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Research article

Characteristics of road traffic accident types and casualties in Guangzhou, China, from 2007 to 2020: A retrospective cohort study based on the general population

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ABSTRACT

Introduction: This study aimed to explore the trend and main influencing factors of road traffic accidents in Guangzhou, China, from 2007 to 2020 and to provide a reference and guidance for government decision-making.

Methods: A retrospective cohort study was used to describe road traffic accidents in Guangzhou. According to the population types, all people with road traffic accidents were divided into migrant workers and the control population. We divided road users, administrative districts, motorcycle types and injury levels into subgroups to investigate the characteristics of road traffic accidents in Guangzhou. The road traffic accident data were derived from the Guangzhou Public Security Traffic Management Integrated System.

Results: The incidence rate of road traffic accidents per 10,000 vehicles in Guangzhou decreased from 36.55 in 2007 to 10.07 in 2012, remained relatively stable at 9.47 in 2017, and finally rose to 11.12 in 2020. The injury rate showed the same trend as the incidence rate, while the mortality rate gradually decreased from 14.21 in 2007 to 5.19 in 2020. Vulnerable road users such as motorized two-to-three-wheeler drivers and migrant workers were casualties in more than 80% of the cases. The proportion of casualties involving mopeds and electric bicycles increased rapidly after 2018. Motor vehicle drivers frequently caused road traffic accidents and were most often uninjured.

Conclusion: Road safety in Guangzhou has shown a clear trend of improvement, but casualties are uneven across administrative districts. More attention should be given to motorized two-to-three-wheelers, migrant workers, and road traffic violations by uninjured individuals.

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1. Introduction

On August 31, 2020, the United Nations [1] General Assembly Resolution 74/299 concluded the first Global Plan for the Decade of Action for Road Safety 2011–2020 and declared 2021–2030 as the second Decade of Action for Road Safety, whose goal remains to reduce the number of deaths and injuries from road traffic accidents (RTAs) by 50%. The first global plan for road safety was declared in March 2010 [2], and the Sustainable Development Goal (SDG) 3·6—to halve deaths and injuries from RTAs by 2020—was stated in 2015 [3]. Reports show that global road traffic fatalities have not fallen [4,5] and reached 1·35 million by 2016 [6]. Only Europe and the Western Pacific regions have seen a decline within the first Decade of Action for Road Safety [7]. In October 2020, the WHO issued the *Global Plan: Decade of Action for Road Safety 2021–2030*, which highlighted that 90% of road traffic deaths occurred in low- and middle-income countries; therefore, there is a strong need for continued attention and support over the next decade [8].

As the world's second-largest economy, China accounts for 19% of the world's population [9], and its RTA fatalities remain above 250,000 every year (approximately 19% of the world's total) [10]. In 2003, the Chinese government promulgated the *Law of the People's Republic of China on Road Traffic Safety* [11], which made clear regulations on overall traffic rules. The 'crime of dangerous driving' was added to *the Criminal Law of the People's Republic of China* in 2011 [12]. Relevant studies [13-15] show that RTA casualties have been reduced by varying degrees after these legal revisions. Over the past decade, many scholars have conducted research on China's overall road safety. A survey by Central South University reported that raw and age-adjusted mortality rates of RTAs in China from 2006 to 2016 showed an initial upward trend followed by a decrease [16]. Tsinghua University's research showed that although the overall RTAs in China have declined, the accident severity has increased [17]. Another study from Zunyi Medical University noted that deaths from motor vehicle RTAs fell between 2007 and 2015, in contrast to nonmotor vehicle deaths that rose since 2012 [18].

Research based on 1,632 cities worldwide found that the magnitude and nature of road traffic injuries are closely related to differences between types of cities and highlights the need to design urban spaces to reduce the global burden of road transport injuries [19]. There are large geographical and economic differences between regions and cities in China, resulting in distinct road traffic conditions [20-23]. Therefore, it is necessary to investigate road safety in different regions and adopt targeted intervention policies according to local conditions.

This study analyzed the relevant information on RTAs in Guangzhou from 2007 to 2020 and examined the leading indicators of road transport in terms of the changing picture and main risk factors for RTAs. We aimed to provide a helpful reference for government decision-making.

2. Materials and methods

2.1. Study design

This was a retrospective cohort study. The development trend of RTAs in Guangzhou was analyzed from the incidence rate per 10,000 vehicles (based on possession of civil vehicles) and the mortality and injury rates per 100,000 people (based on the population of permanent residents; Appendix Table 1). Changes in mortality and injury rates were compared with road users as subgroups. The annual average mortality and injury rates in the 11 administrative districts in different stages (2007–2012, 2013–2017 and 2018–2020) were mapped, excluding accidents that occurred on highways. Population types were the focus of this study and were

Table 1
Dynamic series of road traffic accident incidence rates per 10,000 vehicles and injury and mortality rates per 100,000 people in Guangzhou, 2007–2020.

Year	Incidence rates per 10,000 vehicles			Injury rates per 100,000 people			Mortality rates per 100,000 people		
	Rate	Annual percentage change in growth rate	Descriptive statistics	Rate	Annual percentage change in growth rate	Descriptive statistics	Rate	Annual percentage change in growth rate	Descriptive statistics
2007	36.55	.	Stage 1 Mean:	78.53	.	Stage 1 Mean:	14.21	.	Mean: 0.0906
2008	29.27	−0.20	0.1869 95% CI[a]:	58.79	−0.25	0.2723 95% CI[a]:	11.69	−0.18	95% CI[a]: 0.0922
2009	21.73	−0.26	0.1900 to −0.1838	43.30	−0.26	0.2737 to 0.2709	11.62	−0.01	to −0.0891 SE[b]:
2010	16.07	−0.26	SE[b]: 0.00157	30.79	−0.29	SE[b]: 0.00072	10.36	−0.11	0.00079
2011	11.46	−0.29		20.54	−0.33		9.65	−0.07	
2012	10.07	−0.12		17.97	−0.13		8.10	−0.16	
2013	10.18	0.01	Stage 2 Mean:	17.67	−0.02	Stage 2 Mean:	8.03	−0.01	
2014	10.78	0.06	0.0527 95% CI[a]:	17.09	−0.03	0.0323 95% CI[a]:	8.03	0.00	
2015	10.97	0.02	0.0550 to −0.0503	16.44	−0.04	0.0329 to −0.0316	7.89	−0.02	
2016	10.49	−0.04	SE[b]: 0.00119	13.37	−0.19	SE[b]: 0.00034	7.41	−0.06	
2017	9.47	−0.10		11.08	−0.17		6.91	−0.07	
2018	9.86	0.04	Stage 3 Mean:	12.68	0.14	Stage 3 Mean:	5.80	−0.16	
2019	10.81	0.10	0.0482 95% CI[a]:	14.32	0.13	0.0624 95% CI[a]:	5.32	−0.08	
2020	11.12	0.03	0.0461 to 0.0504	14.23	−0.01	0.0567 to 0.0681	5.19	−0.03	
			SE[b]: 0.00111			SE[b]: 0.00290			

[a] 95% confidence interval.
[b] Standard error.

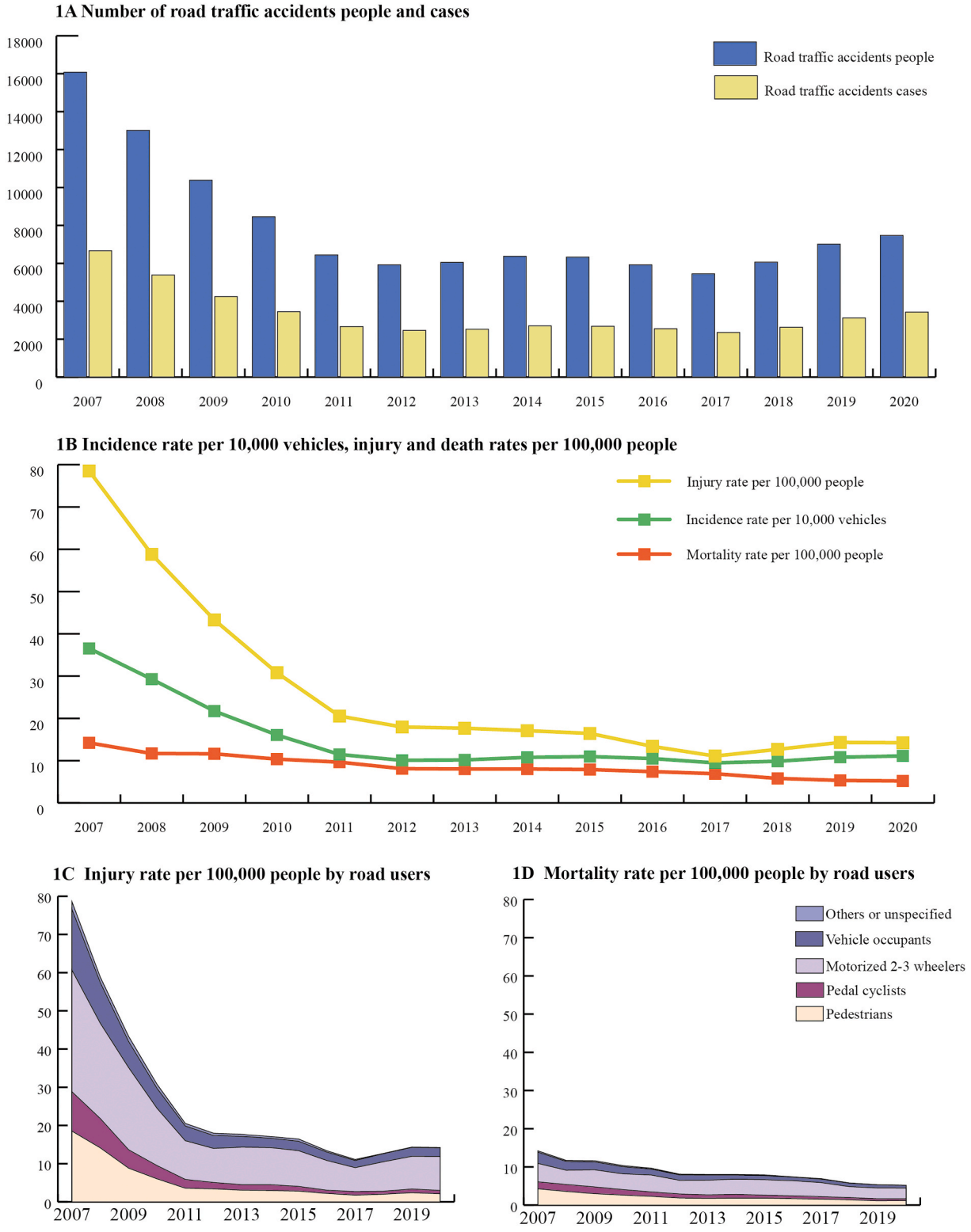

Fig. 1. Road traffic accidents in Guangzhou, 2007-2020. Number of road traffic accidents and cases (1A), incidence rate per 10,000 vehicles and injury and mortality rates per 100,000 people (1 B), injury (1C) and mortality (1D) rates per 100,000 people by road users.

divided into migrant workers and a control population (nonmigrant workers), according to their registration data. To better describe current road safety in Guangzhou, we included information on population types and road users on maps from 2018 to 2020. As motorized two-to-three-wheelers were the primary source of casualties, we compared the development trends and contributions of motorized two-to-three-wheelers according to motorcycle type (Appendix Table 2). Finally, the road users and responsibility determination of the uninjured and injured individuals were compared.

This project was reviewed and approved by the Biomedical Ethics Committee of Southern Medical University, Guangzhou, China

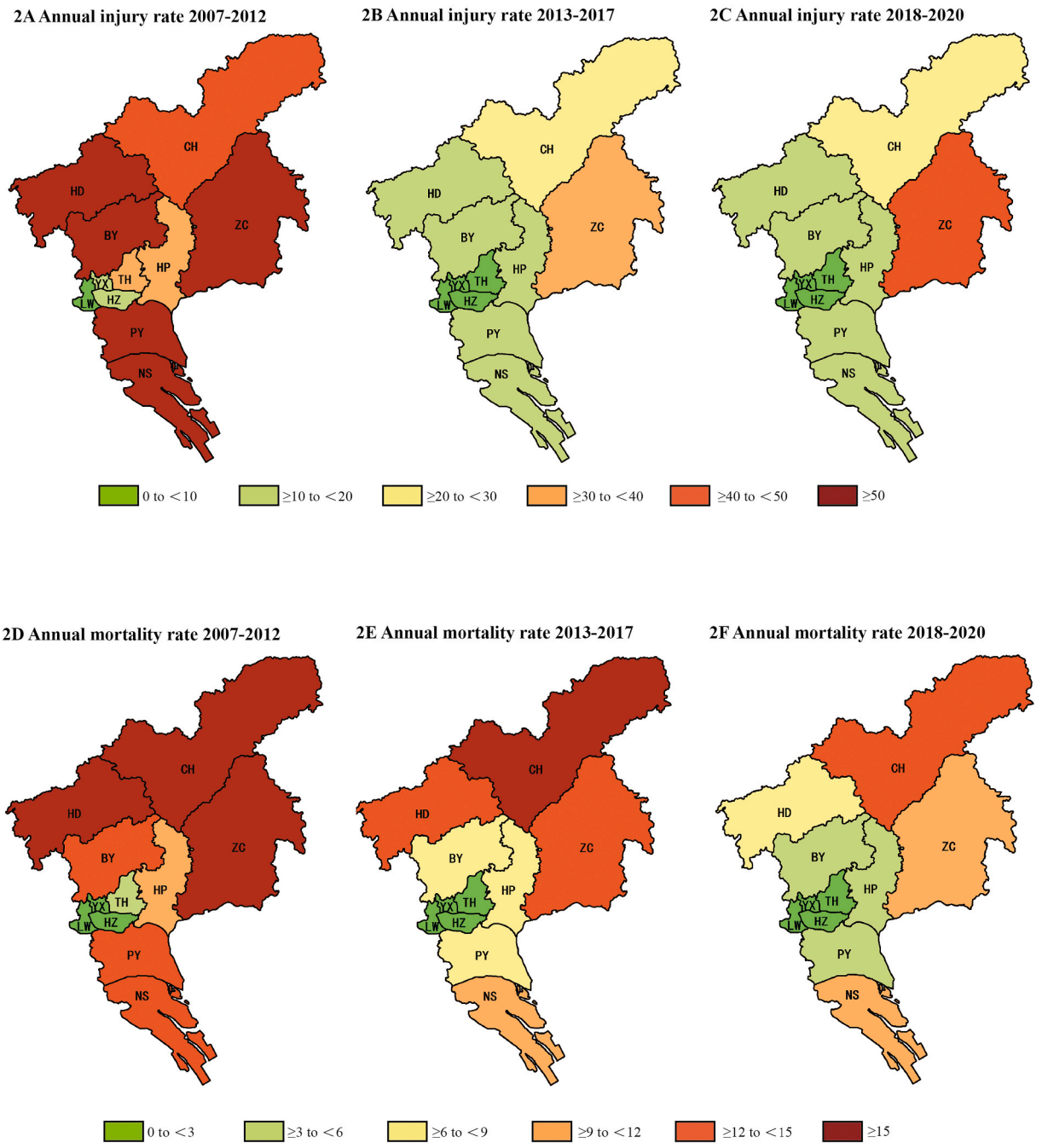

Fig. 2. Road traffic accident average annual injury and mortality rates per 100,000 people by administrative district in Guangzhou. Injury rates: 2007–2012 (2A), 2013–2017 (2B) and 2018–2020 (2C). Mortality rates: 2007–2012 (2D), 2013–2017 (2E) and 2018–2020 (2F). BY: Baiyun, CH: Conghua, HD: Huadu, HP: Huangpu, HZ: Haizhu, LW: Liwan, NS: Nansha, PY: Panyu, TH: Tianhe, YX: Yuexiu, ZC: Zengcheng. Central urban areas: HZ, LW, TH, YX; outer urban areas: BY, HD, HP, NS, PY, ZC; ecoregions: CH. Road traffic accidents in all administrative districts did not include accidents that occurred on highways.

(NO NYLS-2022-001).

2.2. Variables

Following the International Classification of Diseases and Related Health Problems (ICD-11) [24], the road users in this study were divided into five categories: pedestrians (PA00), pedal cyclists (PA02), motorcyclists (PA03), vehicle occupants (PA04–PA09 and PA0A–PA0D), and other or unspecified road users (PA0Y and PA0Z). However, the ICD-11 does not clearly classify electric bicycles. Many electric bicycles are sold in China, causing an increasing number of RTAs. Therefore, we merged electric bicycle riders and motorcyclists into motorized two-to-three-wheeler drivers. Migrant workers were defined in this study as internal migrants per the International Organization for Migration [25]. These individuals were migrant laborers with nonurban registration, including registered laborers from other towns and rural areas outside the Guangzhou area, and were a special group under the Chinese registration system [26]. The control population was defined as mainly local residents of Guangzhou and a small number of college students and businessmen from other provinces. RTA injury levels were divided into 'uninjured' and 'injured' (including injuries and deaths) groups based on the severity of the injury from the source data. Human damage (HD) and the case fatality rate (CFR) were used to measure RTA severity [17]. The cause of the accident was determined according to the *Law of the People's Republic of China on Road Traffic Safety* [11] and the *Road Traffic Safety Regulations of Guangdong Province* [27].

2.3. Data sources

The RTA data in this study were derived from the Guangzhou Public Security Traffic Management Integrated System. After the front-line traffic police from each brigade handled the accident, they uploaded the data to the platform according to the accident handling navigation requirements, and the data were uniformly summarized and stored by the Guangzhou Public Security Bureau. We selected 2007 to 2020 as the study window. Indicators related to population and road transportation were obtained from the *Guangzhou Statistical Yearbook 2021* issued by the Guangzhou Statistics Bureau [28]. The data on road traffic injury indicators worldwide and in different countries were accessed from the SDG Global Database of the WHO [10].

2.4. Statistical analysis

Dynamic series were used to describe the change rate of the incidence rate per 10,000 vehicles and the mortality and injury rates per 100,000 people, and 95% confidence intervals (CIs) and standard errors (SEs) were used to show the difference in their annual change rates, which was helpful to comprehend the overall RTAs in Guangzhou. Average annual mortality and injury rates were mapped to show differences in stages and administrative districts. A chi-square test was used to analyze the significance of the proportion of road users' deaths and injuries among migrant workers and the control population.

The RTA registration form was prepared to use Microsoft Excel 97–2003. IBM SPSS Statistics 26·0 was used for statistical analysis, Adobe Illustrator 2021 was used for statistical drawing, and MapInfo 17·02 was used for map production. The statistical test standard $\alpha = 0{\cdot}05$ when $P < 0{\cdot}05$ was considered statistically significant. All the hypothesis tests were two-tailed.

3. Results

3.1. Overall situation

From 2007 to 2020, a total of 46,829 RTAs occurred in Guangzhou, with 1,10,957 people (Fig. 1A), of whom 16,664 were killed, 47,614 were injured, and 46,679 were uninjured. The HD of the RTAs was $1{\cdot}40 \pm 0{\cdot}001$, and the CFR was $0{\cdot}32 \pm 0{\cdot}001$ (Appendix Tables 3 and 4). The incidence rate was described in 3 stages: (1) from 2007 to 2012, the incidence rates decreased from 36·55 to 10·07, and the injury rates decreased from 78·53 to 17·97. (2) From 2013 to 2017, the two variables remained relatively stable at 9·47 and 11·08, respectively. (3) From 2018 to 2020, rates increased to 11·12 and 14·23, respectively. The mortality rate per 100,000 people decreased from 14·21 in 2007 to 5·19 in 2020 (Fig. 1B; Table 1; Appendix Tables 5–7). The injury and mortality rates of road users showed a downward trend in line with the general trend (Fig. 1C and D;Appendix Tables 8 and 9). Deaths and injuries of vulnerable road users accounted for 82·15% and 80·26% of the total deaths and injuries, respectively. Motorized two-to-three-wheeler drivers had the highest proportion (45·67% of deaths and 50·64% of injuries), followed by pedestrians (24·75% of deaths and 19·58% of injuries).

3.2. Distribution of administrative districts

There were differences in the annual average RTA mortality and injury rates among the 11 administrative districts of Guangzhou. The central urban areas had lower average mortality and injury rates than the outer urban areas and ecoregions (Appendix Table 10; Fig. 2A–F). The annual average injury rate in all administrative districts from 2018 to 2020 was lower than that from 2007 to 2012. Between 2018 and 2020, only one district (LW) had a higher annual average mortality rate than in 2007–2012 (1·15 vs. 2·09), while the rate declined in the other districts.

3.3. Migrant workers vs. the control population

The injuries of migrant workers in RTAs accounted for 59·18% of total injuries, and migrant worker deaths accounted for 54·71% of total deaths. For migrant workers and the control population, the main road traffic casualties occurred among motorized two-to three-wheeler drivers, followed by pedestrians and vehicle occupants. The chi-square test showed a significant difference in the distribution of road users killed and injured in RTAs between the population types ($p < 0·0001$, Table 2 and Table 3; Appendix Tables 11–14). The proportion of deaths and injuries in motorized two-to-three-wheelers for migrant workers was higher than that for the control population (deaths: 52.39% for migrant workers vs. 37.55% for the control population; injuries: 58.14% for migrant workers vs. 39.78% for the control population), while the proportion of migrant workers killed or injured as pedestrians and vehicle occupants was lower than that of the control population. From 2018 to 2020, there were significant differences in RTA deaths and injuries between population types and the distribution of road users (Fig. 3A–B; Appendix Tables 15 and 16).

3.4. Changes in motorized 2–3 wheelers

There were 25,149 motorized two-to-three-wheeler-related RTAs in Guangzhou, in which 7,610 motorized two-to-three-wheeler drivers were killed and 24,114 were injured between 2007 and 2020. The number of injuries first decreased, then stabilized, and finally increased, while the number of deaths increased slightly (496 in 2007 vs. 515 in 2020). The deaths and injuries caused by RTAs related to ordinary motorcycles and their proportions decreased, while those associated with mopeds and electric bicycles increased, especially after 2018 (Fig. 4A–D; Appendix Tables 17 and 18).

3.5. Uninjured vs. injured individuals

Between 2007 and 2020, 46,679 participants in RTAs were unaffected (uninjured individuals). Among these, 84% were vehicle occupants, of which 99% were drivers and 86% were responsible for the accident. Conversely, among those injured, 17% were vehicle occupants (81% were vulnerable road users), 43% of those were drivers, and 36% were responsible for the accident. Regardless of the group, more than half of the pedestrians were not responsible for RTAs, while most motorized two-to three-wheeler users were responsible (Fig. 5A–B; Appendix Table 19).

4. Discussion

In Guangzhou, the RTA mortality rate decreased from 10·36 in 2010 to 5·19 in 2020, and the injury rate was nearly halved from 30·79 to 14·23; however, the severity of RTAs remained high. Vulnerable road users' deaths and injuries accounted for more than 80% of all deaths and injuries, with casualties involving motorized two-to-three-wheelers being the highest. There were large differences in road safety across administrative districts. Migrant workers had the highest number of casualties. Among them, the proportion of casualties caused by two-to three-wheelers was higher than that in the control group. There was an upward trend in casualties from moped- and electric bicycle-related RTAs. Most uninjured individuals were vehicle occupants, who were also mainly responsible for the accidents.

The second Decade of Action for Road Safety has begun, and the WHO has clearly stated that the priority is to ensure the quality of data collection, especially of the number of injuries, which was a data gap in the previous decade [8]. Recently, research on the severity of RTAs has become an important focus [29-33]. In China, RTA injuries are linked to sentencing and conviction, and the *Standards for Identification of Human Injury Degree* [34] is the basis for judging the degree of injury. In contrast, an injured person who needs more than 24 h of hospital care is regarded as seriously injured by the United Nations [35], while more than six days of hospital care is the definition in France [36]. If the above regulations are followed, the injured individuals in this study belong to the most seriously injured category. In Guangzhou, injuries were approximately 2·86 times more frequent than deaths, which is quite different from the WHO global estimate (1·3 million deaths and approximately 20–50 million injuries). However, the results of this study are similar to those reported by Tsinghua University [17].

Since the beginning of the 21st century, many policies and regulations have effectively improved road safety in Guangzhou [37] (Appendix Figure 1). In 2006, Guangdong Province adopted the *Road Traffic Safety Regulations of Guangdong Province* [27]. In 2007, several traffic management policies were promulgated: the motorcycle ban policy in urban areas, the adjustment policy for high-speed toll charges, and the limited range for trucks, which eased traffic congestion [38]. In the following years, the incidence and injury rates of RTAs decreased significantly. However, since 2012, the incidence and injury rates have not dropped significantly, which may be due to the following reasons: (1) newly increased population size and motor vehicle numbers are positively correlated with casualties in

Table 2
The chi-square test of road traffic accident deaths by road users between migrant workers and the control population in Guangzhou, 2007–2020.

Road user	Pedestrian	Pedal cyclist	Motorcyclist	Vehicle occupant	Other or unspecified	Total
Migrant workers	1864	1100	4776	1241	136	9117
Control population	2260	856	2834	1434	163	7547
Total	4124	1956	7610	2675	299	16664

Pearson $\chi^2 = 436.362$, $P < 0.0001$.

Table 3
The chi-square test of road traffic accident injuries by road users between migrant workers and the control population in Guangzhou, 2007–2020.

Road user	Pedestrian	Pedal cyclist	Motorcyclist	Vehicle occupant	Other or unspecified	Total
Migrant workers	4440	2864	16383	3955	537	28179
Control population	4885	1911	7731	4264	644	19435
Total	9325	4775	24114	8219	1181	47614

Pearson $\chi^2 = 1791.695$, $P < 0.0001$.

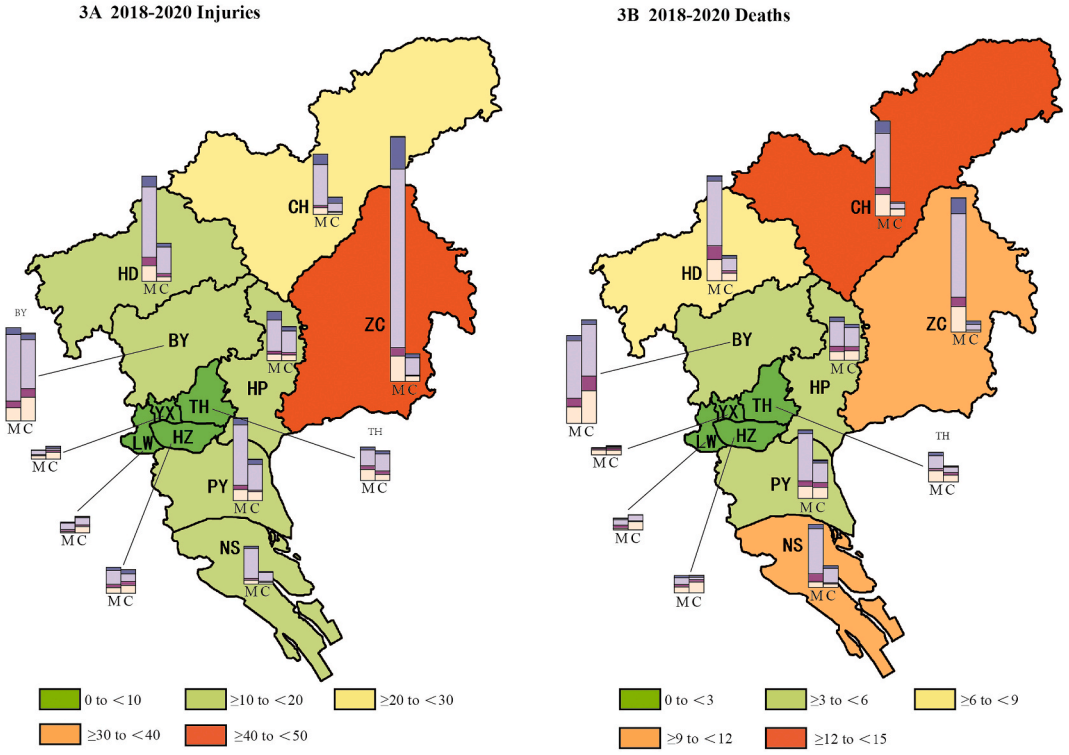

Fig. 3. Comparison of road traffic accident injuries and deaths among migrant workers and the control population in Guangzhou by road users. Based on the average annual injury and mortality rates per 100,000 people by administrative districts and the distribution of population types and road users, 2018–2020: injuries (3A) and deaths (3B). BY: Baiyun, CH: Conghua, HD: Huadu, HP: Huangpu, HZ: Haizhu, LW: Liwan, NS: Nansha, PY: Panyu, TH: Tianhe, YX: Yuexiu, ZC: Zengcheng. Central urban areas: HZ, LW, TH, YX; outer urban areas: BY, HD, HP, NS, PY, ZC; ecoregions: CH. M: migrant workers; C: control population. Road traffic accidents in all administrative districts did not include accidents that occurred on highways.

RTAs [39,40]. From 2007 to 2020, the number of civilian vehicles in Guangzhou increased by 69·07%, while the population increased by 80·77%, increasing the pressure on road safety. (2) With the implementation of the motorcycle ban policy, the number of registered motorcycles in 2020 decreased to 9·14% of that in 2007. This has prompted electric bicycles and mopeds to gradually become another important mode of travel for individuals, which has brought severe challenges for road traffic management. (3) The proportion of subways in the city's total public transportation system increased from 35% in 2012 to 57% in 2020. They have been substantially developed and have become an important mode of public transportation [41].

This study showed that the deaths of vulnerable road users in Guangzhou accounted for 82·15% of total deaths, which is higher than the number reported by the WHO (54%) [6] and a previous study by Central South University (75%) [16]. Similarly, the proportion of vulnerable road users injured was also relatively high. Motorized two-to-three wheelers were the largest contributors to road user casualties, similar to the case in Southeast Asia [42]. Although the casualties associated with motorized two-to-three-wheelers declined after the promulgation of the motorcycle ban policy, it is still a major problem area. Research shows that electric bicycles and moped-related road traffic injuries are emerging public health problems that are likely to worsen [43]. In 2020, China's electric bicycle production reached 41·26 million [44]. We also found a clear upward trend in the number and proportion of deaths and injuries among electric bicycle riders and moped riders after 2018.

There are many reports [16,36,45] on the differences in road users and mortality from RTAs between regions and urban/rural areas. Guangzhou suffers from the same problem. This study found that the road traffic mortality and injury rates in central urban areas remained low, similar to those of developed countries in Europe, while those in the outer urban areas and ecoregions were decreasing

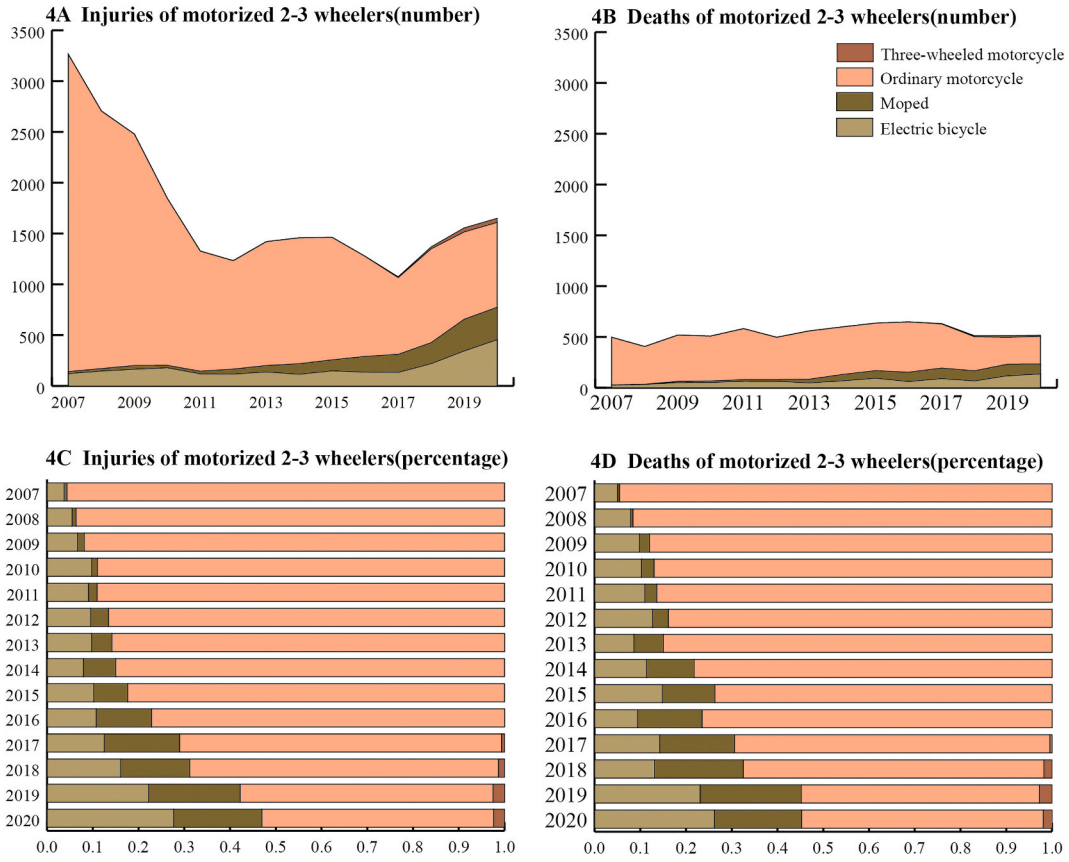

Fig. 4. Motorized two-to three-wheeler driver injuries and deaths in road traffic accidents by motorcycle type in Guangzhou, 2007-2020. Number of injuries (4A) and deaths (4B). Percentage of injuries (4C) and deaths (4D).

but much higher than those in central urban areas. This may be related to less or no exposure to motorcycle bans and the distribution of migrant workers in these areas.

Since the 1980s, large numbers of migrant workers have poured into developed cities along China's eastern and southern coasts, which has brought various social problems [46]. However, there is little research on migrant workers and road safety. A study found that the floating population is more likely to have RTAs than local residents [47]. Our study also found that more than half of the casualties in RTAs were migrant workers who used mainly motorized two-to-three-wheelers and were mostly concentrated in outer urban areas and ecoregions. From the perspective of distribution, road traffic injuries in a district were positively related to migrant workers. In 2020, the income of migrant workers in eastern and southern China was $630·58 per month [48]. This low income, together with jobs, medical care, public housing, and children's education that are far inferior to those of local residents, means that these people often choose to live in areas with low costs of living [49]. However, the frequent occurrence of RTAs is undoubtedly worse for them. Socioeconomic status has an important impact on the medical treatment of migrant workers, and low-income groups often utilize fewer medical services than high-income groups [50]. Therefore, properly handling the road safety issues of migrant workers can effectively reduce their economic burden. Many reports related to road traffic injuries focus on the investigation of sex, age, road users, urban and rural areas, and differences between road types [16,36,51,52]. However, the actual RTA casualties of migrant workers are alarming, and the government should pay greater attention to them.

Currently, most existing RTA studies focus on deaths and injuries, and there are few comparative studies on uninjured and injured individuals. Approximately 92% of road traffic fatalities in China are caused by automobile drivers [43]. We found that 84% of the uninjured individuals in RTAs were vehicle occupants, of which 99% were drivers and 86% were responsible for the accident. Therefore, it is important to systematically investigate their illegal behavior. In the future, we will further improve the study of the illegal behaviors of uninjured individuals and conduct a comparative analysis with those who suffer damage.

This study has certain limitations. First, although migrant workers were the primary victims of RTAs in Guangzhou, the lack of data on these individuals made it impossible to check trends. Their casualties remained low in 2015–2017, which may be related to population movements, so caution must be taken when drawing conclusions. Second, the lack of a base for research into electric bicycles and mopeds is also a disadvantage for statistical analysis. Due to the limitation of the length of this paper, we did not analyze factors related to sex, age, road environment, injury site, etc. The RTA injury registration is based on the *Standards for Identification of Human Injury Degree* [34], a general standard in forensic identification in China, and is quite different from that of other countries. If we

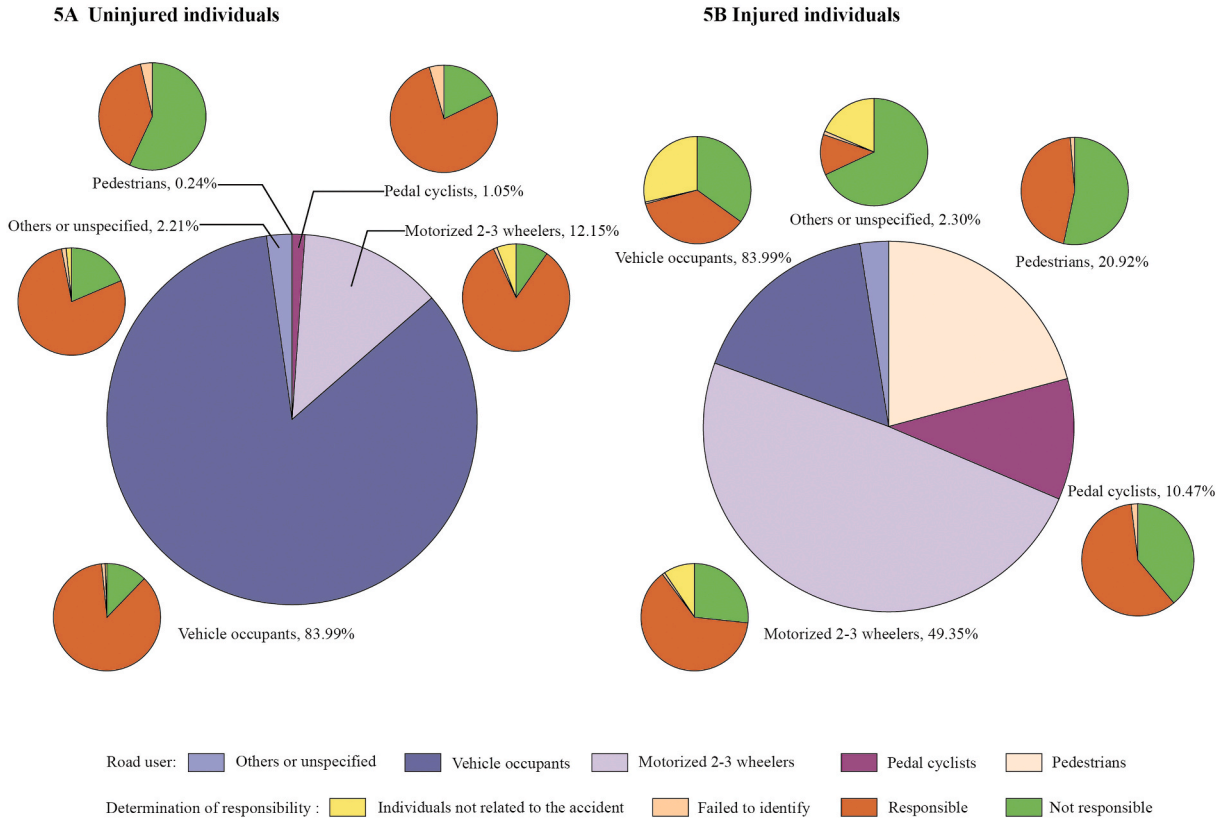

Fig. 5. Contrast of road traffic accidents between uninjured and injured individuals by road users and responsibility determination. Uninjured (5A) and injured (5B) individuals. Individuals not related to the accident were the passengers of the vehicles, including two-wheeled, three-wheeled, and four-wheeled motor vehicles.

follow the definition of the United Nations [35], the actual injuries may be far worse than those shown. However, the trend in the injury rate is still worthy of reference.

5. Conclusion

The incidence, injury, and mortality rates of RTAs in Guangzhou have generally declined; however, the incidence and injury rates have been on the rise in recent years. Our study provides the necessary reference for the government to formulate management policies that focus on migrant workers and motorized two-to three-wheeler drivers as the primary victims who need to be effectively managed and given regular road safety education. The RTA mortality and injury rates in outer urban areas and ecoregions are still high, and more emergency medical resources and accident handlers should be devoted to these areas. In addition, the increased usage of electric bicycles and mopeds deserves more attention as an emerging public health concern.

The authors also suggest conducting comparative research on uninjured and injured individuals in the future, especially examining motor vehicle drivers, who tend to suffer fewer injuries but are often the perpetrators of traffic accidents. Studying the illegal behaviors of this population will have crucial implications for improving road traffic safety. As a first-tier city in China, the characteristics of RTAs in Guangzhou may be shared by other first-tier cities in developing countries.

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Declaration of interests

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e12822.

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