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Global, regional, and national burden of road injuries 1990–2023 : a systematic analysis for the Global Burden of Disease Study 2023

GBD 2023 Road Injuries Collaborators

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Summary

Background Road injuries are a leading cause of mortality and morbidity worldwide. Years of international efforts have aimed to strengthen policy engagement, including the 2020 UN General Assembly's proclamation of the Second Decade of Action for Road Safety (2021–30), targeting a 50% reduction in road traffic deaths and serious injuries by 2030. The aim of this study is to provide estimates to monitor progress and identify intervention gaps.

Methods As part of the Global Burden of Diseases, Injuries, and Risk Factors Study 2023, we estimated incidence, mortality, and morbidity of road injuries for 204 countries and territories from 1990 to 2023. Four road injury types and 47 nature-of-injury categories were examined. Morbidity and mortality data from clinical records, vital registration, and police reports were harmonised using meta-analytic techniques to ensure consistency and correct for systematic bias. Incidence was modelled with the meta-regression tool Disease Modelling-Meta-Regression version 2.1 and cause-specific mortality with the Cause of Death Ensemble model, both incorporating location-specific covariates to support interpolation. Years of life lived with disability (YLDs) were estimated from the prevalence and severity of the nature of road injury, and years of life lost (YLLs) from the number of cause-specific deaths multiplied by the standard life expectancy at the age of death. Disability-adjusted life-years (DALYs) were the sum of YLLs and YLDs. All metrics were calculated with 95% uncertainty intervals (UIs).

Findings In 2023, there were 50·9 million (95% UI 46·1–56·1) road injury incident cases, 1·34 million (1·04–1·58) deaths, and 75·3 million (59·8–89·2) DALYs globally. Road injuries were the leading global cause of death among males aged 10–39 years. Between 1990 and 2023, age-standardised incidence decreased by 38·3% (95% UI 36·9–39·7) and mortality decreased by 32·3% (6·1–49·0), but progress varied widely by World Bank income group. Mortality in low-income countries (43·8 [95% UI 31·7–56·0] deaths per 100 000 population) was approximately six times higher than in high-income countries (7·5 [7·1–7·9] deaths per 100 000), despite the high-income countries showing the highest age-standardised incidence rates (858·1 [95% UI 781·9–947·1] cases per 100 000). In the past decade, many countries achieved notable reductions in road injuries, but others, including Ghana and the USA, saw increases. More severe injuries tended to occur in low-income and middle-income countries.

Interpretation Although global incidence, mortality, and DALY rates from road injuries have declined, progress remains uneven, with pronounced disparities across income groups reflecting systemic inadequacies in infrastructure, vehicle standards, enforcement, and post-crash care. Strengthening emergency response, improving road design, enforcing safety measures, and adapting policies to the evolving demographics remain essential.

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Introduction

Road injuries are a long-standing public health issue.[1,2] In the past two decades, numerous global initiatives have sought to bring road injuries into public health focus.[3] WHO released its first global strategy for road injury prevention in 2001,[4] followed by the UN General Assembly's inaugural road safety resolution in 2003[5] and the creation of the UN Road Safety Collaboration in 2004. Dedicated sources of financing were established, including the Global Road Safety Facility fund in 2006[6] and the UN Road Safety Fund in 2018. Private philanthropy has complemented these multilateral efforts, such as Bloomberg Philanthropies, who have invested more than US$865 million in road safety since 2007.[7] Following the UN's Decade of Action for Road Safety (2011–20)[8] and guided by the Stockholm Declaration,[9] the Second Decade of Action commenced in 2021 with an ambitious target of halving road traffic deaths and injuries by 2030.[10] Despite these global initiatives, investment and policy implementation lag behind what the target requires.[2,11]

A key barrier to progress is the persistent paucity of reliable data.[12] To raise awareness, monitor progress, and inform policy development, this study presents the most

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Research in context

Evidence before this study

The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2017 was the last comprehensive and globally comparable assessment of global morbidity and mortality from road injuries. To identify subsequent evidence, we restricted our search to studies published after 2017. We conducted a review of English-language articles in PubMed from Jan 1, 2017, to Dec 1, 2025, using search terms on road injuries and burden estimates (appendix 1 p 3). We included studies reporting road injury incidence, mortality, morbidity, or disability-adjusted life-years (DALYs), and excluded articles focused solely on clinical management, rehabilitation, or non-road-related injuries. We also reviewed key global sources, including WHO road safety reports and World Bank reports. The WHO Global Status Report on Road Safety (GSRRS), tracking road safety progress across more than 190 countries, estimated 1·19 million road injury deaths in 2021 in its most recent 2023 edition. The report also highlighted that road injury deaths remain the leading cause of mortality in children and young people aged 5–29 years, with 90% of all traffic deaths occurring in low-income and middle-income countries. However, the GSRRS provides only mortality estimates, without quantifying non-fatal outcomes such as years lived with disability (YLDs) or DALYs, and its most recent data extend only to 2021. Other published literature was limited to specific countries or regions, focused on particular age groups or road users, or offered only cross-sectional snapshots rather than long-term, standardised trend estimates.

See Online for appendix 1

Added value of this study

This study addresses key gaps in the existing evidence by providing the most up-to-date and comparable estimates of road injury incidence, mortality, and disability using data up to 2023 on the global, regional, and national levels. Using data from a broad range of sources, including hospital and emergency department records, vital registration and verbal autopsy data, censuses, surveys, and police records, we generated internally consistent estimates of road injury mortality, incidence, and disability by age, sex, location, and calendar year. The estimation framework accounts for under-reporting and misclassification and propagates uncertainty across all inputs. Unlike previous global assessments, this study systematically disaggregates road injuries by detailed road user categories resulting from nature-of-injury profiles, enabling comprehensive quantification of both fatal and non-fatal health loss. By generating burden estimates (years of life lost, YLDs, and DALYs) within a unified framework, this work enables direct comparison of road injury burden across populations, over time, and relative to other causes of health loss.

Implications of all the available evidence

Road injuries remain a major, preventable cause of premature death and disability. While international commitments, including the UN's Sustainable Development Goals and Second Decade of Action for Road Safety, signal ambition and seek to reinvigorate political will, meaningful progress demands concrete steps that galvanise cross-sector cooperation and secure sustained investment to support continuous, operational efforts.

recent findings on road injuries from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2023, a comprehensive epidemiological study that produces internally consistent and comparable estimates for 375 diseases and injuries and 88 modifiable risk factors for 204 countries and territories.[13,14] We examine estimates of incidence, mortality, years of life lost (YLLs), years of life lived with disability (YLDs), and disability-adjusted life-years (DALYs) from 1990 to 2023 by country, by 21 GBD regions, and by four World Bank income groups.[13,14] Estimates are disaggregated by sex, age, nature of injury, and five specific road user types: motor vehicle occupants, motorcyclists, cyclists, pedestrians, and other road users. This report was produced as part of the GBD Collaborator Network and in accordance with the GBD Protocol.

Methods

Case definitions

Road injuries in GBD are defined as death or disability due to an unintentional interaction with an automobile, motorcycle, pedal cycle, or other vehicle. In the GBD four-level cause hierarchy, which orders causes from broad groupings to increasingly specific ones, road injuries are one of 176 Level 3 causes (other examples include falls and interpersonal violence) and are further disaggregated into five mutually exclusive Level 4 causes by road user types: motor vehicle road injuries, motorcyclist road injuries, bicycle road injuries, pedestrian road injuries, and other road injuries (eg, animal riders, occupants of animal-drawn vehicles, and tram occupants).[13,14] Intentional road injuries (eg, self-harm or assault) or other transport injuries (eg, aeroplane, train, and boat injuries) are excluded.

The nature of injury, referring to the specific bodily harm sustained, was also examined. GBD includes 47 nature-of-injury categories, grouped into seven broader classes: amputations, burns, fractures, head injuries, spinal injuries, minor injuries, and other injuries. Each cause of injury is mapped to a single nature-of-injury category; when multiple injuries are recorded for the same case, the category associated with the highest burden is selected.[13]

Data sources

Road injury morbidity was estimated using data from hospital inpatient records, emergency departments, outpatient encounters, and population-representative surveys.[13] To exclude clinically insignificant injuries (eg, scrapes), cases were restricted to injuries that

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required some form of health care in a system with full health-care access.[13] Clinical data sources were mapped to road injury causes using ICD-9 and ICD-10 codes (appendix 1 p 4). Injuries that would have required care but were not treated due to financial or geographical barriers were accounted for by survey data.[13] Road injury mortality was estimated using data from vital registrations, verbal autopsies, mortality surveillance, censuses, surveys, and police records.[14]

Road injury incidence

Road injury incidence was estimated using Disease Modelling-Meta-Regression version 2.1 (DisMod-MR 2.1),[15] a Bayesian meta-regression tool to synthesise epidemiological data within a compartmental disease model while ensuring internal consistency across incidence, prevalence, remission, and mortality.[13] Input data were adjusted using standard GBD methods, to account for underascertainment, variation in care-seeking, and systematic differences in case definitions across data sources.[13,16] Country-level covariates included in the DisMod-MR 2.1 models were the age-standardised summary exposure value and vehicles per capita. Incidence estimated with DisMod-MR 2.1 corresponded to road injuries requiring inpatient care. The number of outpatient cases was derived by estimating the ratio of inpatient to outpatient cases using meta-regression—Bayesian, regularised, trimmed. Further methodological details are given in the GBD 2023 capstone appendices.[13]

Road injury mortality

Cause-specific mortality from road injuries was estimated using the Cause of Death Ensemble model (CODEm), an ensemble framework that evaluates multiple model classes and covariate sets and combines the best-performing models into a weighted ensemble.[14,17] All cause-of-death input data underwent standard GBD processing, including the redistribution of ill-defined causes of death. In settings with sparse or no direct mortality data, CODEm generates estimates by drawing on covariates and the hierarchical mixed-effects structure of its component models, allowing information to be borrowed across countries and regions.[17] Location-level covariates varied by road injury type and included, among others, the Socio-demographic Index,[18] the Healthcare Access and Quality Index,[19] and the proportion of two-wheeled vehicles. Further details are available in the GBD capstone appendices.[14,20]

Calculation of YLDs, YLLs, and DALYs

YLDs were estimated by multiplying the prevalence of each nature-of-injury sequela by its corresponding disability weight.[13] Because injury-related disability is determined by the nature of bodily harm rather than the external cause alone, incidence estimates were first mapped to nature-of-injury categories, informed by cause–nature distributions derived from clinical data sources that report both the cause and nature of injury.[13] Prevalence by nature of injury was then derived by multiplying these incidence estimates by nature-specific and severity-specific duration estimates for short-term sequelae, with an estimated proportion of cases progressing to long-term (permanent) health loss. Disability weights, ranging from 0 (full health) to 1 (equivalent to death), were assigned according to the injury nature and severity, with separate weights for short-term and long-term sequelae, and, where relevant, for treated and untreated cases.[13]

YLLs were calculated by multiplying the number of cause-specific deaths in each age-sex-location-year stratum by the standard life expectancy at the age of death.[14,18] DALYs were calculated as the sum of YLDs and YLLs. Further details are available in previous publications.[13,14,20]

For all estimates, the mean was calculated across 250 draws from the posterior distribution, and 95% uncertainty intervals (UIs) were derived from the 0·025 and 0·975 percentile values across these draws.[13,14] Age-standardised rates were computed using the GBD standard population to enable comparisons across settings with different demographic structures.[18] Data visualisations were done with Python (version 3.11.9). This study adheres to GATHER (appendix 1 p 5).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or the writing of the report.

Results

In 2023, there were an estimated 50·9 million (95% UI 46·1–56·1) road injury incident cases globally, corresponding to an age-standardised incidence rate of 623·0 (95% UI 566·9–686·8) cases per 100 000 population (table 1; appendix 1 pp 7–9). In the World Bank income groups, the lowest incidence rate was observed in the lower-middle-income group (446·4 [405·3–491·1] cases per 100 000), while the highest age-standardised incidence rate was seen in the high-income group (858·1 [781·9–947·1] cases per 100 000; table 1; appendix 1 pp 7–9). Between 1990 and 2023, the global age-standardised road injury incidence declined by 38·3% (95% UI 36·9–39·7), with reductions observed across all income groups, ranging from decreases of 14·7% (12·8–16·6) in the lower-middle-income group to 49·0% (47·8–50·1) in the high-income group (appendix 1 pp 7–9, 34). Decreases in incidence were estimated in 179 of 204 countries and territories, while ten had increases in incidence (appendix 1 pp 10–12, 35).

Of Level 4 causes of road injuries, motor vehicle injuries accounted for the largest share of road injury cases globally (19·8 million [95% UI 17·5–22·6] cases, 38·8% of the global total) in 2023, followed by pedestrian (11·6 million [10·0–13·4] cases, 22·7%), cyclist (10·1 million [8·40–12·1]

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	Incidence		Mortality	
	Age-standardised incidence rate (per 100 000), 2023	Percentage change in age-standardised incidence rate, 1990–2023	Age-standardised mortality rate (per 100 000), 2023	Percentage change in age-standardised mortality rate, 1990–2023
Road injuries				
Global	623·0 (566·9–686·8)	−38·3% (−39·7 to −36·9)	16·1 (12·5–19·0)	−32·3% (−49·0 to −6·1)
Low income	558·7 (525·8–595·3)	−25·6% (−27·4 to −23·9)	43·8 (31·7–56·0)	16·2% (−21·9 to 85·7)
Lower-middle income	446·4 (405·3–491·1)	−14·7% (−16·6 to −12·8)	19·1 (13·2–24·3)	−0·7% (−29·2 to 44·1)
Upper-middle income	751·3 (672·6–836·0)	−29·1% (−31·7 to −26·8)	13·2 (10·9–15·3)	−54·5% (−66·6 to −26·0)
High income	858·1 (781·9–947·1)	−49·0% (−50·1 to −47·8)	7·5 (7·1–7·9)	−61·1% (−62·7 to −58·5)
Motor vehicles				
Global	244·1 (216·1–279·0)	−42·3% (−44·0 to −41·0)	6·3 (5·0–7·9)	−26·4% (−48·9 to 7·2)
Low income	271·5 (252·0–294·8)	−30·2% (−32·5 to −28·1)	19·6 (13·3–27·3)	7·6% (−30·5 to 72·5)
Lower-middle income	171·9 (153·3–194·6)	−22·5% (−24·6 to −20·2)	6·2 (4·5–8·5)	−15·9% (−43·4 to 33·6)
Upper-middle income	234·4 (202·7–272·9)	−31·5% (−34·9 to −28·5)	4·8 (3·8–5·8)	−37·0% (−66·1 to 3·0)
High income	453·8 (400·0–521·7)	−48·3% (−49·6 to −46·9)	4·5 (4·2–4·7)	−54·9% (−58·1 to −51·5)
Motorcyclists				
Global	81·6 (69·3–96·2)	−16·0% (−18·6 to −12·5)	3·8 (2·6–5·0)	38·2% (−27·4 to 146·6)
Low income	39·0 (33·5–44·7)	−4·6% (−7·4 to −1·5)	4·5 (2·7–6·8)	106·5% (−10·0 to 381·5)
Lower-middle income	71·1 (60·8–83·7)	13·3% (10·4 to 17·4)	5·4 (3·0–7·5)	81·7% (−8·1 to 242·4)
Upper-middle income	107·0 (90·5–126·1)	−6·0% (−10·4 to −1·1)	3·6 (2·8–4·4)	9·6% (−46·8 to 107·6)
High income	80·7 (67·3–97·2)	−38·5% (−41·0 to −35·9)	1·1 (1·0–1·2)	−44·1% (−52·4 to −36·4)
Cyclists				
Global	122·8 (103·0–149·3)	−30·9% (−33·3 to −28·6)	1·0 (0·7–1·5)	8·4% (−50·1 to 98·3)
Low income	64·0 (54·3–77·1)	−17·9% (−20·7 to −15·1)	1·9 (1·0–3·6)	64·5% (−36·5 to 331·5)
Lower-middle income	78·9 (65·4–96·1)	−3·6% (−7·3 to 0·4)	1·2 (0·6–2·0)	54·1% (−36·1 to 233·0)
Upper-middle income	161·0 (134·6–195·1)	−15·7% (−19·9 to −11·5)	1·1 (0·7–1·5)	−6·2% (−68·5 to 105·8)
High income	183·8 (149·9–225·4)	−43·0% (−45·0 to −40·8)	0·3 (0·3–0·3)	−56·0% (−61·1 to −50·4)
Pedestrians				
Global	137·3 (119·1–159·1)	−45·0% (−46·9 to −43·0)	4·8 (3·5–6·4)	−57·7% (−71·9 to −35·0)
Low income	148·1 (133·5–162·1)	−23·8% (−26·0 to −21·7)	17·2 (11·1–24·8)	9·1% (−35·8 to 104·9)
Lower-middle income	96·0 (84·0–110·0)	−19·2% (−22·0 to −16·6)	6·1 (3·9–8·7)	−23·3% (−55·2 to 33·7)
Upper-middle income	198·2 (168·6–232·0)	−39·5% (−42·4 to −36·9)	3·5 (2·8–4·5)	−78·8% (−85·6 to −61·0)
High income	107·8 (91·1–125·0)	−63·5% (−65·1 to −62·0)	1·6 (1·4–1·7)	−76·0% (−78·6 to −72·7)
Others				
Global	37·1 (28·2–46·1)	−39·1% (−42·4 to −35·4)	0·2 (0·1–0·3)	−17·7% (−65·1 to 69·8)
Low income	36·1 (27·1–44·3)	−25·7% (−29·3 to −21·7)	0·5 (0·2–0·7)	73·2% (−37·3 to 432·0)
Lower-middle income	28·5 (21·6–35·7)	−24·9% (−28·7 to −21·5)	0·2 (0·1–0·4)	18·5% (−58·7 to 239·5)
Upper-middle income	50·8 (38·9–62·8)	−40·6% (−44·5 to −35·6)	0·2 (0·1–0·2)	−45·4% (−76·5 to 8·7)
High income	32·1 (23·2–41·6)	−42·1% (−45·2 to −38·8)	0·0 (0·0–0·1)	−63·8% (−70·8 to −56·5)

Data in parentheses are 95% uncertainty intervals. Negative percentage values indicate declines in age-standardised rates. Uncertainty intervals crossing zero indicate statistical uncertainty about the direction of change.

Table 1: **Age-standardised road injury incidence and mortality rates in 2023, and their percentage change from 1990 to 2023 globally, by World Bank income groups, and by road user type**

cases, 19·8%), and motorcyclist (6·70 million [5·71–7·91] cases, 13·2%) injuries (appendix 1 pp 13, 36). In the high-income group, cyclist injuries accounted for 20·9% (2·38 million [1·99–2·80] cases) of all road injuries, making them the second-largest Level 4 cause. At the regional level, cyclist road injuries surpassed motor vehicle injuries to constitute the largest contributor to road injuries in high-income Asia Pacific, while in tropical Latin America, motorcyclist injuries exceeded those from motor vehicles (appendix 1 p 36). Further regional and income-group patterns are in appendix 1 (p 36). From 1990 to 2023, age-standardised incidence rates decreased for all Level 4 road injury types globally (table 1; appendix 1 p 37). Consistent decreases were observed across income groups, except for motorcyclist road injuries in the lower-middle-income group (table 1; appendix 1 p 37). At the regional level, motorcyclist injuries showed marked heterogeneity, with decreases over this period in 11 regions

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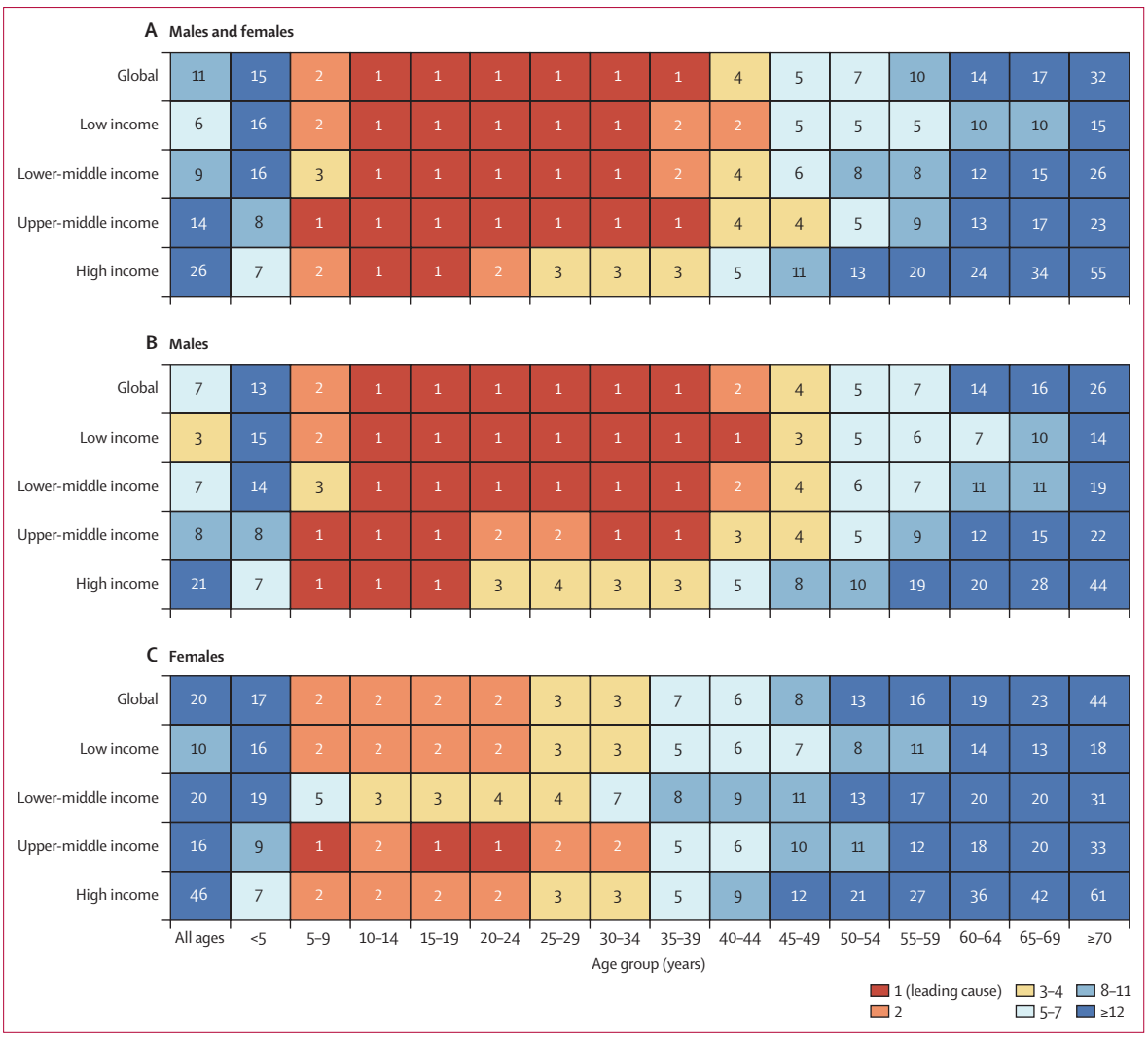


Figure 1: **Ranking of road injury deaths relative to all Level 3 causes of death, 2023**
(A) Data for males and females combined. (B) Ranking among males. (C) Ranking among females. The ranking is based on counts and is shown across age groups.

but increases in eight regions, particularly across Latin American regions (appendix 1 p 37).

There were an estimated 1·34 million (95% UI 1·04–1·58) deaths due to road injuries in 2023, corresponding to an age-standardised mortality rate of 16·1 (95% UI 12·5–19·0) deaths per 100 000 population (table 1; appendix 1 pp 14–16). Road injuries ranked 11th of all Level 3 causes of mortality globally (figure 1). More than 90% of global road injury deaths occurred in the low-income and middle-income groups (appendix 1 p 38). The high-income group had the lowest age-standardised mortality rate, estimated at 7·5 (7·1–7·9) deaths per 100 000, followed by the upper-middle-income (13·2 [10·9–15·3] deaths per 100 000) and lower-middle-income (19·1 [13·2–24·3] deaths per 100 000) groups (table 1; appendix 1 p 39). This pattern contrasted with age-standardised incidence rates, which were highest in the high-income group. The highest mortality rate was in the low-income group, at 43·8 (31·7–56·0) deaths per 100 000—almost six times higher than in the high-income group (table 1; appendix 1 p 39).

Between 1990 and 2023, the global age-standardised mortality from road injuries decreased by 32·3% (95% UI 6·1 to 49·0; table 1; appendix 1 p 39). Considerable reductions occurred in the high-income group (61·1% [58·5 to 62·7]) and the upper-middle-income group (54·5% [26·0 to 66·6]). The lower-middle-income and low-income groups had no detectable changes in age-standard mortality rates from 1990 to 2023 (table 1; appendix 1 pp 14–16, 39). Focusing on the period from 2010 to 2023, which coincides with the years of the UN Decades of Action for Road Safety, the change in global age-standardised mortality rates was –13·3% (–25·8 to 3·8). Significant reductions were observed in 80 countries and territories, 12 of which had decreases exceeding 50% (figure 2; appendix 1 pp 17–19). However,

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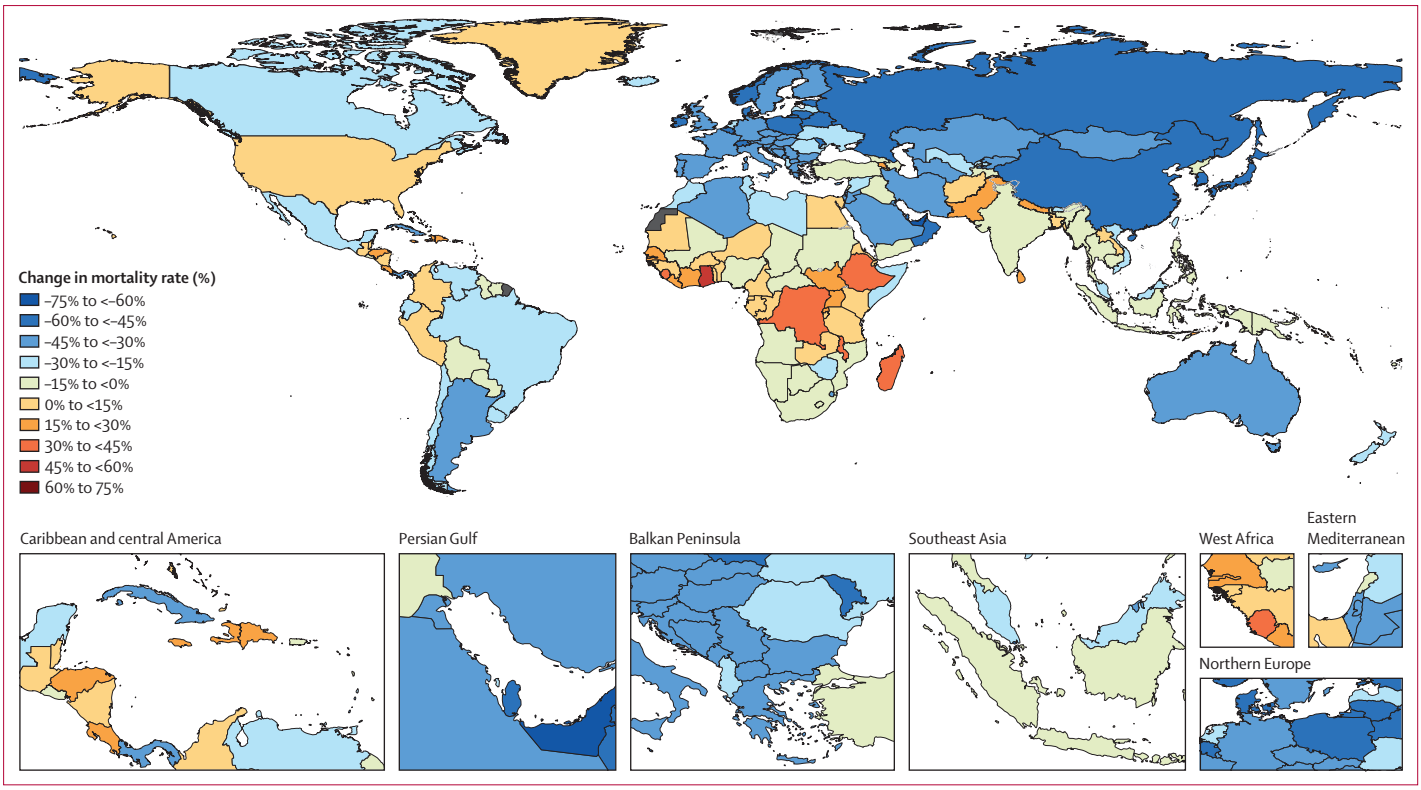


Figure 2: **Change in age-standardised mortality rates attributable to road injuries, 2010–23**

six countries had significant increases during this period, ranging from 13·2% (6·3 to 20·3) in the USA to 48·5% (8·3 to 107·5) in Ghana.

Motor vehicle road injuries accounted for the largest share of road injury deaths worldwide in 2023 (518 000 deaths [95% UI 417 000–648 000], 38·6% of the total), followed by pedestrian injuries (401 000 deaths [295 000–532 000], 29·9%; appendix 1 pp 13, 40). Although motorcyclists represented only 13·2% (6·70 million [5·71–7·91] cases) of road injury incidence, they accounted for 23·8% (319 000 deaths [217 000–416 000]) of road injury deaths. Although motor vehicle and cyclist road injury incidence rates were highest in high-income countries, the corresponding mortality rates were lowest (table 1).

Progress on addressing road injury mortality since 1990 has been uneven, with motorcyclist road injuries showing the most heterogeneous patterns, ranging from a decrease of 44·1% (95% UI 36·4 to 52·4) in the high-income group to a change of 106·5% (–10·0 to 381·5) in the low-income group (table 1; appendix 1 p 41). Despite decreases in age-standardised incidence rates, the trajectories of age-standardised mortality rates diverged between income groups for all road injury types, with the greatest reductions in the high-income group and no significant change in the low-income group (table 1).

Globally, road injuries resulted in 66·7 million (95% UI 51·5–79·4) YLLs and 8·56 million (6·25–11·2) YLDs, together accounting for 75·3 million (59·8–89·2) DALYs in 2023 (appendix 1 pp 20–28). Age-standardised YLL rates were nearly six times higher in the low-income group (2134·9 [95% UI 1546·6–2734·4] per 100 000) than in the high-income group (381·5 [362·7–401·3]) (appendix 1 pp 20–22, 42), whereas YLD rates showed a contrasting pattern, being highest in the high-income group (113·7 [82·9–152·5] per 100 000; appendix 1 pp 23–25, 43). The age-standardised DALY rate was 2229·4 (1637·2–2840·5) per 100 000 in the low-income group compared with 495·3 (457·4–541·8) per 100 000 in the high-income group (appendix 1 pp 26–28, 44). Large disparities in DALY rates were also seen at the country level (appendix 1 pp 29–31, 45). Between 1990 and 2023, global age-standardised YLL, YLD, and DALY rates all decreased significantly (appendix 1 pp 20–28), although reductions in YLL and DALY rates were confined to the high-income and upper-middle-income groups (appendix 1 p 46).

Road injury incidence rates were consistently higher in males than in females across all age groups in 2023, except among children younger than 5 years (figure 3). In males, incidence peaked in young adults aged 20–29 years, whereas in females, the highest rates were observed in young children (younger than 5 years). Age and sex patterns by road user type are shown in appendix 1 (p 47).

The greatest mortality burden was concentrated in people younger than 39 years (appendix 1 pp 48–49).

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Road injuries were the leading Level 3 cause of death for individuals aged 10–39 years globally and the second leading cause of death in children aged 5–9 years (figure 1). In males aged 20–24 years, road injuries accounted for 20·7% (95% UI 15·6–24·9) of all deaths globally, corresponding to 98 000 (95% UI 71 600–121 000) deaths (appendix 1 pp 32, 48).

The most common nature of injury from road injuries was fractures, constituting 38·1% (95% UI 34·6–41·9) of all non-fatal road injury cases, corresponding to 19·4 million (95% UI 16·7–22·1) cases (table 2). Minor injuries ranked second, accounting for 35·3% (95% UI 31·2–39·1) of all non-fatal road injury cases, corresponding to 18·0 million (95% UI 15·5–20·7) cases. Head injuries occurred in 10·4% (95% UI 9·0–11·8) of road injury cases, corresponding to 5·27 million (95% UI 4·43–6·30) cases. Most head injuries were classified as moderate or severe traumatic brain injuries (appendix 1 p 50), representing 7·1% (95% UI 5·9–8·3) of all non-fatal road injury cases, corresponding to 3·62 million (95% UI 2·92–4·35) cases (table 2). Low-income, lower-middle-income, and upper-middle-income groups had a disproportionately high proportion of moderate or severe traumatic brain injuries, constituting more than 70% of head injuries (appendix 1 p 50). Motorcyclist road injuries had the highest proportion of head injuries of all road user types (13·9% [95% UI 11·3–16·6]), corresponding to 930 000 cases (95% UI 730 000–1 140 000), of which 78·9% (734 000 cases [95% UI 549 000–914 000]) were moderate or severe traumatic brain injuries (appendix 1 pp 33, 51). Of the total YLDs attributable to road injuries, fractures accounted for 47·2% (95% UI 42·8–51·1), corresponding to 4·05 million (95% UI 2·80–5·60) YLDs. Head injuries accounted for 21·3% (95% UI 17·8–24·8) of road injury YLDs, corresponding to 1·82 million (95% UI 1·27–2·46) YLDs, with moderate or severe traumatic brain injuries alone resulting in 1·58 million (1·10–2·12) YLDs (table 2).

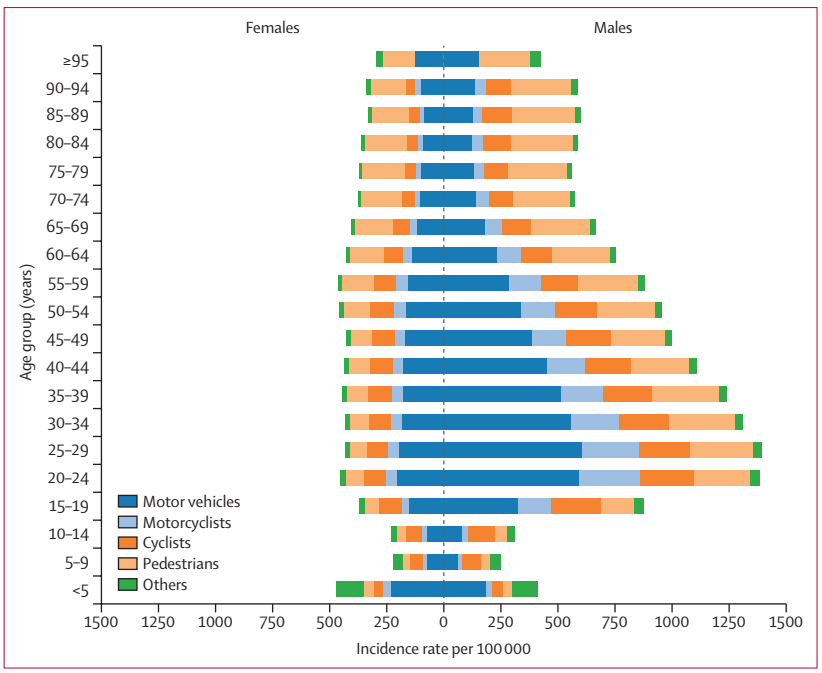


Figure 3: **Global road injury incidence rate stratified by sex, age group, and Level 4 road injury causes, 2023**

Discussion

This study provides a comprehensive global assessment of road injury burden from 1990 to 2023. With nearly 51 million incident cases, 1·34 million deaths, and over 75 million DALYs estimated in 2023, road injuries remain one of the leading causes of disease burden worldwide. Although global age-standardised incidence, mortality, and DALY rates have declined, progress varied by geography. Our findings align with the WHO Global Status Report on Road Safety 2023,[2] which estimated 1·19 million deaths globally in 2021. Although exact point estimates differ due to methodological divergence, both studies found a disproportionate mortality burden in low-income and middle-income countries (LMICs).[2] Overall, road injuries present a heterogeneous epidemiological landscape, where progress and stagnation stand in juxtaposition.

Global reductions in road injury incidence and mortality, driven largely by trends in the high-income group, reflect the importance of strengthened regulation, improved policy, heightened awareness, and post-crash and trauma care.[2] In high-income countries, the age-standardised incidence rate decreased by 49·0% and the mortality rate decreased by 61·1% from 1990 to 2023. These improvements have occurred alongside a shift in safety philosophy that reframes road safety as a public health issue rooted in preventable system failures rather than individual driver error.[21] The Vision Zero principle, which holds that no road death is acceptable or inevitable, exemplifies this shift and, since its introduction in Sweden in 1997,[22] has been adopted by many countries.[23] Closely related is the Safe System approach, premised on designing transport systems that accommodate human vulnerability and error, and endorsed by WHO and the UN for the Second Decade of Action for Road Safety 2021–30.[10] However, implementing these frameworks requires sustained political commitment, cross-sectoral coordination, and technical and infrastructural capacity;[23,24] prerequisites that can be difficult to realise in low-resource settings.

Profound inequity defines road injury burden, with 90% of deaths occurring in LMICs. The mortality rate in the low-income group was nearly six times higher than in the high-income group, more than three times higher than in the upper-middle-income group, and more than two times higher than in the lower-middle-income group. Despite the existence of international guidelines, progress in LMICs has been constrained by limited national capacity to operationalise them.[25] In many LMICs, rapid motorisation and urbanisation have outpaced the development of road safety measures,

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leaving large proportions of road users exposed to high-risk environments.[26] Variations in regulatory standards illustrate these gaps: in 2022, 86% of high-income countries mandated seatbelts and seatbelt anchorages, compared with 26% of low-income countries.[2] This disparity is even more pronounced for advanced safety features such as front-impact and side-impact protection, which are mandated in less than 10% of LMICs compared with 76% of high-income countries.[2] Road infrastructure quality similarly lags, with most road length in low-income countries rated as unsafe.[27] These deficiencies are further compounded by underdeveloped post-crash response and data systems, hindering timely care and the ability to identify intervention priorities.[26,28,29]

The disparities in road safety standards across income groups coincide with an asymmetry in mortality–morbidity burden and differences in the nature of injuries. Road injuries resulted in high levels of premature mortality in LMICs, with age-standardised YLL rates three to six times higher in the low-income group than in the high-income group. By contrast, road injury burden in the high-income group manifested primarily in disability, reflected in higher YLD rates. Road injuries in low-income, lower-middle-income, and upper-middle-income groups were also more severe in nature; more than 70% of head injuries resulting from road injuries in these groups were moderate to severe traumatic brain injuries. These patterns are consistent with lower rates of helmet and seatbelt use, suboptimal speed regulation, delayed access to post-crash care, and the lack of essential trauma and surgical resources in LMICs.[2,26,30–32] However, it is important to acknowledge that some of the discrepancies in mortality and morbidity patterns observed across the income groups might also reflect how road injuries are ascertained in different contexts, particularly in LMICs, where under-reporting is pervasive.[12]

Addressing these challenges demands prioritising solutions that deliver the largest reductions in road injury mortality per unit of investment.[33] WHO-led

	Incidence		YLDs	
	Incident cases (thousands), 2023	Percentage of all road injury cases, 2023	YLDs (thousands), 2023	Percentage of all road injury YLDs, 2023
Fractures				
Global	19 400 (16 700–22 100)	38·1% (34·6–41·9)	4050 (2800–5600)	47·2% (42·8–51·1)
Low income	1370 (1210–1540)	38·0% (34·2–42·3)	187 (131–260)	42·1% (37·3–46·3)
Lower-middle income	5290 (4550–6040)	38·3% (34·7–42·6)	878 (608–1210)	43·7% (39·0–48·1)
Upper-middle income	8510 (7280–9830)	38·6% (35·0–42·9)	1840 (1260–2560)	46·7% (42·2–50·9)
High income	4200 (3630–4750)	36·9% (33·5–40·9)	1140 (789–1590)	52·4% (48·4–55·7)
Head injuries				
Global	5270 (4430–6300)	10·4% (9·0–11·8)	1820 (1270–2460)	21·3% (17·8–24·8)
Low income	354 (302–409)	9·8% (8·5–11·3)	85·6 (60·0–116)	19·3% (16·6–21·9)
Lower-middle income	1480 (1250–1760)	10·7% (9·2–12·2)	426 (297–578)	21·3% (18·2–24·6)
Upper-middle income	2500 (2080–3010)	11·3% (9·8–12·9)	981 (685–1320)	24·9% (20·7–29·2)
High income	940 (758–1150)	8·3% (6·9–9·9)	328 (225–441)	15·2% (12·6–17·7)
Moderate or severe traumatic brain injury				
Global	3620 (2920–4350)	7·1% (5·9–8·3)	1580 (1100–2120)	18·5% (15·3–21·8)
Low income	248 (206–290)	6·9% (5·7–8·1)	77·6 (54·5–105)	17·5% (14·9–20·1)
Lower-middle income	1070 (875–1280)	7·8% (6·5–9·1)	388 (271–526)	19·4% (16·5–22·5)
Upper-middle income	1860 (1500–2270)	8·4% (7·0–9·9)	892 (626–1200)	22·7% (18·7–26·8)
High income	427 (337–520)	3·8% (3·0–4·6)	218 (154–289)	10·1% (8·1–12·2)
Minor traumatic brain injury				
Global	1660 (1200–2270)	3·3% (2·4–4·4)	244 (168–334)	2·9% (2·5–3·3)
Low income	106 (74·4–147)	2·9% (2·1–4·1)	8·00 (5·46–11·1)	1·8% (1·6–2·1)
Lower-middle income	400 (286–549)	2·9% (2·1–4·0)	38·4 (26·1–52·9)	1·9% (1·7–2·2)
Upper-middle income	637 (453–878)	2·9% (2·1–3·9)	88·5 (59·7–121)	2·2% (1·9–2·6)
High income	513 (358–693)	4·5% (3·3–6·0)	109 (73·6–150)	5·0% (4·3–5·9)
Spinal injury				
Global	98·0 (68·1–137)	0·2% (0·1–0·3)	805 (576–1020)	9·5% (7·2–11·9)
Low income	5·03 (3·47–7·04)	0·1% (0·1–0·2)	32·9 (24·5–41·2)	7·5% (5·8–9·3)
Lower-middle income	21·7 (15·1–30·4)	0·2% (0·1–0·2)	154 (112–193)	7·8% (5·9–9·6)
Upper-middle income	38·5 (27·0–54·7)	0·2% (0·1–0·2)	318 (228–402)	8·2% (6·1–10·2)
High income	32·7 (22·7–45·3)	0·3% (0·2–0·4)	299 (213–386)	13·9% (10·3–17·8)

(Table 2 continues on next page)

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	Incidence		YLDs	
	Incident cases (thousands), 2023	Percentage of all road injury cases, 2023	YLDs (thousands), 2023	Percentage of all road injury YLDs, 2023
(Continued from previous page)				
Other injuries				
Global	6970 (5840–8360)	13·7% (12·0–15·9)	762 (549–1020)	8·9% (7·9–10·1)
Low income	503 (434–588)	14·0% (12·1–16·3)	48·1 (33·7–65·3)	10·9% (9·3–12·7)
Lower-middle income	1930 (1600–2300)	14·0% (12·1–16·3)	197 (143–263)	9·8% (8·5–11·5)
Upper-middle income	3070 (2520–3760)	13·9% (12·1–16·3)	308 (222–417)	7·8% (6·9–9·0)
High income	1470 (1250–1750)	12·9% (11·3–15·0)	208 (148–279)	9·6% (8·7–10·6)
Amputations				
Global	675 (491–929)	1·3% (1·0–1·8)	572 (408–793)	6·7% (5·8–7·8)
Low income	52·2 (37·2–73·9)	1·5% (1·1–2·1)	40·5 (29·5–54·5)	9·1% (8·2–10·2)
Lower-middle income	200 (145–279)	1·4% (1·1–2·0)	174 (126–234)	8·7% (7·8–9·6)
Upper-middle income	321 (234–444)	1·5% (1·1–2·0)	275 (191–385)	7·0% (6·0–8·4)
High income	101 (69·1–145)	0·9% (0·6–1·3)	81·8 (52·8–124)	3·8% (3·0–4·8)
Burns				
Global	501 (302–751)	1·0% (0·6–1·5)	361 (268–466)	4·2% (3·9–4·6)
Low income	44·0 (25·6–66·5)	1·2% (0·7–1·9)	42·4 (31·1–54·0)	9·6% (8·5–10·9)
Lower-middle income	156 (93·0–231)	1·1% (0·7–1·7)	144 (105–182)	7·2% (6·5–8·0)
Upper-middle income	229 (141–336)	1·0% (0·6–1·5)	143 (106–193)	3·6% (3·3–4·1)
High income	71·2 (42·5–110)	0·6% (0·4–1·0)	31·8 (20·8–48·9)	1·5% (1·2–1·8)
Minor injuries				
Global	18 000 (15 500–20 700)	35·3% (31·2–39·1)	191 (91·0–366)	2·2% (1·2–3·8)
Low income	1280 (1100–1440)	35·4% (31·1–39·2)	6·63 (3·17–12·7)	1·5% (0·8–2·6)
Lower-middle income	4740 (4090–5470)	34·3% (30·1–38·1)	31·9 (15·0–60·7)	1·6% (0·8–2·7)
Upper-middle income	7380 (6280–8610)	33·5% (29·2–37·3)	71·9 (34·3–137)	1·8% (1·0–3·1)
High income	4560 (3970–5200)	40·1% (35·7–44·0)	80·1 (37·8–155)	3·7% (2·0–6·3)

Data in parentheses are 95% uncertainty intervals. Count data are presented to three significant figures. In the Global Burden of Diseases, Injuries, and Risk Factors Study framework, head injury corresponds to the traumatic brain injury category, which is disaggregated only into minor traumatic brain injury and moderate or severe traumatic brain injury. Non-traumatic brain injury head trauma is captured elsewhere: skull and facial fractures under the fractures categories, and superficial head lesions under open wounds and other injuries. YLDs=years of life lived with disability.

Table 2: **Nature-of-injury incident cases and YLDs attributable to road injuries, and the share of each nature-of-injury category in total road injury incidence and YLDs, globally and across World Bank income groups, 2023**

cost-effectiveness analyses have identified scalable, context-specific intervention packages for LMICs, ranging from speed management, random breath testing, and helmet enforcement in southeast Asia to a broader package including seatbelt enforcement in eastern sub-Saharan Africa.[34,35] Strengthening health-system capacity is equally crucial. Evidence suggests that more than 200 000 lives could be saved each year through enhanced trauma care coverage in LMICs.[30] Although policy priorities might differ by country, cross-setting analysis confirms that comprehensive strategies yield the greatest gains.[33] India's Zero Fatality Corridor initiative exemplifies the potential of multisectoral action; combining engineering, enforcement, and emergency response, it achieved a 43% reduction in mortality within 4 years and has since expanded to more than 100 national highways across India,[36] illustrating that meaningful progress is possible with targeted investment and multisectoral coordination.

For high-income countries, decreases in road injury burden are not assured; the USA had some of the largest increases in road injury mortality rates between 2010 and 2023. The increase, driven predominantly by pedestrian road injuries, has been associated with the uptake of larger vehicles and changes in road design.[37] In other high-income countries, changing transport patterns are redefining the distribution of road injury burden. Cyclist injuries have surpassed pedestrian injuries to become the second leading cause of road injury DALYs in several Nordic countries, whereas in high-income Asia Pacific countries such as Japan and Singapore, they now constitute the primary cause of road injury cases. A growing ageing population also necessitates an essential reassessment of infrastructure and technology, demanding inclusive and adaptable engineering that accommodates age-related needs.[38,39] Road safety strategies must evolve alongside shifting road user profiles and transport behaviour to sustain these hard-earned gains and further advance road injury reduction.

Beyond the human toll, the economic cost of road injuries is enormous, projected at $1·8 trillion between

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2015 and 2030.[40] Yet, road safety remains underfunded. Within health-related official development assistance, less than 1% was directed to trauma care.[41] This chronic underfunding is further compounded by a broader contraction in official development assistance in recent years.[42] The World Bank estimated that a minimum of $200 billion of additional investment is required to meet the global road safety target of halving the number of global road injury deaths and injuries by 2030.[11] Recasting road safety as a core sustainability concern and positioning it squarely within the environmental, social, and governance agenda is essential for mobilising the scale of resources needed to achieve these goals.[43]

This study has several limitations. First, road injury data are not routinely captured across all countries or disaggregated by age-sex groups, and empirical data on non-fatal injuries and long-term disability are often sparse. In such cases, we relied on covariates and spatiotemporal models to interpolate missing information; uncertainty intervals are consequently wide for some locations and road user types and should be interpreted with caution, and some residual uncertainty remains, particularly in data-sparse settings. These data gaps highlight the importance of strengthening road injury surveillance systems. Second, GBD disability weights capture only the direct health consequences of injury and do not capture broader social, economic, and psychological effects, which remain important for policy considerations and rehabilitation planning. Third, GBD assigns a single nature-of-injury category per case, selecting the category associated with the greatest health loss; when multiple concurrent injuries occur, total morbidity burden might be underestimated, although this applies mainly to cases with substantial multimorbidity profiles. Fourth, subnational variations are not captured in this analysis; future work could explore subnational GBD estimates. Fifth, our analysis is descriptive and does not evaluate the causal effects of specific policies or interventions. Additionally, the impact of the COVID-19 pandemic must be considered when interpreting findings, as disrupted mobility patterns and constrained access to emergency care between 2020 and 2022 might have influenced observed trends independently of road safety policy.

As we approach the midpoint of the Second Decade of Action for Road Safety, global progress in reducing road injury burden has been marked by heterogeneity. Disparities in road injury outcomes expose deep inequities in political governance, technological capacity, and access to health care. Existing investments fall short of what is needed for meaningful progress. While cost-effective measures exist, realising them demands structural reform and long-term commitment.

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See Online for appendix 2

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Data sharing

Input data used in these analyses are available on the Global Health Data Exchange GBD 2023 website at https://ghdx.healthdata.org/gbd-2023. All results from this study are publicly accessible. To download estimates produced in these analyses, please visit the GBD Results tool.[44] All GBD estimates, including the different measures, metrics, causes, locations, age groups, sex, and years, are publicly available via the GBD Results tool for registered users.[44]

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