The injury mechanism spectra and injury pyramids among children and adolescents in Zhuhai City, China

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Abstract

Background: The unclear spectra and severity of injuries in the injury pyramids for Chinese children and adolescents prevent the prioritization interventions. This study aimed to describe the injury mechanism spectra and injury pyramids in this population to provide a priority for injury prevention strategies.

Methods: Death, hospitalization, and outpatient/emergency department visit data from patients aged 0~17 years with injuries were obtained from January 1, 2013, to December 31, 2017, in Zhuhai City, China. The injury mechanism ratios were calculated, and the injury pyramids were drawn in proportion by using injury mortality and the incidence of both injury hospitalizations and outpatient/emergency department injury visits.

Results: The top three mechanisms for injuries in children and adolescents seen in outpatient/emergency departments were falls (52.02%), animal bites (14.57%), and blunt injuries (10.60%). The top three mechanisms for injury hospitalizations were falls (37.33%), road traffic injuries (17.87%), and fire/burns (14.29%), while the top three mechanisms for injury deaths were drowning (32.91%), road traffic injuries (20.25%) and falls (13.92%). The incidence rate of outpatient/emergency department injury visits for children and adolescents was 11210.87/100,000; the incidence rate of injury hospitalization was 627.09/100,000, and the injury death rate was 10.70/100,000. For each injury death, there were 59 injury hospitalizations and 1,047 outpatient/emergency injury visits.

Conclusions: The injury spectra were different for injury-related outpatient/emergency department visits, hospitalizations, and deaths among children and adolescents. The different sexes had different injury spectra at different stages of child development, and interventions should be formulated based on this finding. The size and shape of the injury pyramids varied by age, sex, region, and injury mechanisms; minor nonfatal injuries were more common in children and adolescents. The differences in the severity and extent of the injuries suggested that injury interventions in Chinese children and adolescents still have a long way to go.

Background

Children and adolescents are high-risk groups and key populations for injury prevention. In recent years, the global injury mortality rate of children has declined overall, but the phenomenon of inequality in injury mortality between high-income countries (HICs) and lower-middle- and upper-middle-income countries (LMICs) has expanded. Road traffic injuries were the leading cause of child deaths worldwide, followed by drowning. According to China's monitoring data for 2014, the death rate for children and adolescents aged 0~17 was 22.90/100,000. Approximately 65,000 children died from injuries each year. Injury was the leading cause of death for children aged 1~17. Approximately 140,000 children suffer from nonfatal injuries; the main cause of death among Chinese children and adolescents is drowning and road traffic injuries. The injury mortality rate or incidence rate, mechanism of occurrence, and injury patterns of different countries, regions and data sources vary widely.
Although mortality is often used as a criterion for understanding the severity level of an injury, this approach represents an “iceberg” effect for injury. The severity of an injury may vary depending on the injury mechanism, demographic characteristics, and prognosis, so it is not possible to fully understand injury status through mortality or a single source of injury statistics\[^8\]. The bottom of the injury pyramid includes the injury cases seen in outpatient/emergency departments, injury hospitalizations, and injury deaths. Depicting the “injury pyramid” can help us understand and grasp the whole picture of the injury. Lee\[^9\] described the injury pyramid ratio for children and adolescents living in Massachusetts in the United States as 1:36:1014. The injury pyramid ratio among South Korean teenagers (13–18 years old) was 1:162:492\[^10\]. The unintentional injury pyramid ratio in South Korea was 1:54:231\[^8\]. The injury pyramid ratio of the Missouri and Nebraska population of the United States was 1:10:147\[^11\]. Based on family surveys, the injury pyramid ratio in Iran was 1:50:646\[^12\]. The injury pyramid ratio varies among different countries, regions, and populations. In some areas of China, research on the injury pyramids of the whole population has been carried out\[^13,14\], but to date, there have been no reports on the injury pyramid for Chinese children and adolescents. The unclear spectra and severity of the injuries in the injury pyramids for Chinese children and adolescents prevent priority interventions.

The comprehensive use of injury information that integrates deaths, hospitalizations, and outpatient/emergency department visit can provide a reliable basis for the development of injury prevention strategies. Zhuhai City, one of the monitoring points of the Chinese National Injury Surveillance System (NISS), is one of the core cities in the Greater Bay Area of Guangdong, Hong Kong and Macau, and one of the leading frontier cities in China's globalization process. Continuous and systematic collection of injury-related information and standardized comprehensive injury monitoring databases have resulted in the accumulation of authoritative, valuable first-hand data for the analysis of injury spectra and pyramids for Chinese children and adolescents.

### Methods

**Data collection**

The period for obtaining data was from January 1st, 2013, to December 31st, 2017.

**Outpatient/Emergency Departments** Injured patients aged 0~17 years who first visited an outpatient/emergency department in one of the three injury monitoring hospitals in Zhuhai City were selected as subjects. The personal information of the injured patient, the basic situation of the injury event, and the clinical information related to the injuries were derived from the NISS.

**Hospitalization** The inpatients who were 0~17 years old, had experienced their first hospitalization because of injuries and were diagnosed with an injury (indicated by an external cause code of V01-Y98) according to The International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) were selected as subjects. The data came from the Medical Information Management Platform of Zhuhai City, which collected information such as personal information on inpatients and
clinical features of injuries. There were 24 monitoring hospitals covering all hospitals in the city with inpatient treatment wards.

The external causes of injuries and the corresponding ICD-10 code were as follows: road traffic injuries (V01-V89); falls (W00-W19); bruise/crush/glass or knife cut/machine accident (W20-W31); foreign matter entering the eye or other cavity/cutting and puncture device injuries (W41-W49); boxing and punching injuries in sports (W50- W52); animal bites (W53-W59); drowning (W65-W74); asphyxiation (W75-W84); fires and burns (X00-X19); poisoning (X20-X29,X40-X49); overwork/travel and poverty (X50- X57); self-harm/suicide (X60-X84); harm by others (X85-Y09); drug reaction/medical accident/surgery and medical complications (Y40-Y84); and others (W32-W40, W60, W64, W85-W99, V90-V99, X30-X39, X58-X59, Y10-Y34, Y35-Y36, Y85-Y89,Y90-Y98).

**Death** The death data came from the Chinese national population death information registration management system. According to their current address, all the children and adolescents aged 0-17 who died from injuries (root causes of death code V01-Y98) in the resident population were identified. The data collected by this registry system included the personal information of the deceased, the place of death, and the basis causes of disease diagnosis.

**Population data** The population data from residents 0 to 17 years old from 2013 to 2017 were derived from the basic information system in the Chinese disease prevention information control system. In the resident population data, there was a specific value for every 1 year of age between 0 and 9 years, but summations were provided for the children/adolescents aged 10 to 14 and 15 to 19 years old. We divided the population of subjects aged 10 to 14 years old and 15 to 19 years old evenly and added them to the specific populations of other age groups to calculate the population numbers for the subjects aged 6 to 11 years, 12 to 14 years and 15 to 17 years (Table 1).

**Statistics**

According to the ratio of injury mechanisms, the children and adolescent injury spectra were calculated.

The injury pyramid was drawn as shown in the figure: A = incidence of inpatient injuries / injury mortality, which means that every injury death occurred accompanying A injury hospitalization cases; B = incidence of injuries in outpatient/emergency department visits / injury mortality, which represented every injury death that occurred accompanying B outpatient/emergency department injury cases (Figure 1).

Because the injury pyramid for drowning was in the shape of an inverted triangle, A = incidence of inpatient injuries / incidence of injuries in outpatient/emergency department visits, which means that every outpatient/emergency department visit was accompanied by A inpatient injuries; and B = injury mortality / incidence of injuries in outpatient/emergency department visits, indicating that each case of outpatient/emergency visit injury, there were B deaths.

**Statistical indicators**
Injury mortality (1 / 100,000) = total deaths (due to injury) in a certain period / number of resident population × 100,000 / 100,000.

Incidence of inpatient injuries1/100,000= number of inpatient injuries cases / number of resident population × 100,000 / 100,000. Because the current resident area was unknown for 1175 cases of hospitalized injuries, these cases were split evenly between the number of urban and rural hospitalizations for injuries to calculate the incidence of injury hospitalizations.

Incidence of outpatient/emergency department injury visits (1/100,000)= total number of outpatient emergency department injury visits (n / p) / number of resident population × 100,000 / 100,000.

\( p \): Using community survey results to estimate the probability that injury patients visit outpatient/emergency departments at NISS monitoring hospitals, based on the literature\(^{14} \), \( p =0.251 \). \( n \): Number of injury cases that saw a doctor at an outpatient/emergency department in an NISS monitoring hospital.

Statistical Package for the Social Sciences(19.0; IBM Corp Armonk, NY, USA) was used for statistical analysis.

**Results**

**Injury mechanism spectra**

The top three mechanisms for injuries in outpatient/emergency departments for children and adolescents were falls (52.02%), animal bites (14.57%), and blunt injuries (10.60%). The top three injury mechanisms for hospitalizations were falls (37.33%), road traffic injuries (17.87%), and fire/burns (14.29%), while the top three mechanisms for injury deaths were drowning (32.91%), road traffic injuries (20.25%) and falls (13.92%). In addition, cuts, poisoning, asphyxiation, self-harm/suicide and so on also had a large impact on the health of children and adolescents (Table 2).

Falls were the leading mechanism of outpatient/emergency department visits and hospitalizations for injured children and adolescents in urban and rural areas. Animal bites to children and adolescents in urban areas were a secondary mechanism of outpatient/emergency visits, while in rural areas, the secondary mechanism was road traffic injuries. Among the mechanisms of injury deaths, road traffic injuries ranked first in urban areas, while drowning ranked first in rural areas.

Among the mechanisms of injuries in outpatient/emergency department visits for boys and girls, the top two were falls and animal bites; blunt injuries accounted for the third mechanism for boys, and road traffic injuries accounted for the third mechanism for girls. Boys and girls had the same top five ranking injury mechanisms among injury hospitalizations. Among the mechanisms of injury deaths, drowning and road traffic injuries accounted for the first two for boys and girls, and the third ranking mechanisms were falls for boys and asphyxiation for girls.
Comparing the injury spectra of children and adolescents in different age groups, it was found that in the outpatient/emergency department visits, in addition to falls, which were the first ranking mechanism of injury in each age group, fires and burns for children aged 0 ~ 2 years old, animal bites among those ages 3-14 years, and blunt injuries among those ages 15-17 years old were the secondary injury mechanisms. Among injury hospitalizations, the top three ranking injury mechanisms in all age groups were falls, road traffic injuries, fires and burns (in different order). Regarding the injury death mechanisms, drowning ranked first for children and adolescents aged 0 to 11 years, the second mechanism of death for children aged 0 to 2 years was suffocation, and the second mechanism of death for children aged 3 to 11 years old was road traffic injuries. The first mechanism of injury death among children and adolescents aged 12 to 17 years was road traffic injury, the second was self-harm/suicide, and the third was drowning (Table 3).

**Injury pyramid**

The incidence rate of outpatient/emergency department injury visits for children and adolescents was 11210.87/100,000, the incidence rate of injury hospitalization was 627.09/100,000, and the injury death rate was 10.70/100,000. For each injury death, there were 59 hospitalized injuries and 1,047 outpatient/emergency visits for injuries. Injury mortality among children and adolescents from 2013 to 2017 ranked first among all causes of death from those aged 1 to 17 years old.

The injury pyramid ratios among children and adolescents in urban areas was 1:74:1618 (8.46/100,000: 624.68/100,000: 13,688.03/100,000), and among rural children and adolescents, the ratio was 1:46:593 (13.57/100,000: 630.16/100,000: 80504.49/100,000). The injury pyramid ratio among boys was 1:65:1116 (12.22/100,000: 790.77/100,000: 13,638.37/100,000), and among girls, the ratio was 1:48:933 (8.86/100,000: 428.08/100,000: 8259.64/100,000) (Figure 2).

The injury pyramid ratio was 1:39:753 (22.34/100,000: 867.94/100,000: 16820.13/100,000) among children aged 0 to 2 years, 1:55:1160 (16.43/100,000: 899.61/100,000: 19051.17/100,000) among children aged 3 to 5 years, 1:77:1397 (8.06/100,000: 622.70/100,000: 11257.02/100,000) among children aged 6 to 11 years, 1:70:1049 (6.95/100,000: 485.35/100,000: 7268.78/100,000) among children and adolescents aged 12 to 14 years, and 1:72:1007 (6.02/100,000: 43.51/100,000: 6055.17/100,000) among adolescents aged 15 to 17 years (Figure 3).

As for falls, the injury pyramid ratio was 1:105:2609 (2.24/100,000: 234.12/100,000: 5832.28/100,000). The injury pyramid ratio for road traffic injuries was 1:17:149 (6.57/100,000: 111.77/100,000: 981.31/100,000). The injury pyramid ratio for self-harm/suicide was 1:1.2:10 (1.69/100,000: 2.03/100,000: 16.46/100,000).

The injury pyramid for drowning was in the shape of an inverted triangle, with an injury mortality rate of 10.30/100,000, an incidence of injury hospitalizations of 2.51/100,000, and an outpatient/emergency injury visit rate of 1.89/100,000; each outpatient/emergency injury visit that occurred was accompanied by 1.3 injury hospitalizations and 5 injury deaths (Figure 4).
Discussion

The average injury mortality rate of children and adolescents in Zhuhai City from 2013 to 2017 was 10.70/100,000, which was lower than the global population mortality rate (66.90/100,000) \cite{15} higher than the HIC children and adolescents injury mortality rate (7.70/100,000), and lower than the injury mortality rate of LMIC children and adolescents (37.20/100,000) \cite{16}; while the average injury mortality rate of children and adolescents in Zhuhai City was also lower than the total injury mortality rate of children aged 0–17 in China in 2014 (22.90/100,000) \cite{4}, and lower than the injury death rate of the entire population in Guangdong Province in 2015 (43.11/100,000) \cite{17}, injury also ranked first among all causes of death among children and adolescents aged 1–17.

Drowning and road traffic injuries were the main causes of death among children and adolescents in Zhuhai City, which is consistent with the major causes of death among children in China \cite{18}. Road traffic injuries are the leading cause of child injury deaths worldwide, followed by drowning \cite{3}. The main causes of child injury deaths in the United States were road traffic injuries and firearm injuries. There are differences in injury mortality patterns in different countries and regions.

Drowning is one of the leading causes of death among children aged 5 to 14 years old in China \cite{19}. The average drowning mortality of children and adolescents in Zhuhai was 10.30/100,000, which was higher than the national average mortality (7.46/100,000) in China \cite{4}. Drowning in Malaysia was estimated at 5 per 100,000 people, including nondeath cases \cite{20}. The overall drowning mortality rate in Nepal was 1.90 per 100,000, but 53.00% occurred in people under 20 years old, and most drowning occurred in rivers (natural bodies of water) \cite{21}. Drowning ranked first in injury deaths among children and adolescents in rural areas in Zhuhai City. Drowning is closely related to temperature, environmental risks, and water-related risk activities \cite{22}, especially in rural areas of Zhuhai, where there are many rivers and ponds. In addition, the factor of high temperatures lasting longer during the year was related to children and adolescents' tendency to swim in natural water.

The average death rate attributable to road traffic injuries for children and adolescents in Zhuhai was 6.57/100,000, which was slightly lower than the national death rate of road traffic injuries for children and adolescents (6.66/100,000) \cite{4}. From 1991 to 2015, the death rate attributable to road traffic injuries among children and adolescents aged 1 to 14 years in Ireland decreased from 2.10/100,000 to 0.32/100,000 \cite{23}. From 2006 to 2012, the incidence of road traffic injuries in Canadian children was 70.91/100,000, and the hospitalization rate for injuries decreased from 85.51/100,000 to 58.77/100,000 \cite{24}. With the implementation of the global "traffic safety promotion", the use of seat belts and appropriate child safety seats has steadily increased, and the production of safer cars, better road construction, and increased public awareness of driving risk behaviors have reduced road traffic injuries among children and adolescents \cite{25,26}. Although road traffic injuries for children and adolescents in Zhuhai City were slightly lower than the mortality rate for children and adolescents in China, road traffic
injuries were still the main cause of death, hospitalization and outpatient/emergency department visits, and there is still much more space for improvement.

The global burden of disease estimates indicate that 172 million falls result in short-term or long-term disability annually[27]. A cohort study in Brazil found that falls were the most commonly reported injuries in all age groups among children[28]. Falls among children and adolescents in Zhuhai City were the main reason for hospitalization and outpatient/emergency department visits. A large household survey covering more than one million people in Bangladesh in 2013 found that nonfatal falls were the most common injuries[29].

Animal bites were one of the main reasons for children and adolescents to visit the outpatient/emergency department for injuries. A study showed that the incidence of animal bites in China was 245.05 per 100,000 in 2016[30]. Although animal bites are mostly minor injuries, as more and more pets enter the family, the problems caused by animal bites could not be ignored; this is especially true for dog bites as they are prone to rabies, and the potential harm is greater.

A multicountry survey of children aged 14–17 years found that 8.90% of girls and 2.60% of boys reported self-harm incidents in the past year[31]. Studies by Muehlenkamp[32] and Swannell[33] showed that self-harm/suicide behavior was prevalent in adolescents in clinical and community samples. The suicide mortality rate of children and adolescents in Zhuhai City was 1.69/100,000. Most of them were older children aged \( \geq \) 12 years, and the suicidal tendency increased with age. The self-harm/suicide rates of children and adolescents are rising in many high-income countries[34,35,36]. The development trajectory, cultural background, risk factors and mechanisms, and independent diagnosis of self-harm/suicide among children and adolescents in China will be the focus of future research.

Studies in several countries have shown that rural children and adolescents have higher injury mortality rates than urban children[37,38]. Rural children and adolescents in Zhuhai had an injury mortality rate of 13.57 per 100,000, which was 1.60 times that of urban areas. Road traffic injuries were the leading cause of injury deaths among children and adolescents in urban areas and drowning injuries were the leading cause of injury deaths among children and in rural areas. These urban-rural differences could be caused by environmental factors, residents' behavioral factors, different infrastructure investments, and differences in access to emergency medical services[39].

The mechanisms of injury deaths, injury hospitalizations, and outpatient/emergency department injury visits showed obvious age characteristics, and there were differences in the injury spectra at different stages of child development. A study in the United States showed that drowning was the most common cause of death for children aged 1 to 4 years, and the causes of death from injuries among those aged 10 to 19 years was mainly road traffic injuries, firearm injuries and suffocation[40]. The main mechanisms of injury hospitalizations for children aged 0–16 years in Australia were violence, poisoning, burns and road traffic injuries[41]. Falls were the most common mechanisms of nonfatal injuries to children in Nepal, followed by burns in preschool children, and road traffic injuries were the most likely mechanisms of
injury during adolescence\textsuperscript{[42]}. For outpatient/emergency department injury visits and injury hospitalizations, falls were the leading cause of injury for all age groups in Zhuhai City. Children in the younger age group had more outpatient/emergency department visits because of burns and animal bites. In the older age group, there were more blunt injuries and cuts. Drowning was the main cause of injury death among young children, and road traffic injuries were the main cause of injury death among children and adolescents in older age groups.

As a model for injury research, the injury pyramid can visually show the relative effects of fatal and nonfatal injuries\textsuperscript{[43]}. This study showed that, for every injury death among children and adolescents in Zhuhai, there were 59 injury hospitalizations and 1,047 outpatient/emergency department visits for injuries. Similar to the injury pyramid (1: 36: 1014) described by Lee\textsuperscript{[9]} for children and adolescents ≤ 19 years old living in Massachusetts, USA, Ballesteros\textsuperscript{[44]} also found that every injury death among children in the United States was accompanied by approximately 1,000 injury-related outpatient/emergency department visits. Compared with the injury pyramid for South Korean adolescents (1: 162: 492)\textsuperscript{[10]}, for every injury death, the percentage of injury hospitalizations of children and adolescents in Zhuhai City was small, while the proportion of outpatient/emergency department visits was high. This difference may be due to different medical guarantees in different countries, and China may have a relatively heavy burden of hospitalization costs, which limits hospitalizations. In addition, the severity of the injury and the timeliness of treatment can also affect hospitalizations.

Compared with the whole population injury pyramid, the rate of outpatient/emergency department injury visits among children and adolescents was greater. The injury pyramid ratio for unintentional injuries among the entire South Korean population was 1: 54: 231\textsuperscript{[8]}. The injury pyramid ratio in the entire population in Missouri and Nebraska was 1: 10: 147\textsuperscript{[11]}. The injury pyramid ratio Iran, based on a household survey, was 1: 50: 646 (deaths / hospitalizations / all injuries)\textsuperscript{[12]}. Studies in the same country still showed a higher rate of injury among children and adolescents seen in the outpatient/emergency departments. For example, the injury pyramid ratio for children who were ≤ 10 years old and came from Alberta, Canada, was 1: 73: 1612\textsuperscript{[45]}, and the injury pyramid ratio for children who were ≥ 12 years old and came from Ontario, Canada, was 1: 25: 363\textsuperscript{[46]}. Fatal injuries were at the top of the injury pyramid, but minor nonfatal injuries were more common in children and adolescents than adults, and the burden of minor nonfatal injuries cannot be ignored.

This study showed that rural children and adolescents had higher injury mortality rates than urban children and adolescents, while the incidence of outpatient/emergency department visits for injuries was higher in urban areas than in rural areas. Compared to the urban injury pyramid (1: 74: 1618), the rural injury pyramid has a narrower shape (1: 46: 593), which was related to the difference between injury-related death rates, hospitalization rates, and injury mechanisms in urban and rural areas. Incidence/mortality was higher at all levels in boys than in girls. The frequency of fatal and nonfatal injuries was higher in males than in females. Research in South Korea found that the injury pyramid of children and adolescents aged 0 to 6 years (1: 151: 3657), 7 to 12 years (1: 280: 3011), and 13 to
18 years (1: 132: 594) showed that the younger the age, the wider the bottom of the pyramid. This study showed that the bottom of the injury pyramid was the widest among participants aged 6 to 11 years; with each injury death that occurred, there were the most injury hospitalizations and outpatient/emergency department injury visits. The highest injury mortality was observed in children aged 0 to 2 years, and this injury pyramid had the narrowest bottom (1: 39: 753). The rest of the children aged 3 to 5 years (1: 55: 1160), 12 to 14 years (1: 70: 1049), and 15 to 17 years (1: 72: 1007) had similar pyramid shapes. Injuries were more lethal to children in younger age groups.

Wadman MC proposed 3 types of pyramids (A / B / C) based on different lethalities. The ratio of injury pyramid of self-harm/suicide among South Korean youth was 1:7:15, showing a steep pyramid (type C); this was similar to the injury pyramid of self-harm/suicide among children and adolescents in Zhuhai City (1:1.2:10), indicating that self-harm/suicide had considerable lethality. The drowning injury pyramid was in the shape of an inverted triangle, indicating that, for every outpatient/emergency department injury visit that occurred; there were 1.3 injury hospitalizations and 5 injury deaths. It was observed that self-harm/suicide and drowning had a very high mortality rate, but the number of outpatient/emergency department visits for this mechanism was very small, resulting in a steep and narrow pyramid.

The mortality rate of road traffic injuries among South Korean youth was 3.00 / 100,000, with an injury pyramid ratio of 1:195:341. The death rate of road traffic injuries for children and adolescents in Zhuhai was 6.57 / 100,000, and the injury pyramid ratio was 1: 17: 149. The shape of the injury pyramid for road traffic injuries was type A, indicating that the mortality rate was low, but the degree of injury was high. Type A injury pyramids have a cumulative effect on the use and cost of the medical system that is far greater than type C. The injury pyramid ratio for falls among children and adolescents in Zhuhai was 1:105:2609. Falls had a low mortality rate, but the outpatient/emergency department visits were large in scale, forming a type B pyramid. An injury mechanism with high lethality can reduce the occurrence of the injury itself through primary prevention; however, although the fatality rate of falls was very low, the scale of occurrence was large, and the consumption of medical resources may be more serious.

Limitations

The injury hospitalization data used in this study were derived from a medical information management platform. However, due to a problem with platform integration, only 6 medical institutions were included in 2013; this number increased year by year until it reached 24 included institutions in 2017 (basically covering all medical institutions with the ability to treat injuries). Therefore, the incidence of injury hospitalizations may be underestimated. In addition, there was a lack of information on some subjects’ current addresses, and the urban or rural area residence of some subjects could not be determined. The incidence of outpatient/emergency department injury visits was estimated based on the results of community surveys in the literature; these estimation methods may make the estimation efficiency low.
Most minor injuries were difficult to estimate because they did not seek health care services. In addition, there may be injury sequelae among survivors of severe injuries, leading to even more important estimates of disability levels. Ideally, the injury pyramid should include untreated cases and injuries caused by disability, which is also a direction for future efforts.

**Conclusions**

The injury spectra were different among outpatient/emergency department visits, hospitalizations, and death among children and adolescents. Falls, animal bites, road traffic injuries, fires and burns were the main injuries which children and adolescents sought medical treatment; drowning and road traffic injuries were the main causes of injury deaths. The sexes have different injury spectra at different stages of child development, and interventions should be formulated accordingly.

For every case of injury death among children and adolescents, there were nearly 60 hospitalized injuries and thousands of injury-related outpatient/emergency department visits. Minor nonfatal injuries were more common in children and adolescents. The size and shape of the injury pyramid varied by age, sex, and region; that is, there were differences in the severity and extent of the injuries. The injury pyramids suggested that self-harm/suicide and drowning had a very high mortality rate. Road traffic injuries had a low mortality rate and a high degree of injury; falls had a low mortality rate, but the scale of outpatient/emergency visits was large.

**Abbreviations**

HIC: High-income countries; LMIC: Lower-middle- and Upper-middle-income countries; NISS: National Injury Surveillance System.

**Declarations**

**Ethics approval and consent to participate**

This study protocol had been approved by the Ethics Committee of Center for Disease Control and Prevention in Zhuhai, and followed the tenets of the Declaration of Helsinki.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets generated or analysed during the current study are available from the corresponding author on reasonable request.

**Competing Interests**
The authors declare no conflict of interest.

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Authors Contributions

Dr. Yin XL conducted the data analysis, and drafted and revised the manuscript. Mr. Dai WC collected the data and critically reviewed the manuscript. Dr. Du YK reviewed the manuscript. Dr. Li DY conceived and designed the study, directed the statistical analysis. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Tables

Table 1 Number of residents aged 0-17 in Zhuhai City, 2013 ~ 2017.

| Years | Male | Female | Urban | Rural | 0~2 | 3~5 | 6~11 | 12~14 | 15~17 | Total |
|-------|------|--------|-------|-------|-----|-----|------|-------|-------|-------|
| 2013  | 156000 | 132045 | 165540 | 122505 | 44367 | 36315 | 84196 | 44647 | 78520 | 288045 |
| 2014  | 155127 | 133815 | 166034 | 122908 | 44505 | 36415 | 84444 | 44774 | 78804 | 288942 |
| 2015  | 162682 | 128763 | 167556 | 123889 | 44894 | 36783 | 85243 | 45223 | 79302 | 291445 |
| 2016  | 159388 | 136586 | 170113 | 125861 | 45170 | 37394 | 86700 | 45976 | 80734 | 295974 |
| 2017  | 176769 | 135017 | 158304 | 153482 | 49305 | 53957 | 93816 | 49727 | 64981 | 311786 |
| Rank | Injury mechanism          | N (%)       | Injury mechanism          | N (%)       | Injury mechanism          | N (%)       |
|------|---------------------------|-------------|---------------------------|-------------|---------------------------|-------------|
| 1    | Falls                     | 21610(52.02)| Falls                     | 3456(37.33) | Drowning                  | 52(32.91)   |
|      | Animal bites              | 6051(14.57) | Road traffic injuries     | 1654(17.87) | Road traffic injuries     | 32(20.25)   |
| 2    | Blunt injuries            | 4403(10.60) | Fires and burns           | 1323(14.29) | Falls                     | 22(13.92)   |
| 3    | Road traffic injuries     | 3636(8.75)  | Bruise/crush/glass or knife cut/machine accident | 974(10.52) | Asphyxiation              | 17(10.76)   |
| 4    | Cuts                      | 2566(6.18)  | Poisoning                 | 394(4.26)   | Self-harm/suicide         | 12(7.59)    |
| 5    | Fires and burns           | 2309(5.56)  | Foreign matter entering the eye or other cavity/cutting and puncture device injuries | 359(3.88)   | Poisoning                 | 8(5.06)     |
| 6    | Poisoning                 | 159(0.38)   | Overwork/travel and poverty | 268(2.90)   | Harm by others            | 5(3.16)     |
| 7    | Firearm injuries          | 8(0.02)     | Harm by others            | 159(1.72)   | Fires and burns           | 3(1.90)     |
| 8    | Drowning                  | 7(0.02)     | Boxing and punching injuries in sports | 156(1.69)   | Others                    | 7(4.43)     |
| 9    | Asphyxiation/Hanging      | 5(0.01)     | Drug reaction/medical accident/surgery and medical complications | 138(1.49)   | /                         | /           |
| 10   |                           | /           |                           | /           |                           | /           |
| 11   | Sexual assault            | 3(0.01)     | Asphyxiation/Hanging      | 77(0.83)    | /                         | /           |
| 12   | Others                    | 782(1.88)   | Drowning                  | 37(0.40)    | /                         | /           |
| 13   | /                         | /           | Animal bites              | 33(0.36)    | /                         | /           |
| 14   | /                         | /           | Self-harm/suicide         | 30(0.32)    | /                         | /           |
| 15   | /                         | /           | Others                    | 199(2.15)   | /                         | /           |
|      |                           | /           |                           | 41539(100.00) | /                         | 9257(100.00) |
|      |                           |             |                           |             |                           | 158(100.00) |
Table 3 Injury mechanism spectra among different regions, sexes, and age groups of children and adolescents in Zhuhai City, China.

| Rank | Region       | Injury mechanism | Outpatient / emergency department visits % | Injury mechanism | Hospitalizations % | Injury mechanism | Deaths % |
|------|--------------|------------------|------------------------------------------|-----------------|-------------------|-----------------|----------|
|      |              |                  | Inpatient and emergency department visits |                  |                   |                 |          |
| 1    | Urban        | Falls            | 56.12                                    | Falls           | 42.69             | Road traffic injuries | 20.00    |
|      |              | Animal bites     | 16.32                                    | Road traffic injuries | 15.12            | Falls           | 18.57    |
|      |              | Blunt injuries   | 8.76                                     | Fires and burns | 12.44             | Drowning        | 17.14    |
|      |              | Cuts             | 6.36                                     | Bruise/crush/glass or knife cut/machine accident | 10.89            | Asphyxiation | 15.71    |
|      |              | Road traffic injuries | 5.31                                  | Overwork/travel and poverty | 4.26            | Self-harm/suicide | 7.14     |
| 2    | Rural        | Falls            | 43.14                                    | Falls           | 29.86             | Drowning        | 45.45    |
|      |              | Road traffic injuries | 16.23                                  | Road traffic injuries | 20.74            | Road traffic injuries | 20.45    |
|      |              | Blunt injuries   | 14.58                                    | Fires and burns | 16.46             | Falls           | 10.23    |
|      |              | Animal bites     | 10.77                                    | Bruise/crush/glass or knife cut/machine accident | 10.51            | Self-harm/suicide | 7.95     |
|      |              | Fires and burns  | 6.97                                     | Poisoning       | 7.74              | Asphyxiation     | 6.82     |
| 3    | Male         | Falls            | 52.92                                    | Falls           | 36.64             | Drowning        | 35.35    |
|      |              | Animal bites     | 12.75                                    | Road traffic injuries | 17.81            | Road traffic injuries | 19.19    |
|      |              | Blunt injuries   | 11.78                                    | Fires and burns | 14.36             | Falls           | 16.16    |
|      |              | Road traffic injuries | 8.72                                  | Bruise/crush/glass or knife cut/machine accident | 10.65            | Asphyxiation | 9.09     |
|      |              | Cuts             | 6.69                                     | Poisoning       | 4.20              | Self-harm/suicide | 8.08     |
| 4    | Female       | Falls            | 50.22                                    | Falls           | 38.88             | Drowning        | 28.81    |
|      |              | Animal bites     | 18.22                                    | Road traffic injuries | 17.99            | Road traffic injuries | 22.03    |
|      |              | Blunt injuries   | 11.78                                    | Fires and burns | 14.13             | Asphyxiation     | 13.56    |
|      |              | Road traffic injuries | 8.72                                  | Bruise/crush/glass or knife cut/machine accident | 10.24            | Falls           | 10.17    |
|      |              | Fires and burns  | 6.89                                     | Poisoning       | 4.38              | Harm by others  | 6.78     |
| 5    | Age group, years old | Falls | 57.05                                    | Falls           | 43.51             | Drowning        | 43.14    |
| 0~2  |              | Fires and burns  | 14.00                                    | Road traffic injuries | 17.31            | Asphyxiation     | 25.49    |
|      |              | Animal bites     | 9.16                                     | Fires and burns | 12.72             | Falls           | 11.76    |
|      |              | Blunt injuries   | 7.85                                     | Bruise/crush/glass or knife cut/machine accident | 9.99             | Road traffic injuries | 7.84     |
|      |              | Road traffic injuries | 4.69                                  | Overwork/travel and poverty | 3.03            | Harm by others  | 3.92     |
| 3~5  |              | Falls            | 58.73                                    | Falls           | 35.53             | Drowning        | 33.33    |
|      |              | Animal bites     | 13.03                                    | Fires and burns | 17.16             | Road traffic injuries | 27.27    |
|      |              | Blunt injuries   | 8.93                                     | Road traffic injuries | 16.82            | Falls           | 24.24    |
|      |              | Road traffic injuries | 8.77                                  | Bruise/crush/glass or knife cut/machine accident | 10.74            | Asphyxiation | 9.09     |
|      |              | Cuts             | 4.23                                     | Poisoning       | 4.48              | Others          | 6.07     |
| 6~11 |              | Falls            | 51.15                                    | Falls           | 33.20             | Drowning        | 28.57    |
|      |              | Animal bites     | 20.64                                    | Road traffic injuries | 18.34            | Road traffic injuries | 17.14    |
|      |              | Blunt injuries   | 10.06                                    | Fires and burns | 14.86             | Falls           | 17.14    |
|      |              | Road traffic injuries | 8.07                                  | Bruise/crush/glass or knife cut/machine accident | 10.54            | Poisoning | 14.29    |
|      |              | Cuts             | 6.02                                     | Poisoning       | 5.32              | Fires and burns | 5.71     |
| 12~14|              | Falls            | 48.87                                    | Falls           | 36.94             | Road traffic injuries | 31.25    |
|      |              | Animal bites     | 16.24                                    | Road traffic injuries | 19.50            | Self-harm/suicide | 31.25    |
### Figures

**Figure 1**

Schematic diagram of the injury pyramid
Figure 2

Injury pyramids of children and adolescents in Zhuhai City, China

Figure 3
Figure 4

Injury pyramids among key types of injuries of children and adolescents in Zhuhai City, China. Note: The scale for falls was 300, and the remaining scales were 20. The shape of the pyramid for drowning was an inverted triangle. The figure shows that, for each patient who visited outpatient/emergency departments because of drowning, there were 1.3 hospitalizations and 5 deaths.