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# Trends in transport injuries burden and risk factors among children under 14 years old in China: 1990–2019

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## Abstract

**Background** Transport injuries (TI) remains one of leading causes of death in children in China. This study aimed to analyze the temporal trend of disease burden and associated risk factors of TI among children aged 0–14 years in China, utilizing data from 1990 to 2019.

**Methods** We retrieved data of disease burden and risk factors of TI among children aged 0–14 year in China from 1990 to 2019 from the Global Burden of Disease (GBD) dataset. We estimated incidence rate, death rate, and disability adjusted life years (DALYs) rate with a 95% uncertainty interval (95% UI), stratified by age, sex, and all type-road users. Trends in disease burden with annual percentage changes (APC) and average annual percent change (AAPC) were performed by Joinpoint regression model.

**Results** The incidence rate (AAPC = 1.18%, $P < 0.001$) of TI among children aged 0–14 years showed an increasing trend, whereas mortality rate (AAPC = -3.87%, $P < 0.001$) and DALYs rate (AAPC = -3.83%, $P < 0.001$) decreased annually. Notably, boys experienced a higher increase in incidence (1.30%) compared to girls (1.06%), but a faster decrease in mortality and DALYs rate (-3.90% vs. -3.82%, -3.88% vs. -3.79%, respectively) ($P_{all} < 0.001$). Declines in death rates and DALYs rates were observed across all age groups ($P_{all} < 0.001$), while remained the highest among children aged 0–4 in 2019. Among different road-type users, cyclist road injuries were identified as the primary cause of TI (182.3 cases per 100,000) while pedestrians were the group with the highest mortality (2.9 cases per 100,000) and DALYs rate (243 cases per 100,000) in 2019. Besides, alcohol use was a significant risk factors for TI, while low temperature appeared to be a protective factor.

**Conclusion** Future efforts must prioritize raising awareness among children and their guardians to mitigate the disease burden of TI in children. It's critical to enhance preventive interventions for boys, children aged 0–4 and vulnerable road users such as pedestrians and cyclists in future.

**Keywords** Road injuries, Disease burden, Children, Joinpoint regression

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## Introduction

Traffic accidents pose an intractable global challenge, significantly affecting sustainable transportation and public health [1]. Children, in particular, are among the most vulnerable to these incidents. Over the last three decades, the proportion of Transport injuries (TI) death to overall injury-related deaths has generally increased, highlighting the growing public health concern of childhood TI. It's estimated that over 180,000 children die in TI worldwide annually, causing a substantial economic strain on both nations and households [2, 3]. Despite ongoing enhancements in global traffic safety regulations, TI continues to be a critical public health issue, with the World Health Organization (WHO) predicting it could become the 7th leading cause of death among children (0–14 years) by 2030 [4]. This underscores the need for immediate and concerted global action.

Rapid urbanization and economic growth in China, coupled with high population density and intricate traffic dynamics, have resulted in uneven safety standards and practices, significantly impacting children's health through TI. With the implementation of drink-driving legislation and improvements in road traffic construction infrastructure have lightened the disease burden of road traffic injuries among children in China. A meta-analysis revealed that from 2006 to 2016, the combined incidence rate for children aged 0–14 was 2.68% (95% CI: 1.96%-3.66%) [5], which is an 8% decrease compared to the previous decade [6]. Despite this progress, the incidence in China remains significantly higher than in developed countries, such as the United Kingdom, where it stands at a mere 0.13% [7]. In addition, the death rate and disability-adjusted life years (DALYs) rate among children involved in road traffic accidents in China remains alarmingly high. An estimated 18,500 children aged 0–14 die annually from road traffic injuries [8], with DALYs rates of 773.86 and 402.87 per 100,000 for children aged 0–4 and 5–14, respectively [9], imposing a significant burden on public health. To effectively mitigate the disease burden of TI among children in China and provide a basis for the formulation of road traffic safety regulations, it is imperative to comprehensively understand the epidemiological patterns of TI and analyze the associated risk factors.

Currently, research on the disease burden of TI have predominantly targeted the general population, overlooking the specific burden among children (0–14 years old). Moreover, variations in income levels, cultural contexts, and road user types across different nations can lead to diverse trends in road traffic injury-related disease burdens [10].Therefore, we assessed trend in disease burden of TI stratified by age, sex, and all type-road users and try to find out associated risk factors among children aged 0–14 years in China with results from the Global burden of diseases (GBD 2019) dataset, aiming to identify pediatric TI preventive priority.

## Materials and Methods

### Data collection

Estimates of TI under the category of injuries among children (≤14 years) in China from 1990 to 2019 were retrieved from GBD 2019 using the Global Health Data Exchange (GHDx) query tool (https://ghdx.healthdata.org/gbd-2019). As a secondary data analysis study, we followed the GBD 2019 Data and Tools Overview as a guideline to identify the indicators and measurement criteria used in the study, as detailed in Supplementary Table 1.

### Statistical analysis

Joinpoint regression analysis was employed to evaluate the temporal trends in the burden of TI over the study period. This method segments the timeline into distinct intervals, with each featuring a separate regression line, thereby allowing for a nuanced evaluation of trend changes over time [11]. This approach surpasses traditional regression models by capturing localized fluctuations in trends [12, 13], a capability particularly valuable in epidemiological research for understanding disease pattern shifts that can guide policy and intervention strategies [14, 15]. We employed the software provided by the United States National Cancer Institute (version 4.9.1.0, 2022) for the analysis, focusing on key indicators including annual percentage change (APC), average annual percentage change (AAPC) and 95% confidence intervals (95% *CI*). A trend was considered significant if the APC differed from zero, with APC < 0 indicating a decrease and APC > 0 indicating an increase. Consistency in trend was inferred when APC equaled to AAPC, signifying the absence of inflection points. The threshold for statistical significance was set at $P < 0.05$.

Stratified analyses were conducted to further assess the burden of TI by controlling for confounders including age (0–4, 5–9, or 10–14 years) and gender, and measuring outcomes in terms of incidence, deaths, and DALYs. This approach allowed us to identify trends within subgroups and to determine any significant disparities in trends across these groups. The same set of indicators (APC, AAPC, 95% *CI*) was used to evaluate trends across different categories (e.g., by age and gender). Differences in APCs were used to identify meaningful changes in trends, with statistical significance determined at $P < 0.05$.

Descriptive statistics were used to summarize the data on incidence rates and their 95% *CI* of TI, which was determined by the nature of the injury (e.g., fracture or head injury). Additionally, associated risk factors for TI were identified and categorized according to their impact on the likelihood of injury.

## Results

### Changes in the proportion of TI-related mortality in children from 1990 to 2019

As depicted in Fig. 1, injury-related deaths as a percentage of total causes of death has increased, climbing from 16% in 1990 to 24% in 2019. There has been a noticeable increase in the proportion of TI-related death rate to total injuries among children, as evidenced by an increase in the percentage of TI-related death from 19% of all injury-related deaths in 1990 to 25% in 2019.

### Joinpoint regression analysis of TI disease burden in children from 1990 to 2019

Figure 2 illustrated the joinpoint analysis for the incidence rate, death rate, and DALYs rate of TI between 1990–2019. Figure 2A presented that the incidence of the TI among children under 14 generally exhibited an upward trend, with an average annual increase of 1.18% (t = 10.60, $P < 0.001$). During this period, the overall incidence rose from 322 to 463 per 100,000, with 4 significant junction points observed ($P < 0.05$). Initially, there was a downward trend from 1990 to1995, which was followed by an upward shift, reaching a peak from 2003 to 2010, with an average annual increase of 3.26% (t = 11.98, $P < 0.001$).

Conversely, both the overall death rate and DALYs rate displayed a downward trend, with an average annual decrease of 3.87% (t = -16.2, $P < 0.001$) and 3.83% (t = -16.6, $P < 0.001$), respectively (Fig. 2B, Fig. 2C). A temporary upward trend was observed from 2007 to 2010, but with no statistical significance (APC = 2.86, $P = 0.199$ and APC = 2.49, $P = 0.247$, respectively). However, the remaining three linkage points showed a progressively increasing average annual decline, reaching up to 6.7% for mortality and 6.45% for DALYs ($P_{both} < 0.001$).

### Disease burden stratified by age, gender and road-type user groups in 1990 and 2019

The overall incidence of TI increased from 322 in 1990 to 463 cases per 100,000 children in 2019 (Supplementary Table 2). The incidence of TI in different age groups increased with advancing age. For mortality, we found that the total death rate declined from 14 to 5 per 100,000 children with a rate of 70% decline. It also showed that overall DALYs rate of TI is more pronounced in younger children. Despite DALYs rate has decreased considerably during study period (by 80%), 0–4 age group remained the highest (446 cases per 100,000). When stratified by gender, we found that boys exhibited a higher incidence, mortality and DALYs rate of TI than girls (Supplementary Table 2).

Table 1 showed Joinpoint regression analysis in the incidence, mortality and DALYs of TI between different age and gender groups in China from 1990 to 2019. When stratified by age, we found the trends of disease burden were generally aligned with the overall trends across all age groups, except for a notable exception in the incidence among children aged 0–4 years old (AAPC = -4.69%, $P < 0.001$). The mortality rate of children attributable to TI presented a declining trend in all age groups, and the highest AAPC exhibited in children aged 0–4 years old (AAPC = -4.84%, $P < 0.001$). DALYs rate of TI among children in 0–4, 5–10 and 10–14 years also decreased, with annual rates of reduction at 4.81%, 3.21% and 1.97%, respectively (Table 1). Although the DALYs

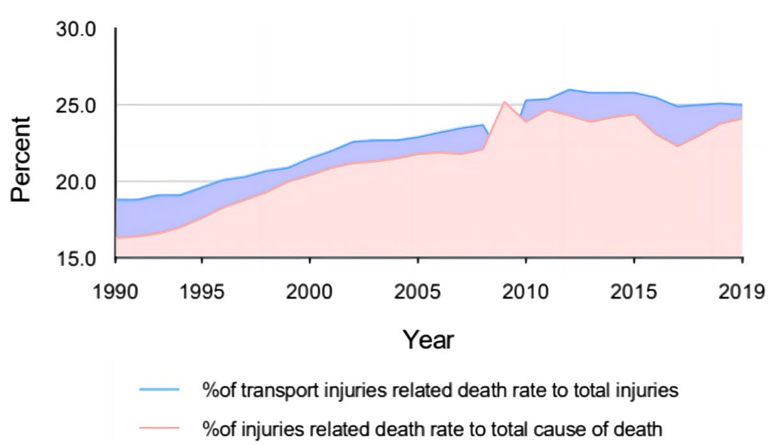


**Fig. 1** Variations in the proportion of TI-related deaths to total causes of death among children aged 0–14 from 1990 to 2019. The blue line represents the changes in the proportion of deaths attributable to TI compared to total fatal injuries, while the red line illustrates changes in the composition of fatal injuries as a proportion of all causes of death

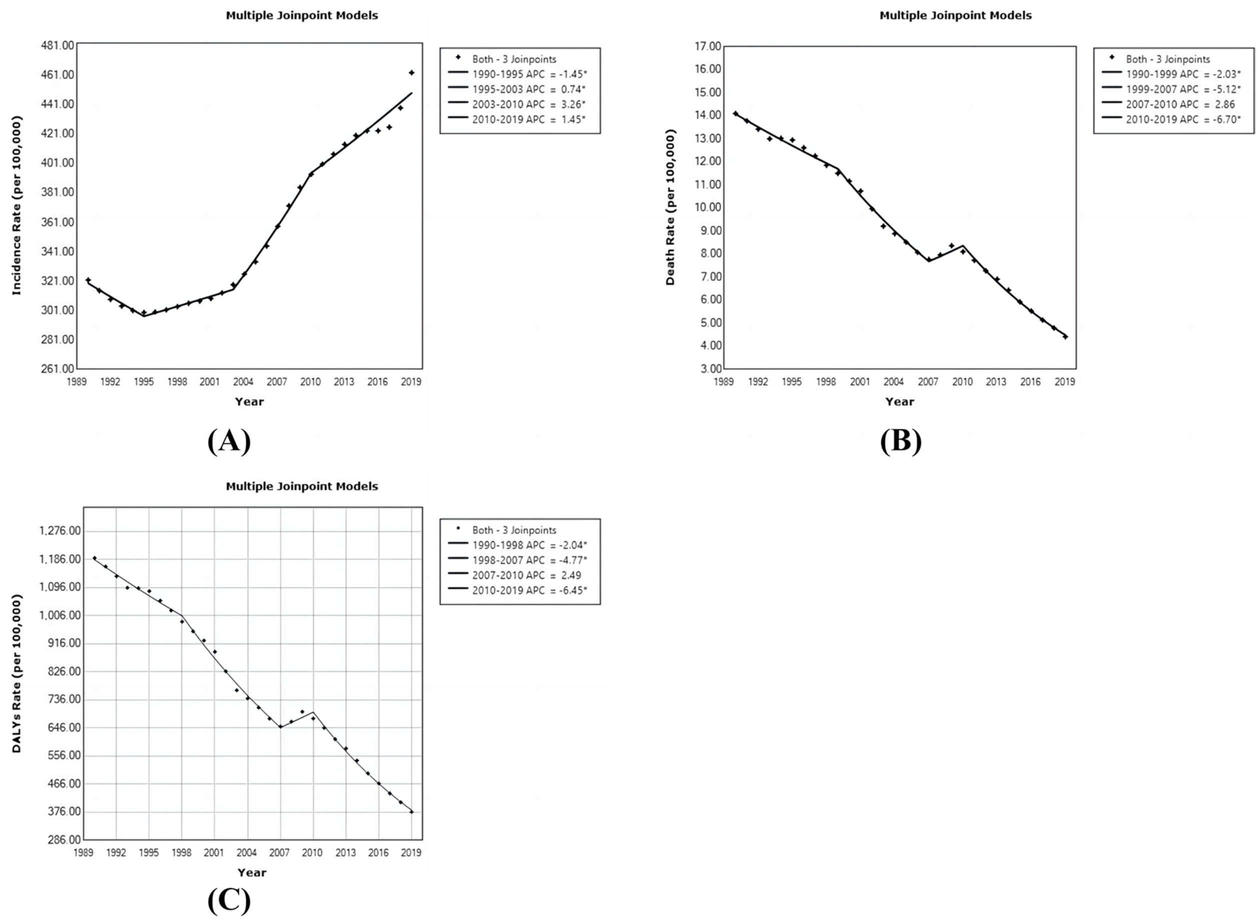


**Fig. 2** Joinpoint regression analysis of trends in incidence rate (**A**), death rate (**B**) and DALYs rate (**C**) among children aged 0–14 in China from 1990 to 2019. denotes data points for disease burden indicators (incidence rate, death rate, DALYs rate) for each study period, with the Average Percent Change (APC) calculated for each inflection point. * indicates statistically significant differences

rate has dropped considerably during these three decades, 0–4 age group remained the highest (446 cases per 100,000) (Supplementary Table 2).

Gender stratification (Table 1) revealed that the average annual increase in TI incidence was higher in girls (1.30%) compared to boys (1.06%), especially among the 5–9 age group (1.47% vs. 1.11%). What's more, our research indicated that faster average annual decrease in mortality and DALYs of TI in boys than in girls (-3.90% vs. -3.82%, -3.88% vs. -3.79%, respectively). However, this pattern was not consistent across all age groups. Specifically, for children aged 10–14 years, the APC in mortality was -2.19% for girls and -2.10% for boys, and the APC in DALYs rate was -2.01% for girls and -1.98% for boys.

Disease burden of different road-type users in 1999 and 2019 were presented in Supplementary Table 3. We found that cyclist road injuries emerged as the primary contributors to TI, with a significant increase from 111.4 per 100,000 (95% UI: 69.4–164.2) in 1990 to 182.3 per 100,000 (95% UI: 116.7–260.7) in 2019, followed by other transport injuries and motorcyclist road injuries. Pedestrian road injuries were the dominant cause of TI deaths, with 10.1 in 1990 to 2.9 cases per 100,000 in 2019, decreased by 70%. The second leading cause of TI deaths was motor vehicle road injuries, decreased by 50% with 1.6 cases per 100,000 in 1990 to 0.7 in 2019. Among different road-type users, pedestrians were the group with the highest DALYs (243 cases per 100,000), which is almost twice as the sum of DALYs in other road-type users. In addition, Motor vehicle road injuries are not negligible which attributed to the second highest rate of DALYs. Notably, the incidence rate of motorcyclist and motor vehicle-related injuries grew by over 80% from 1990 to 2019, with a higher rate of increase observed in girls compared to boys. Pedestrian, motorcyclist, and other transport injuries showed a predominantly mortality in boys. The risk of disability was higher for boys than for girls in different TI types by gender, especially among pedestrians and motorcyclists.

**Table 1** Presentation of trends in the incidence, mortality and DALYs rate of TI between different age and gender groups in China from 1990 to 2019. Based on the results of Joinpoint regression analysis, trends in TI burden were segmented by time periods, with the calculation of Average Percent Change (APC) and Average Annual Percent Change (AAPC) differences among different age and gender groups

| | Age | boys | | | girls | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (year) | time | APC(%) | AAPC(%) | time | APC(%) | AAPC(%) | time | APC(%) | AAPC(%) |
| **Incidence** | | | | | | | | | | |
| | 0–4 | | | | | | | | | |
| | | 1990–1992 | -4.01* | -5.02** | 1990–1994 | -5.97** | -4.69** | 1990–1992 | -4.38* | -4.84** |
| | | 1992–2000 | -7.11* | | 1994–2001 | -8.44** | | 1992–2001 | -7.37** | |
| | | 2000–2017 | -3.56* | | 2001–2014 | -1.71 | | 2001–2015 | -2.68 | |
| | | 2017–2019 | -9.75* | | 2014–2019 | -5.96** | | 2015–2019 | -6.75** | |
| | 5- | 1990–1995 | -0.26 | 1.11** | 1990–1997 | 1.55** | 1.47** | 1990–1997 | 0.22 | 1.26** |
| | | 1995–2006 | -3.64** | | 1997–2005 | -3.32** | | 1997–2006 | -3.69** | |
| | | 2006–2009 | 6.2** | | 2005–2010 | 4.72** | | 2006–2009 | 5.66** | |
| | | 2009–2019 | 0.16 | | 2010–2019 | 0.94** | | 2009–2019 | 0.45* | |
| | 10–14 | 1990–1994 | -3.19** | 1.32** | 1990–1995 | 0.49 | 1.17** | 1990–2001 | -2.25 | 1.27 |
| | | 1994–2000 | 4.83** | | 1995–2000 | 8.37** | | 2001–2007 | 5.99** | |
| | | 2000–2008 | 0.16 | | 2000–2008 | -3.1** | | 2007–2010 | -1.09** | |
| | | 2008–2019 | 1.97** | | 2010–2019 | 1.5** | | 2010–2019 | 1.8** | |
| | 0–14 | 1990–1994 | -2.41** | 1.06** | 1990–1993 | -1.07 | 1.30** | 1990–1995 | -1.45** | 1.18** |
| | | 1994–2001 | -0.31 | | 1993–2004 | 0.94** | | 1995–2003 | 0.74* | |
| | | 2001–2010 | 3.56** | | 2004–2019 | 2.04** | | 2003–2010 | 3.26** | |
| | | 2010–2019 | 1.24** | | | | | 2010–2019 | 1.45** | |
| **Mortality** | | | | | | | | | | |
| | < 5 | | | | | | | | | |
| | | 1990–1992 | -4.01 | -5.02** | 1990–1994 | -5.97** | -4.69** | 1990–1992 | -4.38** | -4.84** |
| | | 1992–2000 | -7.11** | | 1994–2001 | -8.44** | | 1992–2001 | -7.37** | |
| | | 2000–2017 | -3.56** | | 2001–2014 | -1.71** | | 2001–2015 | -2.68** | |
| | | 2017–2019 | -9.75** | | 2014–2019 | -5.96** | | 2015–2019 | -6.75** | |
| | 5- | 1990–1996 | 1.31** | -3.48** | 1990–1997 | 8.03** | -2.94** | 1990–1997 | 3.22** | -3.27** |
| | | 1996–2006 | -4.00** | | 1997–2005 | -9.31** | | 1997–2006 | -5.95** | |
| | | 2006–2009 | -3.07 | | 2005–2010 | 2.52 | | 2006–2009 | 5.2 | |
| | | 2009–2019 | -7.56** | | 2010–2019 | -8** | | 2009–2019 | -7.57** | |
| | 10–14 | 1990–2002 | 2.83* | -2.1* | 1990–2000 | 7.49** | -2.19* | 1990–2001 | 4.33** | -2.11* |
| | | 2002–2007 | -7.55** | | 2000–2006 | -11** | | 2001–2007 | -8.12** | |
| | | 2007–2010 | 6 | | 2006–2010 | 3.78 | | 2007–2010 | 6.56 | |
| | | 2010–2019 | -7.81** | | 2010–2019 | -8.64** | | 2010–2019 | -8.17** | |
| | 0–14 | 1990–2001 | -2.61** | -3.90** | 1990–1998 | -0.84* | -3.82** | 1990–1999 | -2.03** | -3.87** |
| | | 2001–2007 | -4.46** | | 1998–2006 | -6.96** | | 1999–2007 | -5.12** | |
| | | 2007–2010 | 1.46 | | 2006–2010 | 2.68 | | 2007–2010 | 2.86 | |
| | | 2010–2019 | -6.80** | | 2010–2019 | -6.34** | | 2010–2019 | -6.70** | |
| **DALYs rate** | | | | | | | | | | |
| | < 5 | 1990–1992 | -4.01** | -4.99** | 1990–1994 | -5.97** | -4.67** | 1990–1992 | -4.37** | -4.81** |
| | | 1992–2000 | -7.12** | | 1994–2001 | -8.44** | | 1992–2001 | -7.37** | |
| | | 2000–2017 | -3.52** | | 2001–2014 | -1.69** | | 2001–2015 | -2.64** | |
| | | 2017–2019 | -9.66** | | 2014–2019 | -5.89** | | 2015–2019 | -6.68** | |
| | 5- | 1990–1996 | 1.27** | -3.42** | 1990–1997 | 7.92** | -2.87** | 1990–1997 | 3.16** | -3.21** |
| | | 1996–2006 | -3.98** | | 1997–2005 | -9.22** | | 1997–2006 | -5.90** | |
| | | 2006–2009 | 3.12 | | 2005–2010 | 2.56 | | 2006–2009 | 5.23 | |
| | | 2009–2019 | -7.43** | | 2010–2019 | -7.79** | | 2009–2019 | -7.41** | |

**Table 1** (continued)

| Age | boys | | | girls | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| (year) | time | APC(%) | AAPC(%) | time | APC(%) | AAPC(%) | time | APC(%) | AAPC(%) |
| 10–14 | 1990–2002 | 2.77** | -1.98* | 1990–2000 | 7.3** | -2.01* | 1990–2001 | 4.23** | -1.97* |
| | 2002–2007 | -7.28** | | 2000–2006 | -10.59** | | 2001–2007 | -7.85** | |
| | 2007–2010 | 5.71 | | 2006–2010 | 3.44 | | 2007–2010 | 6.18 | |
| | 2010–2019 | -7.43** | | 2010–2019 | -8.05** | | 2010–2019 | -7.73** | |
| 0–14 | 1990–2001 | -2.77** | -3.88** | 1990–1998 | -1.15* | -3.79** | 1990–1998 | -2.04** | -3.83** |
| | 2001–2007 | -4.34** | | 1998–2006 | -6.83** | | 1998–2007 | -4.77** | |
| | 2007–2010 | 1.33 | | 2006–2010 | 2.65 | | 2007–2010 | 2.49 | |
| | 2010–2019 | -6.58** | | 2010–2019 | -6.09** | | 2010–2019 | -6.45** | |

* $P<0.05$

** $P<0.001$

**Table 2** Incidence of transport injuries by nature of 0–14 years old in 2019

| Sort | nature | Incidence (per 100,000) |
|---|---|---|
| 1 | Superficial injury of any part of the body | 67.1 (42.9–102.6) |
| 2 | Contusion in any part of the body | 44.3 (27.3–70.1) |
| 3 | Open wound(s) | 39.5 (26.5–57.7) |
| 4 | Muscle and tendon injuries, including sprains and strains lesser dislocations | 38.3 (23.9–58.4) |
| 5 | Fracture of patella, tibia or fibula, or ankle | 33.6 (22.9–48.5) |
| 6 | Minor TBI | 23.3 (14.5–36.1) |
| 7 | Fracture of skull | 19.1 (11.2–31.4) |
| 8 | Fracture of clavicle, scapula, or humerus | 18.1 (11.7–27.9) |
| 9 | Moderate/Severe TBI | 17.2 (11.8–24.6) |
| 10 | Internal hemorrhage in abdomen and pelvis | 13.2 (7.9–20.4) |

Top 10 for all natural injuries at Level 2. Parentheses indicate 95% uncertainty intervals (UI)

### Injuries by nature of TI

Natural injuries caused by TI contained 7 classifications, including amputations, burns, fractures, head injuries, spinal injuries, minor injuries, other injuries and their 47 sub-groups. Table 2 summarized the incidence of the top 10 sub-groups of natural injuries attributable to TI in 2019. Among these, minor injuries such as superficial injuries (68 cases per 100,000), contusions (45 cases per 100,000) and open wounds (40 cases per 100,000) were more common in the context of TI.

### Risk factor of TI

We estimated death rate and DALYs rates for TI-related risks for 0–14 years in 2019. Risk factors contained environmental changes, occupational hazards, behavioral risks, and metabolic risks in GBD 2019. Table 3 specifically outlines the risk factors that have a significant impact on TI. The results showed that the alcohol use is the most prominent risk factor of TI among children, with death rate of 0.3/100,000 (95% UI:0.2 to 0.4) and DALYs of 25.7/100,000 (95%UI: 15.3 to 36.4), respectively. Surprisingly, our data revealed that both mortality and DALYs associated with TI were negatively correlated with low temperature, with mortality of -0.2 (95% UI: -0.4 to -0.1) and DALYs of -18.6 (95% UI: -29.3 to 8.6). It

**Table 3** Risk factor of transport injuries related DALYs and death rate of 0–14 years old and total persons in 2019

| SI.NO | Risk factor | Death (per 100,000) | DALYs (per 100,000) |
|---|---|---|---|
| 1 | All risk factors | 0.1 (-0.1–0.3) | 8.6 (-5.3–23.1) |
| A | Environmental risks | -0.2 (-0.4 to -0.1) | -18.3 (-28.9 to -8.4) |
| A.1 | Non-optimal temperature | -0.2 (-0.4 to -0.1) | -18.3 (-28.9 to -8.4) |
| A.1.1 | High temperature | 0 (0 to 0) | 0.3 (-0.1 to 0.9) |
| A.1.2 | Low temperature | -0.2 (-0.4 to -0.1) | -18.6 (-29.3 to -8.6) |
| B | Behavioral risks | 0.3 (0.2 to 0.4) | 25.7 (15.3 to 36.4) |
| B.1 | Alcohol use | 0.3 (0.2 to 0.4) | 25.7 (15.3 to 36.4) |

Parentheses indicate 95% uncertainty intervals (UI) suggested that low temperature could potentially serve as a protective factor, reducing the risk of disability or death in children affected by TI.

## Discussion

To our knowledge, the study provides the first comprehensive assessment of the burden, associated risk factors, and nature of TI among children under 14 years in China from 1990–2019. Our findings indicate a consistent annual increase in the incidence of TI since 1995, contrasted with a general decline in mortality and DALYs, with the exception of a temporary reversal observed between 2007 and 2010. Stratified analysis revealed that the incidence of TI increased with the age of the child, yet the rates of death and DALYs correspondingly decreased. Cyclist road injuries were identified as the primary cause of TI. Pedestrian injuries and motor vehicle injuries were the leading causes of death of TI. Besides, alcohol use was risk factors for TI, while low temperature appeared to be a protective factor.

Despite the increasing incidence, the significant decline in mortality and DALYs among children aged 0–14 years can be largely credited to the evolution of laws and policies pertaining to child traffic safety in China. These include interventions such as the enforcement of drunk driving laws, mandatory restraints, safety helmets, speed limits, and the differentiation between different types of road users and driver's license levels before 2015 [16].. The revision of the Law of the People's Republic of China on Road Traffic Safety in 2011 was associated with a reduction in annual life expectancy across various demographics, including boys, girls, all age groups, pedestrians, motor vehicle users, other road users, and traffic deaths due to alcohol and tobacco use [17, 18]. The promotion of helmet use among children with bicycles and motorcyclist has effectively enhanced their safety [19].

With the growth of motor vehicle ownership in China, child motor vehicle crash safety has become a primary concern. The 2021 revision of the Law of the People's Republic of China on the Protection of Minors proposed measures for child restraint systems to protect the safety of child passengers. However, there is a lack of awareness and education about the legislation, resulting in low compliance. For instance, despite local legislation in 19 cities mandating child restraint use, awareness and usage remain low [20]. A robust road safety accountability system and a collaborative mechanism between multiple departments are crucial for further improvement [21]. Legal publicity and education in schools, communities, and through multimedia are essential for both parents and children.

In stratified analysis, we found that the incidence of TI increased with age, yet the rates of death and DALYs decreased. It might be explained by adolescents' increased exposure to risky behaviors and lack of supervision. For the higher burden of death and DALYs in younger children, it might be related to the characteristics of being more vulnerable, lack self-protection abilities and more dependent on parental supervision [22, 23]. In the event of a traffic accident, the lack of adequate protection results in severe injuries or even death, imposing a significant burden on families and the country.

Our research confirms that boys have a higher risk of TI incidence, death rate, and DALYs rate than girls. It appears that boys are more likely to be involved in TI [24, 25] and are at higher risk for both minor and serious injuries [26]. The frequency of travel and exposure to road risk, with boys (11.5 trips) having a higher average number of road trips per day than girls (9.6 trips) [27]. In addition, boys may also tend to make weaker decisions in risky situations. On contrary, girls cautious nature might contribute to lower risk to exposure among them [28].

We found that cyclist road injuries were the primary cause of TI, consistent with the global trends [29]. Children often lack road safety knowledge and awareness, engaging in riskier behaviors than adults [30, 31].. Head injuries and fractures are common in cyclist injuries [32], highlighting the importance of protective helmet use, which can reduce the risk of serious injury by 70% and the risk of death by 40% in accident [33].

In terms of injuries and fatalities, the burden of death and DALYs from pedestrian road injuries dominated the burden of child traffic crashes. Approximately 35% of collisions involving pedestrians and automobiles were caused by pedestrians in China [34]. High student populations, traffic flow, road density, number of intersections, and pedestrian flow contribute to the frequency of pedestrian accidents [35]. Intersection crossing, playing on the road, and running red lights are high-risk behaviors that frequently occur among children and can easily lead to injuries [36]. If children lack knowledge of pedestrian safety, they may unconsciously commit violations, such as playing on the roadside, chasing with each other, running across the street, and ignoring red lights [37]. Moreover, pedestrian road injury can occur when crossing the street, standing on the side of the road, or walking on the side of the road, with a higher likelihood of collision especially when crossing the street [38]. According above, three levels of education-engineering-enforcement can be used to reduce pedestrian road injuries among children. Education is child pedestrian road safety, some cases in point are the safe child photography voiceover programs, multimedia campaigns, school education, family education [39]. On the one hand, it can improve children's awareness of pedestrian safety and avoidance of dangerous walking behaviors [40]. On the other hand, it raises parents' awareness of pedestrian safety to enhance adult supervision [24]. Engineering designates the construction of a pedestrian road environment, similar to the posting of additional vehicle speed signs near schools to remind drivers to slow down and stop for child pedestrians [41]. Enforcement can be implemented by enhancing the traffic environment near schools during the school season and by using traffic officers at high traffic volume intersections to monitor pedestrian and vehicle behavior.

We also found that the risk of disability and death from motor vehicle road injuries was second only to that of pedestrians. Some studies have reported higher levels of fatal injuries from motor vehicle-related collisions [42]. Nearly half (47%) of all crash injuries occur within 5 miles of the injured person's home [43]. When motor vehicle collisions occur, head-on collisions, rollovers, and side impacts all result in more severe levels of passenger injuries [44]. In addition, front seat or unrestrained child passengers in a car have a higher risk of death and disability in a motor vehicle collision. When a fatal collision occurs, the rear seat has a 29.1% higher survival rate than the front seat, and the middle rear seat has a 25% higher survival rate than the other rear seats [45]. The fatality rate for children without optimal restraint is about twice that of children with optimal restraint [46]. Child restraint systems are proven to be an effective means of protecting children from motor vehicle crashes [47–49], but CRS use rate among children under 5 years of age in China is only 14.2% [50]. Children should be seated in the rear seat of the vehicle and appropriately adjusted to use the current age and size appropriate device (infant car seat, rear-facing seat, forward-facing seat), but should avoid wearing the seat belt alone [51]. Therefore, facilitating the use of child restraint systems is an effective measure to protect children from motor vehicle crash injuries. Parental knowledge gaps, perceptions of risk, mixed motivation, and limited enforcement of child restraint legislation are key influences on restraint use [52]. There is an urgent need for public safety education programs to be combined with legal literacy to improve parental knowledge, attitudes, and safety of children.

After analyzing the nature of TI, we found that minor injuries were more common in the context of TI. While these injuries were more likely to occur, they generally pose a lower risk to the torso. Notably, the impact of fractures (e.g., patella/tibia/fibula/ankle, skull, clavicle/scapula/humerus) and head injuries (ranging from minor to severe traumatic brain injury) on children is more severe and has a worse prognosis. Therefore, mitigating the incidence of fractures and head injuries among child passengers involved in severe traffic collisions are still the most fundamental to diminishing child mortality.

Alcohol use was identified as the most prominent risk factor for TI among children, with a death rate of 0.3 per 100,000 and DALYs of 25.7 per 100,000, supporting that the impact of alcohol use on driver behaviors significantly increases the risk of TI among children. It's evidenced that interventions focus on stricter enforcement of drink-driving laws could reduce year of life lost (YLLs) due to traffic deaths in China [53], urging the need to further enforce against drink-driving. Interestingly, low temperatures were found to be a protective factor, with negative death and DALYs rates. This is consistent with the study in Athens, which concluded that motor vehicle mobility in cold weather reduced the record of traffic accident injuries in Athens [54]. However, some other evidence from epidemiological studies suggest that low temperatures increase the risk of traffic injuries [55, 56]. The inconsistency might be attributable to the different composition of basic demographic characteristics of the study population. There have been no studies on the impact of meteorological factors on road traffic injuries in children under 14 years of age, so we conclude that this is likely due to reduced outdoor activity and increased caution during colder weather. In the future, more investigation of environmental factors should be needed for exploring the mechanisms of these factors contributing to TI risk and identify potential interventions.

Our study is not without limitations. First, although the GBD uses multiple methods to try to communicate the strength of data or evidence underlying a finding, users of the GBD results may not understand the true uncertainties in the measurements [57], which may affect the representativeness and reliability of the results. Second, in addition to the effects of gender, age and road-type users, we should take more factors into consideration such as differences in subnations [58] and urban–rural areas [59, 60]. Future research could focus on assessing the regional variations and urban–rural disparities in TI among children. Third, in statical analysis study, we mainly rely on the modeling process, and the choice of model and parameter settings may also affect the results.

## Conclusion

The risk of TI leading to death and disability among children aged 0–14 years in China remains serious. Motor vehicle and motorcyclist TI in the 0–4 years group, and motor vehicle, pedestrian, other road injuries in the 5–9 and 10–14 years groups should be paid close attention to. Based on our study, we recommend the following to mitigate the burden of traffic injuries among children in China: develop targeted policies to enhance traffic safety education and awareness, focusing on cyclist and pedestrians; strengthen and enforce traffic safety legislation, including mandatory use of child safety seats and helmets; incorporate road safety education into school curricula for children aged 5–14; implement gender- and age-specific interventions; improve the quality and accessibility of emergency and rehabilitation services; manage environmental and behavioral risk factors through strict alcohol control; and upgrade traffic infrastructure, such as pedestrian crossings, bicycle lanes, and sidewalks, to ensure children's safety and consider their needs in urban planning.

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**Authors' contributions**
YC performed data analysis and prepared figures and tables. FW designed the methodology, completed data collection and disposal. Both wrote the original manuscript. KD validated, reviewed and edited writing. ZM supervised, reviewed and edited writing. LL was in charge of the conception and supervised the design of the study framework. All authors reviewed the manuscript.

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**Availability of data and materials**
The data that support the findings of the study are available in Global burden of disease database (GBD) 2019 by using the Global Health Data Exchange (GHDx) query tool at following URL: https://vizhub.healthdata.org/gbd-results/

## Declarations

**Ethics approval and consent to participate**
Not applicable.

**Consent for publication**
Not applicable.

**Competing interest**
The authors declare no competing interests.

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