Prevalence of type 2 diabetes mellitus among inland residents in China (2000–2014): A meta-analysis

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Keywords
China, Prevalence, Type 2 diabetes mellitus

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J Diabetes Investig 2016; 7: 845–852
doi: 10.1111/jdi.12514

ABSTRACT

Aims/Introduction: Besides the aging population in China, the following have become serious public health problems: increasing urban population, lifestyle changes and diabetes. We assessed the epidemiology of type 2 diabetes mellitus in China between 2000 and 2014, and analyzed time trends to better determine the prevalence status of diabetes in China and to provide a basis for prevention and decision-making.

Materials and Methods: In our systematic review, we searched China National Knowledge Infrastructure, Chinese VIP Information, Wanfang and PubMed databases for studies on type 2 diabetes mellitus between 2000 and 2014 in China. Two investigators extracted the data and assessed the quality of the included literature independently. We excluded studies that did not use 1999 World Health Organization criteria for diabetes. We also excluded reviews and viewpoints, studies with insufficient data, studies that were not carried out in mainland China and studies on troops, community, schools or physical examination people. We used STATA 12.0 to combine the prevalence of all studies, calculated the pooled prevalence and its 95% confidence interval, and analyzed the differences among men/women, urban/rural areas and year of study. We calculated the prevalence of seven geographic areas of China, respectively, and mapped the distribution in the whole country to estimate the pooled prevalence of each area.

Results: Our search returned 4,572 studies, 77 of which satisfied the inclusion criteria. The included studies had a total of 1,287,251 participants, in which 680,574 cases of type 2 diabetes mellitus were recorded. The overall prevalence (9.1%) has been increasing since the 1970s, and it increased rapidly with age. The prevalence of the 65–74 year group was as high as 14.1%. Meanwhile, the prevalence among men/women and urban/rural areas was significantly different. The prevalence was 9.9% for men and 11.6% for women, which were significantly higher than the average at the end of the last century and the beginning of this century. The prevalence rate in urban areas (11.4%) was significantly higher than that in rural areas and in urban-rural fringe areas, and the prevalence in rural areas (8.2%) was slightly higher than that in urban-rural fringe areas (7.5%). In addition, the prevalence in each geographic area were estimated and mapped, which showed a large imbalance in the map.

Conclusions: Our analysis suggested that type 2 diabetes mellitus is highly prevalent in China. These results underscore the urgent need for the government to vigorously strengthen the management of diabetes prevention and control.

INTRODUCTION

Type 2 diabetes mellitus is a major global health problem causing significant morbidity and mortality1. The International Diabetes Federation has predicted that the number of individuals
with diabetes will increase from 240 million in 2007 to 380 million in 2025, and will further increase to 439 million in 2030\(^2\).\(^3\).

The largest developing country, China, has experienced a high-speed scientific, technological progress and socioeconomic development in the past two decades. The number of diabetic patients is estimated to increase from 20.8 million in 2000 to 42.3 million in 2030\(^4\). It is reported that China has overtaken India, and has become the top country with the highest number of people with diabetes for 92.4 million adults affected\(^5,6\).

Since the 1970s, many diabetes epidemiology studies have been carried out both nationwide\(^5,7\)\(^-\)\(^9\) and at regional levels. The prevalence of diabetes was reported to be approximately 1\% in the 1980 National Diabetes Survey among 159,900 participants aged 20 years or older\(^7\), 2.5\% in the 1994 China National Diabetes Survey among 224,251 participants aged between 25 and 64 years\(^8\), and 2.6\% in the 2002 Fourth National Nutritional Survey among 98,509 participants aged 18 years or older, of which 4.5\% were in urban areas and 1.8\% were in rural areas\(^10\). These studies have documented a marked increase in the prevalence of diabetes, which use uniform diagnostic criteria. However, nationally representative data of long-term trends are lacking because of incomparability.

Although previous comprehensive reviews\(^11\)\(^-\)\(^13\) had reported the prevalence of diabetes in China, these studies only reported the prevalence of diabetes, not type 2 diabetes mellitus. One review\(^14\) reported the prevalence of type 2 diabetes mellitus; however, it focused on comparing the prevalence between mainland China, Hong Kong and Taiwan.

As a result, there is a need for a comprehensive review of trends of type 2 diabetes mellitus over the past 15 years. To better understand the prevalence of type 2 diabetes mellitus, we comprehensively summarized the prevalence trends of type 2 diabetes mellitus among inland residents from 2000 to 2014. First, we calculated the overall prevalence of type 2 diabetes mellitus, the pooled prevalence of different age periods, men/women, urban/rural areas and the different year of the studies, respectively. Second, we analyzed the differences of trends among men/women, urban/rural areas and the year of the studies. Third, we calculated the prevalence of seven geographic areas of China, respectively, and mapped the distribution in the whole country. We aimed to provide data that can be used to create a management decision. Our results can provide a basis for the rational allocation of health resources and health policy planning.

**MATERIALS AND METHODS**

**Search strategy**

We searched the China National Knowledge Infrastructure (CNKI), Chinese VIP Information (VIP), Wanfang and PubMed databases. Searches, which were limited to studies published between 2000 and 2014, were carried out in parallel by LLY and JS. We used the following search terms: “type 2 diabetes”, “type 2 diabetes mellitus”, “epidemiology”, “prevalence”, “morbidity”, “China” and “Chinese”.

For the China National Knowledge Infrastructure, see http://www.global.cnki.net. For Wanfang, see http://www.wanfang-data.com. For VIP, see http://en.cqvip.com.

**Inclusion and exclusion criteria**

The inclusion criteria were as follows: (i) the object of the study should be from mainland China, published in English or Chinese; (ii) the diagnosis criteria mentioned in the studies should be in accordance with 1999 World Health Organization criteria for diabetes\(^15\). It was defined based on fasting capillary whole blood glucose level (\(\geq 6.1 \text{ mmol/L} \)) or plasma glucose measurement (FPG \(\geq 7.0 \text{ mmol/L} \)) and/or 2-h postprandial blood glucose \(\geq 11.1 \text{ mmol/L} \) during an oral glucose tolerance test or previously diagnosed diabetes; (iii) the studies should be cross-sectional or longitudinal, which report the prevalence of type 2 diabetes mellitus, or we can calculate the prevalence from the data provided; (iv) the population should be representative for a certain area’s population (e.g., a province or city); and (v) the prevalence of type 2 diabetes mellitus should include previously known and new (undiagnosed) diabetes.

The exclusion criteria were as follows: (i) type 1 diabetes and gestational diabetes articles; (ii) studies representing a special population (e.g., troops, community, schools or physical examination people); (iii) studies involving a Chinese population, but were completed outside of mainland China; (iv) reviews, viewpoints or reports articles; (v) duplicates within and between the databases; and (vi) studies with insufficient data.

**Data extraction**

Two reviewers (Lili Yang, Jing Shao) read the trials, and extracted data independently according to search strategy and the inclusion/exclusion criteria. Data regarding author, title, age (including the number of cases of all age groups), study area (urban/rural), survey date, year of publication, total and sample size (number of men and women separately), diagnostic criteria and method were extracted. When the information was incomplete, we would try to contact the author to obtain the complete data. A third author (Yaoyao Bian) was consulted for the resolution of disagreements.

**Quality of literature evaluation**

For the evaluation of the searched studies, we used the literature quality assessment criteria proposed by Khambalia and Seen\(^16\) (Table 1).

**Statistical analysis**

We used Stata 12.0 (StataCorp, College Station, TX, USA) to combine the prevalence of all studies, and calculate the pooled prevalence and its 95\% confidence interval (CI). We carried out homogeneity tests for heterogeneity (size of test \(P > 0.1 \) and \(I^2 < 50\% \)). If the aforementioned two conditions were satisfied, the combined test was shown as homogenous and we used a
fixed effect model to carry out the meta-analysis. When the combined tests were heterogeneous, the random effect model was used for analysis. Subgroup analysis included age, men/women, urban/rural areas and the year of the study. We calculated the prevalence of seven geographic areas of China, respectively, and mapped the distribution in the whole country to estimate the pooled prevalence of each area. GraphPad Prism 5 software (GraphPad Software, La Jolla, CA, USA) was used to draw the histogram and analyze the datum for investigating trends over time.

RESULTS

Literature retrieval process and results

Our initial screening returned 3,450, 849, 193 and 80 results from the CNKI, VIP, Wanfang and PubMed, respectively. A total of 77 studies (Table S1) satisfied all the inclusion criteria (Figure 1). The main details of the studies are listed in Table S2.

We analyzed the quality of the 77 studies included as follows: three studies scored as 1, 21 studies scored as 2, 47 studies scored as 3 and the other six studies scored as 4. The total sample size of the study was 1,287,251 cases. The overall prevalence was 9.1% (95% CI 8.2–10.1%), and the heterogeneity was large ($I^2 = 99.8\%$, $P < 0.01$). Among the 77 studies, the maximum sample size was 769,792 cases, whereas the minimum was 1,058 cases. Epidemiology investigation of location showed that the cases were from 20 provinces and autonomous regions, among which Zhejiang (8 cases); Shandong, Jiangsu, Shanghai (7 cases); Guangdong, Sichuan (6 cases) accounted for the top three proportions (Table S3).

Different age groups of type 2 diabetes mellitus prevalence

These data were from 77 studies that reported the prevalence for different age groups. Therefore, we adjusted the data for the purpose of comparability. For example, we pooled the 35–39 years and 40–44 years age groups into the 35–44 years group. The trend of 20–34 years to more than 75 years age groups was much more pronounced. The prevalence of type 2 diabetes mellitus increased rapidly with age (Figure 2). The prevalence rates were 0.9% (95% CI 0.6–1.2%) in the 20–34 years age group, 2.7% (95% CI 2.0–3.4%) in 35–44 years age group, 7.3% (95% CI 5.8–8.7%) in the 45–54 years age group, 11.0% (95% CI 9.0–13.0%) in the 55–64 years age group, 14.1% (95% CI 12.3–16.0%) in 65–74 years age group and 11.0% (95% CI 9.0–13.0%) in the more than 75 years age group. The highest incidence of age was observed in the 65–74 years age group (14.1%), followed by the 55–64 years and more than 75 years age groups (11.0%).

Different periods of type 2 diabetes mellitus prevalence

According to the midpoints across time, we divided the 77 studies into three groups: 2000–2004, 2005–2009 and 2010–2014 for the purpose of comparability. We analyzed the type 2 diabetes mellitus prevalence in each group, and the pooled prevalence rates of the groups were as follows: 7.1% (95% CI 5.4–8.8%), 9.3% (95% CI 7.7–11.0%), and 10.1% (95% CI 8.4–11.7%) for 2000–2004, 2005–2009 and 2010–2014, respectively. Therefore, the type 2 diabetes mellitus prevalence trended over time (Figure 3).

Different prevalence rates of type 2 diabetes mellitus among men and women

Of the 77 included studies, 70 studies reported the prevalence of type 2 diabetes mellitus among men and women. Meta-analysis showed that the pooled prevalence rates were as follows: 9.9% (95% CI 8.8–11.0%) and 11.6% (95% CI 10.0–13.1%) for the men and women, respectively. The pooled prevalence was higher in women than in men. Figure 4 shows the men/women prevalence during the study year range 2000–2014. The prevalence rates of men were 6.9% (95% CI 5.4–8.5%) in 2000–2004, 9.8% (95% CI 7.9–11.7%) in 2005–2009 and 11.8% (95% CI 9.2–14.5%) in 2010–2014. Whereas, the prevalence rates of women were 6.6% (95% CI 4.3–8.8%) in 2000–2004, 13.6% (95% CI 9.8–17.3%) in 2005–2009 and 11.8% (95% CI 9.1–14.5%) in 2010–2014.

Different age groups and periods of type 2 diabetes mellitus prevalence rates among men and women

We estimated the prevalence among three periods (2000–2004, 2005–2009, 2010–2014) and five age groups (20–34 years to 65–74 years) in both men and women. It increased with age and increased significantly. The rising trend of the prevalence of type 2 diabetes mellitus was different (Figure 5).

In 2000–2004, the prevalence rates of men were 0.9% (95% CI 0.3–1.5%) in the 20–34 years age group, 3.0% (95% CI 1.3–4.7%) in the 35–44 years age group, 5.7% (95% CI 2.6–8.8%) in the 55–64 years age group, and 13.3% (95% CI 10.7–16.1%) in the more than 75 years age group. The highest incidence of age was observed in the more than 75 years age group (13.3%), followed by the 55–64 years and more than 75 years age groups (12.6%).
in the 45–54 years age group, 8.0% (95% CI 6.3–9.8%) in the 55–64 years age group and 13.9% (95% CI 12.4–15.4%) in the 65–74 years age group. In 2005–2009, the prevalence rates of men were 1.5% (95% CI 0.8–2.2%) in the 20–34 years age group, 4.7% (95% CI 0.8–8.6%) in the 35–44 years age group, 12.5% (95% CI 4.0–21.0%) in the 45–54 years age group, 14.4% (95% CI 11.1–17.6%) in the 55–64 years age group and 15.3% (95% CI 11.5–19.1%) in the 65–74 years age group. In 2010–2014, the prevalence rates of men were 1.6% (95% CI 0.2–3.0%) in the 20–34 years age group, 3.9% (95% CI 1.2–6.7%) in the 35–44 years age group, 9.1% (95% CI 2.5–15.7%) in the 45–54 years age group, 8.5% (95% CI 2.6–14.3%) in the 55–64 years age group and 18.2% (95% CI 11.2–25.2%) in the 65–74 years age group.

Whereas in 2000–2004, the prevalence rates of women were 1.1% (95% CI 0.6–1.6%) in the 20–34 years age group, 2.7% (95% CI 1.2–4.1%) in the 35–44 years age group, 5.7% (95% CI 2.6–8.9%) in the 45–54 years group, 12.6% (95% CI 9.4–15.7%) in the 55–64 years age group and 15.2% (95% CI 11.5–
19.0%) in the 65–74 years age group. In 2005–2009, the prevalence rates of women were 0.6% (95% CI 0.3–0.9%) in the 20–34 years age group, 2.5% (95% CI 1.3–3.6%) in the 35–44 years age group, 7.8% (95% CI 6.1–9.6%) in the 45–54 years age group, 16.7% (95% CI 12.7–20.7%) in the 55–64 years age group and 17.0% (95% CI 12.2–21.7%) in the 65–74 years age group. In 2010–2014, the prevalence rates of women were 0.5% (95% CI 0.1–0.9%) in the 20–34 years age group, 3.2% (95% CI 0.3–6.0%) in the 35–44 years age group, 4.8% (95% CI 1.4–8.2%) in the 45–54 years age group, 9.4% (95% CI 3.7–15.1%) in the 55–64 years age group and 17.4% (95% CI 8.5–26.4%) in the 65–74 years age group.

The general trend in men and women was that the prevalence in 2005–2009 was higher than both in 2000–2004 and in 2010–2014 at the age of 45–54 years and 55–64 years. The difference between men and women was inconsistent too. The prevalence rate of men was higher than that of women at the age of 35–54 years in 2005–2009.

Different prevalence rates of type 2 diabetes mellitus in urban/rural areas

Meta-analysis showed that the pooled prevalence rates were 11.4% (95% CI 9.5–13.3%), 8.2% (95% CI 6.3–10.0%), and 7.5% (95% CI 6.2–8.9%) for urban, rural and urban-rural fringe areas, respectively. The prevalence rate in urban area was significantly higher than that in rural areas and in urban-rural fringe areas, and the prevalence in rural areas was slightly higher than that in urban-rural fringe areas. Figure 6 shows the prevalence in urban/rural areas during the study years 2000–2014. The prevalence rates in urban areas were 8.9% (95% CI 6.8–10.9%) in 2000–2004, 11.3% (95% CI 8.3–14.4%) in 2005–2009 and 13.6% (95% CI 10.2–17.0%) in 2010–2014; in rural areas were 6.1% (95% CI 0.1–12.9%) in 2000–2004, 8.3% (95% CI 5.5–11.2%) in 2005–2009 and 8.2% (95% CI 5.8–10.6%) in 2010–2014; and in urban-rural fringe areas were 5.9% (95% CI 2.9–8.9%) in 2000–2004, 7.4% (95% CI 4.9–10%) in 2005–2009 and 9.2% (95% CI 6.2–12.1%) in 2010–2014.

Different prevalence rates of type 2 diabetes mellitus in geographic areas

A total of 77 included studies involved three national studies. The main details of the other 74 studies are listed in Table S2. Figure 7 shows the imbalance prevalence of type 2 diabetes mellitus in different geographic areas for the past 15 years; that
is, Northeast China, North China, East China, South China, Central China, Northwest China and Southwest China, the pooled prevalence rates of type 2 diabetes mellitus were as follows: 22.1% (95% CI 8.0–3.6%), 11.5% (95% CI 9.6–13.3%), 8.1% (95% CI 6.8–9.4%), 8.4% (95% CI 5.1–11.8%), 8.4% (95% CI 9.7–8.3%), 6.4% (95% CI 4.8–7.9%) and 8.9% (95% CI 6.4–11.4%), respectively. Northeast China including Heilongjiang (30.6%) and Jilin (17.9%) had the highest prevalence of diabetes. Whereas in Northwest China the prevalence of type 2 diabetes mellitus was low, such as Ningxia (5.7%) and Xinjiang (6.8%).

DISCUSSION

The present meta-analysis showed that the overall prevalence of type 2 diabetes mellitus was 9.1%, being nearly consistent with the study (9.7%)\(^5\). The stratified analysis showed that type 2 diabetes mellitus prevalence increased significantly, which was 7.1% in 2000–2004, 9.3% in 2005–2009 and 10.1% in 2010–2014. The data showed that the prevalence of type 2 diabetes mellitus has increased gradually in the past 15 years. We also found that the prevalence is increasing more quickly than other Asian countries (i.e., India, Pakistan, Indonesia)\(^18,19\).

According to age groups among men and women, the prevalence rate at the age of 55–74 years was six- to sevenfold higher than that of 20–34 years. Age might be a major factor for diabetes. As China’s population enters the 21st century, the Chinese government has faced the consequences of rapid population aging and needs to pay more attention to health services for the aging population.

In addition, the prevalence rates in men increased linearly in the past 15 years. The prevalence was 9.9% for men and 11.6% for women, and these rates were significantly higher than the average at the end of the last century and the beginning of this century. Some researchers have suggested a 26% increase in risk for men than women\(^20\). The increasing incidence has been attributed ecologically to an increasing prevalence of central obesity, total dietary intake, a shift in the ratio of refined vs unrefined carbohydrates and simple sugars, increased portion sizes, and decrease in energy expenditure\(^21,22\).
In 2005–2009, the prevalence was 13.6% in women and 9.8% in men, which is not similar to the results of the study reported by Yang et al. This might be due to a lack of exercise among women, and irrational dietary structure and irregular lifestyle. For example, consuming too much sugar-sweetened beverages, such as soft drink and fruit juice, might increase the risk of developing hyperglycemia23. However, in 2000–2004 and 2010–2014, the prevalence rates were similar to the result of another study12.

China has experienced high-speed socioeconomic development during the past two decades, which has resulted in rapid modernization and urbanization. Simultaneously, the prevalence rate differs in urban/rural areas. The prevalence rate in urban areas (13.6%) in 2010–2014 increased by 2.3% from the prevalence rate (11.3%) in 2005–2009, and these rates were significantly higher than those in the rural, urban-rural fringe areas. This result is consistent with the findings of previous studies carried out among different populations and in different areas8,9,24–26. Residents of urban areas were more sedentary and more exposed to high-calorie foods than residents of rural areas27.

We also found that the prevalence in the whole country is imbalance in geographic areas from the map, and not directly related to the number of studies. The prevalence was as high as 30.6% in Heilongjiang and 17.9% in Jilin, whereas in some provinces the prevalence was as low as 3.6% in Yunnan and 5.7% in Ningxia. Zhejiang (8 cases) accounted for the top one portion and its prevalence was 5.9%, which was much lower than Hunan (1 case) and its prevalence was 12.5%.

There were some important limitations in our review. First, although we selected studies carried out in nearly 20 provinces and autonomous regions, just three studies were carried out throughout the whole country. Our sample size was very small for China, which has a large population. Many studies did not provide prevalence data disaggregated by men/women and urban/rural location, which might cause sampling bias and publication bias. Second, an obviously imbalanced geographical variation existed, and the highest type 2 diabetes mellitus prevalence rate was recorded in Northeast China. These limitations caused difficulties during data analysis and result comparisons of the different studies because of inconsistencies in the age group. Third, in order to understand the relationship between prevalence and age, we categorized age groups for the purpose of comparability. For example, we pooled the 35–39 years and 40–44 years group into the 35–44 years group. In addition, the trend of the 20–34 years to more than 75 years age groups was much more pronounced. However, some studies did not categorize as such. It might cause publication bias.

To carry out an epidemiological survey of diabetes more scientifically in our country, we suggest that the relevant academic departments or agencies should formulate a unified method and age group.

In summary, the present results showed that diabetes is highly prevalent in China. Given its large population, China might bear a higher diabetes-related burden than any other countries28. Carrying out publicity campaigns and diabetes prevention measures is considerably significant. The government should continue to boost diabetes awareness and promote healthy behavior among citizens. Health education and regular screening should also be carried out to increase the rates of diabetes identification.

ACKNOWLEDGMENTS
This study was supported by the National Natural Science Foundation (81271668), and the Ministry of Science and Technology Innovation Fund Projects (12C26213202418).
DISCLOSURE
The authors declare no conflict of interest.

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SUPPORTING INFORMATION
Additional Supporting Information may be found in the online version of this article:
Table S1 | The full list of studies included in the meta-analysis.
Table S2 | Main details of the studies included in the meta-analysis.
Table S3 | The description of geographic distributions in the subgroup analysis.