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RESEARCH

Cost effectiveness of strategies to combat road traffic injuries in sub-Saharan Africa and South East Asia: mathematical modelling study

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Abstract

Objective To identify and estimate the population costs and effects of a selected set of enforcement strategies for reducing the burden of road traffic injuries in developing countries.

Design Cost effectiveness analysis based on an epidemiological model.

Setting Two epidemiologically defined World Health Organization sub-regions of the world: countries in sub-Saharan Africa with very high adult and high child mortality (AfrE); and countries in South East Asia with high adult and high child mortality (SearD).

Interventions Enforcement of speed limits via mobile speed cameras; drink-drive legislation and enforcement via breath testing campaigns; legislation and primary enforcement of seatbelt use in cars; legislation and enforcement of helmet use by motorcyclists; legislation and enforcement of helmet use by bicyclists.

Main outcome measures Patterns of injury were fitted to a state transition model to determine the expected population level effects of intervention over a 10 year period, which were expressed in disability adjusted life years (DALYs) averted. Costs were expressed in international dollars ($Int) for the year 2005.

Results The single most cost effective strategy varies by sub-region, but a combined intervention strategy that simultaneously enforces multiple road safety laws produces the most health gain for a given amount of investment. For example, the combined enforcement of speed limits, drink-driving laws, and motorcycle helmet use saves one DALY for a cost of $Int1000–3000 in the two sub-regions considered.

Conclusions The potential impact of available road safety measures is inextricably bound by the underlying distribution of road traffic injuries across different road user groups and risk factors. Combined enforcement strategies are expected to represent the most efficient way to reduce the burden of road traffic injuries, because they benefit from considerable synergies on the cost side while generating greater overall health gains.

Introduction

Road traffic injuries represent a leading and increasing contributor to regional and global disease and injury burden. It is estimated that in 2002 road crashes killed over one million people worldwide and injured or disabled a further 20–50 million.[1] Road traffic injuries are projected to become the third largest contributor to global disease burden by 2030.[2] Most of the projected increase will occur in low and middle income regions of the world because of the rapid growth in motor vehicle numbers increasing exposure to risk factors such as speed and alcohol, and exacerbated by inadequate enforcement of traffic safety regulations and public health infrastructure.[1 3 4]

There is marked variation across the world in the way that roads are used and injuries are caused, which have important implications for road safety policy and practice. Road traffic injuries in highly motorised countries mostly involve car drivers, whereas in certain countries of Asia it is motorcycle riders and in many low income countries it is occupants of multiple passenger vehicles (such as buses) and pedestrians. There is also variation in the breakdown of these injuries by underlying cause (road infrastructure versus vehicle design versus exposure to risk factors such as speeding or not wearing a seatbelt). In order to estimate the potential impact of different road safety measures on health at the population level, therefore, a good understanding of underlying patterns of road use and injury

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General appendix (referred to by all the papers in this cluster)
Appendices A–D: Modelling the impact and cost of road safety interventions (A), estimates of road safety effect size (B), estimates of resource inputs and prices (C), and results of probabilistic uncertainty analysis (D)

burden is required. Despite the existence of injury surveillance systems in several countries, such information is in short supply. There is also a shortage of evidence on the comparative population level costs and cost effectiveness of different intervention strategies for reducing traffic injuries—an important gap in the knowledge base needed to attract new investment and guide decision making.[5 6]

As a contribution to studying the public health response to road safety at the global level, this study set out to identify and estimate in different world regions the population level costs and effects of a limited set of currently used and potentially applicable interventions for reducing the burden of road traffic injuries.

Methods

Several analytical steps were required in order to estimate the cost effectiveness of road safety measures in these different regions of the world: age and sex specific attribution of the global burden of fatal and non-fatal road traffic injuries, both by road user group and by injury risk factor; identification, estimation, and modelling of intervention effectiveness at the population level; and intervention costing. Further details relating to the methods used in this analysis can be found in a WHO working paper.[7]

Consistent with this and the earlier cost effectiveness series, we report results for two WHO reporting sub-regions:

AfrE—Countries in the WHO sub-Saharan African region with very high levels of child and adult mortality (such as Kenya and Tanzania)

SearD—Countries in the WHO South East Asia region with high levels of child and adult mortality (such as India and Nepal).

Attribution of road traffic injuries by road user group and risk factor

A comprehensive literature search was undertaken in order to synthesise existing country level information relating to the proportion of fatal or non-fatal road traffic injuries occurring among defined road user groups (pedestrians, bicyclists, motorcyclists, car occupants, and bus or truck occupants).[8] On the basis of the findings of this review, we constructed weighted averages for each of the WHO sub-regions. The breakdown of fatal injuries in the two settings used in this analyses are shown in the figure⇓. In the South East Asian sub-region, motorcyclists and bus and truck occupants are the largest contributors to road traffic fatalities (an estimated 46%), with car occupants constituting less than 20% of total fatalities. In the African sub-region, by contrast, more than half (55%) of fatal injuries are estimated to be among pedestrians.

We also determined the attributable fractions for age, sex, and specific region for specific risk factors relating to road traffic injury: seatbelt non-use, helmet non-use, driving under the influence of alcohol, and speeding. All road traffic injuries not accounted for by these discrete risk factors were grouped together under a residual category of mainly vehicular and environmental risk factors (see figure⇓). The contribution of alcohol as a risk factor to levels of road traffic injury has already been analysed as part of a comparative risk assessment.[9] For speeding, we relied on directly measured estimates from a number of countries, which consistently indicate that speeding accounts for 30–50% of all crashes and associated injuries. For remaining risk factors, we adopted a population attributable fraction approach, which relates the proportion of road users with the risk factor exposure of interest (seatbelt non-use, motorcycle helmet non-use, and bicycle helmet non-use) to the relative risk of injury for a road user with the risk factor exposure.[7] Again, country specific data were used to generate weighted averages for each WHO sub-region.

Most road crashes involve more than one risk factor. For example, alcohol intake increases the likelihood of driving at excessive speed. Simply summing up the attributable fractions as described above would exaggerate the true contribution of each risk factor to overall injury rates. The degree of overlap or joint risk also varies by age, with young male adults being a prominent example of a socioeconomic group in which multiple risk exposures are liable to be present simultaneously. Accordingly, we applied age-specific adjustment factors to ensure that the total road traffic injury envelope for each age group was not exceeded.

Estimation and modeling of intervention effectiveness

The World Health Organization—Choosing Interventions that are Cost effective (WHO-CHOICE) project employs an epidemiological approach to the estimation of population level effects of different health interventions.[10 11] Specifically, the effect of a given intervention on the healthy life expectancy of a population is derived with reference to two epidemiological situations, one with the intervention in place (for a period of 10 years), the other without the intervention or a counterfactual situation referred to as a “null scenario” (derived by subtracting the known effects of currently implemented interventions). The difference between these two situations over the lifetime of the population (set at 100 years) represents the net effect of the intervention, expressed in terms of disability adjusted life years (DALYs) saved. These epidemiological scenarios can be estimated via a multistate population model, which traces the development of a population, taking into account births, deaths, and the disease or injury in question (see general appendix on bmj.com).

For the road traffic injury model, non-fatal acute injuries of short term duration were excluded from the analysis (cuts, bruises, most fractures of the leg or arm, etc), since they represent less than 10% of the estimated non-fatal burden of road traffic injuries.[12] Accordingly, the key parameters of interest are the acute mortality from road traffic injury and the incidence, prevalence, and case fatality of long term road traffic injury (as well as its associated level of disability). These rates, together with data sources and derivation methods, are detailed in appendix A on bmj.com.

Interventions selected for this analysis draw on the recommendations of the *World Report on Road Traffic Injury Prevention*,[1] and are specifically focused on those pre-event road safety measures that are capable of changing human factors (since they have robust evidence for their effectiveness and are amenable to intervention costing at the population level). These include enforcement of speed limits (via mobile speed cameras), drink-drive legislation and enforcement (via breath testing campaigns), legislation and primary enforcement of seatbelt use in cars (drivers and passengers), legislation and enforcement of helmet use by motorcyclists (all riders), and legislation and enforcement of helmet use by bicyclists (aged <15 years).

The specific impact of the selected enforcement strategies on different road user groups is shown in table 1⇓. Certain strategies are specific to certain road user groups (such as seatbelts and helmets) whereas others affect all road users (such as speeding, alcohol use). Effect sizes for fatal and non-fatal injury prevention were taken from the international literature,[13-24] which is described in relation to each intervention in appendix B on bmj.com. The effects of these road safety measures on levels of population health were considered independently and then in combination (at a target coverage level of 80%). A multiplicative relationship was used to ascertain the joint effect of different combinations.

Estimation and modelling of intervention costs

For the selected interventions in this analysis, costs are incurred at a programmatic level, including the resource costs associated with legislation, programme management, and law enforcement (see appendix C on bmj.com for a description of resource inputs and prices used in the analysis). Even though certain road safety measures are already in force in most regions of the world, the reference point or counterfactual used here is the situation of doing nothing, so we estimate the full set of resource inputs needed to develop and maintain interventions. The comprehensive costing of such programme level costs has recently been made as part of the WHO-CHOICE programme.[25 26] Accordingly, we used existing templates for these categories of programme cost for calculating the resource requirements of the road safety measures considered. In addition to these programme costs, we include the cost of equipping bicycle and motorcycle riders with helmets, since this represents an integral cost component of these road safety measures. Likewise, we estimated the cost of fitting front and rear seatbelts in cars that do not already have such safety equipment (estimated at 50% in low income sub-regions).

Costs were calculated for a 10 year implementation period, discounted at 3% and expressed in international dollars ($Int), which adjust for differences in the relative price and purchasing power of countries and thereby facilitate comparison across regions (that is, $Int1 buys the same quantity of healthcare resources in Kenya or India as it does in the United States; for the African and Asian sub-regions used in this analysis, $Int1 is worth US$0.44 and US$0.32, respectively).

Uncertainty analysis

Baseline DALYs have been discounted (at a rate of 3%) and subjected to an age weighting function that attaches greater value to the middle years of life and less to the young and old; results without these weights were also assessed. A series of (one-way) sensitivity analyses were performed on a number of variables for which particular uncertainty exists (such as the proportion of vehicles stopped each year at checkpoints, which is a key determinant of effective coverage in the population). Cost and outcome data (together with coefficients of variation amounting to 20–25% above and below baseline values) were also subjected to a probabilistic uncertainty analysis using Monte Carlo simulation (1000 runs were made using a truncated normal distribution).[11] The likelihood that interventions would fall below a defined set of cost effectiveness thresholds was evaluated: WHO-CHOICE denotes as “cost effective” an intervention that produces a healthy year of life for less than three times the gross domestic product (GDP) per capita, and as “very cost effective” an intervention that produces a healthy year of life for less than the GDP per capita.

Results

Population level effect of interventions

The population level health gains associated with the five intervention strategies at target coverage levels (80%), alone and then in various combinations, are presented in table 2⇓. Effectiveness results are expressed in terms of DALYs saved—or healthy life years gained—per million population per year of implementation. Because of the prominence of excessive speed and its negative consequences across all road user groups, enforcement of speed limits (via mobile cameras) is the single most effective strategy in the two sub-regions considered here (84 and 167 DALYs averted per million population per year in the South East Asian and African sub-regions, respectively). Legislation and enforcement of drink-driving laws also produce consistent gains in these populations (50–66% of the gain estimated for mobile speed cameras). Seatbelt laws and enforcement produce lower effects again (30–35% of the gain for mobile speed cameras). Unsurprisingly, legislation and enforcement of motorcycle helmet use has a relatively large impact in the South East Asian sub-region, with its heavy use of motorcycles, but only a modest impact in the African sub-region, where the motorcycle fleet is appreciably smaller. Assuming baseline effect sizes, legislation and enforcement of bicycle helmet use among children is among the most effective single strategies in the African setting, but has least impact on population health in the Asian context. The combined effect of implementing some or all the selected measures is also shown in table 2⇓.

Population level cost of interventions

The total annualised cost of implementing each single or combined intervention over a 10 year implementation period, expressed in millions of international dollars ($Int) per million population (that is, cost per capita), is also presented in table 2⇓. Of the single interventions, measures aimed at speeding and drink-driving carry the highest costs ($Int0.10–0.30 per capita) because of the additional equipment and human resources needed to mount effective and sustained roadside enforcement campaigns. Total cost estimates for increased seatbelt use by car occupants and increased helmet use by motorcyclists and bicyclists are comprised of two elements: the cost to households of purchasing the safety equipment, and the cost of passing and enforcing laws. Seatbelt purchase costs consistently account for a third to a half of total costs; for helmets, costs are largely determined by motorisation rates, such that in the African sub-region they represent only a small component of total cost, whereas in the South East Asian sub-region they account for more than half of total costs.

Combinations of different interventions exhibit notable economies of scope because of significant synergies that exist between individual enforcement strategies. For example, the incremental cost of adding seatbelt enforcement to an existing roadside drink-driving campaign would be modest because the essential resource ingredients for implementing the combined programme—enforcement officers, vehicles, roadside equipment, etc—are largely in place already. Accordingly, a clear levelling out or plateau effect can be seen as multiple roadside interventions with a large degree of joint costs are packaged together. One intervention that we did not assume could be so easily integrated with other roadside enforcement policies is increased helmet use by child bicyclists on the grounds that it would involve targeting a different road network (much less reliance on busy intercity roads).

Cost effectiveness of interventions

Dividing total implementation costs by total effects provides an estimate of the cost per unit of effect, relative to the common reference point of doing nothing (the null scenario); this is referred to as the average cost effectiveness ratio for each intervention (table 2⇓). The most cost effective individual strategy varies by sub-region—bicycle helmets in the African region, speeding control in the South East Asian one—but generally speaking a combined intervention strategy that simultaneously enforces multiple road safety laws produces the most health gain for a given amount of investment; for example, each DALY averted by the combined enforcement of all strategies costs $Int1380 in both sub-regions.

Uncertainty analysis

All of the results reported above are imbued with a degree of uncertainty, either as a result of specific analytical choices (such as the discount rate or the age weights applied to DALYs) or as a result of lack of precise information concerning data input values (specific items identified above include the effect size for bicycle helmets, the cost of fitting seatbelts in a proportion of the motor vehicle fleet, and the roadside enforcement rate). Removing age weights from the DALY calculus—so that each DALY averted is treated as equal, no matter at what age group it accrues to—had a minimal impact on baseline cost effectiveness ratios (5–15% higher). Removal of discounting, on the other hand, has a marked impact on results, such that unadjusted DALYs averted (with no discounting or age weighting) are close to double their baseline value; this would result in cost effectiveness ratios that are nearly 50% lower (more favourable) than baseline estimates.

Because of the uncertainty about the effectiveness of bicycle helmets, we assessed the impact of reducing baseline relative risk reductions, first by 50% and then by 75%, which has the effect of increasing cost effectiveness ratios by 100% and 300% respectively. In the African sub-region, where baseline results showed bicycle helmets to be a cost effective option, the sensitivity analysis indicates that, even if assumed effectiveness is reduced by 50% (for example, a relative risk reduction of about 35% rather than 70% with respect to fatal injury), this intervention remains one of the more efficient injury prevention strategies. On the cost side, an important driver of traffic enforcement campaigns relates to the proportion of vehicles that need to be pulled over in order to derive the expected level of effective coverage in the population; halving (to 5%) or doubling (to 20%) the baseline pull-over rate of 10% has a large impact on cost effectiveness, particularly for interventions affecting multiple road user groups such as speeding and drink-driving countermeasures (average cost effectiveness rates are 30% more or 60% less than baseline values respectively).

The results of a probabilistic uncertainty analysis on baseline results are shown at appendix D on bmj.com. In both sub-regions enforcement strategies straddle the threshold value for considering an intervention to be highly cost effective (that is, below GDP per capita, which is close to $Int2000 in these two sub-regions), but all interventions are shown to have a very high or complete likelihood of falling within the cost effective threshold (three times GDP per capita).

Discussion

Research findings and implications

To date, few attempts have been made to document the breakdown of road traffic injuries by risk factor or the injury burden that can be averted via (cost) effective road safety measures. Those attempts that have been made are partial in terms of intervention or geographical coverage, which is perhaps unsurprising in view of the availability of data.[5 6] Subject of course to the limitations of economic modelling, our analysis of risk exposure and intervention cost effectiveness for road traffic injury prevention provides an improved basis for decision making and resource allocation in global road safety.

Our findings can provide a useful analytical baseline against which more country-specific assessments can be made (such as that already carried out in Vietnam). Even at the aggregated level of whole sub-regions of the world, discernible patterns emerge of "what works where," depending on the underlying patterns of road traffic injury. For example, in settings where there is low overall motorisation (as in sub-Saharan Africa) or a high dependence on bicycles as a mode of transport, injuries to bicyclists account for a large share of the avertable burden (>10%), and increased use of bicycle helmets could bring substantial health benefits and is a relatively low cost option. In other settings such as South East Asia, other strategies dominate in terms of value for money (including motorcycle helmet use and speed reduction).

Unsurprisingly, given the large proportion of road traffic injuries attributed to speeding in all sub-regions of the world, interventions that affect this risk factor have important public health implications. In this analysis we assessed the costs and effects of one speeding related intervention (roadside checkpoints using handheld speed cameras) and found it to be an effective and worthwhile strategy.

A further policy message to emerge from the analysis is that, more than individual interventions, combined enforcement strategies are the most efficient way to respond to the burden of road traffic injuries because they benefit from significant synergies in cost while generating greater overall health gains. In other words, once the basic infrastructure of roadside checkpoints has been created or scaled up—in terms of human resources, vehicles, and equipment—the marginal cost of adding an extra road safety check such as for wearing seatbelts is low.

Study limitations

Fitting a mathematical model to the complex reality of risky road use behaviours and their prevention requires many simplifying assumptions to be made, as well as extrapolation of available data to other geographical or socioeconomic settings. Results therefore need to be interpreted in light of these analytical drawbacks. For example, the accuracy of regional weighted average estimates of the distribution of injuries by road user group depends on how representative are the data sources from which they are constructed. As the road user mix may vary dramatically between different sections of a country (rural *v* urban), studies of urban hospitals may not be representative of the distribution of road traffic injuries by road user category for an entire country. However, the paucity of available population level data meant that we had to rely on hospital based studies to derive sub-regional weighted average estimates. Also, estimates of the incidence and prevalence of non-fatal injuries were informed by only a small number of health facility datasets from WHO member states, and we restricted ourselves to a prominent subset of severe, long term causes (which between them account for around 80% of the non-fatal road traffic injury burden). Exclusion of other long term injuries and all minor injuries (not requiring hospitalisation) therefore reduces the total non-fatal injury burden (by 10–20%), and this implies that the estimated population level impact of prevention strategies is underestimated. The degree of underestimation, however, is expected to be modest because the main benefits to be reaped from these interventions come from their impact on mortality and severe, long term injury.

While the assessed interventions affect key risk factors for different road user groups, they represent only a fraction of the total set of strategies that could be taken to reduce the burden of road traffic injuries,[1 5 6] including improved road design or layout (such as the construction of barriers, special zones, and separate lanes to separate moving vehicles from pedestrians). Although there is evidence of safety improvements associated with such strategies, estimation of the resources and costs needed to achieve them is highly problematic at the international level, and calculation of their relative cost effectiveness was outside the scope of our study. In a similar vein, there are considerable difficulties in correctly establishing the number (and cost) of speed bumps required at the population level in order to produce the effects observed in certain studies, and this led us to drop this intervention from the final economic analysis even though it has been highlighted by others as a potentially cost effective measure for curbing speeding in developing countries.[5 6] In their analysis of speed bumps, Bishai and Hyder[5] made the simplifying assumption that 50% of urban road traffic fatalities occur at junctions, but that may be an overestimate in the road environment of most developing countries and does not take into account the broader road network that is needed for a population level analysis.[27]

Although estimates of intervention impact or effect are drawn from the best available sources in the international literature, these sources are heavily biased towards evaluative research carried out in high income countries, where the road use and healthcare environment are different from those found in low or middle income countries. For example, estimates of intervention effectiveness drawn from high income countries with good emergency and trauma services may understate the true independent effect of road safety devices such as motorcycle helmets in low and middle income regions. Separation of the influence of emergency and trauma care on road traffic injury outcomes, both in economically developed and developing countries, would have enabled us to calculate the independent effect of our selected interventions with greater precision.

Finally, it is important to acknowledge the defined scope of cost effectiveness analysis, which is focused on maximising health gains within available resource limits, and does not explicitly consider other welfare consequences of enhanced road traffic enforcement, including reduced property damage and environmentally harmful emissions, plus higher levels of economic productivity resulting from reduced injury rates. Set against these benefits, there is the cost of purchasing bicycle or motorcycle helmets, which, although only a small fraction of the cost of a bicycle or motorcycle, nevertheless exerts additional pressure on household budgets that may already be squeezed to the limit.

Research gaps and needs

High quality evaluative research of the specific impact of traffic enforcement strategies such as mobile speed cameras or roadside breath testing needs to be carried out in low and middle income countries in order to determine more accurately the independent effect of different road safety measures.

There are also important gaps in knowledge concerning the interaction of multiple risk factors that precede or precipitate road crashes, particularly in the context of developing countries, where the confluence of different risk factors or causes may be distinct from those in high income countries. In order to take some account of these known (but uncertain) interactions, adjustment factors were derived that ensured that the total envelope of injuries for specific age groups were not exceeded, but there is still considerable uncertainty around these interactions, which may exaggerate or diminish the contribution of specified risk factors to the overall toll of road traffic injury.

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What is already known on this topic

Rapid motorisation of low and middle income countries has led to increasing rates of road traffic injury

The core principles and measures for improved road safety globally have been articulated

There is inadequate surveillance data and economic evidence on which to identify targeted priorities for investment

What this study adds

For two developing world regions, this study provides a breakdown of road traffic injury by road user group (such as pedestrians) and by risk factor (such as speeding, not wearing a helmet), estimates the cost and health impact of key enforcement strategies (such as helmet use and checkpoints for speeding)

A combination of strategies—such as the joint enforcement of speed limits, drink-driving laws, and motorcycle helmet use—are expected to offer the best value for money (one healthy year of life can be gained for a cost of $Int1000–3000 in the two settings assessed)

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Tables

Table 1| Intervention effect sizes for road traffic injuries

Intervention	Type of road traffic injury	Data source	Effect size (%)					
			Pedestrians	Bicycles	Motorcycles	Cars and vans	Buses	Other
Enforcement of speed limits (via mobile speed cameras)	Long term non-fatal	Elvik et al[13]	−6	−6	−6	−6	−6	−6
	Crash mortality	Elvik et al[13]	−14	−14	−14	−14	−14	−14
Drink-drive legislation and enforcement (via breath testing campaigns)	Long term non-fatal	Ridolfo et al[16], Rehm et al[9]	−15	−15	−15	−15	−15	−15
	Crash mortality	Shults et al[14], Peek-Asa[15]	−25	−25	−25	−25	−25	−25
Legislation and enforcement of seatbelt use in cars (all occupants)	Long term non-fatal	Elvik et al[13]	—	—	—	−18	—	—
	Crash mortality	Elvik et al[13]	—	—	—	−11	—	—
Legislation and enforcement of helmet use by motorcyclists (all riders)	Long term non-fatal	Liu et al[17], Kelly et al[18], Shankar et al[19], Orsay et al[20]	—	—	−18 to −29*	—	—	—
	Crash mortality	Liu et al[17]	—	—	−36	—	—	—
Legislation and enforcement of helmet use by bicyclists aged <15 years	Long term non-fatal	Thompson et al[21], Haileyesus et al[22], Robinson[23]	—	−17 to −28†	—	—	—	—
	Crash mortality	Attewell et al[24]	—	−69	—	—	—	—

*Effect size of a 72% risk reduction[17] is applied to all non-fatal motorcycle injuries attributable to head injuries (25–40%).[18–20]
†Effect size of a 69% risk reduction[21] is applied to all non-fatal bicycle injuries attributable to head injuries (25–40%).[22 23]

Table 2| **Costs, effects, and cost effectiveness of road safety measures in WHO sub-Saharan African sub-region AfrE and South East Asian sub-region SearD**

Intervention (legislation and enforcement)	WHO African sub-region AfrE				WHO Asian sub-region SearD			
	Annual cost per capita ($Int)	Annual DALYs saved per million population	Cost effectiveness ratio		Annual cost per capita ($Int)	Annual DALYs saved per million population	Cost effectiveness ratio	
			Average*	Incremental†			Average*	Incremental†
Speed limits	0.28	167	1668	Dominated‡	0.13	84	1589	Dominated‡
Drink-driving	0.26	114	2236	Dominated‡	0.12	43	2731	Dominated‡
Seatbelt use	0.23	50	4579	Dominated‡	0.07	29	2502	Dominated‡
Motorcycle helmet use	0.13	19	6683	Dominated‡	0.10	62	1696	Dominated‡
Bicycle helmet use	0.14	114	1233	1233	0.07	19	3678	Dominated‡
Speed limits + drink-driving	0.40	282	1406	Dominated‡	0.18	127	1439	Dominated‡
Seatbelt use + motorcycle helmet use	0.38	69	5472	Dominated‡	0.20	91	2239	Dominated‡
Speed limits + drink-driving + seatbelt use	0.49	333	1483	Dominated‡	0.20	156	1305	Dominated‡
Speed limits + drink-driving + motorcycle helmet use	0.40	302	1333	1395	0.23	189	1237	Dominated‡
Drink-driving + seatbelt use + motorcycle helmet use	0.50	184	2725	Dominated‡	0.26	134	1919	Dominated‡
Speed limits + seatbelt use + motorcycle helmet use	0.50	237	2116	Dominated‡	0.26	175	1466	Dominated‡
Speed limits + drink-driving + seatbelt use + motorcycle helmet use	0.50	353	1428	Dominated‡	0.26	218	1181	1181
Speed limits + drink-driving + seatbelt use + motorcycle helmet use + bicycle helmet use	0.64	469	1376	1452	0.33	238	1382	3641

DALYs=disability adjusted life years. $Int=international dollars.

*$Int per DALY averted relative to no intervention.

†$Int per DALY averted, within intervention cluster

‡Intervention is more costly or less effective than other more efficient interventions, and results are therefore not included here.

Figure

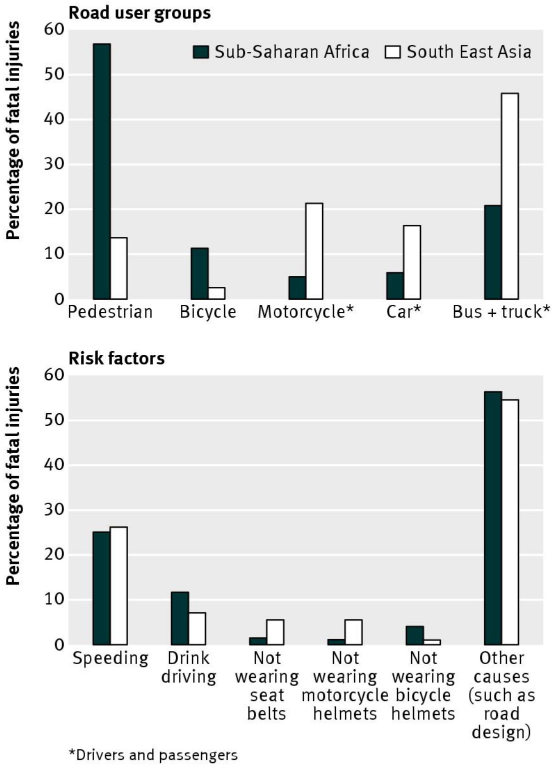

Fig 1 Attribution of fatal road traffic injuries by road user group and risk factor in WHO sub-regions in sub-Saharan Africa (AfrE) and in South East Asia (SearD)