



A systematic review of the effectiveness of interventions to reduce motor vehicle crashes and their injuries among the general and working populations

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ABSTRACT

Objective. *To summarize the best available international scientific evidence on the effectiveness of interventions to reduce motor vehicle collisions and their consequences among the working and general populations.*

Methods. *A broad and systematic review was conducted of the literature available in biomedical databases and grey literature. At least two investigators working in parallel performed data extraction, synthesis, and risk of bias analysis.*

Results. *Forty-one studies with low to moderate risk of bias were included. Of these, 18 had an ecological design (time series), 10 were quasi-experimental, one was a population survey, one was a randomized clinical trial, and 11 were systematic reviews.*

Conclusions. *The interventions that most consistently show a positive effect on incidence, morbidity, and mortality due to motor vehicle collisions are national policies or programs that: regulate, enforce, and penalize driving under the influence of alcohol; improve driving safety and driver conditions; improve road infrastructure with the purpose of preventing collisions; and educate and penalize drivers with a history of road violations.*

Keywords

Accidents, traffic; accidents, occupational; occupational mortality; occupational injuries; driving under the influence.

In 2013, motor vehicle collisions were the leading cause of death among the population 15 – 29 years of age, killing 1.25 million individuals globally (1). While there has been a worldwide tendency towards stabilization of deaths from road crashes, significant inequity

between high-income countries and low- and middle-income countries persists (1). From an occupational viewpoint, vehicle crashes are one of the most frequent types of work trajectory accidents and pose the greatest risk of death and disability, especially for workers with jobs related to driving or transportation (2). From the perspective of economic costs, the burden of road collisions is very significant, estimated at 2% of the gross domestic product in the United States of America (3),

and at 1.5% – 3.9% in countries of Latin America (4).

Observational studies have pinpointed a variety of risk factors for this public health problem, some of which are: being male, having low income, having a low education level, poor road infrastructure, safety conditions related to vehicles, careless driving, driving under the influence of alcohol or other drugs, and deficient accident emergency-response (5–7). In addition, there are specific work-related risk factors, such as fatigue due to long

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driver shifts, driver workload leading to tension, lack of driver training, and other factors that reflect organizational safety policy and culture (8).

The World Health Organization (WHO) has been monitoring the global scope of this health problem and has proposed several important public policies to address it. Several countries have implemented these measures, to varying degrees. The countries with the worst indicators have been slow and superficial in following these policy recommendations (1).

In the context of global concern for the consequences of traffic collisions, the 2015 the United Nations 2030 Agenda for Sustainable Development (9) includes a target of reducing road traffic deaths and injuries by one-half by 2020. To achieve this goal, the United Nations is urging governments to adopt policies and programs geared toward reducing the incidence of traffic fatalities and injuries. This, in turn, creates the need to rigorously and comprehensively analyze interventions in order to further define priorities and guide decisionmaking. Particularly in low- and middle-income countries, where 90% of crashes occur with more than double the mortality (1), it is especially important that government and business decision-makers have access to quality information. In other words, understanding the effectiveness of interventions is important at not only the population and national levels, but also in the workplace where interventions target the employee population.

This study aimed to identify, analyze, and synthesize the best available international scientific evidence on the effectiveness of interventions to reduce motor vehicle collisions and their consequences among the general and working populations. It was commissioned by a workers' health and safety organization, *Mutual de Seguridad de la Cámara Chilena de la Construcción* (Santiago, Chile) to help inform policy decisions on motor vehicle-related deaths and injuries among the working population.

MATERIALS AND METHODS

Search strategy

A broad and specialized search was conducted of the main international databases that contain biomedical scientific articles and grey literature: PubMed/

MEDLINE (U.S. National Library of Medicine, Bethesda, Maryland, United States); Cochrane Library (The Cochrane Collaboration, London, United Kingdom); LILACS (Latin American and Caribbean Center on Health Sciences Information, Pan American Health Organization/WHO, São Paulo, Brazil); EMBASE (Excerpta Medica Database, Elsevier, Amsterdam, the Netherlands); HTA and DARE (Health Technology Assessments and Database of Abstracts of Reviews of Effects, Centre for Reviews and Dissemination, University of York, York, United Kingdom); and Epistemonikos (Epistemonikos Foundation, Santiago, Chile).

The websites of the following sources were also searched: Work Zone Safety Inc. (Crest Hill, Illinois, United States); European Agency for Safety and Health at Work (Bilbao, Spain); International Labor Organization, International Road Traffic and Accident Database (Paris, France); Networks of Employers for Traffic Safety (Vienna, Austria); World Bank (Washington, DC, United States); *Instituto Nacional de Seguridad e Higiene en el Trabajo* (Madrid, Spain); Inter-American Development Bank (New York, United States); Safe Cube Project (Loughborough, United Kingdom); WHO (Geneva, Switzerland); and the Organization for Economic Cooperation and Development Library (Paris, France).

To improve the search specificity and relevance of the search strategy, the appropriate thesaurus for each database was utilized, such as MeSH (Medical Subject Headings, U.S. National Library of Medicine, Bethesda, Maryland, United States) and DeCS (Health Science Descriptors, Latin American and Caribbean Center on Health Sciences, São Paulo, Brazil). The MeSH descriptors used were: "accidents, traffic;" "public policy;" "accidents, occupational;" "policy;" "programs;" "public sector." The DeCS descriptors were: "accidentes de tránsito;" "política social;" "accidentes de trabajo;" "políticas;" "programas;" "sector público." When no specific or more complex descriptors were available in these thesauruses, synonyms were used to enhance the search, for example: "implementation," "intervention," "worker," "effectiveness," "public intervention," "business," "public program," and "road traffic injuries." The specific search strategies for each source are available from the authors upon request.

Considering the significant amount of information published on the topic, the search was limited to a period of 10 years (January 2006 – October 2016), with the understanding that systematic reviews would cover prior periods, and to papers published in either English or Spanish.

Study selection

Considering that motor vehicle collisions are a population problem, selection criteria sought to identify studies with a broad array of epidemiological research designs. The inclusion criteria were the following: studies in human beings; original research on interventions with results on outcomes, such as reduced incidence, injuries, and/or mortality from road traffic crashes; and quantitative assessment of results. Also included were: experimental studies (randomized clinical trials, population trials); observational studies (systematic reviews with or without meta-analysis, ecological studies, cohort studies, and case reports); and quasi-experimental studies; as well as systematic reviews, which in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (10), can be considered a specific research design that answers overarching and complex public health questions.

Articles excluded were those that only reported conceptual frameworks, goals, processes, or qualitative assessment of programs and interventions without quantitative analysis of their estimated effect; non-systematic reviews and clinical practice guidelines; articles that reported changes in knowledge, attitudes, or other surrogate variables; market studies, polls, and surveys; and studies with poor methodological quality per the critical analysis criteria of this study.

Data extraction and analysis

Data and references were extracted and systematized into results tables. Two of the researchers worked in parallel extracting and assessing the methodological quality of the recruited studies. Differences were solved by consensus or were refereed by a third researcher. Studies were categorized into high, medium, and low risk of bias. For quality assessment, a critical analysis tool was created. For randomized controlled trials, this tool was based on the Centre for Evidence Based Medicine of the University

of Oxford (11); for systematic reviews, on the AMSTAR guidelines (12); and the observational studies, on the STROBE initiative (13). Lastly, for quality assessment of quasi-experimental and ecological studies, a structured guide was created to detect the main risks of bias. The final instrument is available from the authors upon request.

Studies with a high risk of bias were excluded. The results were compiled in tables and in narrative form, and included the type of intervention, research methods, reported outcomes, and effectiveness.

RESULTS

Initially 66 studies were evaluated. Of those, 41 studies were selected that had a low- or medium-risk of bias and that answered the study question. Of these, 18 had an ecological design (mostly time-series); 10 were quasi-experimental; one was a population survey; one was a randomized clinical trial; and 11 were systematic reviews. Figure 1 shows the PRISMA flow diagram and the reasons

for exclusion. A complete list of excluded documents is available from the authors upon request.

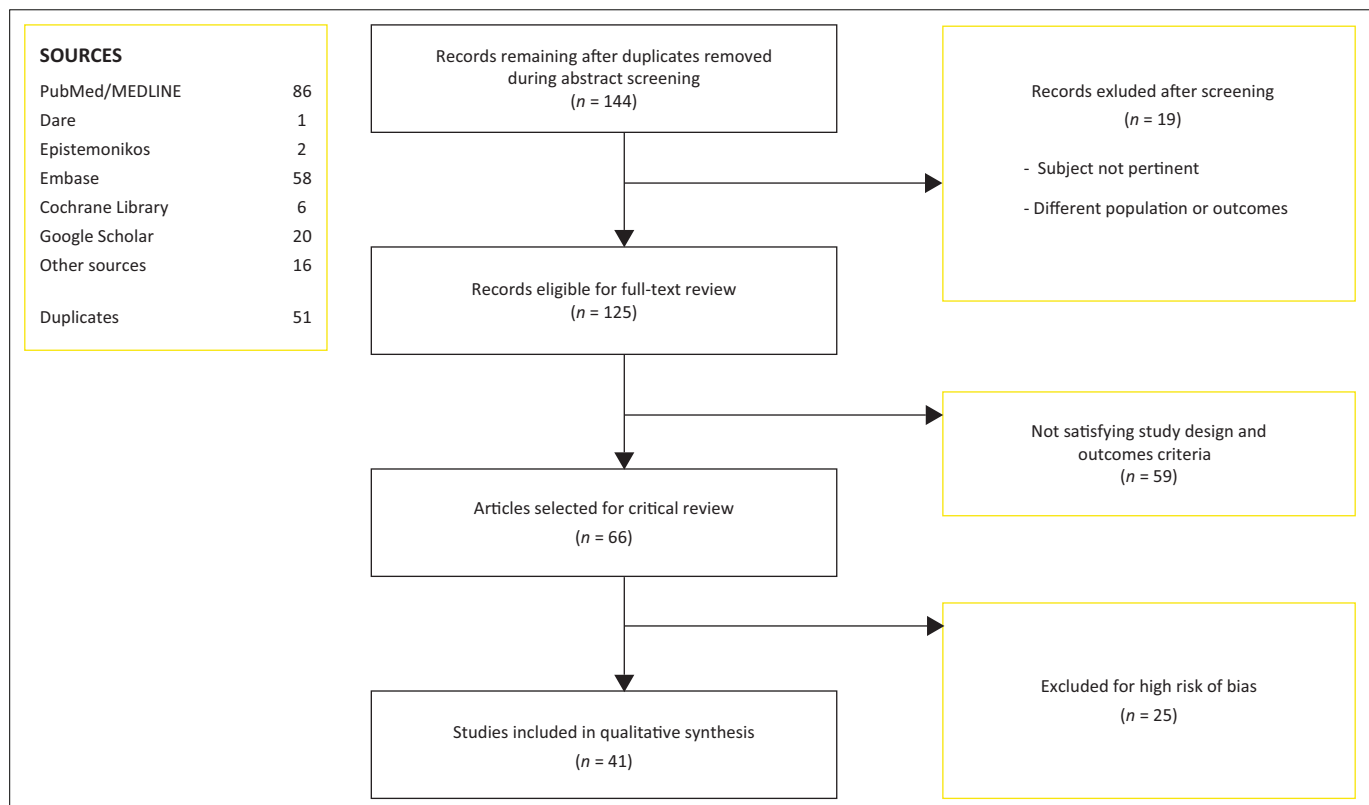
The types of interventions that were most frequently assessed included regulatory policies on alcohol consumption; programs or policies designed to enhance driving and driver safety; educational interventions; and programs or interventions on road infrastructure or safety. Less frequently assessed interventions were improvements on vehicle safety, police enforcement, increases in the price of gasoline, and brief interventions on populations with an alcohol consumption problem. An assessment of the impact of tobacco restriction laws was also identified.

Most of the studies focused on the prevention of motor vehicle collisions and their consequences on the general population. Only three studies evaluated workplace interventions, two of which used a quasi-experimental design and one that was an ecological study (14 – 16). These studies assessed programs based on stringent control of alcohol consumption among drivers (15)

and enforcement of safety standards in the United States (14). As shown in Table 1, all three showed a positive effect, but the greatest was specific enforcement of safety measures (14) that resulted in a 19.2% yearly average reduction in traffic accidents (95% Confidence Interval [95%CI]: 13.3 – 25.1).

With regards to interventions to prevent traffic crashes and their consequences among the general population, this review comprises a significant body of evidence that reports a significant positive effect of programs and policies to regulate alcohol consumption. Interventions that stand out in terms of quantity and quality of evidence were: raising alcohol taxes (17, 18); reducing permissible alcohol blood levels in drivers (17, 19 – 23); blocking automatic car ignition with a blood-alcohol level sensor in previously penalized drivers (19, 24); restricting alcohol sales to under-age persons (22); police enforcement with inhaled alcohol tests (22, 25, 26); and a set of laws called “zero tolerance” that consist of a series of regulations to restrict alcohol consumption in drivers

FIGURE 1. PRISMA^a flow diagram for search and exclusions in a systematic review of the effectiveness of interventions to reduce motor vehicle crashes and their injuries among the general and working populations, January 2006 – October 2016



^a Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Source: Prepared by the authors from the study results.

TABLE 1. Brief description of studies on work place interventions to reduce traffic accidents among the working population, January 2006 – October 2016

| Study | Study design | Intervention | Results | Risk of bias | Effect |
|----------------|--------------------|--|---|--------------|-----------|
| Chen, 2008 | Quasi-experimental | A United States federal program monitoring motor carrier safety and regulatory compliance of trucking companies using a Compliance Review (CR). | Among those who had CR, the number of crashes increased on average 19.2% annually in the years before the CR year (95% Confidence Interval [95%CI]: 13.3 – 25.1) and decreased on average 27.2% in the CR year (95%CI: 20.5 – 33.9). | Medium | Positive |
| Brady, 2009 | Quasi-experimental | A mandatory alcohol-testing program to reduce alcohol involvement in motor carrier crashes, including pre-employment testing; random testing before, during and after driving shift; and post-accident testing. Drivers with a blood alcohol concentration of 0.02-0.03 g/dL are removed from duty for 24 hours. In the case of accident, drivers are tested within 2 hours. | The odds of alcohol involvement after implementation of the program was reduced by 48% for motor carrier drivers (adjusted odds ratio [aOR] = 0.52; 95%CI: 0.43 – 0.64) and by 32% for other drivers (aOR=0.68; 95%CI: 0.65 to 0.71). | Medium | Positive |
| Marlenga, 2006 | Ecological | Law-mandated tractor certification course for youth operators. | No statistically significant reduction in crashes after enactment. | Medium | No effect |

Source: Prepared by the authors from the study results.

and to increase penalties for driving under the influence (17, 20, 27). One of these studies showed that a 1% increase in beer taxes resulted in a 0.37% decrease in alcohol-related traffic fatalities per 100 000 population (17). Likewise, heightened police enforcement through publicized sobriety checkpoint programs (26) resulted in a 14.0% – 16.7% reduction of fatal crashes ($P < 0.05$). On the other hand, it has been shown in the United States that lowering the legally allowable blood-alcohol concentration for drivers reduced the incidence of fatal crashes (21), such that a 0.01 g/dL change in the limit resulted in an increase of 0.228 times in the rate of monthly deaths per state ($P < 0.05$). In contrast, a study showed that lifting the Sunday ban on alcohol sales is associated with increased motor vehicle crashes (33), a finding that was also corroborated in New Mexico (29), but not in Japan (30).

Educational interventions have not been shown to be effective in reducing traffic accidents or ensuing injuries, neither those designed for at-risk populations, such as young drivers or cyclists, nor those carried out in high-alcohol consumption settings (31 – 33).

Another group of interventions with a significant number of good quality studies is comprised of driver and driving safety programs and policies. These interventions share a common focus on risky driving behaviors, together with driver capacity and training. This review found the most effective interventions were mandatory seat belts (33 – 36),

antilock brake systems (37), camera speed control (38 – 40), helmet use by motorcycle drivers (36), and graduated driver licensing for new drivers (27, 41 – 44). Several studies assessed graduated driver licensing in the United States, both federally and in states, and showed that implementation of this program reduced accidents in young, inexperienced drivers by 19% – 39% (27).

Road safety programs associated with infrastructure projects, such as street and intersection lighting (27), public works and road investment in black spots or areas with a high number of traffic incidents (45), and dedicated streetcar rights-of-way (46) have proven effective in reducing motor vehicle crashes. Interventions that target black spots (45) have resulted in an estimated 15% reduction in urban and rural crashes ($P < 0.001$), 29% reduction of accidents in roundabouts, 19% for traffic island on approach, 59% for bike lanes, and 52% for ban on right turns ($P < 0.001$).

Increasing the price of gasoline has also been shown to be effective in reducing road accident rates. A study found that a 10% increase in gasoline prices was associated with a 2.0% decrease in monthly crashes among male drivers and 2.1% among female drivers (47).

Table 2 summarizes the interventions and their estimated effects. The complete table with the detailed descriptions and analysis of the included studies for the general population is available as Supplementary Material.

DISCUSSION

The results of this review show that among the general population, the interventions that most consistently decrease road crash incidence, injuries, and fatal outcomes are policies or programs to:

- Regulate, enforce, and penalize driving under the influence of alcohol, such as limiting blood-alcohol concentration, police sobriety checkpoints, raising alcohol taxes, ignition blocking for penalized drivers, and restricting alcohol sales to under-age people.
- Enhance safety driving and driver standards, such as graduated driver licensing, mandatory seatbelts, camera speed control, and bicycle and motorcycle helmets.
- Improve road infrastructure to prevent crashes, such as street and cross-roads lighting and structural changes to areas with high risk of crashes.
- Educate and penalize drivers with a history of traffic accidents and misbehavior.

Among the working population, interventions most frequently shown to be effective are enforcement of national safety standards in the workplace (for companies that have transport operations) and interventions that use mandatory testing to prevent and severely restrict alcohol consumption.

Our review of the literature also confirms the importance of speeding and alcohol consumption as part of the multiple causes of motor-vehicle crashes.

TABLE 2. Summary of interventions to reduce motor vehicle crashes and related injuries among the general and working populations, by category, description, and estimated effect, January 2006 – October 2016

| Intervention category | Description | Effect |
|---|---|-----------|
| Educational intervention | Educational programs geared to bicyclists | No effect |
| | Educational interventional on alcohol-consuming settings | No effect |
| | School-based educational intervention on young drivers | No effect |
| Policies or programs that regulate alcohol consumption | Increasing taxes and restricting sales on certain days | Positive |
| | Reducing limits on blood alcohol concentration and increasing penalties | Positive |
| | Ignition blocking on convicted drivers | Positive |
| | Alcohol product and sales deregulation | No effect |
| | Lifting Sunday bans to alcohol sales | Negative |
| | Brief intervention on alcohol consumption for persons involved in car accidents | No effect |
| | Alcohol sales restricted for minors | Positive |
| | Suspending license of convicted drivers | Positive |
| | Police enforcement with alcohol breath test | Positive |
| | Zero tolerance laws | Positive |
| Policies or programs on driver, passenger, and driving safety | Mandatory use of seatbelts | Positive |
| | Graduated driver licensing | Positive |
| | Speed camera controls | Positive |
| Programs that enhance road safety and infrastructure | Crossing guards | No effect |
| | Interventions and infrastructure investment on high-risk road intersections (hot spots) | Positive |
| | Street lighting | Positive |
| | Streetcar right-of-way | Positive |
| Company and workplace interventions | Programs that enforce safety measures in transportation companies | Positive |
| | Alcohol control program with mandatory checks for motor-vehicle drivers | Positive |
| | Educational intervention and certification of tractor drivers | No effect |
| Interventions on vehicle safety | Antilock brake system | Positive |
| Interventions that target problem drivers | Educational and punitive programs for problem drivers | Positive |
| Economic policies | Increasing the price of gasoline | Positive |
| Other types of interventions | Tobacco control policies | No effect |

Source: Prepared by the authors from the study results.

We found that there is a need to restrict and regulate these behaviors in drivers, based on enforcing existing regulations.

On the other hand, this review found that implementation of educational measures and communications campaigns on a stand-alone basis are not effective in reducing public health indicators related to motor vehicle collisions, except in the case of graduated driver licensing that target inexperienced drivers. They aim to promote technical competencies in driving motorized vehicles, have a duration of several years, and its beneficiaries are young populations that are more receptive to behavioral changes.

Limitations. This study had three limitations worth considering. First, the search was restricted to articles in English or Spanish, thereby excluding studies in other languages. Second, most studies on this topic were either quasi-experimental

or ecological. Though based on real-world interventions, which have inherent pragmatic value, these studies are more prone to bias and have limited capacity for explaining causality. Lastly, the study was affected by a gap in the research—studies that evaluate interventions for occupation-related motor vehicle injury and fatality are lacking. This is an important shortcoming, particularly because occupational health authorities specifically commissioned this review. This gap limits options for decisionmakers charged with recommending and implementing policies specifically geared to work-related hazards.

Conclusions

In conclusion, this review provides an overview on the effectiveness of programs and policies that aim to reduce injuries and deaths from motor crashes. These interventions regulate and enforce measures regarding driving under the

influence of alcohol; educate and train young drivers through graduated licensing programs; mandate the use of seatbelts and motorcycle helmets; use cameras to limit speeding; implement road infrastructure improvements; and educate and restrict drivers with a history of traffic violations.

The results of this review are consistent with most of the WHO recommendations on road crash prevention. The findings also contribute quality information to aid decisionmakers striving to reduce the social consequences and burden of motor-vehicle collisions and to prioritize policy and enforcement measures based on the best available scientific evidence. Our review also warns policymakers not to overrate stand-alone educational and communications campaigns, as they have not demonstrated a significant impact. Such campaigns have not proven their worth as of yet, and can instead detract from proven, effective measures.

Finally, one of the least studied areas is the effectiveness of interventions geared toward preventing road crashes among the working population. More studies are needed on the specifics of workplace hazards and interventions to reduce work-related road crashes and collisions. Additional research on these avoidable injuries and fatalities would provide a broader basis for evidence-informed policy on occupational health and safety.

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RESUMEN

Revisión sistemática de la efectividad de las intervenciones para reducir las colisiones de vehículos de motor y lesiones Asociados Resultantes en la población general y la población económicamente activa

Palabras clave

Objetivo. Resumir la mejor evidencia disponible a nivel internacional sobre la efectividad de las intervenciones para reducir el número de colisiones de vehículos de motor y sus consecuencias en la población general y la población económicamente activa.

Métodos. Revisión amplia y sistemática de la bibliografía contenida en las bases de datos biomédicas y la literatura gris. Al menos dos investigadores trabajando en paralelo realizaron la extracción de datos, la síntesis y el análisis del riesgo de sesgo.

Resultados. Se incluyeron 41 estudios con un riesgo de sesgo bajo o moderado. De ellos, 18 tenían un diseño ecológico (series de tiempo), 10 eran cuasiexperimentales, 1 era una encuesta poblacional, 1 era un ensayo clínico aleatorizado y 11 eran revisiones sistemáticas.

Conclusiones. Las intervenciones que muestran más sistemáticamente un efecto positivo sobre la incidencia, la morbilidad y la mortalidad por colisiones de vehículos de motor son las políticas o programas nacionales que reglamentan, hacen cumplir los reglamentos y sancionan a quienes conducen bajo los efectos del alcohol; mejoran la seguridad al conducir y con respecto a los conductores; mejoran la infraestructura vial a fin de prevenir las colisiones; y educan y sancionan a los conductores con antecedentes de infracciones de las leyes de tránsito.

Accidentes de tránsito; mortalidad laboral; accidentes de trabajo; traumatismos ocupacionales; bajo la influencia.

**Revisão sistemática da
efetividade de intervenções
para reduzir os acidentes de
trânsito e ferimentos na
população geral e na
população ativa**

RESUMO

Objetivo. Sintetizar as melhores evidências científicas internacionais disponíveis sobre a efetividade das intervenções para reduzir os acidentes de trânsito e suas consequências na população geral e na população ativa.

Métodos. Foi realizada uma ampla revisão sistemática da literatura em bases de dados biomédicas e da literatura cinzenta. A extração e a síntese dos dados e a análise de risco de viés foram conduzidas em paralelo por, pelo menos, dois pesquisadores.

Resultados. Foram selecionados para análise 41 estudos com risco de viés baixo a moderado. Destes, 18 possuíam design ecológico (série temporal), 10 eram estudos quase-experimentais, um estudo era um levantamento populacional, um era um estudo clínico randomizado e 11 eram revisões sistemáticas.

Conclusões. As intervenções que sistematicamente demonstraram um efeito positivo na incidência, morbidade e mortalidade de acidentes de trânsito são as políticas ou programas nacionais para regulamentar, cumprir as leis e aplicar sanções aos condutores que dirigem sob influência de álcool, melhorar a segurança e condições para condução de veículos, melhorar a infraestrutura viária visando evitar acidentes e educar e multar os condutores com histórico de infrações.

Palavras-chave

Acidentes de trânsito; mortalidade ocupacional; acidentes de trabalho; traumatismos ocupacionais; dirigir sob a influência.
