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Road traffic injury mortality and morbidity by country development status, 2011–2017

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ABSTRACT

Purpose: This research examined road traffic injury mortality and morbidity disparities across of country development status, and discussed the possibility of reducing country disparities by various actions to accelerate the pace of achieving Sustainable Development Goals target 3.6 – to halve the number of global deaths and injuries from road traffic accidents by 2020.

Methods: Data for road traffic mortality, morbidity, and socio-demographic index (SDI) were extracted by country from the estimates of the Global Burden of Disease study, and the implementation of the three types of national actions (legislation, prioritized vehicle safety standards, and trauma-related post-crash care service) were extracted from the Global Status Report on Road Safety by World Health Organization. We fitted joinpoint regression analysis to identify and quantify the significant rate changes from 2011 to 2017.

Results: Age-adjusted road traffic mortality decreased substantially for all the five SDI categories from 2011 to 2017 (by 7.52%–16.08%). Age-adjusted road traffic mortality decreased significantly as SDI increased in the study time period, while age-adjusted morbidity generally increased as SDI increased. Subgroup analysis by road user yielded similar results, but with two major differences during the study period of 2011 to 2017: (1) pedestrians in the high SDI countries experienced the lowest mortality (1.68–1.90 per 100,000 population) and morbidity (110.45–112.72 per 100,000 population for incidence and 487.48–491.24 per 100,000 population for prevalence), and (2) motor vehicle occupants in the high SDI countries had the lowest mortality (4.07–4.50 per 100,000 population) but the highest morbidity (428.74–467.78 per 100,000 population for incidence and 1025.70–1116.60 per 100,000 population for prevalence). Implementation of the three types of national actions remained nearly unchanged in all five SDI categories from 2011 to 2017 and was consistently stronger in the higher SDI countries than in the lower SDI countries. Lower income nations comprise the heaviest burden of global road traffic injuries and deaths.

Conclusion: Global road traffic deaths would decrease substantially if the large mortality disparities across country development status were reduced through full implementation of proven national actions including legislation and law enforcement, prioritized vehicle safety standards and trauma-related post-crash care services.

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Introduction

“To halve the number of global deaths and injuries from road traffic accidents by 2020” was proposed by the United Nations as Sustainable Development Goals (SDGs) target 3.6.¹ However, according to the Global Status Report on Road Safety 2018,² the ambitious target is unlikely to be reached despite global improvement in key domains of legislation, vehicle standards and access to

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post-crash care services. This situation raises a challenge for global health decision-makers and researchers as we move into and beyond the year 2020, how can we accelerate global progress to reduce the burden of road traffic injuries (RTIs) and deaths worldwide and achieve the SDG target belatedly?

Substantial research evidence suggests that there is much heavier road traffic injury burden in underdeveloped countries compared to developed ones.^{2–6} The Global Status Report on Road Safety 2018 suggested that 93% of the 1.35 million global road traffic deaths occurred in low- and middle-income countries in 2016, and age-adjusted road traffic mortality was 3 times higher in low-income countries *versus* high-income countries (27.5 vs. 8.3 deaths per 100,000 population).² Remarkably, the report also indicated the number of road traffic deaths did not decrease in any low-income country between 2013 and 2016, but reductions were observed over that time span in 48 middle- and high-income countries.²

In light of the disproportional road traffic injury burden and slow or no progress in reducing RTIs in underdeveloped countries, a feasible and reasonable approach to address the global challenge to halve RTIs is to reduce heavier burden in countries with lower development statuses. This goal also corresponds to the global goal to offer all humans an equal opportunity to enjoy a better quality of life.^{4,6,7}

The present study aims to examine the recent progress in reducing road traffic injury both mortality and morbidity disparities across country development statuses, as well as to assess how that progress corresponds to the three types of recommended national actions from the World Health Organization (WHO): legislation and enforcement, adoption of motor vehicle safety standards, and implementation of trauma-related post-crash care services. These three actions have been proven to be effective in reducing road traffic injury burden.² In order to explore the global performance, to indicate where the weaknesses were and to offer the reference for adopting relevant actions, our analysis purposely linked and examined the implementation of WHO recommended actions with country development statuses.

Morbidity rates do not always correspond to mortality rates, as an example, improved post-crash care services may lead to a crucial reduction in mortality but an increase in prevalence of hospitalization. Other prevention strategies, such as road traffic legislation and prioritized vehicle safety standards, may reduce both morbidity and mortality.

We used two data sources for our analysis, the latest mortality and morbidity estimates by the Global Burden of Disease (GBD) study 2017⁸ and implementation data concerning the three national actions from the Global Status Report on Road Safety.^{2,9,10} We examined the progress to reduce disparities in road traffic mortality and morbidity across country development status from 2011 to 2017 as well as progress in implementing the recommended three types of national actions during the study time period.

Methods

Data sources

The GBD study is the only data source providing annual and comparable estimates of both fatal and non-fatal road traffic injury indicators by age group, sex, sub-cause, year, and geography at global, regional, national, and subnational levels from 1990 to 2017.^{11,12} The GBD 2017 updated estimates can be freely accessed through the online data visualization tool “GBD Compare | Viz Hub” which was established and maintained by the Institute for Health Metrics and Evaluation at the University of Washington.⁸ Mortality and morbidity (incidence and prevalence) were both considered in our analyses.

The Global Status Report on Road Safety is regularly released by the WHO to offer information concerning implementation of national actions recommended for road traffic injury prevention.^{2,9,10} We extracted data concerning three key national actions: legislation and law enforcement from 180 countries, vehicle safety standards from 183 countries, and trauma-related post-crash care services from 185 countries, and matched them with GBD estimates one country by one country for subsequent analyses. It was noted that data concerning the three types of national actions were missing for a few countries in the WHO reports.

We used the socio-demographic index (SDI) to measure country development status. The SDI is a composite indicator defined by the GBD study group based on per capita income, educational attainment, and total fertility rate in each country. SDI ranges continuously from zero (the lowest developmental status) to one (the highest developmental status) and reflects the development status of a country or a region. The SDI is strongly correlated with health outcomes.¹³ Using the SDI values of 2017, the GBD study group divided 195 countries and territories into five development levels: high, high-middle, middle, low-middle, and low.

Data analysis

Corresponding with the time period for the Global Plan for the Decade of Action for Road Safety 2011–2020¹⁴ and the SDGs,¹ we selected data from 2011 to 2017 for analyses. Line graphs were plotted to demonstrate trends in age-standardized road traffic injury mortality, incidence, and prevalence from 2011 to 2017 by country development level (SDI category). Mortality, incidence and prevalence were calculated based on the number of deaths, new cases, prevalent cases and population estimated by the GBD 2017. Joinpoint regression analysis was fitted to examine the trends in mortality and morbidity from 2011 to 2017 to describe and distinguish significant changes over time.¹⁵ The average annual percent change (AAPC) and its 95% confidence interval (CI) both from joinpoint regression analysis were used to quantify the average speed of rate change from 2011 to 2017. Subgroup analyses were conducted to explore disparities in mortality and morbidity across SDI category by road users (pedestrian, pedal cyclist, motorcyclist and motor vehicle occupant).

By matching SDI data from the GBD updates and the WHO reports one country by one country, we also examined progress in the implementation of the three national actions (legislation, prioritized vehicle safety standards, and trauma-related post-crash care services)² from 2011 to 2017 by country SDI category. Legislation involves the enactment and enforcement of five national road traffic laws (speed limit law, drink-driving law, motorcycle helmet law, seat-belt law, and child restraint law). A score from zero to ten was used to quantify the enactment and enforcement of the road traffic laws; a score of zero reflects the lack of relevant laws or the weakest enforcement and a score of ten reflects the law's presence plus the strongest enforcement.² The implementation of the four prioritized United Nations vehicle safety standards (frontal impact protection, electronic stability control, pedestrian protection, and motorcycle anti-lock braking system)² and three trauma-related post-crash care services (national single emergency care access phone number, formal training and certification for prehospital providers, and presence of a national trauma registry)² were also assessed. Please note that data concerning implementation of vehicle safety standards were available for 2014 and 2018 only.

Joinpoint regression analysis was conducted through Joinpoint Regression Program Desktop version 4.7.0.0. Mortality and morbidity changes with *p* values less than 0.05 were considered statistically significant.

Results

Primary analysis

Generally, age-adjusted road traffic mortality decreased significantly as the SDI increased, which suggested that countries with higher SDI tended to have a lower mortality rate. Mortality disparities consistently existed across the five SDI categories from 2011 to 2017 (Fig. 1A). Age-adjusted mortality significantly decreased in all five SDI categories, with the greatest decrease in the high-middle SDI countries (AAPC: -2.7%, 95% CI: -2.9% – -2.5%, $p < 0.05$) and the smallest decrease in the high SDI countries (AAPC: -1.2%, 95% CI: -1.4% – -0.9%, $p < 0.05$).

In contrast, age-adjusted morbidity showed a very different spectrum across the five SDI categories. Countries with a higher SDI tended to have a higher morbidity rate (Fig. 1B for incidence and Fig. 1C for prevalence). Notably, both the incidence and prevalence gradually increased in the middle SDI countries from 2011 to 2017 (AAPC: 1.3%, $p < 0.05$ for incidence and 1.2%, $p < 0.05$ for prevalence) but decreased slightly in the other four SDI categories during the study time period (AAPC: -1.0% – -0.2%, all $p < 0.05$ for

incidence and -0.9% – -0.4%, all $p < 0.05$ for prevalence). Although morbidity in the higher SDI countries was initially higher, high (AAPC: -1.0%, $p < 0.05$ for incidence and -0.9%, $p < 0.05$ for prevalence) and high-middle (AAPC: -0.8%, $p < 0.05$ for incidence and -0.9%, $p < 0.05$ for prevalence) SDI countries showed the decreases which were more dramatic than the decreases in low-middle (AAPC: -0.2%, $p < 0.05$ for incidence and -0.4%, $p < 0.05$ for prevalence) and low (AAPC: -0.5%, $p < 0.05$ for incidence and -0.8%, $p < 0.05$ for prevalence) SDI countries.

Subgroup analysis by road user

Subgroup analysis demonstrated generally similar results to those for overall road traffic mortality, incidence and prevalence. The two most notable differences were during the study period of 2011 to 2017: (1) pedestrians in the high SDI category generally had the lowest mortality and morbidity (incidence and prevalence) (Fig. 1-A1, B1 and C1); and (2) the mortality and morbidity of motor vehicle occupants demonstrated quite distinct gaps across the five SDI categories – the high SDI category had the lowest mortality but the highest morbidity (incidence and prevalence) (Fig. 1-A4, B4 and C4).

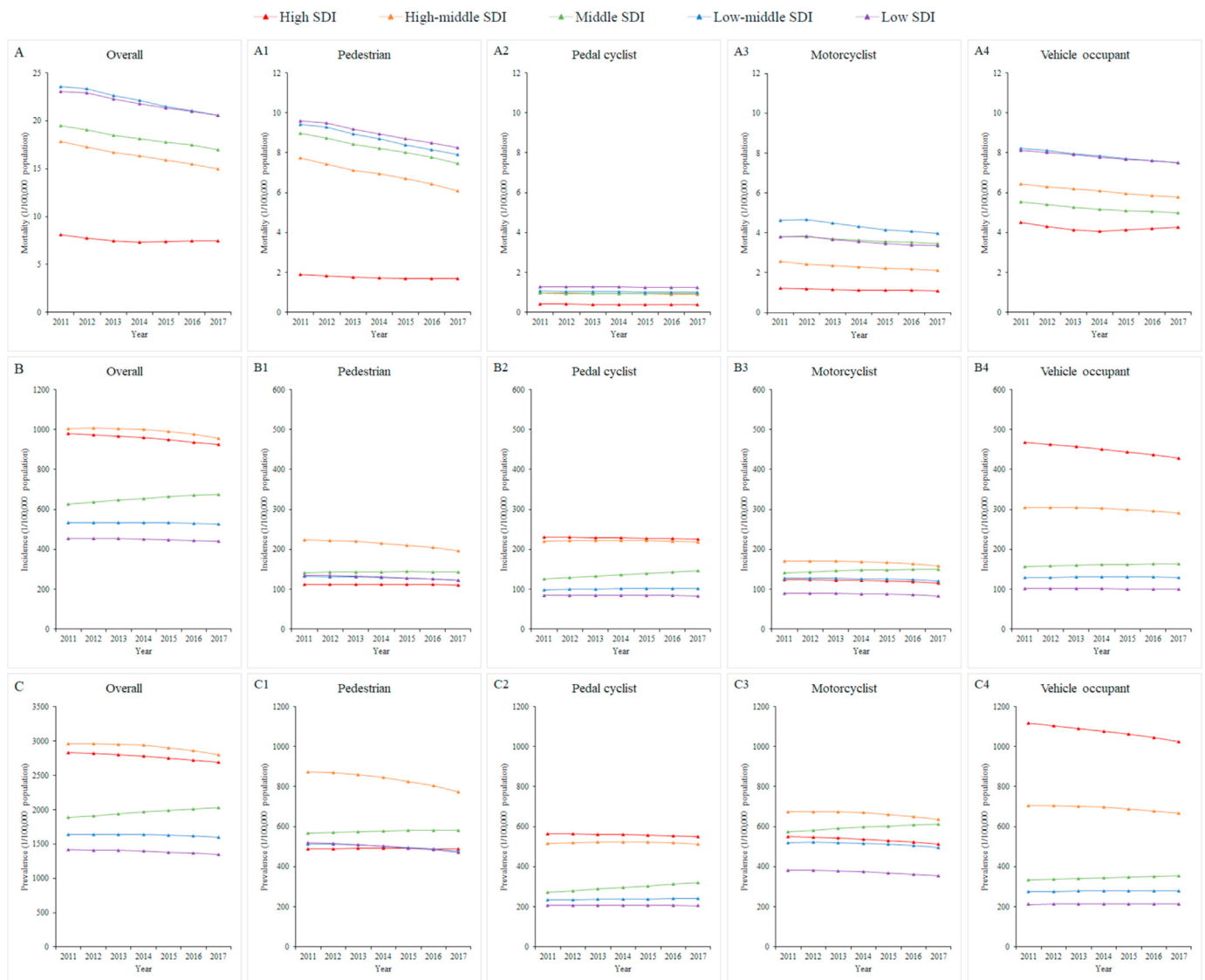


Fig. 1. Age-standardized road traffic injury mortality, incidence and prevalence by socio-demographic index (SDI), 2011-2017.

Implementation of the three types of recommended national actions

The median score of legislation and enforcement of the five types of national road traffic laws (speed limit law, drink-driving law, motorcycle helmet law, seat-belt law, and child restraint law) gradually increased as the SDI level increased (Table 1). The highest SDI countries had median scores between seven and nine, while the lowest SDI countries had median scores between zero and four. The median scores generally remained stable for all the five SDI countries between 2011 and 2017, except for a sharp increase in child restraint laws for the high-middle SDI category. Notably, the median scores remained at zero for child restraint laws in the three lower SDI categories in both 2011 and 2017, suggesting no progress in those countries in using child restraint laws to protect child motor vehicle occupants.

Implementation of the four prioritized motor vehicle safety standards increased as country SDI increased (Table 2). Four prioritized United Nations vehicle safety standards²: (1) frontal impact protection ensures that cars withstand the impact of frontal impact crashes at certain speeds to protect occupants, (2) electronic stability control prevents skidding and loss of control in cases of oversteering or understeering to reduce both fatal crash deaths and non-fatal crash injuries, (3) pedestrian protection provides softer bumpers and modifies the front ends of vehicles to reduce the severity of a pedestrian impact with a car, (4) motorcycle anti-lock braking system helps motorcycle operators maintain control during an emergency braking situation and reduces the likelihood of both fatal crash deaths and non-fatal crash injuries. Almost all high SDI countries adopted these standards, while countries with high-middle or lower SDI only partially implemented the four standards. Remarkably, no low SDI countries and very few low-middle SDI countries implemented any prioritized vehicle safety standards designed to guarantee the safety of pedestrians and occupants.

As for the performance of three trauma-related post-crash care services, the higher SDI countries had comparatively higher proportions of having national and single emergency care access numbers, of providing formal training and certification for all

prehospital providers, and of having a national trauma registry compared to the lower SDI countries (Table 3).

Discussion

Key findings

This study identified five key findings: (1) age-adjusted road traffic mortality significantly decreased in all the five SDI categories, but large disparities persisted from 2011 to 2017, with the higher SDI countries having lower mortality rates than the lower SDI countries, (2) age-adjusted road traffic morbidity (incidence and prevalence) presented contrary disparities across the study time period, with the higher SDI countries having higher morbidity rates than the lower SDI countries, (3) age-adjusted morbidity decreased slightly in all the SDI categories from 2011 to 2017, except for a significant increase in the middle SDI category, (4) both age-adjusted mortality and morbidity for pedestrians were the lowest in the high SDI category during 2011-2017, a contrast to the broad road traffic injury mortality and morbidity spectrum across the five SDI categories as well as the spectrum for other road users, and (5) the implementation of five national road traffic laws, four prioritized motor vehicle safety standards, and three trauma-related post-crash care services remained nearly unchanged in all five SDI categories from 2011 to 2017, but continued to be stronger in the higher SDI countries than in the lower SDI countries.

Interpretation of findings

Mortality disparities across the country SDI concord with differences reported in previous publications: mortality rates are lower in the developed countries compared to the developing countries.^{2,3,16} These disparities are often attributed to a range of factors, including discrepancies in road infrastructure, unsafe behaviors of road users, legislation and enforcement of road traffic laws, implementation of vehicle safety standards, and pre-hospital emergency medical services and hospital treatments.^{2,9,10,17} The

Table 1
Median and quartile range enforcement score of five types of national road traffic laws by country SDI (2011 vs. 2017).

SDI group	Speed limit law				Drink-driving law				Motorcycle helmet law				Seat-belt law				Child restraint law			
	2011		2017		2011		2017		2011		2017		2011		2017		2011		2017	
	M	QR	M	QR	M	QR	M	QR	M	QR	M	QR	M	QR	M	QR	M	QR	M	QR
High (n = 35)	7.00	1.00	7.00	2.00	7.00	3.00	7.00	2.00	8.00	2.00	9.00	2.00	7.00	2.00	7.00	2.00	7.00	3.00	7.00	2.00
High-middle (n = 35)	6.00	2.00	6.00	2.00	7.00	3.00	7.00	3.00	6.00	3.00	7.00	4.00	6.00	4.00	7.00	2.00	1.00	5.00	4.00	7.00
Middle (n = 39)	4.00	4.00	5.00	3.00	5.00	3.00	5.00	4.00	6.00	3.00	7.00	4.00	6.00	3.00	6.00	2.00	0	2.00	0	4.00
Low-middle (n = 37)	4.00	2.50	5.00	2.00	4.00	3.50	5.00	4.00	6.00	4.00	6.00	4.50	5.00	4.00	6.00	4.00	0	0	0	0
Low (n = 34)	3.00	2.25	3.00	4.25	3.00	2.00	2.00	5.00	2.00	4.25	4.00	3.50	3.00	5.00	4.00	6.00	0	0	0	0

SDI: socio-demographic index, M: median, QR: quartile range, QR is the 3rd quartile minus the 1st quartile.
Data source: global status report on road safety 2013⁹ and global status report on road safety 2018.²

Table 2
Number of countries adopting four prioritized United Nations vehicle safety standards by SDI (2014 vs. 2018), n (%).

SDI group	Frontal impact protection		Electronic stability control		Pedestrian protection		Motorcycle anti-lock braking system	
	2014	2018	2014	2018	2014	2018	2014	2018
High (n = 35)	34 (97.14)	34 (97.14)	34 (97.14)	34 (97.14)	32 (91.43)	32 (91.43)	/	29 (82.86)
High-middle (n = 35)	10 (28.57)	10 (28.57)	7 (20.00)	8 (22.86)	7 (20.00)	7 (20.00)	/	4 (11.43)
Middle (n = 40)	2 (5.00)	2 (5.00)	2 (5.00)	2 (5.00)	2 (5.00)	2 (5.00)	/	1 (2.50)
Low-middle (n = 39)	1 (2.56)	2 (5.13)	1 (2.56)	1 (2.56)	1 (2.56)	2 (5.13)	/	1 (2.56)
Low (n = 34)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	/	0 (0)

"/": Data were not included in the global status report on road safety 2015.

SDI : socio-demographic index.

Data sources: global status report on road safety 2015¹⁰ and global status report on road safety 2018.²

Table 3
Number of countries with trauma-related post-crash care services by SDI (2011 vs. 2017), n (%).

SDI group	National single emergency care access phone number		Formal training and certification or prehospital providers		National trauma registry	
	2011	2017	2011	2017	2011	2017
High (n = 36)	31 (86.11)	33 (91.67)	24 (66.67)	25 (69.44)	/	20 (55.56)
High-middle (n = 35)	27 (77.14)	31 (88.57)	19 (54.29)	26 (74.29)	/	13 (37.14)
Middle (n = 40)	19 (47.50)	21 (52.50)	22 (55.00)	20 (50.00)	/	13 (32.50)
Low-middle (n = 40)	16 (40.00)	16 (40.00)	13 (32.50)	17 (42.50)	/	10 (25.00)
Low (n = 34)	12 (35.29)	13 (38.24)	3 (8.82)	8 (23.53)	/	3 (8.82)

“/”: Data were not included in the global status report on road safety 2013.
SDI : socio-demographic index.

Data sources: Global status report on road safety 2013⁹ and Global status report on road safety 2018.²

research also suggests that mortality risks decrease with the implementation of interventions addressing these problems, including road infrastructure improvement,¹⁸ reduction of unsafe behaviors,² stronger legislation and enforcement of road traffic laws,¹⁹ stricter implementation of vehicle safety standards,²⁰ and higher quality pre-hospital emergency rescue and hospital treatments.²¹ One challenge for safety intervention is that road users in the developing countries display higher rates of unsafe behavior than those in the developed countries, such as failing to abide by road signs and signals, not using seatbelts and helmets, reckless and speedy driving, drinking and distracted driving and walking, and failing to respect a pedestrian’s right-of-way.^{2,22} Continued effort to address these behaviors through cultural diversity, normative behavior, and legislation is needed worldwide, and particularly in the lower SDI countries.

Our findings offer novel results to the field. First, we found inconsistent results for mortality and morbidity data across the five SDI categories. Over the course of our study, the mortality from road traffic crashes decreased but the morbidity rose. This may be partly result from higher quality emergency response and post-injury care, and motorization. Crashes may occur, but survival rates become higher. Whatever the cause, the burden of RTIs appears to be slowly transformed from deaths to non-fatal injuries, some of which lead to lifelong disability. Globally, humans may survive road traffic crashes and experience extended life, but they may also suffer disability and lost quality of life.^{23,24} Researchers and policy-makers should consider the consequences of these data for efforts to improve injury rehabilitation, work placements for disabled individuals, and improved quality of life for victims of serious RTIs.

We also found disparities across road users among the five SDI categories. In particular, pedestrians in the high SDI category had the lowest mortality and morbidity rates while motor vehicle occupants in the high SDI countries had the lowest mortality but the highest morbidity rates. These data patterns likely reflect the effect of exposure: people may drive and ride in cars more often in the wealthy nations than in poor nations, but walk less often.

The pattern of rapid global motorization is also likely contributing to our results, especially concerning increased road traffic morbidity.^{2,14} According to WHO reports,² the cumulative number of total registered vehicles in circulation in 2016 was 766,060,506 (37.5%) in the high SDI countries, 532,765,962 (26.0%) in the high-middle SDI countries, 430,922,455 (21.1%) in the middle SDI countries, 294,186,940 (14.4%) in the low-middle SDI countries, and 21,460,672 (1.0%) in the low SDI countries; the proportions of registered motor vehicles clearly differ from the proportions of populations for the five SDI categories in 2016 (15.1%, 18.3%, 27.5%, 22.3%, and 16.8%), causing large discrepancies between exposure-based metrics and population-based metrics. Equally important, however, the growth of the number of registered motor vehicles from 2010 to 2016 varied across the SDI categories (8.1%, 35.7%,

52.6%, 76.8%, and 87.3% for high, high-middle, middle, low-middle, and low SDI countries, respectively). Thus, the rapid rise of registered motor vehicles in the lower SDI countries partially influences the pattern of RTIs globally. A recent study by Cheng et al.,²⁵ for example, reported large discrepancies in using exposure-based and population-based road traffic mortality to compare rates across countries and over time.

Implications

Our findings have at least two major implications. First, we illustrated the presence of significant road traffic mortality differences across the five SDI categories between 2011 and 2017. The high SDI countries had the lowest mortality rates and the strongest prevention efforts. The global road injury deaths in 2017 would have decreased by 58% (from 1.24 million to 0.52 million, saving over 700,000 lives)⁸ if the four lower SDI categories had the same mortality rate as the high SDI category (9.1 per 100,000 population).⁸ The SDGs target to halve road traffic deaths and injuries by 2020 might be met in the upcoming years if our society implement technically feasible prevention not only to strengthen legislation and law enforcement, apply the recommended vehicle safety standards, but also to improve the pre-hospital rescue services and hospital treatments effectively. Of course, implementation of these initiatives worldwide would require substantial resources. Continued work, likely under the leadership of the United Nations and the WHO, is needed to mobilize and coordinate each country of the world to implement prevention strategies. International aid may be required to support many the low- and middle-income countries.

Second, the inconsistent morbidity disparities across the five SDI categories reveal the challenge of using population-based metrics instead of exposure-based metrics to study road traffic injury rates. When exposure data are preferential and available, data patterns are easier to interpret.²⁵ To facilitate monitoring and evaluating the SDGs progress for road traffic injury precisely, we encourage key stakeholders in the field, including the GBD study group and the WHO, to include valid exposure-based metrics in their annualized updates⁸ and regular reports.² Besides this, improving the reliability and quality of existing data and integration of distinct data sources to diminish the inconsistency of various data and misreporting (including under-reporting and over-reporting) are urgently needed.^{26–28}

Limitations

This study was primarily limited by the GBD estimates, which are restricted by the availability of high-quality mortality, morbidity and relevant covariates at the country level. In fact, very few countries in the world have regular and high-quality data sources for the estimation of burden of diseases, particularly for

morbidity and covariate data.^{29–31} Therefore, the GBD study group uses a variety of models and methods to address data challenges and estimate road traffic injury mortality and morbidity.¹² Assumptions used in the GBD estimation models are optimized to the extent possible but remain sub-optimal in some cases and may yield unexpected biases to the final estimates.³² This limitation could be solved to some extent by integrating new high-quality data sources and improving the GBD models, stepping the GBD study group routinely engages in.^{11,12}

In conclusion, the lower SDI countries continued to have a higher mortality from road traffic injury, and weaker prevention efforts, from 2011 to 2017. Prevention efforts recommended by the United Nations and the WHO should be fully implemented in all countries globally, including but not limited to legislation and law enforcement, mandated vehicle safety standards, and improved pre-hospital rescue services & hospital treatments. International aid and cooperation are needed, as implementation of evidence-based prevention strategies could have a substantial impact on global public health. In addition, efforts to improve the reliability and validity of road traffic mortality and morbidity estimates should be expedited. Such efforts include use of exposure-based metrics, regular collection of high-quality data, integration of diverse data sources, and improvement of the accuracy of models for estimating RTIs.

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Ethical statement

This research used anonymous open-access data and did not involve personal information from individuals. This analysis was approved by ethics committee of Xiangya School of Public Health, Central South University, Changsha, China (NO.XYGW-2019-033).

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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