Global trends in adolescents’ road traffic injury mortality, 1990–2019

Uzma Rahim Khan,1,2 Junaid A Razzak,3 Martin Gerdin Wärnberg1

ABSTRACT

Objective The aim of this study was to determine the trends of road traffic injury (RTI) mortality among adolescents aged 10–14 years and 15–19 years across different country income levels with respect to the type of road user from 1990 to 2019.

Methods We conducted an ecological study. Adolescents’ mortality rates from RTIs at the level of high-income countries (HICs), upper-income to middle-income countries (UMICs), lower-income to middle-income countries and low-income countries were extracted from the Global Burden of Disease study. Time series were plotted to visualise the trends in mortality rates over the years. We also conducted Poisson regression using road traffic mortality rates as the dependent variable and year as the independent variable to model the trend of the change in the annual mean mortality rate, with incidence rate ratios (IRRs) and 95% CIs.

Results There were downward mortality trends in all types of road users and income levels among adolescents from 1990 to 2019. HICs had more pronounced reductions in mortality rates than countries of any other income level. For example, the reduction in pedestrians in HICs was IRR 0.94 (95% CI 0.90 to 0.98), while that in UMICs was IRR 0.97 (95% CI 0.95 to 0.99) in adolescents aged 10–14 years.

Conclusions There are downward trends in RTI mortality in adolescents from 1990 to 2019 globally at all income levels for all types of road users. The decrease in mortality rates is small but a promising finding. However, prevention efforts should be continued as the burden is still high.

INTRODUCTION

The global mortality rate due to road traffic injuries (RTIs) has plateaued since 2007 and has shown a slight reduction since 2013.1–6 High-income countries (HICs) have experienced a larger reduction than lower-income to middle-income countries (LMICs).7 Motor vehicle users predominate among fatalities in HICs, while pedestrians, motorcyclists and cyclists account for most deaths in LMICs.3

RTIs are the leading cause of death worldwide among children and young adults aged 5–29 years, third among adolescents aged 10–14 years and first among adolescents aged 15–19 years.8–10 The current literature on RTI mortality in adolescents is mostly based on HICs and specific geographical regions.11–13 This literature largely combines data on both children and adolescents and shows that pedestrians and car occupants account for the majority of RTI mortalities.14

The burden and causes of RTI mortality are, however, likely to be different in children than in adolescents. Children may unintentionally be involved in risks on the road, whereas adolescents tend to indulge in risk-taking behaviours.12 The mortality rates due to RTIs are reported to decline in both the 10–14 years and 15–19 years age groups, with a variation in the magnitude of the reduction in deaths across geographical locations.10,15

There are several gaps in the current literature. First, the variations in road user-specific mortality rates among adolescents are not known according to the income level of countries. Second, trends in adolescents’ mortality among different types of road users over the years are unknown; therefore, it is critical to know the context of countries’ income level. The trend of mortality rate by road user type will help contextualise problems and design local evidence-based interventions.

The aim of this study was to determine the trends of RTI mortality among adolescents aged 10–14 years and 15–19 years across different country income levels with respect to the type of road users from 1990 to 2019.
**METHODS**

**Study design**
We conducted an ecological study.

**Setting**
We extracted global and income-level country mortality rates of RTIs from the Global Burden of Disease (GBD) study by the Institute of Health Metrics and Evaluation from 1990 to 2019, categorising the income levels as high-income countries (HICs), upper-income to middle-income countries (UMICs), lower-income to middle-income countries (LMICs) and low-income countries (LICs). It is important to highlight that the income level of countries was not static over the years, and there has been an increase in the number of countries labelled HICs and subsequently a decrease in LICs since 1993.

**Variables**
We used yearly estimates of mortality rates of RTIs per 100 000 people in adolescents aged 10–14 years vs 15–19 years for analysis. We had road user types as all road users, pedestrians, cyclists, motorcyclists and motor vehicle users. All road injuries included ‘other road users’, in addition to the four abovementioned categories. ‘Other road users’ are road users that cannot be classified as any of the aforementioned four types, such as riders of animals or occupants of animal-drawn vehicles injured in road crashes.

**Data sources/measurement**
The GBD study uses multiple data sources, including vital registration, verbal autopsy, mortality surveillance, censuses, surveys, hospitals, police records and mortuaries, to calculate mortality estimates. The GBD study assesses data quality, including completeness, missing data rates and accuracy, and then applies sophisticated modelling strategies to capture patterns in the data and to reduce estimation error. The modelling of these data has been defined in greater detail in previous publications.

**Analyses and statistical methods**
All statistical analyses were conducted using R. Descriptive statistics are reported as mean rates with SD. Time series were plotted with the y-axis on the non-linear log scale to visualise the trends in mortality rates over the years. We also conducted Poisson regression with a log link to quantify the percentage change in the rate per year. The road traffic mortality rate was the dependent variable, and year was the independent variable. Income level, road user type and age were used to stratify the model. We report the model coefficients and incidence rate ratios (IRRs) with 95% CIs.

**RESULTS**
There were 1500 data points in this analysis from five country income groups, five road user types and a span of 30 years for two age groups.

From 1990 to 2019, the mean mortality rate for all road users was higher among adolescents ages 15–19 years than among those aged 10–14 years at all income levels except that the mean rates of cyclist injuries were comparable in both age groups. In HICs, the highest mean mortality rate for motor vehicle injuries was 11.7 (SD 3.9) vs 1.7 (SD 0.6) in the age groups of 15–19 years and 10–14 years, respectively. The difference in motorcycle injuries was also large between the two age groups; the mean mortality rates were 4.1 (SD 0.4) and 4.5 (SD 0.3) in adolescents aged 15–19 years vs 0.6 (SD 0.1) and 0.7 (SD 0.1) in those aged 10–14 years in LMICs and LICs, respectively.

For all income levels, the mean mortality rates were highest for motor vehicle injuries in adolescents aged 5–19 years except in LICs, where the mean mortality rate for pedestrian injuries was the highest. In adolescents aged 10–14 years, the highest mean mortality rates were of pedestrian injuries in all income levels, with the exception of motor vehicle injuries in HICs (table 1).

The time-series plots in figure 1 show slight downward trends in the mortality rate of all types of road users from 1990 to 2019 for adolescents aged 15–19 years and 10–14 years. The downward trend is more pronounced in HICs for all types of road users compared with other income levels.

The mortality rates for 15- to 19-year-olds were higher than those for 10- to 14-year-olds for all types of road users and country income levels. Within facet differences in mortality rate trends between the two age groups were larger for motor vehicle users and motorcyclists than for pedestrians and cyclists in all country income groups and even more so in HICs.

At the same time, the trends in the two age groups were parallel at all income levels for all road users, showing constant differences in the rates in both age groups. The trends were not parallel for cyclists in HICs. The trends in motorcycle and motor vehicle injuries in UMICs, LMICs and LICs were close to static, particularly in the age group of 15–19 years. The trends in cyclists were irregular in LMICs and LICs in both age groups.

The IRRs for all road user groups in all locations for both age groups showed annual decreases in mortality rates with only

<table>
<thead>
<tr>
<th>Income levels</th>
<th>Age (years)</th>
<th>All road users</th>
<th>Pedestrians</th>
<th>Cyclists</th>
<th>Motorcyclists</th>
<th>Motor vehicle road users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>15–19</td>
<td>15.3 (2.3)</td>
<td>4.5 (0.9)</td>
<td>0.7 (0.1)</td>
<td>3.9 (0.4)</td>
<td>6.2 (1.0)</td>
</tr>
<tr>
<td></td>
<td>10–14</td>
<td>5.8 (1.1)</td>
<td>2.8 (0.7)</td>
<td>0.4 (0.1)</td>
<td>0.6 (0.1)</td>
<td>1.9 (0.2)</td>
</tr>
<tr>
<td>High-income countries</td>
<td>15–19</td>
<td>17.3 (6.0)</td>
<td>2.2 (0.8)</td>
<td>0.5 (0.2)</td>
<td>2.8 (1.2)</td>
<td>11.7 (3.9)</td>
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<tr>
<td></td>
<td>10–14</td>
<td>3.6 (1.5)</td>
<td>1.2 (0.6)</td>
<td>0.5 (0.2)</td>
<td>0.2 (0.1)</td>
<td>1.7 (0.6)</td>
</tr>
<tr>
<td>Upper-income to middle-income countries</td>
<td>15–19</td>
<td>17.4 (1.7)</td>
<td>6.3 (0.9)</td>
<td>0.6 (0.1)</td>
<td>2.0 (0.2)</td>
<td>8.5 (0.6)</td>
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<tr>
<td></td>
<td>10–14</td>
<td>7.7 (0.8)</td>
<td>3.6 (0.5)</td>
<td>0.3 (0.1)</td>
<td>0.6 (0.1)</td>
<td>3.2 (0.2)</td>
</tr>
<tr>
<td>Lower-income to middle-income countries</td>
<td>15–19</td>
<td>13.1 (1.6)</td>
<td>3.4 (0.6)</td>
<td>0.6 (0.1)</td>
<td>4.1 (0.4)</td>
<td>4.8 (0.6)</td>
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<tr>
<td></td>
<td>10–14</td>
<td>5.2 (0.8)</td>
<td>2.5 (0.4)</td>
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<td>1.7 (0.2)</td>
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</tr>
</tbody>
</table>

have been known since at least the late 1960s to 1970s.\(^1\)\(^8\) HICs:753–757. doi:10.1136/archdischild-2020-319184.

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...present in adolescents aged 10–14 years. LICs have a high burden of pedestrian injuries, and the protection of potential victims has been enhanced through vehicle safety and protected lanes.\(^2\)\(^4\)\(^5\) The aforementioned factors, consisting mainly of measures targeting road users of all ages, have also benefited adolescents. Nonetheless, many measures, such as separate cycle lanes, zebra crossings, priority traffic rules for vulnerable road users and traffic calming around schools and residential areas, are still uncommon in LICs. For example, only 6% of LICs have applied helmet best practices, including for child/adolescent passengers on motorcycles.\(^4\) Moreover, the decrease in mortality rate should also be cautiously interpreted in countries where data coverage is low.

While the decrease in road traffic mortality rates is a success, much more is required to achieve global targets. The Stockholm declaration in 2020 calls for a new global target of reducing road traffic injuries and deaths by 50% by 2030.\(^2\)\(^6\) Even successful road safety interventions are still not implemented in the majority of countries. Political influence is required for the uptake of safety strategies for road safety. The Stockholm declaration calls for strengthening all five pillars of the Global Plan for the Decade of Action: better road safety management; safer roads, vehicles and people; and enhanced postcrash care.\(^2\)\(^7\)

The burden of RTIs varies by road users across different income levels. The burden of mortality due to motor vehicles is high in HICs in both age groups. It is also high in UMICs and LMICs for adolescents ages 15–19 years. The majority of the world population and vehicles are in middle-income countries (MICs) and HICs. Approximately 76% and 15% of the world’s population lives in MICs and HICs, respectively, and the corresponding portions of registered vehicles are 59% and 40%, respectively.\(^2\)\(^3\) UMICs and LMICs have a high burden of pedestrians in adolescents aged 10–14 years. LICs have a high burden of pedestrian

by implementing a combination of multisectoral strategies.\(^5\)\(^1\)\(^9\) In addition, there has been a striking increase in mortality due to RTIs in LMICs. Overall, the agenda of injury prevention and control has gained momentum in the last few decades and has also been observed for other types of injuries, including falls, drowning, fire and poisoning.\(^2\)\(^8\) Some recent studies have also indicated a decrease in RTI mortality in specific age groups, such as those under 5 years, 0–14 years and 0–19 years.\(^1\)\(^9\)\(^1\)\(^8\)\(^1\)\(^6\)\(^2\)\(^1\)\(^8\)\(^1\)\(^9\)\(^1\)\(^8\) These studies reported decreasing rates at the global level or at the level of geographical regions or compared the ‘LMICs’ with the ‘HICs’, and the years being compared also varied.

The reduction in adolescent RTI mortality rates in LMICs may be due to a series of changes to the benefit of many road users, which are already present in HICs. Advances in road infrastructure, the implementation and enforcement of safety legislation, and progress in emergency trauma care may have contributed. Additionally, the type and duration of traffic exposure of adolescents have been reduced through decreased walking and independent commuting,\(^2\)\(^2\)\(^2\)\(^3\) and the protection of potential victims has been enhanced through vehicle safety and protected lanes.\(^2\)\(^4\)\(^5\) The aforementioned factors, consisting mainly of measures targeting road users of all ages, have also benefited adolescents. Nonetheless, many measures, such as separate cycle lanes, zebra crossings, priority traffic rules for vulnerable road users and traffic calming around schools and residential areas, are still uncommon in LICs. For example, only 6% of LICs have applied helmet best practices, including for child/adolescent passengers on motorcycles.\(^4\) Moreover, the decrease in mortality rate should also be cautiously interpreted in countries where data coverage is low.

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### DISCUSSION

To the best of our knowledge, this study is the first on RTI mortality with a focus on adolescents aged 10–14 years and 15–19 years by type of road user and country income level. Our study shows downward trends in RTI mortality in adolescents from 1990 to 2019 for all road users globally and for all country income levels. HICs have more prominent downward trends from 1990 to 2019 for all road users globally and for all country income levels. HICs have more prominent downward trends from 1990 to 2019 for all road users globally and for all country income levels. HICs have more prominent downward trends from 1990 to 2019 for all road users globally and for all country income levels.

A global reduction in road traffic mortality in all age groups was observed between 2007 and 2010, but with disparities across countries.\(^2\) The downward trends in RTI mortality rates in HICs have been known since at least the late 1960s to 1970s.\(^1\)\(^8\) HICs have achieved the greatest gains in RTI prevention, most likely

### Table 2: Poisson regression of road traffic mortality rates and years (1990–2019) by type of road user and country income level in adolescents 15–19 years of age

<table>
<thead>
<tr>
<th>Income levels</th>
<th>All road injuries IRR (95% CIs)</th>
<th>Pedestrian injuries IRR (95% CIs)</th>
<th>Cyclist injuries IRR (95% CIs)</th>
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<th>Motor vehicle injuries IRR (95% CIs)</th>
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</thead>
<tbody>
<tr>
<td>Global</td>
<td>0.98 (0.97 to 0.99)</td>
<td>0.98 (0.96 to 1.00)</td>
<td>0.99 (0.94 to 1.04)</td>
<td>0.99 (0.97 to 1.01)</td>
<td>0.98 (0.97 to 1.00)</td>
</tr>
<tr>
<td>High-income countries</td>
<td>0.96 (0.95 to 0.97)</td>
<td>0.96 (0.93 to 0.99)</td>
<td>0.96 (0.90 to 1.02)</td>
<td>0.96 (0.93 to 0.98)</td>
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</tr>
<tr>
<td>Upper-income to middle-income</td>
<td>0.99 (0.98 to 1.00)</td>
<td>0.98 (0.96 to 0.99)</td>
<td>0.99 (0.94 to 1.04)</td>
<td>1.00 (0.98 to 1.02)</td>
<td>0.99 (0.97 to 1.01)</td>
</tr>
<tr>
<td>Lower-income to middle-income</td>
<td>0.99 (0.98 to 1.00)</td>
<td>0.98 (0.96 to 1.00)</td>
<td>0.99 (0.94 to 1.04)</td>
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IRR, incidence rate ratio.
Global child health under-type. The clear majority in this category were four-our comparison and conceal the burden by individual vehicle
nunities to address road traffic injuries in these groups are lost. Policies
the larger category of children, the unique challenges and opportu-
ment. Their commuting expands from being pedestrians, cyclists
and passengers to drivers of motorcycles and other motor vehicles, leading to a larger difference between rates of adolescents aged 15–19
years vs 10–14 years within motorists and motor vehicle users at
all income levels. Undoubtedly, risk-taking behaviour increases the
chances of road crashes, but not just that. A better understanding
of the unique relationship between adolescents and the transport
system is determined by the confluence of multiple factors dictated
by the practical needs of mobility and the physical and mental devel-
opment of adolescents. A societal expectation for increased mobility,
a lack of access to safer transportation options, and a perception that
motor vehicles are a source of recreation, independence and prestige
determine this complex relationship. Policies that influence societal
norms and expectations in the local road safety context need further
development. Exploring the influence of mainstream and social
media, safe role models, and changing normative behaviour require
specific strategies for the adolescent age group.

The study highlights some critical areas for adolescents’ road safety
that have implications. When the two age groups are combined within
the larger category of children, the unique challenges and opportu-
nities to address road traffic injuries in these groups are lost. Policies
such as graduated licensing, restriction in night-time driving and
mobility management (intervention that promotes walking, cycling and
public transport instead of private cars) might be effective and
need broad implementation after testing for effectiveness in specific
contexts. Additionally, the emphasis on teen drivers to obtain valid
licences may help in their understanding of rules and regulations
related to driving. Safe commuting of adolescents as pedestrians and
cyclists is a daunting task and needs proper road infrastructure plan-
ing and resources, but has the potential to save many preventable
deaths and could encourage healthy living for many generations to
come.

Limitations
A first limitation is the merged data of motor vehicles, as they
included both three-wheelers and four-wheelers, which hinder
our comparison and conceal the burden by individual vehicle
type. The clear majority in this category were four-wheelers, as
the overall use and mortality rate of three-wheelers are very low.
Second, the coverage of mortality data for road injuries could be
under-reported for LMICs. Nevertheless, GBD was modelled to
predict the estimates by capturing all sources of uncertainty level,
and the reporting might have improved over the years. Third,
the threshold for World Bank classification of the world’s econ-
omies has been annually adjusted for inflation, so the number
of countries in each category continues to change each year. A
high number of countries would have been at a low-income level
in the 1990s compared with recent years. However, this annual
reclassification is applicable for all four income levels and is an
inherent feature of this classification.

CONCLUSIONS
There has been a downward trend in adolescents’ mortality due
to RTIs over the period 1990–2019 for all country income levels
for pedestrians, cyclists, motorcyclists and motor vehicle users.
The downward trend in mortality rates is a promising finding in
all income levels, but this finding should not relax prevention
efforts, particularly in MICs and LICs, because the burden is still
at an alarming level. Furthermore, the trends and risks for RTI
mortality should always be studied with respect to specific age
groups and road users; for example, in the case of adolescents,
those who are adolescents aged 10–14 years vs 15–19 years have
unique challenges.

Table 3 Poisson regression of road traffic mortality rates and years (1990–2019) by type of road user and country income level in adolescents
10–14 years of age

<table>
<thead>
<tr>
<th>Income levels</th>
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<tr>
<td>High-income countries</td>
<td>0.95 (0.93 to 0.98)</td>
<td>0.94 (0.90 to 0.98)</td>
<td>0.95 (0.88 to 1.01)</td>
<td>0.95 (0.86 to 1.04)</td>
<td>0.96 (0.93 to 0.99)</td>
</tr>
<tr>
<td>Upper-income to middle-income countries</td>
<td>0.98 (0.96 to 0.99)</td>
<td>0.97 (0.95 to 0.99)</td>
<td>0.99 (0.93 to 1.04)</td>
<td>0.99 (0.95 to 1.04)</td>
<td>0.98 (0.95 to 1.02)</td>
</tr>
<tr>
<td>Lower-income to middle-income countries</td>
<td>0.98 (0.97 to 1.00)</td>
<td>0.98 (0.95 to 1.01)</td>
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IRR, incidence rate ratio.

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Contributors URK conceptualised and drafted the study. URK, JAR and MGW developed the research objective. MGW supervised all analysis. MGW and JR critically reviewed all the drafts.

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Competing interests None declared.

Ethics approval Ethical clearance for this study was not required, as it uses secondary data from the Global Burden of Disease, which are publicly available.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data are available upon reasonable request. The study data are taken from Global Burden of Diseases data and have also been uploaded in GitHub (https://github.com/martingedlin/Paper-1).

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