Trends and seasonality in cause-specific mortality among children under 15 years in Guangzhou, China, 2008-2018

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Abstract

**Background:** This study analyzed the trends and seasonality in mortality among children aged 0-14 years in Guangzhou, China during 2008-2018. Understanding the epidemiology of this public health problem can guide policy development for children mortality prevention.

**Methods:** A population-based epidemiological retrospective study was conducted. 7,265 individual data of children mortality were obtained from the Guangzhou Centre for Disease Control and Prevention. The Poisson regression was used to quantify the annual average reduction rate and the difference in mortality rate between gender and age groups. Incidence ratios with 95% confidence intervals (CI) were calculated to determine the ratio of the observed number of deaths to the expected deaths (i.e. the average assuming no variations) by month, season, school term, weeks and holidays deaths.

**Results:** Between 2008 and 2018, the children mortality rate in Guangzhou decreased from 54.0 to 34.3 per 100,000 children, with an annual reduction rate of 4.6% (95%CI: 1.1%-8.1%), especially the under-5 mortality rate decreased by 8.3% (95%CI: 4.8%-11.6%) per year. The decline trend varied by causes of death, even with an upward trend for the mortality of asphyxia and neurological diseases. The risk of death among male children was 1.78 times (95%CI: 1.61-1.98) that of females. The distribution of causes of death differed by age groups. Maternal and perinatal, congenital and pneumonia were the top three causes of death in infants and cancer
accounted for 17% of deaths in children aged 1-14 years. Moreover, the injury-related mortality showed significant temporal variations with higher risk during the weekend.

And there was a summer peak for drowning and a winter peak for asphyxia.

**Conclusions:** Guangzhou has made considerable progress in reducing mortality over the last decade. The findings of characteristics of children mortality would provide important information for the development and implementation of integrated interventions targeted specific age groups and causes of death.

**Keywords:** Mortality, Seasonality, Children, China, Poisson model
Background

Prevention of child deaths is a key target for public health policy intervention at the national and international level, and child mortality is a widely used indicator of economic and social development [1]. In 2018, there were approximately 5.3 million deaths among children under 5 years of age and 0.9 million deaths among children aged 5–14 years globally [2]. The global under-5 mortality rate decreased by 82% from 216.0 deaths in 1950 to 38.9 deaths per 1000 live births in 2017 [3], and this number declined from 50.8 to to 10.7 in China between 1996 and 2015, with an average annual rate of reduction of 8.2% [4]. However, the World Health Organization (WHO) reported that the annual mortality reduction rate since 2000 was lower among children aged 5–14 years compared with under-5 children (2.7% vs 4.0%) [5]. The deaths at the age of 5-14 are predominantly from avoidable causes [5] but have largely been ignored by the global health community. The children at this stage of life undergo rapid developments which have major health consequences over the lifetime. It is suggested that some relevant global health targets, including the 2030 UN Sustainable Development Goals (SDGs), need to consider children up to age 15 years and not only younger than 5 years [6]. This consideration would require better understanding the characteristics of mortality in children aged 5–14 years. However, most of the mortality data published were obtained from disease surveillance points or estimated from mathematical models rather than the whole population.
The Global Burden of Disease (GBD) Study 2016 accounted for more than 3 million deaths to unintentional injury in 2015 with nearly 20% of them in children under the age of 15. This amounts to 10% of the world’s children mortality in 2015 [7]. Approximately 90% of injury, mainly resulting from transport accidents, drowning, and asphyxia, is unintentional and can be prevented and controlled [8]. Previous studies showed children injury mortality may vary seasonally. Shinsugi et al. [9] observed a summer peak for transport accidents and drowning mortality and more deaths in winter for asphyxia in Japanese children. However, few recent and comprehensive studies have examined the differences in under-15 children mortality by day of the week, school term and holidays. It is of great importance to understand thoroughly the temporal patterns of children's injury mortality for injury prevention.

The distribution of the causes of children death is influenced by the development of the social economy and healthcare [10]. Guangzhou, one of the fastest-growing economies in China, is currently experiencing the most rapid developments in the economy and healthcare. This offers us an opportunity to determine the potential changes in the epidemiology of children deaths over time. This study aimed to examine under-15 children mortality by cause, year, gender and age group in Guangzhou during the period of 2008-2018 and to particularly elucidate the seasonal variations of injury-related deaths.
Methods

Data sources

In Guangzhou, all deaths are compulsorily registered and recorded in the mortality dataset by the Guangzhou Centre for Disease Control and Prevention. We obtained individual death data for the entire population of Guangzhou during 2008-2018, including gender, date of birth, date of death and cause of death. The data of children mortality were divided into four age groups: <1 year, 1-4 years, 5-9 years and 10-14 years. Categorization of the causes of death followed the tenth version of International Categorization of Diseases (ICD-10). Causes of death were divided into four broad categories, including communicable, maternal, neonatal, and nutritional diseases (CMNN), non-communicable diseases (NCDs), injury and the ill-defined. Then, 24 subclasses were considered (see Additional file 1). The ill-defined proportion can be used as a measure of data quality.

Statistical analysis

Annual mortality rate per 100,000 children was calculated for all children and specific age group and gender, using the corresponding census population as the denominator. The average annual rate of reduction (AARR) in the mortality and 95% confidential intervals (CI) were calculated separately for males and females and for each age group using poisson regression analysis as follows:

\[
\log(\text{E}[\text{Death}_{ij}]) = \text{Offset}(\log(\text{Pop}_{ij})) + \beta_0 + \beta_1 * \text{Year}_i.
\]
where $Death_{ij}$ is annual number of gender- or age-standardized deaths for the jth group in the year $i$, $Pop_{ij}$ refers to the annual number of the population for the jth group in the year $i$, $\beta_{1j}$ is the estimation of the coefficient of variable $Year$ for the jth group.

Then, all data were combined and Poisson regression was used to examine the statistical significance of the differences in mortality rate between different gender and age groups, which was specified as

$$\log (E[Death_i]) = \text{Offset}(\log(Pop_i)) + \beta_0 + \beta_1 \times Year_i + \beta_2 \times Gender + \beta_3 \times Agegroup$$

where $Death_i$ is annual number of age- and gender-specific deaths in the year $i$. $Gender$ and $Agegroup$ are the categorical variables.

The stratified analysis for injury-related diseases by month, season, school term, weeks and holidays were conducted. Four seasons were spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Based on the school calendar announced by Department of Education of Guangdong Province and Guangzhou Municipality, the school term was defined as the autumn term, winter vacation, spring term, and summer vacation. The incidence ratio (IR), calculated by $\frac{\pi}{\pi_0}$, was used as a measure of variation in the number of injury deaths.
The calculation of 95%CI was based on a normal approximation as \( \pi/\pi_0 \pm 1.96\sqrt{\pi(1-\pi)/n/\pi_0} \), where \( \pi, \pi_0 \) is the observed and expected proportion (i.e. the average assuming no variations) of injury deaths in a specific time interval, respectively, and \( n \) is the total number of injury deaths for the entire study period [9, 11, 12].

All statistical analyses were completed in R 3.6.1. Statistical significance was set at \( p<0.05 \).

**Results**

A total of 7,265 children aged 0-14 years died during 2008-2018 among which 61% were males. There were 3,101 (42.68%) CMNN deaths, 2,990 (41.16%) NCDs deaths, 946 (13.02%) injury deaths and 228 (3.14%) ill-defined deaths. Figure 1 summarizes the proportion of the leading 10 causes of death by gender and age groups. The causes of death was very similar between males and females, except that males had a higher proportion of injuries than females. The distribution of the causes varied by age groups. The main causes of infant death was CMNN and NCDs, with nearly half from maternal and perinatal deaths and 21%-23% from the congenital diseases. NCDs was a dominant cause in other age groups, followed by injury. The main causes in 1-4 years of children were pneumonia, congenital, cancer, neurological and drowning, each accounting for 8%-13%. For children aged 5-14 years, the proportion of cancer
exceeded 20%, followed by neurological diseases and transport injuries for both males and females. The mortality rate of specific cause of death was shown in Additional file 2 and Additional file 3.

During the 11-year study period, the overall mortality rate declined from 54.0 per 100,000 children in 2008 to 34.3 per 100,000 children in 2018, with an average annual reduction of 4.6% (95%CI: 1.1%-8.1%). The four causes-of-death categories declined by 2.9%-14.9% although the reduction was non-significant for CMNN (Table 1). The mortality risk among males children was 1.78 times (95%CI: 1.61-1.98) as high as among females, while the declining trend in mortality was similar for males and females. Among four age groups, the infant death rate was the highest with 342.1 per 100,000 in 2018 in spite of an annual reduction of 9.3% over the last 11 years. An average annual reduction of 8.9% was also observed for 1-4 years, while a high peak occurred in 2014. The mortality risk was 40.94 times (95%CI: 34.22-49.37) for the infants and 2.61 times (95%CI: 2.13-3.21) for those aged 1-4 years, compared with the expected rate. For children aged 5-9 and 10-14 years, there was no obvious mortality reduction (Table 1, Figure 2).

Among 946 injury deaths, the three most common causes were drowning (25.26%), transport accident (24.95%) and asphyxia (21.35%). Figure 3 illustrates the temporal variations of injury deaths in multiple perspectives. Similar variations by day of the
week were observed in all injuries, drowning, and transport accident deaths, significantly higher on weekends particularly on Saturday than weekdays. For all-cause injury, the mortality was significantly lower during spring (IR: 0.82, 95%CI: 0.72–0.92), and higher during summer (IR: 1.23, 95%CI: 1.11–1.35). An August peak (IR: 1.48, 95%CI: 1.23–1.74) and a lower peak in April, May, and November were observed. The drowning risk was double during July and August with 35.56% of drowning deaths. Consistently, a highest risk during summer vacation was observed (IR: 1.84, 95%CI: 1.55–2.14). In contrast, the risk was significantly lower in March, April, November, and December. Transport accident deaths and asphyxia deaths presented less seasonal variations than drowning deaths. Neither showed variations in different school terms. The transport accident mortality was the lowest in June (IR: 0.62, 95%CI: 0.28–0.95). More asphyxia deaths happened in winter (IR: 1.32, 95%CI: 1.05–1.60), particularly in March (IR: 1.58, 95%CI: 1.01–2.15), while fewer in November and autumn.

**Discussion**

This study assessed the mortality rates in children under 15 years in Guangzhou, China during 2008-2018. We found that the mortality rates declined from 161.7 to 69.3 per 100,000 children for children aged under-5 years and from 1.8 to 0.8 per 1,000 children aged 5 for those aged 5-14 years. Meanwhile, the global under-5 mortality was 39 per 1,000 live births and 7.1 per 1,000 children aged 5 for children
aged 5-14 years in 2018. The low mortality rate in Guangzhou could be attributable to the socioeconomic development and the implementation of life-saving interventions, such as health education [4, 13]. In accordant with a multi-nation study [6], we found that the children mortality rates were greater in males than in females for all of the four causes-of-death categories. One possible reason was that males generally were more likely to engage in more high risk-taking behaviors [14].

In this study, a considerable decline was observed in the mortality rate of children aged under 5 years, which could benefit from the improvement of health services for children [2]. For those aged 5-14 years, reductions in mortality could be accelerated with efforts such as improving school meals, safety and healthy lifestyle education [5]. We found the mortality of children aged 10-14 years was higher than that of those 5-9 years of age and almost remained unchanged over the study period, probably because most of the public health interventions aiming at improving the health of children under 5 years may be beneficial for those 5-9 years of age, with smaller spillover effects to 10-14 age group [15].

Prevention interventions targeting specific age groups are required since the distribution of causes of death varied across age groups [16]. We found that the maternal and perinatal diseases accounted for the largest proportion of infant deaths, followed by congenital diseases. More attention should be paid to the primary and
secondary prevention measures, including antenatal corticosteroids and kangaroo mother care, for preterm birth complications, a major part of maternal and perinatal diseases [17]. In addition, pregnancy at an appropriate age and the prenatal diagnosis are suggested to reduce the occurrence of congenital heart disease [16, 18, 19]. Our study indicated that the main causes of death for children aged 1-4 years were non-communicable diseases, while a national analysis reported injuries were the leading causes at this age group in China [4]. Different study periods or regional inequity in parental monitoring and child care could explain the disparity [20]. Cancer was the leading cause for children aged 5-14 years, most of which cannot be cured currently. This is why the mortality reduction was relatively low at this age group. More potentially curative treatments need to be explored in future studies [6].

Despite a continued reduction in children mortality, asphyxia-related mortality showed an overall upward trend throughout the study period. The key focus of preventative measures should be through training of the guardians on the prevention of food obstruction and bed suffocation to reduce the infant deaths of accidental asphyxia [16, 21, 22]. The death rates from neurological cause among children aged 5-14 years also increased during the study period, especially in females [6] and cardiovascular diseases have been on the rise in recent years. Efforts, such as enhanced monitoring and prevention measures, are needed to mitigate the burden.
This study showed great seasonal variations of injury mortality. The incidence of drowning deaths was higher in summer vacation than in spring and winter. It could be due to the more frequent swimming in rivers and the sea in summer which increased the risk of possible death [9]. Therefore, prevention measures such as wearing a personal floatation device, strengthening the supervision of children’s activities, and teaching survival swimming and resuscitation skills should be implemented to reduce the drowning mortality [23]. We found that asphyxia mortality of showed a higher risk in winter than in other seasons. The winter peak could be attributable to the common mother-infant bed sharing in cold weather [9].

Our findings also revealed that the drowning and transport accident deaths occurred more frequently on weekends than weekdays. This is most likely because children spend more time outside, playing on the road or swimming in a river on weekends and therefore the possibilities of drowning and transport accident deaths increased [9]. Another possible reason is related to the popularity of shared bicycles in Guangzhou and the absence of mandatory requirements of drivers' license or wearing helmet. The emergency system that deal with injuries should be strengthened during the weekends. WHO reported that children up to the age of 9 years are more likely to be accompanied by parents when they go out, while older children tend to be out more independently [20]. Therefore, for children under 9 years, the public education programs which enhance the parental monitoring might be an option for preventing injuries among younger children, meanwhile improving the child's safety awareness is
more important for children aged 10-14 years.

Our study has two strengths. First, we presented children mortality rates in Guangzhou based on the whole population data instead of sampling data, which avoided the problems of representativeness bias and low coverage rate. Second, we considered the temporal variations in cause-specific mortality rates at different time scales (e.g. month, school terms and day of the week), which have been seldom examined in previous studies.

Some limitations of our study should be mentioned. There were potential misclassification of the cause of death according to ICD-10. Although we examined four major cases-of-death categories and top 10 specific causes, we did not perform analysis for some uncommon causes by gender and age group due to the small number of deaths. Some individual and social factors, such as parental socioeconomic status, economy and growth environment, could influence the mortality risk. Further studies can be conducted to explore the impacts of these factors.

**Conclusions**

Between 2008 and 2018 in Guangzhou, the children mortality declined 4.6% annually, particularly with an annual reduction of 8.3% among under-5 children, while the
mortality unchanged among the children aged 10-14 years. The children mortality rate was higher among males and those under five years. Significant temporal variations were observed for injury-related mortality from drowning, transport accidents and asphyxia. The upward trend of mortality due to asphyxia, neurological and cardiovascular diseases strengthens the importance of monitoring and management for specific causes of death. The findings provide important information for the development and implementation of interventions targeting specific causes, seasons and age groups to reduce children mortality.

**List of abbreviations**

CI: Confidence Intervals; WHO: World Health Organization; SDGs: Sustainable Development Goals; GBD: Global Burden of Disease; ICD-10: the Tenth version of International Categorization of Diseases; CMNN: Communicable, Maternal, Neonatal, and Nutritional diseases; NCDs: Non-Communicable Diseases; AARR: Average Annual Rate of Reduction; IR: Incidence Ratio; DEI: Diabetes, Endocrine, and Immune disorders; MP: Maternal and Perinatal; M: Male; F: Female; RR: Relative Risk

**Declarations**

*Ethics approval and consent to participate*

The study proposal was approved by the Ethics Committee of Southern Medical
University, where this study was conducted. Informed consent was not required because Guangzhou Center for Disease Control and Prevention provided the de-identified children mortality data derived from the official death registration system.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The data that support the findings of this study are available from Guangzhou Center for Disease Control and Prevention but restrictions apply to the availability of these data, and so the data are not publicly available. Permission can be requested by contacting Guangzhou Center for Disease Control and Prevention.

**Competing interests**

The authors declare that they have no competing interests.

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Authors' contributions

XXH designed the study, conducted the data analyses, and drafted the manuscript. DH, LWH, LGZ lead the data collection. LL contributed to writing the paper and provided advice. OCQ initiated the study and provided technical support and guidance. All authors read and approved the final manuscript as submitted.

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Table 1 Mortality rates per 100,000 in children by age and gender groups in Guangzhou, China.

| Age (years) | All mortality in 2018 | AARR% (95% CI) |
|-------------|-----------------------|-----------------|
|             | ALL                   | CMNN            | NCDs            | Injury          | Ill-defined     |
| Total       | 34.3                  | 4.6 (1.1 to 8.1)| 2.9 (-0.9 to 6.4)| 5.6 (1.2 to 9.8)| 4.9 (0.8 to 8.9)| 14.9 (11.5 to 18.2) |
| <1          | 342.1                 | 9.3 (6.9 to 11.6)| 8.1 (5.7 to 10.3)| 10.8 (7.5 to 14.1)| 4.6 (-2.1 to 10.9)| 19.5 (16.0 to 22.9) |
| 1-4         | 18.2                  | 8.9 (4.9 to 12.8)| 6.5 (0.0 to 12.5)| 10.4 (5.9 to 14.7)| 6.8 (3.4 to 10.1)| 22.2 (15.3 to 29.0) |
| 5-9         | 8.7                   | 5.7 (3.3 to 8.0)| 3.4 (-3.3 to 9.5)| 4.3 (0.9 to 7.5)| 8.9 (4.7 to 13.0)| 18.5 (-3.2 to 38.0) |
| 10-14       | 10.5                  | 1.4 (-1.5 to 4.3)| 1.2 (-8.1 to 9.8)| -0.5 (-4.4 to 3.3)| 4.4 (-0.6 to 9.2)| -1.1 (-16.9 to 12.8) |

Gender

|             | ALL                   | CMNN            | NCDs            | Injury          | Ill-defined     |
|-------------|-----------------------|-----------------|-----------------|-----------------|-----------------|
| male        | 40.2                  | 7.6 (5.4 to 9.7)| 6.8 (4.3 to 9.3)| 8.1 (5.3 to 10.8)| 6.1 (2.9 to 9.2)| 17.6 (13.5 to 21.6) |
| female      | 27.5                  | 9.3 (7.3 to 11.2)| 8.9 (6.8 to 11.0)| 9.5 (6.6 to 12.4)| 6.4 (2.9 to 9.8)| 20.2 (13.0 to 27.3) |

CMNN, communicable, maternal, neonatal, and nutritional diseases; NCDs, non-communicable diseases; AARR, Average Annual Rate of Reduction; CI, confidence interval.
**Figure captions**

**Figure 1.** Proportion of the leading 10 causes of death by age and gender groups. NCDs: non-communicable diseases; DEI: Diabetes, Endocrine, and immune disorders; MP: maternal and perinatal; M: male; F: female. Only frequencies with a percentage greater than 5 are shown in the figure.

**Figure 2.** Trends of mortality rates (per 100,000 children) by age and gender groups, 2008-2018. Panel (a)-(d) show the mortality for children aged <1 year, 1-4 years, 5-9 years and 10-14 years, respectively.

**Figure 3.** Incidence ratio and 95% confidence interval of all injuries and three categories of injury-related death.
Additional file 1. International Classification of Diseases (ICD) coding ranges used to define specific methods of death in Guangzhou, 2008-2018.

Additional file 2. Leading causes of death for children by gender group in Guangzhou in 2018.

Additional file 3. Leading causes of death for children by age group in Guangzhou in 2018.