Changing Patterns in temporal trends of diabetes mortality in China from 1987-2020: a rapid growth among rural populations

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Research Article

Keywords: Diabetes mellitus mortality, Age–period–cohort model, China urban-rural difference, Trajectory

Posted Date: November 21st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2227986/v1

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Abstract

Diabetes mellitus (DM) is a public health challenge in China. Quantifying changes in DM mortality is of great significance, but related evidence of Chinese older adults is scarce. This study conducted a comprehensive analysis of China's DM mortality changing trajectory. The data from 1987 to 2020 was derived from the National Health Commission of China. Joinpoint analysis and age-period-cohort (APC) model were used to calculate the annual change and the effects of age, period and cohort on DM mortality. The changing trajectory from 1987 to 2020 showed an upward trend, especially among rural groups, and the gap between rural-urban narrowed. Joinpoint analysis showed a consistent upward trend in rural areas (4.9%, 95%CI: 4.0%-5.7%). However, the urban showed an upward trend from 1987–1998 (5.7%) and a slow downward trend from 1998 to 2020 (-1.0%). The APC model showed that the reporting rate increased with age in urban and rural areas. For the effect of time period and cohort, as they proceeded, the rural showed a consistent and significant upward trend, but the trends in urban remained relatively stable. The DM mortality in China has shown an overall upward trend over the past three decades, especially in rural areas. Although the gap between urban-rural has been further reduced, the burden of the oldest-old has risen significantly regardless of areas. It is time to give priority attention to the high mortality of DM among females, the elderly and rural areas, and the government should take measures to curb this trend.

Introduction

Diabetes mellitus (DM) is one of the fourth non-communicable diseases (NCDs), which accounts for 70% of global deaths, and the majority occur in older adults[1]. DM is mainly divided into type 1 and type 2 DM, which is characterized by hyperglycemia caused by defects in insulin secretion, insulin action, or both[2]. The chronic hyperglycemia of DM may lead to dysfunction, and failure of different organs, especially the eyes, kidneys, nerves, heart and blood vessels[3]. Furthermore, DM could increase the overall risk of premature. DM and its complications pose a global major threat.

The burden of mortality and disability rate caused by the epidemic of DM is still a severe public health issue, especially for the lower- and middle-income countries (LMIC)[4]. The International Diabetes Federation reported that 463 million adults were suffering from DM worldwide in 2019. And if we don't take effective preventive strategies, it is expected to reach 700 million by 2045 and the majority will from the regions experiencing an economic transition from low-income to middle-income levels[5]. A study predicted that, from 2010 to 2030, there would be a 67% increasement in DM prevalence in LMIC[6]. Furthermore, increasing patients with DM would pay more burden on the medical expenditure. Multiple factors contribute to the diabetes epidemic, including population ageing, economic development, urbanization, unhealthy diet and sedentary lifestyle[7]. Study evidence suggested that older adults were more susceptible to the implications and mortality of DM[8]. In China, from 2013 to 2018, the estimated prevalence of DM increased from 10.9–12.4%, while among older adults, the prevalence of DM reached 23.9%[9].

Over the past 30 years, China has undergone tremendous changes and invested more on health care. Meanwhile, China is undergoing deepening aging and facing a greater burden of population health. Quantifying changes in DM mortality is an important tool for monitoring changes in the trend of DM and evaluating the effectiveness of relevant policies, programs and clinical interventions. However, data regarding changes in the DM mortality trend of older adults over the last 30 years in China is scarce. Therefore, we conducted a comprehensive analysis of DM mortality changing trajectory from 1987 to 2020 among Chinese older adults. And compared the difference
between urban and rural areas. So as to grasp the changing law of the disease burden of DM among Chinese older adults and provide a reference for related public health policies.

Methods

Data Source

The DM in this study represented all types of DM. The data of DM mortality from 1987 to 2020 was derived from the death registration system of the National Health Commission of China (CNHC). The CNHC integrates related information from five administrative organizations, including the death medical certificate information and the total population information from the Department of Health; the registered permanent residence cancellation information from the Department of Public Security; the cremation information from the Department of Civil Affairs; and the termination of social security information from the Department of Social Security, and then conducted quality control and eliminated redundancy according to the ID, which was a unique identifier for each individual in China. DM mortality data was available by classification of urban, rural, and age-specific. Changing trajectory analysis of DM mortality was performed with 5 years as an age group, including age groups of 60–64, 65–69, 70–74, 75–79, 80–84 and 85 + years old.

Statistical analysis

For the sake of comparison, we used the direct method to calculate the age-standardized mortality rate (ASMR) per 100,000 based on the World Standard Population[10]. Annual variation of DM ASMR and significant change points from 1987 to 2020 were calculated by joinpoint regression analysis based on the Joinpoint Regression Program from the Surveillance Research Program of the National Cancer Institute Version 4.9.1.0 (Statistical Research and Applications Branch National Cancer Institute, USA)[11]. Age-period-cohort model was used to analyze the independent effect of different age, period and birth cohort on DM AMSR[12]. The age-period-cohort model included two parts of net drifts and local drifts, which represented the log-linear trend by period and cohort for the whole population and each age group, individually[12, 13]. Net drift indicated the overall annual percentage change across the study period, and local drift represented the annual percentage changes for each age group relative to the net drift. We calculated mortality and population data in 5-year sets between 1987 and 2020 in order to avoid a graph with too many lines. In terms of the period effect, we used the 2001 to 2005 survey year as the reference period group. The cohort effect indicated the ratio of the age-specific rate in consecutive cohorts among individuals including those born from 1906 to 1956–1960 (median, 1958), with the birth cohort of 1929 to 1933 (median, 1931) as the reference group. The results of age-period-cohort model were obtained from Web Tool designed by the National Cancer Institute of the United States and Wald χ² test was used to examine the statistical significance of the estimable parameters[14]. All figures were plotted with R version 4.1.3.

Results

Long-term trajectory in DM mortality from 1987 to 2020

From 1987 to 2020, the AMSR from DM in China showed an overall upward trend over the past three decades, but the changing trajectory in urban and rural showed different patterns (Fig. 1). Based on the values, the DM ASMR of urban was always higher than rural areas. Nevertheless, based on the variation tendency, the pattern of rural presented continuous rising, but the urban represented rising and then slightly falling and the gap between urban
and rural was gradually narrowing. Specifically, the DM ASMR of rural increased from 1.96 per 100,000 to 8.83 per 100,000 from 1987–2020. For the urban, from 1987 to 2000, the DM ASMR increased from 7.52 per 100,000 to 14.28 per 100,000, and declined to 10.78 per 100,000 in 2020. In terms of gender difference, no matter urban or rural, the DM ASMR of females was higher than males.

The results of joinpoint analysis are shown in Table 1. For the urban areas, the DM ASMR increased by 1.2% per year in total study period. In the different subperiod of joinpoint analysis, the DM AMSR of urban areas increased by 5.7% per year from 1987 to 1998 and inversely declined by 1.0% per year from 1998 to 2020. In subgroups of different gender, the male and female subgroups represented the same pattern. Among the subperiod of decline, the female subgroup declined by 1.7% per year more than the male subgroup declined by 1.0% per year. In terms of rural areas, the DM ASMR increased by 4.9% (95%CI: 4.0%-5.7%) per year in the total study period more than the urban areas. For the subperiod of joinpoint analysis, the DM AMSR of rural areas both showed an upward trend in period 1 and period 2. Particularly, the DM AMSR of rural areas increased by 6.6% per year in period 1 more than 2.0% per year in period 2. The annual average change was similar between rural male and female.

### Table 1

<table>
<thead>
<tr>
<th>Mortality rate (per 100,000)(^a)</th>
<th>Total Study Period</th>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1987</td>
<td>2020</td>
<td>AAPC (%)</td>
</tr>
<tr>
<td>Urban total</td>
<td>7.52</td>
<td>10.78</td>
<td>1.2</td>
</tr>
<tr>
<td>male</td>
<td>6.28</td>
<td>11.17</td>
<td>1.7*</td>
</tr>
<tr>
<td>female</td>
<td>8.44</td>
<td>10.39</td>
<td>0.8</td>
</tr>
<tr>
<td>Rural total</td>
<td>1.96</td>
<td>8.83</td>
<td>4.9*</td>
</tr>
<tr>
<td>female</td>
<td>1.86</td>
<td>8.44</td>
<td>4.6*</td>
</tr>
<tr>
<td>female</td>
<td>2.05</td>
<td>9.18</td>
<td>4.8*</td>
</tr>
</tbody>
</table>

### Net Drift And Local Drift In Urban And Rural

Across the period of 1987–2020, there were differences in the values of net drift and local drift between urban and rural (Fig. 2). The total net drift value of urban was -0.10 [95% CI, (-0.49, 0.28)], whereas the rural total net drift value was 5.10 [95% CI, (4.79, 5.41)]. For the gender difference, in rural areas, the net drift values of male [4.63, 95% CI, (4.27, 4.99)] and female [5.00, 95% CI, (4.65, 5.34)] were both greater than zero, but for the urban, the net drift value of male [0.44, 95% CI, (0.07, 0.81)] was slightly greater than zero and the female [-0.61, 95% CI, (-1.04,
was less than zero. Local drift represented DM mortality trend variation in different age groups. In the group of urban-total, before 80 years old, the local drift values were all below zero (-2.01 per year in 60–64 age group to -0.03 per year in 75–79 age group), but the local drift values were higher than zero after 80 years old (1.88 per year in 80 – 44 age group to 3.47 per year in 85 + age group). For the difference of gender, the local drift value of male was higher than female before 80 years old, but after 80 years old, the female local drift value in turn outnumbered male. Based on the rural areas, the total, male and female local drift values were all higher than zero and the values of local drift increased gradually from 60–64 group to 85 + group. In term of gender difference of rural, the local drift values of female were higher than male in most age groups.

Age-period-cohort Effects On Dm Mortality

Age-Period-Cohort effects on DM mortality showed in Fig. 3. From the perspective of age effect, the trend of urban and rural both showed J shape distribution and DM mortality increased more rapidly in later years. Compared with males, the rising trend of females was higher in urban and rural areas. In term of period effect, there was different distribution in urban and rural. For urban areas, the rate ratio showed a steady tendency no matter in total or different gender. Moreover, in rural areas, the period effect on DM mortality showed a continually rising trend and the risk was about two times than urban in recent years. As far as the cohort effect, the rate ratio was also significantly different between urban and rural. In urban areas, the risk of death from DM remained relatively flat in total and different gender. Furthermore, in rural areas, the cohort effect showed that the risk of death from DM was relatively higher among the recently born populations and it reached the highest in cohort born in 1956 (RR = 1.99, 95% CI: 1.72–2.32).

Discussion

The present study revealed a comprehensive changing trajectory of DM mortality among Chinese older adults from 1987 to 2020. And finding the different pattern between urban and rural. From 1987 to 2020, the mortality from DM in China has shown an overall upward trend over the past three decades, especially in rural areas. Specifically, the DM AMSR of urban and rural increased by 43.29% in urban areas and 350.67% in rural areas. Joinpoint analysis showed that the rural areas indicated increasing in all period, but the urban areas represented upside in period 1 and downside in period 2. Compared with the male, the DM AMSR of females was higher in urban and rural areas. In terms of urban-rural comparison, although the DM AMSR of urban areas had always been higher than rural areas, and the gap between them gradually narrowed due to DM AMSR of rural sharply rising. APC model showed that the reporting rate increased with age in urban and rural. The period effect showed stable in urban, but a rapidly increasing trend in rural and the risk was about two times than urban in recent years. The cohort effect showed that the risk of death from DM was relatively higher among the recently born populations in rural areas, while urban areas remained relatively flat.

Over the past 30 years, China's economy and society have experienced an astonishing improvement, accompanied by a gradual increasement of DM mortality, consistent with the global comparative study of DM mortality. The global comparative study found that developed countries, like the United Kingdom, Germany, etc, showed a declining trend[15]. However, in most developing countries, especially these were experiencing economic transition from low-income to middle-income levels reported a gradually rise tendency of DM mortality[5, 16]. The reason for this difference might be attributable to, on the one hand, reduction of risk factor exposure and better medical
management in developed countries, and on the other hand, lifestyle changes such as high-fat diet, physical inactivity and obesity prevalence brought about by rapid economic growth in developing countries\[17–19\].

DM not only increases the risk of premature death, but also causes complications of other diseases, such as renal function failure, cardiovascular and cerebrovascular diseases, etc\[20, 21\]. Furthermore, DM along with infectious diseases, including influenza, SARS and COVID-19, also increases the risk of premature death\[22–24\]. The occurrence and progression of DM are closely related to socioeconomic level and lifestyle, such as smoking, drinking and unhealthy diet\[16\]. In the past 30 years, China’s urban and rural economy has developed rapidly, which is along with poor lifestyle and diet. The China Health and Nutrition Survey reported that, from 1993 to 2019, the obesity rate rose from 4.0–16.4\%\[9\]. These changes contributed to the rise in DM mortality, which was consistent with the overall increasing trend of DM mortality in urban and rural areas from 1987 to 2020 reported in this study. However, the Chinese government and related researchers were also increasingly discovering the health hazards and burden of non-communicable diseases such as diabetes, and carried out some preventive measures, like health education, program of non-communicable diseases prevention and control program\[25\].

From the perspective of urban-rural comparison, we found that, before about 2000, the growth rate in urban was higher than that in rural areas, which might be due to higher economic status, high-fat diet and higher diagnosis rate. But after 2000 especially in recent years, the growth rate in rural was much higher than urban, which represented a stable and slightly downside. This was similar to the results of one study reported that the gap of DM mortality between urban and rural narrowed\[26\]. The reason for this change might be due to the accelerating economic development, adverse lifestyle transition, lack of self-health awareness and relatively low level of medical care. This gap between urban-rural suggested that we should pay more attention and greater investment in DM prevention strategies in rural areas.

For the difference of gender, we found that the DM mortality of female was higher than male in both urban and rural, which might be connected with the sex hormones and especially physiological or biochemical factors in female\[27\]. It is time to conduct greater intervention in the females to curb this trend. In terms of different stages of old age, we found that, no matter in urban or rural, the DM mortality increased at a higher rate in the oldest-old than in young-old, representing that the oldest-old have a higher risk of DM mortality. This suggested that we need to pay more attention to the risk of death from DM in the oldest-old, especially in rural areas.

There are some strengths of this study. First, the time span of this study data is extensively long, especially for relevant data before 2003, which are not publicly available. Our study obtained the permission from relevant government departments to analyze data from early years. To our best knowledge, this is the longest period to quantify the changing trajectory of DM mortality among Chinese older adults, which could help us comprehensively understand the overall trend of the older adults in China. Second, our study includes analysis of urban-rural and gender differences so that we can identify special high-risk groups. Third, we performed APC model analysis to find the separate effect coefficients of age, period and cohort on ASMR of DM. Our study also has several limitations. Firstly, since we don't have province-level data on DM mortality, so differences between provinces cannot analyze. Secondly, our study is based on the reported data, the DM mortality would be underestimated. Thirdly, our study didn't consider the effect of other covariates, which needed further verification in the future.

Conclusions
This study provides a comprehensive changing trajectory of DM mortality from 1987 to 2020 among Chinese older adults and grasps the difference between urban-rural. Specifically, the mortality from DM in China has shown an overall upward trend over the past three decades, especially in rural areas. In addition, the risk of DM mortality in oldest-older groups has been rising significantly regardless of areas. The high mortality of DM among females, the elderly and in rural areas should be given priority attention and the government should take measures to curb this trend.

**Declarations**

**Acknowledgements**

We sincerely thank all the staff who participated in the data report and sort. Special thanks the support from the National Health Commission of China and the Key Project of the National Social Science Foundation of China (21ZD107), which is based on the Healthy China Strategy to implement the national strategy of actively responding to population aging.

**Author contributions**

Chen Chen, Binbin Su and Xiaoying Zheng contributed to the study design, completed data collection, statistical analyses, results interpreted, drafted and revised the manuscript critically. Yihao Zhao, Yu Wu, Panliang Zhong were involved in acquisition, sort and interpretation of data.

**Conflict of interest**

The authors have no competing interests to declare that are relevant to the content of this article.

**References**


**Figures**

![Age-standardized mortality rate (1/100,000)](image)

**Figure 1**

Legend not included with this version.
Figure 2

Legend not included with this version.
Figure 3

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