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RESEARCH ARTICLE

A SYSTEMIC REVIEW EXAMINING THE ECONOMIC EVIDENCE OF ROAD PREVENTION STRATEGIES IN REDUCING SERIOUS INJURY AND PREVENTING ROAD-RELATED MORTALITY IN SAUDI ARABIA, 2022

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INTRODUCTION

Road traffic accidents have become one of the main causes of trauma globally (Ghaffar & Ahmed, 2015). According to a report by the World Health Organization (WHO, 2015)ⁱ, road traffic injuries constitute one of the leading causes of disabilities that result in Disability Adjusted Life Years (DALYs) lost across all age groups and genders. Evidence suggests that approximately 1.3 million people lose their lives in road traffic accidents, with over fifty million sustaining injuries globally (WHO, 2015). The number of injuries and death caused by road traffic accidents is projected to increase year on year due to the increase in the number of road users, both motorists and pedestrians (Adeloye, et al 2016)ⁱⁱⁱ. The impact of these accidents negatively affects the national economy and the communities in various ways because of the associated health care costs and ill health. Annually, billions of dollars are used globally in health care, treatment, and burial of victims of road accidents

(Mohamed, 2015^{iv}; Sargazi, Sargazi, Jim, Danesh, Aval, Kiani, & Sepehri, 2016; Gebru, 2017). As a result of the increasing number of injuries and deaths through road accidents, many countries such as the United States and the UK have taken vital steps to ensure that the number of road traffic injuries are substantially reduced (Behnood, et al, 2016)^v. According to Cowling, Soljak, Bell, and Majeed (2014), the challenge faced by the emergency trauma care centres originates from the increased rates of road accidents. Efforts made to enhance the delivery of trauma care services are associated with increased economic costs. The Kingdom of Saudi Arabia (KSA) is one of the countries in the Middle East with the highest number of road injuries reported per annum (Barrimah, et al, 2012^{vi}). In the KSA, over 9,000 people were killed in road accidents in the year 2006, which accounted for approximately 12% of the total number of fatal casualties that year. Statistics indicate that that this constitutes one death an hour, with a mean of 25 deaths in one day. The rise in road traffic fatalities has peaked since the year 2007.

In the same year, road accidents rose in the KSA by nearly 3%, resulting in 39,000 injuries. This comprised over 100 injuries a day and a mean of 4.5 casualties per hour. Also, around 80,000 people lost their lives in road traffic accidents in the period between 2006 and 2016, constituting nearly 12% of deaths in the country (Elshinnawey, et al., 2008)^{vii}. However, despite the rising number of road traffic injuries in the world, limited studies have evaluated its economic impact on health care systems (Naik & Reddy, 2017)^{viii}.

Aims and Objectives of the study

Aim: The aim of this systematic review is to examine the economic evidence of road prevention strategies in reducing serious injury and preventing road-related mortality. And to provide policy recommendations to inform public investment decision-makers concerned with the development of road accident prevention strategies in the KSA.

Search strategy: The systematic review considered the grey literature and used a three-phase research strategy recommended by Joanna Briggs Institute guidelines (Peters et al., 2015)^{ix}. The first phase of the strategy involved two steps, with the first step being the search of two databases (Psych INFO and CINAHL) using the keywords: "Motorist," "Law enforcement officers," "Economic impact," "Road accidents," "Road Accident Prevention strategies," "Mortality rates," "Kingdom of Saudi Arabia," "Effectiveness," "Components of road accident prevention," "Road fatalities," and "Health gains." The description of the keys based on the PICO framework is provided in Table 1.

Table 1. The search terms in the PICO framework

PICO Element	Keywords
Population	Law enforcement officers, Motorists
Intervention	Road accident prevention strategies
Comparison	Lack of prevention road accident prevention strategies
Outcome	Mortality rates, Economic impact

RESULTS

A total of 506 articles were obtained from the selected data (Table 2). The articles were assessed for the presence of duplicates using the Ref Works citation platform, with 77 duplicates excluded. The remaining 429 articles were assessed for eligibility using the review's inclusion and exclusion criteria. In the first step of the assessment of the eligibility, 413 articles were excluded based on the outcome of the assessment of the titles and the abstracts as they lacked relevance to the population and review's aim. The remaining 16 studies were then subjected to full-text analysis, which resulted in the exclusion of 7 more articles. The article inclusion following the full-text assessment was determined based on the consideration of the relevance of the study to the review's aim and the methodological quality of the studies as indicated by the outcome of the appraisal of the methodological quality using the Effective Public Health Practice Project quality assessment tool. In total, 9 articles were selected for inclusion in this systematic review. The final phases of the search process involved reviewing the reference lists of the obtained articles for additional studies, however, no additional articles were identified.

Table 1. The obtained articles from the different databases

Database	Title (s)	Agreed titles (n)
Psych INFO,	151	1
Cochrane Library	49	0
CINAHL	147	2
Science Direct	58	3
Pro Quest	74	1
Pro Quest Dissertations and Theses	7	0
COS Conference Papers Index	1	0
WOS Conference Proceedings	3	0
Google Scholar	12	2
Website of the Ministry of Health Saudi Arabia	4	0
Total	506	9

Assessment of the methodological quality: As shown in the description of the included studies, all articles that were reviewed were based on quantitative approaches, therefore, the appraisal process was performed using the Effective Public Health Practice Project tool developed by (Thomas et al. 2004)^x. The outcome of the critical appraisal of the methodological quality showed that the seven of the nine studies had a strong global rating, while the remaining two articles had a moderate global rating (Table 4). Given the fact that only a few of the retrieved studies were able to meet the review's inclusion and exclusion criteria, a decision was taken to include all nine studies for this systematic review. The assessment of the selection bias based on the evaluation of the representativeness of the individuals selected to participate and the proportion of the selected individuals who agreed to take part in each of the studies showed six studies had a strong rating, while the studies by (Novoa et al. 2010)^{xi} and (Abbas et al. 2011)^{xii} had a weak rating. Based on the rating of the various study designs by the Effective Public Health Practice Project tool, it was determined that all the nine included articles were based on study designs that had a moderate rating. Blinding was not applicable to the study designs adopted by the eight of the reviewed studies, except the study conducted by (Novoa et al. 2010), which was noted to have a moderate rating on blinding. The withdrawal and dropout assessment item was also noted to be not applicable to five of the included studies, while the other four (Novoa et al., 2010; Abbas et al., 2011; (Esperat et al., 2012)^{xiii}; (Meehan III et al. 2013)^{xiv} (Alghnam et al. 2018)^{xv} attained a moderate score for the withdrawal and dropouts.

DISCUSSION

The outcome of this narrative summary has addressed this study's aim, which focused on the assessment of the economic evidence of road prevention strategies in preventing road-related mortality and addressing the resulting health outcomes. One of the aims was the determination of the key components of road accident prevention strategies that have the greatest impact on the prevention of injuries and mortality rates. It is evident from this systematic review that the key components of road accident prevention strategies, such as the enforcement of the legislation on speed limits, drink driving, seatbelt use, and motorcycle helmet use, have the potential to reduce the deaths associated with traffic accidents. Furthermore, the adoption of such interventions is associated with significant gains in health. However, it should be noted that despite the positive review findings on the cost-effectiveness of the enforcement of the reviewed traffic accidents prevention strategies, this systematic review does not claim to provide any unique or new insights, given the fact that the outcomes regarding some of the strategies, such as the use of seatbelts, are based on only two studies. In addition, the systematic review findings on the cost-effectiveness based on the averted DALYs are only supported by three studies. Nonetheless, the outcomes of this narrative review are not meaningless, since they provide insights on the cost-effectiveness of different components of road accident prevention strategies, which can be applied to the KSA context, therefore form a basis for the formulation of relevant recommendations. According to this review, the enforcement of speed limit laws and regulations is important in the prevention of road accidents and is associated with considerable health gains (Chisholm et al., 2012). The findings are especially important, since the need for cost-effective speed limit laws in the KSA cannot be overemphasised (Al Turki, 2014)^{xvi}. (Al-Ghamd2006)^{xvii} noted that in areas such as the residential streets with a speed limit of 40 km/h, 100% of motorists have 85th percentile speeds over the speed limit. (Al-Ghamd2006) also reported cases of speed limit violations in the freeways and arterials ways. There are other Saudi-based research studies that have also reported a violation of speed limit (Alshahri et al., 2012)^{xviii}; (Al Turki, 2014). The other aim of the systematic review was to determine the economic impact of road accident prevention strategies on the use of health service resources as well as on wider society. Based on the findings that indicated the variations in the cost-effectiveness of the different strategies used in enforcing the speed

Table 3. Summary of the included studies

Reference	Country	Title	Objective	Methodology	Outcome/Findings
Wali, Ahmed, Iqbal, & Hussain, 2017	178 countries globally	The effectiveness of enforcement levels of the speed limit and drink driving laws and associated factors—Exploratory empirical analysis using a bivariate ordered probit model	Assessment of the effectiveness of the enforcement of traffic safety policies on the reduction in fatalities and use of health services	Quantitative analysis of existing data obtained from WHO Global Status Report on Road Safety (2013)	The adoption of traffic regulations relating to the speed limit and drink driving law leads to a significant reduction in road accident fatalities and the number of hospital bed used
Ditsuwan, Veerman, Bertram, & Vos, 2013	Thailand	Cost-effectiveness of interventions for reducing RTI related to driving under the influence of alcohol	Investigation of the cost-effectiveness of drink driving intervention in the reduction of traffic accident injuries	Quantitative analysis of the existing data obtained from the general population in Thailand (11,700 individuals aged between 15 and 59 years)	The adoption of drinking-driving intervention results in reduced health-related costs Adoption of mass media campaigns, random breath testing, and selective breath tests resulted in incremental cost-effectiveness ratios of 309.9, 430.2 and 391.1 USD/DALYs respectively
Novoa, Pérez, Santamarina-Rubio, Mari-Dell'Olmo&Tobias, 2010	Spain	The effectiveness of speed enforcement through fixed speed cameras: a time series study	Determination of the effectiveness of speed limit initiatives in reducing the numbers of crashes and people injured	Quasi-experimental design using local police data regarding the number of crashes and people injured in RTA in Barcelona between January 2001 and December 2007	The enforcement of the speed limit initiatives results in the reduction in the number of traffic accidents The use of speed cameras led to a 30% reduction in the risks of crashes and a 26% reduction in the people injured
Carnis&Blais, 2013	France	An assessment of the safety effects of the French speed camera programme	The assessment of the effectiveness of the speed limit intervention in the reduction of the burden associated with road accidents	Quantitative analysis of the existing data from the French national database (N = 144)	Adoption of the speed limit intervention resulted in a 21% reduction in the fatality rate per 100,000
Abbas, Hefny, & Abu-Zidan, 2011	46 high-income countries	Seatbelts and road traffic collision injuries	The determination of the effectiveness of the use of safety interventions, such as safety belts, in the reduction of the burden associated with traffic accidents	Quantitative analysis of the existing data from 46 countries from the WHO road traffic injury prevention discussion paper of 2009	The use of the safety belts is negatively correlated with the road traffic deaths
Meehan III, Lee, Fischer, & Mannix, 2013	USA	Bicycle helmet laws are associated with a lower fatality rate from bicycle-motor vehicle collisions	The assessment of the effectiveness of safety intervention in the reduction of the deaths associated with traffic accidents	Cross-sectional study of data of fatal traffic crashes from the Fatality Analysis Reporting System, which is compiled by the US, National Highway Traffic Safety Administration	The use of helmets is associated with the reduction in mortality rates
Chisholm <i>et al.</i> , 2012	Sub-Saharan Africa and South East Asian countries	Cost-effectiveness of strategies to combat RTI in sub-Saharan Africa and South East Asia: a mathematical modelling study	The investigation of the costs and effects of specific enforcement strategies for reducing the burden of road traffic injuries	Quantitative analysis of the existing data on the cost-effectiveness of traffic interventions were collected from 4 countries (Kenya, Tanzania, India, and Nepal)	The enforcement of the interventions, such as speed limits, drink driving laws, and motorcycle helmet use, results in the one DALYs averted for a cost of \$1000
Esperat, Bishai, & Hyder, 2012	Brazil, Cambodia, China, Egypt, India, Kenya, Mexico, the Russian Federation, Turkey, and Vietnam	Projecting the health and economic impact of road safety initiatives: a case study of a multi-country project	The projection of the health-related cost-effectiveness and the life-saving potential of an intervention that involved the implementation of drink driving prevention, motorcycle helmets, seat belts, and speed management	Quantitative analysis of the existing data on the projected effectiveness of traffic interventions were collected from 10 low- and middle-income countries	The implementation of the intervention resulted in the saving of 10,310 lives in a period of 5 years
AlghnamTowhari, Alkelya, Binahmad, & Bell, 2018	Saudi Arabia	The effectiveness of introducing detection cameras on compliance with mobile phone and seatbelt laws: a before-after study among drivers in Riyadh, Saudi Arabia	Evaluation of the impact of an automated citation system on the prevalence of seatbelt and mobile phone use among drivers in Riyadh	Pre-post observation evaluation study involving 3400 drivers	The use of the automated citation system improved the overall seatbelt compliance and limited the use of phones while driving

Table 4. Appraisal of the quantitative studies

Reference	Selection Bias	Study design	Confounders	Blinding	Data Collection Methods	Withdrawals and dropouts	Overall rating
Wali <i>et al.</i> , 2017 ¹	Strong	Moderate	NA	NA	Strong	NA	Strong
Ditsuwan <i>et al.</i> , 2013	Strong	Moderate	NA	NA	Moderate	NA	Strong
Novoa <i>et al.</i> , 2010	Weak	Moderate	Strong	Moderate	Strong	Moderate	Moderate
Carnis&Blais, 2013 ¹	Strong	Moderate	NA	NA	Strong	NA	Strong
Abbas <i>et al.</i> , 2011	Weak	Moderate	NA	NA	Strong	Moderate	Moderate
Meehan III <i>et al.</i> , 2013	Strong	Moderate	Moderate	NA	Moderate	Moderate	Strong
Chisholm <i>et al.</i> , 2012 ²	Strong	Moderate	NA	NA	Moderate	NA	Strong
Esperat <i>et al.</i> , 2012	Strong	Moderate	NA	NA	Strong	Moderate	Strong
Alghnam <i>et al.</i> , 2018	Strong	Moderate	NA	NA	Moderate	NA	Strong

limit laws and regulation, caution needs to be taken when adopting the initiative. The outcome of this systematic review suggests that adopting an approach which limits the need for a high number of personnel, such as the use of fixed cameras instead of mobile ones, can reduce the implementation cost, subsequently enhancing the cost-effectiveness of the approach (Chisholm *et al.*, 2012). The high cost-effectiveness of fixed cameras has been reported by other researchers (Wilson, Hendrikz, Le Brocque, & Bellamy, 2010)^{xx}; Babari, Hautière, Dumont, Paparoditis, & Misener, 2012). Given that only one reviewed study (Alghnam *et al.*, 2018) reported the effectiveness of the automated camera-based surveillance system in Saudi Arabia, questions arise regarding the cost-effectiveness associated with the use of fixed cameras and photo radars in the KSA context. The understanding of how much the Saudis are willing to invest in fixed cameras and photo radars as a means of reducing the risk associated with exceeding the speed limit is not directly addressed in this study. Similarly, the actual health gains that the Saudis stand to benefit from the investment (fixed cameras and the photo radars) can be adequately addressed by the primary data from the KSA setting, which were unavailable for this review. However, this systematic review outcome does provide reasons to pursue the use of fixed cameras and the photo radars as a cost-effective approach towards the management of traffic accidents in the country. The second cost-effective component of road accident prevention strategies described in this systematic review is the adoption of traffic rules relating to drink driving (Ditsuwan *et al.*, 2013)^{xx}. The findings relating to the cost-effectiveness of the adoption of the traffic rules relating to the drink driving are important, since drink driving is frequently reported among the motorists in the KSA (Nofal, Saeed & Anokute, 1996)^{xxi}; (De Nicola *et al.*, 2016)^{xxii}; (Mohamed & Bromfield, 2017)^{xxiii}. Although alcohol consumption and drug use are illegal in the KSA, De Nicola *et al.* (2016) argue that there are some drivers who still drive while under the influence of alcohol. (Mohamed and Bromfield 2017) also suggested that the Saudis who usually drive under the influence of alcohol have a higher chance of violating various traffic rules, such violation of speed limits and seat belt usage. According to the outcome obtained in this review, the KSA can benefit from the enforcement of the drink driving laws, which is achieved through the use of mass media and sobriety checkpoints (Ditsuwan *et al.*, 2013).

As noted from the review outcome, the use of checkpoints can help to reduce the number of motorists who drink and drive. However, for the KSA to benefit from the cost-effectiveness of the adoption of the traffic rules relating to the drink driving, there is a need to embrace the combined synergies of mass media campaigns and sobriety checkpoints, with the focus on the increased use of mass media campaigns for the high coverage of the risks and penalties that are associated with drunk driving (Ditsuwan *et al.*, 2013). However, as noted by (Ditsuwan *et al.* 2013), the approach used in the determination of the cost-effectiveness of the reviewed drink driving intervention strategies was reliant on the local (Thailand) parameters, such as the prevailing social and economic variables in that country. Therefore, there are unanswered questions regarding whether the observed cost-effectiveness of the adoption of the traffic rules relating to the drink driving can be obtained in KSA context, which is characterised by different demographics and social economic dynamics. However, despite the highlighted concern, the systematic review outcome on the adoption of traffic rules gives an important insight into the particular strategies that the relevant KSA authorities can adopt to ensure the cost-effective approach to the prevention of traffic accidents in the country. The findings of this systematic review also indicate that the enforcement of the regulation on the safety gear, such as the use of helmets and the safety belts, provides a cost-effective approach for the prevention of road accident (Abbas *et al.*, 2011; Meehan III *et al.*, 2013). The findings regarding the cost-effectiveness of safety gear in reducing the traffic accidents is also important to the KSA context given that fact that various researchers have attributed some fatal traffic injuries in the country to the lack of using safety gear (Barrimah *et al.*, 2012); Al Turki, 2014; Mansuri *et al.*, 2015). The KSA authorities have also enforced seat belt law since 5th December 2000 (Barrimah *et al.*, 2012). According to Barrimah *et al.* (2012), the strategy used by the KSA authorities in enforcing the

seat belt law is the compulsory directive that affects all drivers and front seat passengers. According to the outcome of this review, the compulsory approach to the implementation of the laws regarding the use of safety gear offers most the effective approach, with high adherence and limited cost as opposed to the cost of conducting public education and the media campaigns (Meehan III *et al.*, 2013). However, it is also important to note that the hiring of the personnel, such as the police, required to enforce the compulsory legislation on seat belts and the cost associated with the selection and stopping of motorists for random check of their compliance with the regulation, can lead to increased implementation costs (Chisholm *et al.*, 2012). Furthermore, there are answered questions regarding the potential cost-effectiveness of the use of seat belts considering the review findings regarding the potential abdomen, pelvis, and lumbar spinal injuries as a result of the use of seat belts during a collision (Abbas *et al.*, 2011). Concerning the use of helmets, this systematic review observed that there is limited research regarding the cost-effectiveness of the approach. However, based on the obtained findings, the increased safety and averted deaths because of the enforcement of helmet use laws provide a basis through which the relevant KSA authorities can make the decision about the adoption of the initiative. It is specifically important for the KSA to consider the enforcement of the use of helmets laws given the fact that many accident victims suffer severe head injuries resulting in many kinds of traumatic brain injuries (Al-Habib, 2014).

Importantly, the findings of this systematic review show that the most cost-effective road accident prevention intervention is the one that combines multiple strategies, such as the enforcement of the legislation on speed limits, drink driving, seatbelt use, and motorcycle helmet use, results in higher economic impact (Chisholm *et al.*, 2012; Esperat *et al.*, 2012). The cost-effectiveness of the combined interventions is based on the benefit that is associated with the combined synergies from the individual strategy in achieving greater prevention of loss of life and occurrence of long-term disability, while reducing the overall cost investment in the initiative (Chisholm *et al.*, 2012; Esperat *et al.*, 2012). However, it should be noted that the systematic review findings on the cost-effectiveness of some of the combined strategies, such as the RS-10 initiative, were based on the analysis of the implementation in countries such as Kenya, with a low population size and lower gross national income compared to the KSA (Esperat *et al.*, 2012). Since the KSA is considered a high-income country, it is expected that the findings of this systematic review will be applicable to the country. However, given the fact that country-based economic evaluations are important in the determination of the cost-effectiveness of the reviewed road accident prevention strategies (Ditsuwan *et al.*, 2013), caution should be exercised when adopting the outcome.

CONCLUSION

This narrative review assessed the economic evidence of road prevention strategies in reducing serious injuries and preventing road-related mortality. The systematic review searched and reviewed research findings that presented outcomes relating to the cost-effectiveness of different traffic accident prevention strategies. The findings of this narrative review are based on nine studies conducted across the different jurisdictions and were published after 2010. The systematic review presents important findings of the key components of road accident prevention strategies that are regarded as being effective in the management of road accidents. The systematic review also described the economic impact of the reviewed road accident prevention strategies on mortality rates and the health-associated gains. Concerning the key components of road accident prevention strategies, this systematic review shows that the enforcement of the legislation on speed limits, drink driving, seatbelt use, and motorcycle helmet use form the major strategies. These strategies are shown to be effective in minimising the frequency of accidents. The enforcement of speed limit regulations is important in the reduction of speed limit violations, with significant health gains as shown by the averted DALYS/million population per year (Chisholm *et al.*, 2012).

Furthermore, the use of high coverage mass media campaigns and a minimal use of checkpoints in the enforcement of the traffic rules that control drink driving result in high cost-effectiveness (Ditsuwan *et al.*, 2013). The adoption of regulations on the safety gear is also described as being important in the reduction of the number of deaths following road traffic collisions (Abbas *et al.*, 2011; Meehan III *et al.*, 2013). Finally, the systematic review shows that the enhanced cost-effectiveness can be achieved when the road accident prevention interventions combining multiple strategies are adopted (Chisholm *et al.*, 2012; Esperat *et al.*, 2012).

Implication for practice: Based on the systematic review findings, the policymakers and relevant authorities in the KSA need to choose the type of intervention for enforcing speed limit regulations with a keen interest in reducing the human resources and the instruments required for the implementation. Although the use of the interventions, such as the fixed speed cameras, photo radar devices, and punitive penalties, have been shown to have a positive impact on the averted DALYs, some interventions are more costly (Chisholm *et al.*, 2012). Specifically, there is a need for the relevant authorities in the KSA to thoroughly evaluate the use of mobile cameras, which are associated with a high cost due to the high demand for human resources. However, for the highest cost-effectiveness, the policy formulators need to consider the adoption of road accident prevention strategies that combine multiple interventions. Based on the outcome of this review, it is evident that the implementation of strategies that combine different interventions, such as the enforcement of the legislation on speed limits, drink driving, seatbelt use, and motorcycle helmet use, results in higher economic impact (Chisholm *et al.*, 2012; Esperat *et al.*, 2012). It is also important to ensure that the choice of the interventions to be included in the combined strategy approach reflects the traffic conditions and challenges in the KSA to ensure that only the interventions that address existing traffic problems are incorporated into the strategy future studies should also focus on the country-specific assessment of the cost-effectiveness of the adoption of the traffic rules relating to drink driving and use of helmets. The analysis by future studies should factor in the varying demographic and social economic dynamics as well as the impact on the measures of the cost-effectiveness of traffic accident prevention strategies such as the QALYs

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