EDITOR'S CHOICE

Reducing the burden of road traffic injury: translating high-income country interventions to middle-income and low-income countries

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ABSTRACT

Objective: To increase seat belt restraint use in Guangzhou City, People's Republic of China.
Design: Comparison group pre-test, post-test design.
Setting: Guangzhou City.
Interventions: Interventions to increase the prevalence of seat belt use in high-income countries (enhanced training and enforcement practices along with raising of public awareness) were adapted and implemented in Guangzhou. The prevalence of seat belt use was determined before and after the introduction of the 12-month intervention. Seat belt prevalence was also examined over the same time period in the neighboring city of Nanning, and an incremental cost-effectiveness analysis of the intervention was undertaken.
Main outcome measures: Prevalence rates and incremental cost effectiveness ratios.
Results: A 12% increase in seat belt use was observed in Guangzhou over the study period, increasing from a prevalence of 50% before (error range 30–62%) to 62% after (error range 60–67%) ($p<0.001$) the intervention; an absolute change difference between the intervention and reference city of 20% was achieved. The incremental cost-effectiveness ratio of the intervention was ¥3246 (US$418) per disability-adjusted life year saved.
Conclusions: This city-wide intervention demonstrates that it is possible to increase the prevalence of seat belt use using similar methods to those used in high-income countries and, importantly, that such an approach is cost-effective.

In the People's Republic of China, injuries are the leading cause of death from age 1 to 44 years, accounting for approximately 750 000 deaths and 3.5 million hospitalizations each year.[1] Given that motor vehicle production has tripled since the early 1990s,[2] it is not surprising that much of the injury-related mortality and morbidity is due to road traffic injury. Over a 45-year period (1951–1999), road traffic fatalities and serious injuries in the country increased 4-fold and 10-fold, respectively,[3] with an estimated 100 000 people dying from road traffic injury each year.[4] The increase in road traffic-related mortality and morbidity reflects, in part, the epidemiological transition that has been occurring across much of the country, but particularly among the eastern and south-western provinces, over the past two decades. The resulting societal burden from road traffic injuries in the People's Republic of China is overwhelming and there is an urgency to implement cost-effective interventions particularly in the mega cities such as Beijing, Shanghai, and Guangzhou, where motorization is taking place at a rapid rate.[5]

In 2004, the World Report on Road Traffic Injury Prevention[6] highlighted an array of intervention strategies that have been shown to be effective in high-income countries. However, the report also highlighted the paucity of knowledge about the effectiveness of these strategies in low-income and middle-income countries; seatbelts are a prime example.

There is unequivocal evidence that seat belts are efficacious, with recent research[7] indicating that the risk of death is significantly reduced (by a minimum of 45%) in drivers restrained by a seat belt compared with those unrestrained. Furthermore, there is evidence from systematic reviews[8] that comprehensive intervention programs to increase seat belt use are effective in increasing the prevalence of seat belt use. However, evidence on the effectiveness of these interventions is currently only available from high-income countries.

In 1993, the Ministry of Health of the People's Republic of China instituted a regulation requiring all vehicles less than 6 m in length and/or carrying fewer than 20 passengers to have seat belts fitted in the front seats of the vehicle and their mandatory use by drivers and front-seat passengers. Despite the availability of seat belts in almost all vehicles, the reported rates of use are low; a recent observational study of seat belt use among taxi drivers in Beijing found seat belt use as low as 7.7%,[9] and a national survey found that only 22% of respondents had ever worn a seat belt over the 30 days preceding the survey.[10]

This study sought to determine whether an intervention to increase seat belt use that has been found to be highly effective in high-income countries[8] could be successfully implemented in a middle-income country such as the People's Republic of China. In addition, the study aimed to determine the cost-effectiveness of the intervention, which was implemented in one of the mega cities, Guangzhou.

METHODS

Intervention

The intervention had four components—enhanced police training and enforcement, social marketing, and health education—with the latter two focused on raising public awareness. The intervention was implemented over a 12-month period (September 2005 to August 2006) and was modeled on the outcome from a systematic review that recommended these components as effective in increasing seat belt use.[8]

The enhanced police training and enforcement component involved traffic police educators providing skills-based training and strategies for enhancing the current traffic police enforcement practices. The training followed the ''train-the-trainer'' model whereby selected traffic police (n = 50) undertook an intensive 1-week course which included topics such as safe vehicle interception, safe checkpoint and road block operations, and overcoming barriers to effective traffic enforcement. The trained personnel then hosted the same course for all traffic police in Guangzhou. In total, 1125 police officers (83% of the total personnel) were provided with this training.

Beyond this, the enforcement component involved setting targets for the issuance of infringement notices for drivers not using the available seat belt (as well as infringement notices to drivers carrying unrestrained front-seat passengers). The enforcement involved high-profile mobile patrols combined with static covert operations involving 100–200 police officers at numerous locations throughout Guangzhou. The operation was conducted in five phases over the 12-month period, each of 2–3 days duration. As the intervention aimed to increase seat belt use among not only drivers but also front-seat passengers, the drivers were issued with a fine if the front-seat passenger was not using the available seat belt. A total of 11 000 vehicles were stopped and 2110 infringement tickets issued during the five phases; this resulted in a 40% increase in the usual issuance of tickets (176 vs 120 tickets issued per day).

The aim of the social marketing and health education components of the intervention was to raise public awareness of the safety benefits of seat belts and the need to be restrained by a seat belt while traveling in a vehicle. The target audience for the social marketing campaign (which involved television and radio commercials as well as roadside billboard advertisements (fig 1) and bus signage) was the driving population, including professional drivers, taxi drivers, and drivers in government organizations. The campaign involved a total of 950 television advertisements of 30 s duration, 3240 radio advertisements of 15 s duration, as well as an array of printed marketing materials. Taxi companies, driver training school instructors, and teachers of primary school students were targeted as part of the health education component. A 2 h course was delivered to 120 taxi company managers, educational materials were provided to teachers of primary schools in the city, and a series (n = 8) of 1 h lectures were delivered to driver training schools. The educational component for these activities focused on the known benefits of seat belts, the current laws, and the fitting and correct use of restraints.

Figure 1 Roadside billboard reminding drivers about the importance of using a seat belt.

Study design and evaluation

The effectiveness of the intervention was examined using a reference group in a pre-test, post-test comparison design. Guangzhou was selected as the intervention city, and Nanning was selected as the reference city. The choice of Guangzhou was determined in part by the interest of the provincial government and in part by its poor road safety record (it has the second highest road fatality rate of the eastern seaboard cities),[11] and Nanning was selected on the basis of cost-efficiencies. Each city has an extensive road network, and both are provincial capitals, although Nanning is notably smaller, and has a greater proportion of motorcycle use compared with Guangzhou (table 1).

The prevalence of seat belt use was the primary outcome measure. To estimate the prevalence rate of seat belt use, a random sample of the road network in both the intervention and reference cities was observed at two time points: April–May 2005 (pre-intervention) and September–October 2006 (post-intervention). There is almost no seasonal variation across the selected months.[12] As pilot research highlighted a variation in seat belt use by road type, observational sites were stratified by road hierarchy (local roads, main roads, and expressways). Observations of seat belt use—for all drivers and front-seat passengers—were undertaken over a 7-day period and at various times across the day (8:01am to 6pm; 6:01pm to 9pm) by trained observers. For multi-lane roads, only vehicles traveling on the lane closest to the curb on which the observer was stationed were included in the observational surveys. A total of 34 321 and 28 807 vehicles were observed in the intervention city during the two (pre-intervention and post-intervention) observational periods, respectively, and 26 535 vehicles were observed before and 25 485 after the intervention in the reference city. Seat belts were documented as being worn if the three-point shoulder belt was worn tightly across the chest of the occupant and there was no sign of a bull clip or clamp/nail (to prevent recoil of the belt if not worn).

The prevalence rate was calculated as the number of front-seat occupants correctly using a seat belt over the total number of front-seat occupants observed. The error range was the prevalence rate observed over each day of the pre- and post-intervention periods. Two-sample z tests and the corresponding 95% CIs were computed and used to compare the changes between pre-intervention and post-intervention prevalence rates in each city.

An incremental cost-effectiveness analysis was also undertaken with the net cost and benefits of the intervention

Table 1 Demographic features of the intervention and reference cities

Demographics	Guangzhou (intervention)	Nanning (reference)
Population	11 787 100	6 697 000
Annual income per capita (¥)	15 003	10 078
Length of highways (km)	5438	6127
Vehicle fleet	1 722 105	875 822
Motorcycles	59.7%	75.2%
Cars	38.7%	12.4%
Taxis	0.9%	0.4%

Table 2 Component costs and the incremental cost-effectiveness ratio (ICER)

Component	Amount (¥)
Intervention costs	
Enhanced police training and enforcement	1 013 503
Social marketing	816 468
Health education	289 327
Project management	1 005 428
Total intervention costs	3 124 726
Cost savings	1 404 149
Net costs of intervention	1 720 577
DALYs saved	530
ICER: net cost per DALY saved	3246 (US$418)

DALY, disability-adjusted life year.

compared with standard practice, ie, no enhanced program to promote seat belt use. The perspective for the analysis was societal, and details of the component costs and the incremental cost-effectiveness ratio (ICER) are described in table 2. A time frame of 1 year was adopted for the analysis, which assumed that any increase in seat belt use did not extend beyond the year of the intervention.

All additional costs of implementing the intervention, if it were to become an ongoing program, were included in the analysis. These additional costs consisted of the expenditure on each of the four components involved in the intervention as well as the cost of overall project management. Costs for the analysis were calculated directly from study records or from the relevant government agencies. Infringement costs (fines) for lack of seat belt use were not included in the cost of the intervention; from a societal perspective, these costs can be considered simply as transfer payments. The cost-effectiveness analysis incorporated the cost savings from the reduction in hospital admissions resulting from the intervention; this was based on the observed increase in seat belt use due to the intervention and the assumption that seat belts reduce fatal and serious injuries by up to 45%.[7] However, in the absence of specific documentation on front-seat occupant fatality and serious injury, police estimates were used. These suggested that 30% of the reported fatalities and seriously injured casualties were motor vehicle occupants and that 65% of these were front-seat occupants. Other potential savings in resource use, such as other medical expenses, police investigation costs, and work-place disruption costs, were excluded. The cost of a hospital admission was assumed to be ¥9298 (the average cost at a western medicine ministry level and city level hospital in Guangzhou).[13] Costs presented in the cost-effectiveness analysis are expressed in 2006 Chinese yuan (¥), with ICERs expressed in US dollars (US$).

The health gain from preventing fatalities and injuries through increased seat belt use was measured using disability-adjusted life years (DALYs). Data from the evaluation of the intervention's effectiveness in increasing seat belt use provided the starting point for calculating the DALYs gained from the intervention. An ICER was calculated as the cost of the intervention less the cost savings from fewer hospital admissions, divided by the number of DALYs saved from the increase in seat belt use.

RESULTS

Table 3 gives baseline observations for both the intervention and reference cities. The baseline results highlight substantial differences between the two cities in driver seat belt use particularly by road type, the time of day, and vehicle type observed. Importantly, the prevalence of seat belt use was significantly lower in the intervention city than the reference city, with the prevalence for some observations (eg, drivers of taxis) 30% lower in the intervention city than in the reference city. Overall, there was no significant difference in the prevalence of seat belt use by front-seat passengers between the two cities. Please note that passenger in table 3 refers to front-seat passenger only.

The prevalence of seat belt use by drivers increased significantly from 50% (error range 30–62%) to 62% (error range 60–67%) ($p<0.001$) for the intervention city, compared with a significant decrease from 64% (error range 28–74%) to 56% (error range 41–62%) in the reference city ($p<0.001$). For front-seat passengers, there was an increase from 40% (error range 17–53%) to 53% (error range 47–55%) in the intervention city, whereas the reference city experienced a decline in seat belt use over the same period (38% (error range 18–45%) to 33% (error range 19–42%)). Overall, there was a 12% (95% CI 12% to 13%, $p<0.001$) increase in the prevalence of seat belt use in the intervention city and an 8% (95% CI −8% to 7%, $p<0.001$) decline in the reference city (fig 2).

The greatest change in the prevalence of seat belt use by drivers was observed on local and main roads in the intervention city. The increase in seat belt use by drivers after the intervention was 16% (95% CI 14% to 17%, $p<0.001$) on local roads and 15% (95% CI 14% to 17%, $p<0.001$) on main roads. For drivers observed on expressways, the increase in seat belt use was 5% (95% CI 4% to 7%, $p<0.001$), with 68% of all drivers in Guangzhou correctly using their seat belts on expressways after the intervention (fig 3). The prevalence of seat belt use also increased significantly for both male (12%, 95% CI 11% to 13%, $p<0.001$) and female (18%, 95% CI 14% to 21%, $p<0.001$) drivers in the intervention city (fig 4).

On the basis of the observed increase in seat belt use in the intervention city and the known effectiveness of seat belt use, the likely reduction in road fatalities and serious injuries from the intervention would have been 7.0% (estimated by $0.12\times(0.45/(1-(0.47\times0.45))$). Therefore, the intervention was estimated to have reduced the number of fatalities of front-seat motor vehicle occupants by 24 and the number of front-seat motor vehicle occupants who sustained serious injury by 143. The number of DALYs saved from each fatality and each seriously injured casualty prevented was calculated as 18.63 and 0.58, respectively, giving a present value for the total number of DALYs saved from the intervention of 530. Given the cost of implementing the intervention and the associated cost savings, the ICER of the intervention compared with no enhanced program to promote seat belt use was ¥3246 per DALY saved or the equivalent of US$418 per DALY saved.

DISCUSSION

The results suggest that road safety interventions that are highly effective in high-income countries[14] can be translated to and successfully implemented (as measured by changes in the prevalence of seat belt use) in a middle-income country such as the Peoples' Republic of China.

The prevalence of seat belt use by drivers and front-seat passengers had increased significantly after the intervention in Guangzhou, with an absolute change difference between the intervention and reference city of 20%. Over the period of the study, significant increases in the prevalence of seat belt use

Table 3 Baseline factors for the intervention and reference cities

	Guangzhou (intervention)		Nanning (reference)	
Key factors	**No**	**Prevalence (%)**	**No**	**Prevalence (%)**
Driver seat belt use by road type				
Local roads	5743	45	7516	60
Main roads	4842	44	8301	66
Expressways	6447	63	1145	86
Driver seat belt use by gender				
Male	16208	50	15479	64
Female	811	58	1481	63
Driver seat belt use by time				
Week day	4637	51	4987	70
Week night	4122	49	3984	62
Weekend day	4603	52	4290	64
Weekend night	3670	48	3701	58
Driver seat belt use by vehicle type				
Car	12679	61	10234	68
Taxi	3112	30	5816	60
Other	1224	40	893	46
Passenger seat belt use by road type				
Local roads	1364	31	1376	32
Main roads	1470	33	1542	37
Expressways	2801	51	612	68
Passenger seat belt use by gender				
Male	3652	39	2384	39
Female	1951	41	1144	35
Passenger seat belt use by time				
Week day	1437	40	983	42
Week night	1241	38	839	37
Weekend day	1715	43	898	38
Weekend night	1242	38	810	34
Passenger seat belt use by vehicle type				
Car	4411	46	2761	45
Taxi	800	26	561	24
Other	416	26	199	24

were observed in Guangzhou across most factors: the gender of the driver, the type of road, and the type of vehicle (with a 26% increase in restraint use by taxi drivers). The increased prevalence observed in this study reflects studies in high-income countries in which the same interventions were implemented, achieving a median increase in seat belt use of 16%.[14] If one considers that only half the desired level of enforcement (as requested by the independent police educator contracted to assist with the intervention) was delivered, it is likely that, with greater resources, one could achieve a substantially higher prevalence of seat belt use.

There is now an array of cost-effective road safety interventions for low-income and middle-income countries ranging from traffic calming to reduce speed (US$5 per DALY saved) to

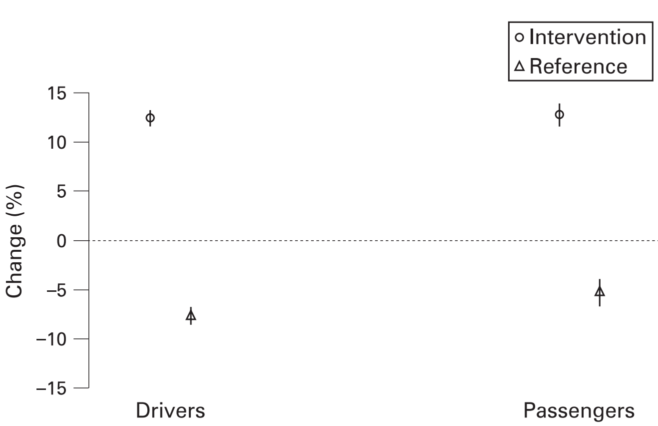

Figure 2 Overall change in the prevalence of seat belt use by car occupants between intervention and reference cities. The vertical solid lines represent 95% CI.

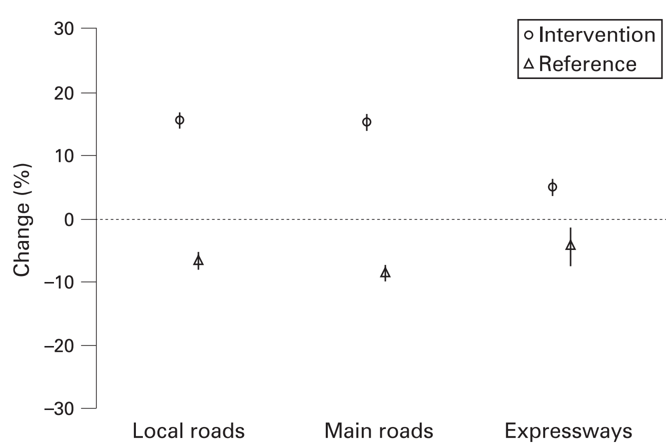

Figure 3 Overall change in the prevalence of seat belt use for drivers by road type between intervention and reference cities. The vertical solid lines represent 95% CI.

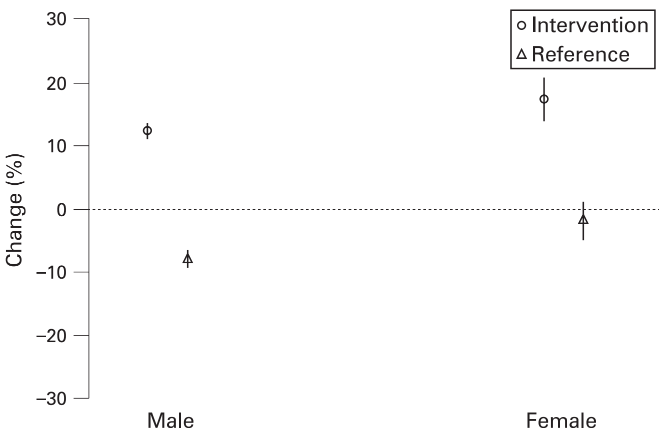

Figure 4 Overall change in the prevalence of seat belt use by male and female drivers. The vertical solid lines represent 95% CI.

motorcycle helmet legislation (US$467 per DALY saved).[15] If one considers interventions where the cost-effectiveness ratio is less than the country's per capita gross domestic product (GDP) to be extremely cost-effective,[16] then the current intervention (with an ICER of ¥3246 (US$418) per DALY saved, which is only 42% of China's reported GDP in 2006[17]) is highly cost-effective.

Despite the significant increase in the prevalence of seat belt use in the intervention city, it remains low compared with highly motorized countries. For example, the post-intervention prevalence of seat belt use in the intervention city (62%) is far below that in the USA (82%)[18] and Australia (95%).[19] A greater intensity of intervention activities over a longer period will be needed to increase the prevalence of seat belt use to that of high-income countries.

There are a number of alternative explanations for the increased prevalence of seat belt use in the intervention city. The first is that the observed changes are due to activities other than the intervention, eg, heavily tinted windows on vehicles (which obscure detection of seat belt use) are now prohibited. However, this change was implemented after the intervention and therefore would not have contributed to the results observed in the study. The government has also increased the financial penalty for non-use (or incorrect use) of the seat belt from ¥20 to ¥200. There is good evidence that higher fines are effective in increasing the prevalence of seat belt use,[20] but this measure was also introduced before the intervention, in both cities. Importantly, both of these legislative changes were nationwide and would therefore have affected the reference city equally.

The most obvious alternative explanation is that the changes in the prevalence estimates of restraint use are biased. This is a possibility given that the observers were not blinded to the intervention status of the city. However, to minimize this potential bias, all observers followed a standardized protocol, underwent a 1-day training program, and were party to random roadside audits by the researchers to ensure that protocols were adhered to. In addition, the same observers were used for both pre-intervention and post-intervention observations. Despite these approaches, we cannot entirely dismiss the possibility of biased estimates, albeit small.

What is already known on this topic

- Comprehensive intervention programs are effective in increasing the prevalence of seat belt use.
- The prevalence of seat belt use is low in The People's Republic of China.

What this study adds

- Road safety interventions used in high-income countries can be successfully translated to middle-income (and potentially low-income) countries.
- Comprehensive seat belt interventions are highly cost-effective; governments in rapidly motorizing countries need to be encouraged to implement such interventions.

IMPLICATIONS FOR PREVENTION

This study suggests that it is possible to successfully implement in middle-income countries specific road safety interventions that are used in high-income countries. Given the speed at which motorization is taking place in these growing economies, there is an urgency to implement these and other effective interventions to reduce the burgeoning incidence of road trauma.

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降低道路交通伤害的负担：将高收入国家的干预措施应用于中低收入国家

书眉标题：低收入国家的道路交通伤

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关键词：安全带，干预，成本效果比，道路安全，流行率

总计：以英文计 2970 个词。

摘要

目的：提高中国广州市的安全带使用率

设计：有对照的前后测量设计

地点：广州市

干预：在高收入国家采用的提高安全带使用率的措施，包括强化培训、执法及提高公众意识等，在广州得到应用和实施。在为期 12 个月的干预前和干预后，评估安全带的使用率，并评估邻近的城市（南宁）同期的安全带使用率，同时对干预的增量成本效果比进行分析。

主要结果：安全带使用率及增量成本效果比

结果：在研究期间广州市安全带使用率提高了 12%，从干预前的 50%（误差范围：30-62%）提高到干预后的 62%（误差范围 60-67%）（P<0.001），在干预城市和对照城市变化绝对差值达到 20%。干预的增量成本效果比（ICER）为每挽回一个 DALY 花费 3,246 人民币（相当于 418 美元）。

结论：这个城市范围的干预项目证明，可以应用与高收入国家近似的办法来提高安全带的使用率，更重要的是，干预活动具有良好的成本效益比。

背景

在中国，伤害是 1-44 岁的人群的首要死因，每年导致 75 万人死亡和 350 万人住院。[1] 很大一部分与伤害有关的死亡和受伤是由道路交通事故引起的。这似乎不足为奇，因为自九十年代早期以来，中国机动车的产量翻了三倍。[2] 从 1951 年到 1999 年的 45 年中，中国的道路交通死亡和严重受伤的数量分别增加了 4 倍和 10 倍 [3]，近年来中国每年由于道路交通事故而死亡约 10 万人。[4] 由伤害导致的死亡和受伤人数的变化，反映出过去二十年中在中国大部分地区的流行趋势发生了变化，但在东部及西南部省份这种变化尤其明显。显然，中国道路交通伤害的社会负担是惊人的，急需在中国，特别是在北京、上海、广州等机动化程度迅速提高的大城市 [5]，采取具良好成本效果比的干预措施。

2004 年《世界道路交通伤预防报告》[6] 中提出了一系列在高收入国家已被证明有效的干预策略，但报告也指出对这些策略在中低收入国家应用的效果所知有限，安全带即是一个例子。

有明确的证据表明安全带能有效保护车乘人员，最近有研究结果 [7] 表明使用安全带的驾驶员与不使用者比，死亡风险显著降低（至少 45%）。而且系统评估 [8] 的证据表明，综合性的干预项目能有效提高安全带的使用率。但是，这些有效性的证据目前基本上来源于高收入国家。

中国公安部在 1993 年颁布规定，要求所有长度在六米以内和 20 座以下的机动车均须在前座安装安全带，并要求驾驶员和前排乘客使用安全带。尽管几乎所有小型客车的前座都已经安装了安全带，安全带的报告使用率仍然比较低。最近一项对北京出租车驾驶员安全带使用率的观察性研究发现，安全带正

确使用率低至 7.7%[9]，而一项全国性的调查发现，只有 22%的被调查者在之前30天内驾乘车时使用过安全带。[10]

本研究旨在判断一项提高安全带使用率的干预活动-这种干预在高收入国家有很好效果-能否成功实施于中等收入国家例如中国。研究同时要判断在大城市如广州实施干预的成本效果比。

方法

干预

干预包括四部分内容，即强化的交警培训和执法、社会营销和健康教育，后两个内容旨在提高公众的意识。干预在 12 个月期（2005 年 9 月至 2006 年 8 月）实施，其模式基于一份系统评估报告，在这份报告中提到上述措施可有效提高安全带使用率。[8]

强化的交警培训和执法部分包括由教员提供改进目前交警执法实践的培训。培训以“培训培训者”的模式，挑选 50 名警官参与一周的培训课程。课程的要点包括安全车辆拦截、安全检查点和路障、克服障碍以有效执法等。经过培训的警官为广州市所有交警提供相同的培训。总共有 1125 名交警（占应培训数的 83%）接受培训。

除此之外，执法内容包括设立对不使用安全带（或搭载的前排乘客不使用安全带）的驾驶员开罚单的目标。执法包括高可见度的流动执法和隐蔽执法，每次在广州市不同地点布置 100-200 名交警。在 12 个月期间开展了 5 次强化执法活动，每次 2-3 天。因为干预不仅要提高驾驶员的使用率，还要提高前排乘客使用率，因此前排乘客不使用安全带，驾驶员也要被处罚。总共有 11000 辆

车被拦截，开出 2110 个罚单，这在日常的基础上有 40%的提升（每天 176 张罚单 vs 120 张罚单）。

干预的社会营销和健康教育的目的是提高公共的安全意识，让他们了解安全带的作用以及在驾乘车时使用安全带的必要性。社会营销活动（包括电视、电台广告、路边的广告牌和汽车广告）针对的群体为驾驶人群，包括职业驾驶员、出租车和政府机关驾驶员。活动包括 950 次的 30 秒电视广告、3240 次的 15 秒电台广告以及一系列的印刷材料。健康教育的目的人群包括出租车公司、驾校教员和小学教师等。给 120 名出租车公司管理人员开展了 2 小时的课程，为城市的小学教师提供了教育材料，同时在驾校开展了 8 次的约 1 小时的课程。这些活动的教育内容集中于安全带的作用、现行法律规定和如何正确使用安全带。

研究设计和评价

使用有对照的前后测量设计对干预的效果进行评价。广州作为干预城市，南宁作为对照城市。选择广州一方面是政府支持本项目，另一方面也是因为它报告的道路交通死亡数在东部沿海城市最高 [11]。南宁的选择则是基于成本和效率的考虑。尽管与广州相比，南宁要小得多且摩托车的比例更高，但这两个城市都是省府城市且都拥有较发达的公路网（见表 1)。

安全带的使用率作为主要的结果指标。为了评估安全带使用率，分别在干预和对照城市随机选择道路作为样本在干预前和干预后进行观察，即 2005 年 4 月-5 月（干预前）和 2006 年 9 月-10 月（干预后）。在干预前后月份的气温并没有明显季节性变化。[12] 由于预调查提示安全带使用率随道路类型有变化，将观察点按道路等级分层为支路、干道和高速公路。在 7 天的时间内，包括每天

的不同时间段（8：01 至 18 时；18：01－21 时），由经培训的调查员对路过车辆的驾驶员和前排乘客安全带使用率进行观察。对多条车道的道路，仅观察最靠近调查员的车道中行驶的车辆。在广州两个阶段（干预前和干预后）共观察了 34321 和 28807 辆车，在对照城市分别观察了 26535 和 25485 辆车。如果三点式安全带的肩带紧贴跨过乘员的胸部，且没有使用夹子、钉子或其他物体（来防止安全带回缩）的迹象，判断为（正确）使用。

使用率为前排乘员正确使用安全带数除以所有观察的前排乘员数。计算每天的观察率以显示干预前和干预后使用率误差范围。用两独立样本的 z 检验和相应的 95%可信区间来比较每座城市干预前和干预后安全带使用率的变化。

按干预的净成本和收益，与（没有干预项目）日常情况相比来进行增量成本效果分析。作成本效果评估时考虑社会成本，干预内容的成本和增量成本效果比见表 2。时间框架为一年，即假定安全带使用率提高的效果在干预期后不再延续。

所有与实施干预有关的增加的费用，如果是作为一个正常运行项目的成本，都包括在分析的范围内。这些增加的成本包括上述 4 个干预内容的支出以及项目管理成本。对未按规定使用安全带开出的罚单没有被计入干预的成本，从社会学的角度来说，这些费用可被简单算成转移支付。成本效果分析计入了由于干预减少的（受伤病例）医院住院花费，根据干预所导致的安全带使用率提高幅度，同时假设使用安全带可减少 45%的死亡和严重受伤计算得到。[7] 但由于没有机动车前排乘客死亡和严重受伤数的详细数据，由交警来估计其比例，即假设 30%的报告死亡和严重受伤数为机动车乘员，其中 65%为前排乘员。其他可能节省的成本，如其他医疗费用、交警事故调查费用及误工损失等

未计入分析。根据广州市省级和市级医院的平均住院成本[13]，设定交通事故重伤住院成本为 9298 元。在成本效果分析中的费用以人民币（2006 年汇率）为单位，增量成本效果比以美元为单位。

因使用安全带减少伤害获得的健康收益，以伤残调整寿命年(DALYs)来表示。对提高安全带使用的干预效果进行评估，得到的数据为计算干预挽回的伤残调整寿命年提供了基础。用干预的成本减去节省的住院花费，再除以由于增加安全带使用率而挽回的伤残调整寿命年来计算增量成本效果比(ICER)。

结果

表 3 描述了干预和对照城市的基线调查结果。基线数据表明在干预和对照城市之间按道路类型、时间和车辆类型之间存在较大差异。更重要的是干预城市与对照城市相比，在按某些因素分类（如出租车驾驶员）的安全带使用率低 30%。总体看来，两个城市前排乘客安全带使用率没有显著性差异。请注意在表 3 中乘客仅指前排乘客。

在干预城市（广州）驾驶员安全带使用率从干预前的 50%（误差范围 30-62%）提高到 62%（误差范围 60-67%），对照城市（南宁）从干预前的 64%（误差范围 28-74%）下降到 56%（误差范围 41-62%）(P<0.001)。干预城市驾驶员安全带使用率从干预前 40%（误差范围 17-53%）提高至 53%（误差范围 47-55%），而对照城市同期从 38%（误差范围 18-45%）下降至 33%（误差范围 19-42%）。干预城市的安全带使用率增加了 12％(95% 可信区间为 12-13%，p<0.001)，而对照城市下降了 8％（95% 可信区间为 8-7%，p<0.001）（见图 1）。

干预城市的驾驶员在支路和干道上安全带使用率提高幅度最大。与干预前相比，干预后驾驶员在支路的使用率增加了 16％（95%可信区间为 14-17%，$p<0.001$），在干道增加了 15％（95%可信区间为 14-17%，$p<0.001$）。在高速路的安全带使用率提高了 5％（95%可信区间为 4-7%，$p<0.001$），干预后 68％的驾驶员在高速路上行驶时正确使用安全带（见图 2）。安全带使用率在男性和女性驾驶员中均得以提高，在男性提高 12%（95%可信区间为 11-13%，$p<0.001$），女性提高 18%（95%可信区间为 14-21%，$p<0.001$）（见图 3）。

根据干预城市安全带使用率的提高以及安全带的效果，干预有可能减少 7% 的道路交通死亡和严重受伤（按 0.12 x (0.45/(1-(0.47 x 0.45)计算)。据此估计干预可以避免 24 个前排乘员死亡和 143 个严重受伤病例。从每一次避免了的死亡和严重受伤事件中挽回的伤残调整寿命年现值分别是 18.63 和 0.58，从干预中挽回总的伤残调整寿命年的现值是 530。考虑到实施干预的成本和节省的费用，与不采取干预措施相比，干预的增量成本效果比是每挽回一单位伤残调整寿命年成本为 3246 元或 418 美元。

讨论

结果提示在高收入国家高度有效的道路安全干预，可以被象中国这样的中等收入国家所引入并且成功实施（以安全带使用率的变化显示）。

驾驶员和前排乘客安全带使用率在广州从干预前到干预后有显著提高，与对照城市比变化的绝对差值达到20%。在干预期内，安全带使用率在广州按各因素分层如驾驶员性别、道路类型和车辆类型均有显著提高（如出租车驾驶员使用率提高了26%）。在这项研究所观察到的使用率增加与高收入国家相似，在高收入国家类似干预提高安全带使用率的中位数为16%。[14]如果考虑到执法的

强度比设想的（按培训教官的要求）要低上近一半，如果投入更多资源的话，这种干预活动能达到更高的安全带使用率。

已有一系列的对中低收入国家道路安全项目的成本效果分析，从交通稳静化（每挽回 1DALY 花费 5 美元）到摩托车头盔立法（每挽回 1DALY 花费 467 美元）。[15] 如果认为每挽回 1DALY 的成本较该国人均 GDP 低就认为干预措施有高度的成本效果比 [16]，那么此项干预（ICER 为每挽回 1DALY 花费 3246 元或 418 美元-相当于中国 2006 年人均 GDP[17] 的 42%）具有很好的成本效果比。

尽管干预城市安全带使用率有显著的提高，但与机动化程度高的国家相比还算是低的。比如在干预城市干预后安全带使用率为 62%，远低于美国（82%）和澳大利亚（95%）。[19] 需要开展持续时间更长、强度更大的干预活动，以进一步提高安全带的使用率，达到高收入国家水平。

关于安全带使用率的变化，也许有其他的解释。首先的解释是观察到的改变是因为干预之外的活动，比如现在对车窗贴膜出台了新的规定（车窗深色贴膜使路边观察变得困难）。但这种规定是在干预后出台的，因此不会对观察结果产生影响。政府部门对不（正确）使用安全带的罚款额度从 20 元提高到了 200 元，有证据表明提高罚款额度能有效提高安全带使用率，但这种规定是在干预前出台的。更重要的是，这些规定是在全国范围内实施的，对对照城市会有相同的影响。

最显而易见的解释是这种率的变化是因为观察的偏倚所致。这是有可能的，因为观察员了解哪个是干预城市。但是为了尽量减少这种偏倚，所有的观察员都遵循标准的观察方案，并接受了一天的培训。同时作者还对观察员进行了督导，以保证他们严格按方案进行观察。同时，我们在干预前和干预后使用

了同样的观察员。尽管这种偏倚的发生机率不大，但我们还是不能完全排除它的可能性。

干预的意义

本研究的结果提示有可能将高收入国家的道路安全干预措施在中等收入国家成功实施。考虑到在这些国家正经历快速机动化进程，迫切需要实施安全带干预及其他有效的干预措施以减少道路交通伤的发生。

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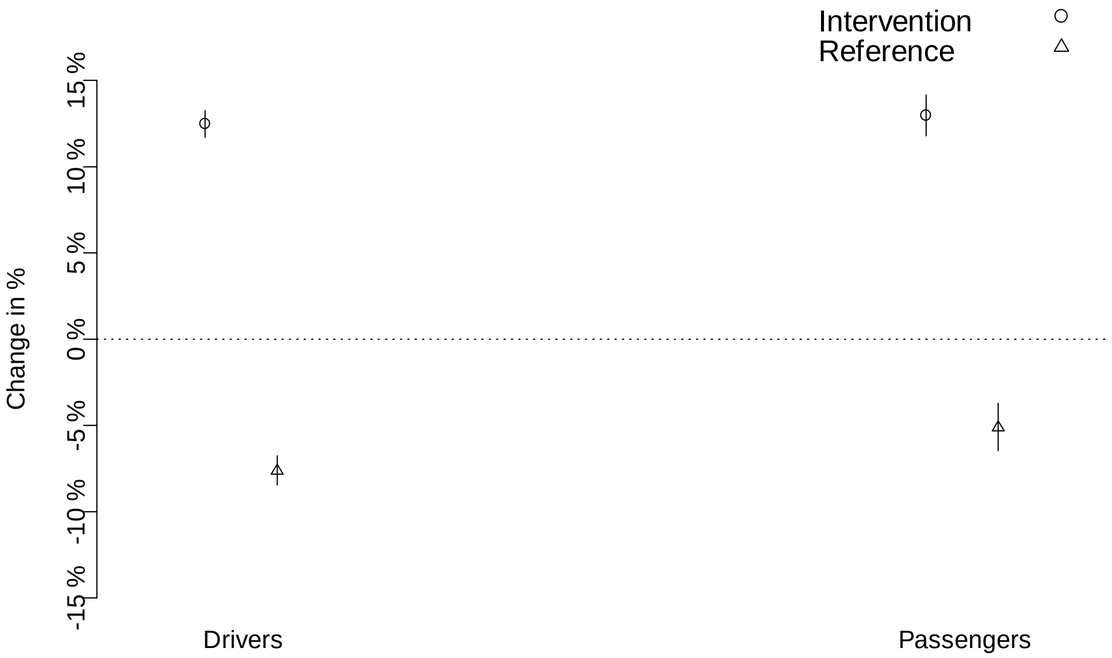
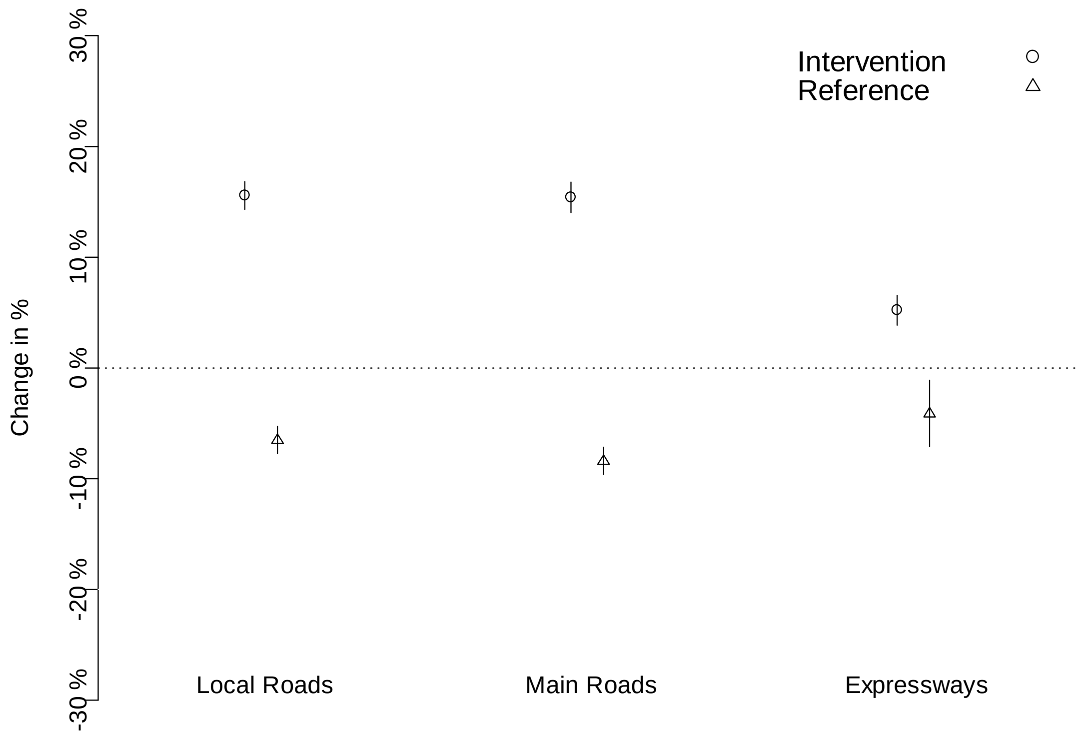
图 1. 干预和对照城市小型客车乘员安全带使用率总的变化情况（竖实线表示 95 ％的置信区间）*



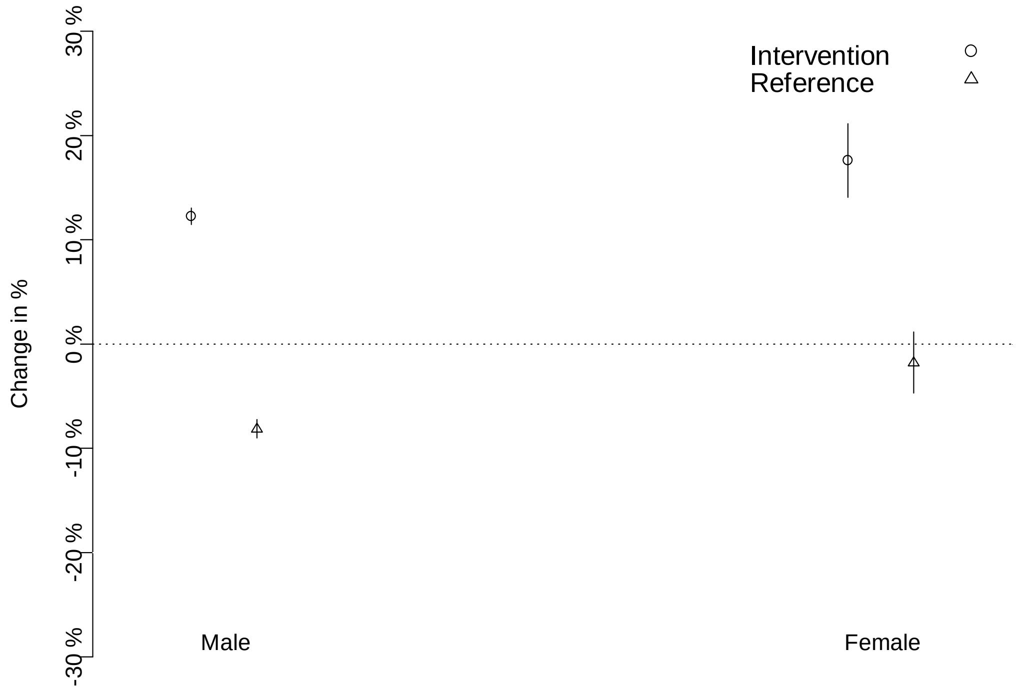
* X 轴左为驾驶员，右为乘客。Y 轴为安全带使用率干预前后变化。图例中圆形为干预城市，三角为对照城市。

图 2. 干预和对照城市驾驶员安全带使用率分道路等级的变化情况(竖实线表示 95％的置信区间)*



* X 轴左为支路，中为干道，右为高速公路。Y 轴为安全带使用率干预前后变化。图例中圆形为干预城市，三角为对照城市。

图 3. 干预和对照城市驾驶员安全带使用率分性别的变化情况（竖实线表示 95％的置信区间）*



* X 轴左为男性，右为女性，Y 轴为安全带使用率干预前后变化。图例中圆形为干预城市，三角为对照城市。

表 1: **干预城市和对照城市的人口统计学特点**

对比项	广州（干预城市）	南宁（对照城市）
人口	11,787,100	6,697,000
人均年收入	15,003 人民币	10,078 人民币
公路里程	5,438km	6,127km
机动车数，其中：	1,722,105	875,822
摩托车	59.7%	75.2%
小型客车	38.7%	12.4%
出租车	0.9%	0.4%

表 2. **项目成本与增量成本效果比（ICER）**

组成	人民币**(CNY)**
干预活动成本	
强化交警培训和执法	1,013,503
社会营销	816,468
健康教育	289,327
项目管理	1,005,428
费用合计	3,124,726
节省成本	1,404,149
干预净成本	1,720,577
挽回的 DALY 数	530
ICER: 每挽回 1DALY 的成本	3,246 (US$ 418)

表 3. 干预和对照城市的基线情况

分层	广州（干预城市）		南宁（对照城市）	
	N	%	N	%
分道路类型的驾驶员安全带使用率				
支路	5743	45	7516	60
干道	4842	44	8301	66
高速路	6447	63	1145	86
分性别的驾驶员安全带使用率				
男性	16208	50	15479	64
女性	811	58	1481	63
分时间的驾驶员安全带使用率				
工作日白天	4637	51	4987	70
工作日晚上	4122	49	3984	62
周末白天	4603	52	4290	64
周末晚上	3670	48	3701	58
分车辆类型的驾驶员安全带使用率				
小型客车	12679	61	10234	68
出租车	3112	30	5816	60
其他	1224	40	893	46
分道路类型的乘客安全带使用率				
支路	1364	31	1376	32
干道	1470	33	1542	37
高速路	2801	51	612	68
分性别的乘客安全带使用率				
男性	3652	39	2384	39
女性	1951	41	1144	35
分时间的乘客安全带使用率				
工作日白天	1437	40	983	42
工作日晚上	1241	38	839	37
周末白天	1715	43	898	38
周末晚上	1242	38	810	34
分车辆类型的乘客安全带使用率				
小型客车	4411	46	2761	45
出租车	800	26	561	24
其他	416	26	199	24