementing a UHL resulted in a reduction of 0.5 pct pts in neck injury-related fatalities.[99] Studies reporting non-fatal injuries found little difference in the prevalence of neck injuries between states with UHLs and states with PHLs or no law (median, −0.6 pct pts; range, −0.6 to 0.1 pct pts),[62,68,69] and minimal changes in prevalence of neck injuries when UHLs were repealed (0.1–0.2 pct pts)[82,127] or implemented (median, 0.0 pct pts; range, −0.3 to 0.6 pct pts).[89,103,104,109]

Other postulated harms of helmet use include hearing or vision impairment, though evidence from laboratory and field research does not show much support for these claims.[141] Finally, some researchers have raised concerns about risk compensation, postulating that riders wearing helmets feel safer and increase their risk-taking behaviors (reviewed by Hedlund[142] in 2000). Evidence on this issue is limited, though authors of one study analyzed data from on-scene, in-depth investigations of motorcycle- related crashes in Los Angeles and concluded that helmet use was not associated with riskier behaviors.[143]

Evidence Gaps

Although substantial evidence shows UHLs are effective across population groups and settings, research gaps remain. Future studies could examine the role of enforcement on helmet law effectiveness, particularly in regard to the use of unapproved helmets.

More research is needed to better understand the impact of helmet laws on riders of low-powered motorized cycles (e.g., scooters, mopeds) that have been gaining popularity, especially in urban settings. In 2016, all types of low-powered cycles were covered in 12 of 19 states with UHLs and 11 of 28 states with PHLs; the remaining states with helmet laws covered motorized cycles above certain thresholds, such as engine displacement greater than 50 cc or those designed to go faster than 30 mph.[6]

CONCLUSIONS

Overall, UHLs are much more effective than partial or no helmet laws in increasing helmet use and reducing fatal and non-fatal motorcycle crash injuries. U.S. states that repealed UHLs and replaced them with PHLs or no law consistently experienced substantial decreases in helmet use and increases in fatal and non-fatal injuries. States that implemented UHLs in place of PHLs or no law consistently experienced substantial increases in helmet use and decreases in fatal and non-fatal injuries. PHLs exist in 29 states in the U.S., and a separate analysis was conducted to compare only UHLs and PHLs (Appendix Table 1, available online), with results nearly identical to the overall analysis that compared UHLs to partial or no helmet laws (Table 1). These findings are generally applicable to all motorcyclists, irrespective of age and gender, in both rural and urban settings.

Studies included in the current review assessed impact of motorcycle helmet laws using a diverse set of outcomes. Many studies attempted to account for potential changes in motorcycle use by providing fatal and non-fatal injuries per registered motorcycle, traveled vehicle mile, or crash. Compared with total count results, these rate results were smaller in magnitude but still demonstrate that UHLs were more effective in reducing fatal and non-fatal injuries than PHLs or no law. Because helmets protect the cranial region, helmet laws can be expected to have a greater impact on head-related fatal and non-fatal injuries than overall fatal and non-fatal injuries; results from the current review confirm this hypothesized relationship.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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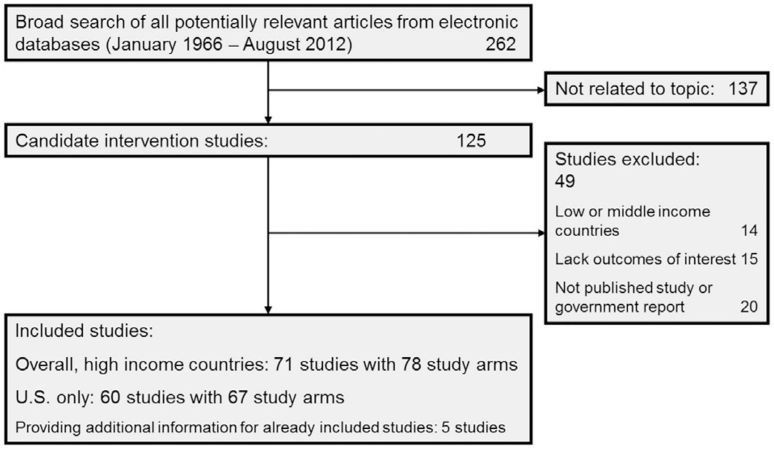

Figure 1.
Search results.

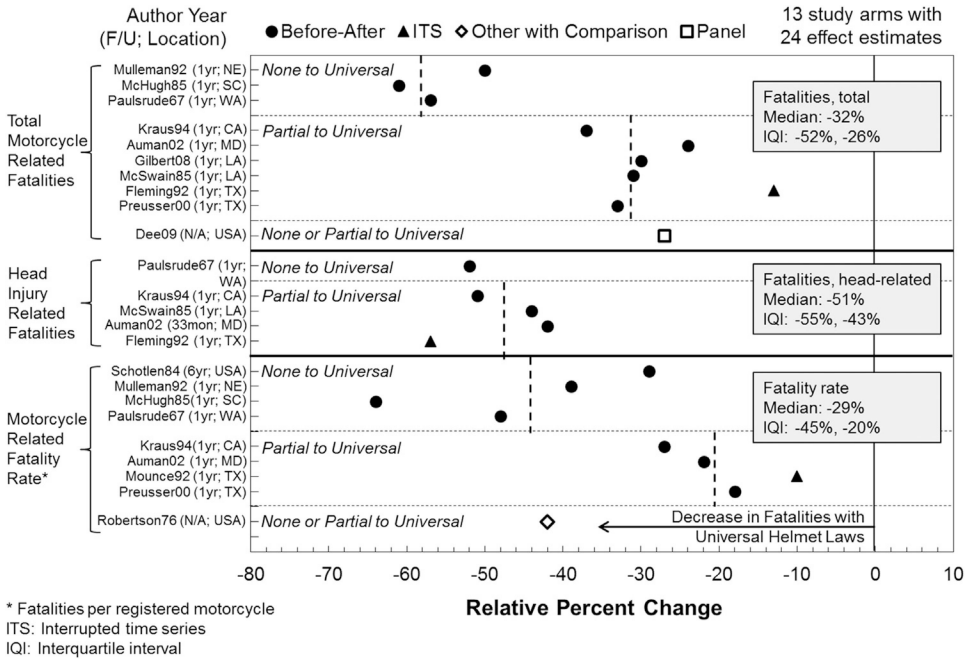

Figure 2.

Impact of implementing UHLs on fatality outcomes.

UHL, universal helmet law.

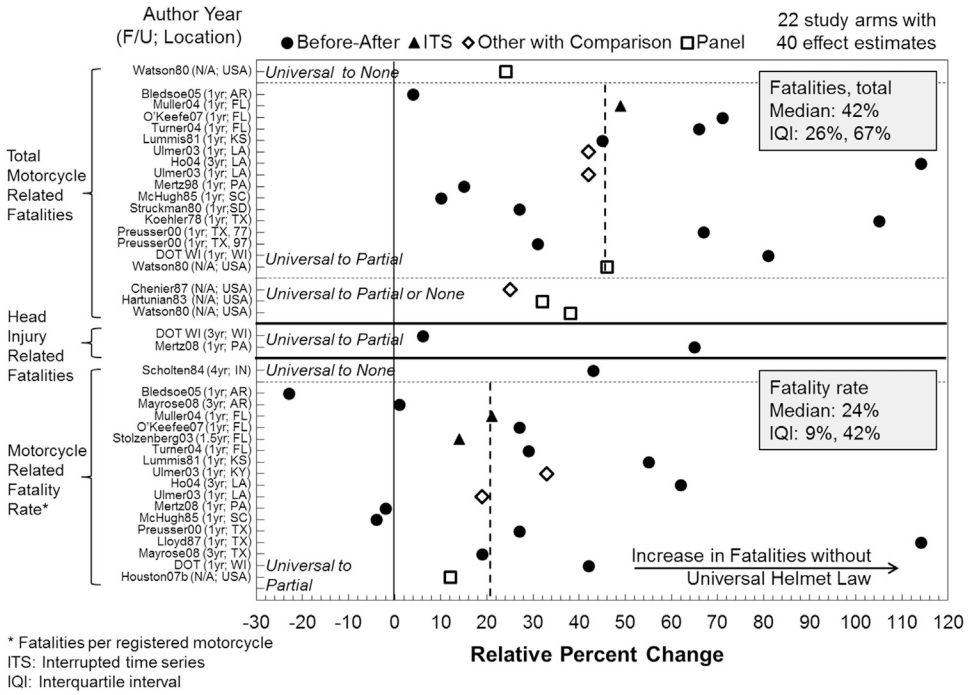

Figure 3.

Impact of repealing UHLs on fatality outcomes.

UHL, universal helmet law.

Table 1.

Impact of UHLs on Helmet Use and Fatal and Non-fatal Injuries

	Law implementing[a]		Law repealing[b]		Law comparison[c]	
Outcome	**No. of study arms**	**Median (IQI/ range)[d]**	**No. of study arms**	**Median (IQI/ range)[d]**	**No. of study arms**	**Median (IQI/ range)[d]**
Helmet use, absolute change	9[e,60,78,88,89,94,99,101,103,104]	49 pct pts (42 to 58 pct pts)	21[e,61,63,72,83,87,90,92,93,96,100,106,108,111,116,122,125,126]	−41 pct pts (−48 to −31 pct pts)	6[96,106,110,113,114,130]	53 pct pts (51 to 60 pct pts)
Fatalities, relative change (total, head-related, rates)						
Total	10[f,60,71,74,78,89,98,99,104,109,111]	−32% (−52% to −26%)	20[f,63,66,72,81,82,87,93,98,100,105,108,111,122,125,126,128]	42% (26% to 67%)	7[76,77,79,86,112,115,120]	−24% (−29% to −22%)
Head-related	5[f,60,74,89,99,109]	−51% (−55% to −43%)	2[f,72,100]	6% and 65%	1[120]	−47%
Fatalities per registered motorcycle	9[f,60,89,98,103,104,109,111,114,116]	−29% (−45% to −20%)	18[f,63,72,82,85,92,93,96,98,100,105,108,111,116,121,125,126]	24% (9% to 42%)	7[64,79,85,86,97,102,120]	−12% (−15% to −4%)
Fatalities per vehicle mile travelled	–	–	3[61,105,125]	23% (14% to 38%)	2[86,97]	−27% and −22%
Fatalities per crash	4[78,98,109,116]	−15% (−29% to −4%)	12[63,70,72,82,87,90,93,98,100,116,122,125]	23% (1% to 36%)	1[120]	−14%
Fatality rate, head, per registered motorcycle	1[109]	−41%	2[72,100]	−5% and 25%	1[120]	−17%
Fatality rate, head, per crash	1[109]	−22%	5[72,100,106]	60% (12% to 362%)	1[120]	−27%
Injuries, relative change (total, head-related, rates)						
Total	7[g,74,88,89,95,101,104,109]	−32% (−39% to −15%)	10[g,63,82,83,93,100,111,122,125,126]	41% (19% to 61%)	1[76]	−20%
Head-related	4[g,74,88,89,95]	−54% (−49% to −59%)	4[g,72,100,111,127]	74% (53% to 83%)	3[62,68,129]	−27% (−12% to −44%)
Injuries per registered motorcycle	4[g,95,103,104,109]	−24% (−28% to −9%)	9[g,63,92,93,100,111,121,125,126]	8% (0% to 38%)	–	–
Injuries per vehicle mile travelled	–	–	1[125]	−8%	–	–
Injuries per crash	1[109]	−1%	7[63,83,93,100,122,125,127]	−1% (−8% to 35%)	–	–
Head-related injuries per registered motorcycle	1[95]	−44%	3[100,111,127]	31% (29% to 39%)	–	–
Head-related injuries per crash	–	–	4[100,111,127]	50% (33% to 105%)	–	–

Outcome	Law implementing[a]		Law repealing[b]		Law comparison[c]	
	No. of study arms	Median (IQI/ range)[d]	No. of study arms	Median (IQI/ range)[d]	No. of study arms	Median (IQI/ range)[d]
Youth						
Helmet use, absolute change	1[99]	31 pct pts	5[82,90,111,125,127]	−17 pct pts (−19 to −3 pct pts)	2[96,106] (4 effect estimates)	42 pct pts (31 to 59 pct pts)
Fatalities, relative change						
Total	1[95]	−48%	3[90,125,127]	125% (116% to 189%)	1[84]	−31%
Fatalities per vehicle mile travelled	–	–	1[90]	97%	–	–
Injuries, relative change						
Total	–	–	–	–	1[68]	8%
Head-related	–	–	–	–	1[129]	−12%

[a] UHLs replaced partial or no helmet laws.

[b] Partial or no helmet laws replaced UHLs.

[c] UHLs versus partial or no helmet laws.

[d] IQIs calculated with ≥5 studies; otherwise ranges reported.

[e] Appendix Figures 2 and 4 (available online).

[f] Figures 2 and 3.

[g] Appendix Figures 3 and 5 (available online).

IQI, interquartile interval; pct pts, percentage points; UHL, universal helmet law.