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THE DIABETES EPIDEMIC IN CHINA: AN INTEGRATED REVIEW OF NATIONAL SURVEYS

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Abstract

Objective—To review trends in the prevalence and incidence of diabetes mellitus (DM) and related risk factors in China.

Methods—We searched the literature using PubMed, China Knowledge Resource Integrated Database, and China Wanfang Digital Database for large epidemiologic studies and national surveys.

Results—During the past 30 years (1980–2010), 7 national diabetes mellitus surveys were conducted in China mainland, indicating that the prevalence of DM has increased 17-fold, from 0.67 to 11.6% of the population. The prevalence of impaired glucose regulation (IGR, including impaired fasting glucose and impaired glucose tolerance) also increased, from 2.09 in 1994 to 27.2% in 2010. There was no national representative study of the incidence of diabetes to date; the reported incidence of type 2 diabetes during past 25 years in several cohort studies varied (2.7 to 15.8 per 1,000 person-years). Potential risk factors which could have contributed to the increasing prevalence and incidence of DM and IGR in the Chinese population include social and economic development, urbanization, dietary pattern, and Westernized lifestyle. Further, genetic studies have suggested that unique inheritable risk factors in the Chinese population may increase the risk for DM when compared to Caucasians.

Conclusion—DM and IGR have become epidemic in China. Public health strategies should focus on modifying lifestyle and dietary factors, particularly among those with a susceptible genetic background.

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DISCLOSURE

The authors have no multiplicity of interest to disclose.

Keywords

Diabetes; Prevalence; Incidence; Risk factors

INTRODUCTION

Type 2 diabetes mellitus (DM) has rapidly become one of the most common noncommunicable diseases globally and is one of the most challenging public health issues (1). The International Diabetes Federation has estimated that 382 million people had diabetes worldwide in 2013, and by 2035, this will rise to 592 million (1). Approximately 80% of people with diabetes live in low- and middle-income countries (1). In China, a rapid increase in the prevalence of DM has been reported (2). Comparing the latest national DM survey in 2010 to the first one in 1981 (3), the prevalence of DM has increased 17-fold (2,3). This is relevant, since diabetes increases the risk of developing microvascular and macrovascular complications as well as premature death, leading to a large economic burden on society and government.

A thorough understanding of the prevalence of diabetes and its modifiable risk factors is important in designing rational prevention programs to reduce the burden of disease. Here, we review the epidemiologic trends, in both prevalence and incidence of DM, and the major modifiable risk factors that may have led to the rapid rise in DM in mainland China, based on national surveys conducted during the past decades.

METHODS

We searched published data from the China Wanfang Digital Database, the China Knowledge Resource Integrated Database, and PubMed using the keywords “diabetes” or “diabetes mellitus,” “China,” or “Chinese,” “prevalence,” “incidence,” and “risk factor.” Reference lists of relevant reviews were also explored for additional studies potentially meeting the screening criteria. We selected national DM surveys to analyze the prevalence trends. High-priority articles included meta-analyses, systematic reviews, cohort studies, well-designed case-control studies, and large cross-sectional studies to explore the risk factors of DM in China. We did not focus on risk factors outside the Chinese population or those that specifically dealt with gestational diabetes or type 1 DM.

PREVALENCE TREND OF DM IN CHINA

In this review, we report the prevalence of diabetes, including both diagnosed (previously known) and undiagnosed diabetes. The undiagnosed individuals were those who did not know that they had diabetes until they were identified during surveys. In total, we identified 7 cross-sectional studies of DM prevalence which were based on national samples of Chinese adults living in mainland China (Table 1). These studies were conducted in 1980 (3), 1994 (4), 1995 (5), 2001 (6), 2002 (7), 2007 (8), and 2010 (2), respectively. In the first study, conducted in 1980, the overall prevalence of DM was 0.67% (DM was screened by urine glucose then diagnosed by 2-hour postprandial glucose and oral glucose tolerance test [OGTT]). However, the DM prevalence increased to 3.2% (diagnosed by fasting plasma

glucose and OGTT) in 1995, 9.7% in 2007 (diagnosed by OGTT), and 11.6% (diagnosed by OGTT) in 2010 (diagnosed by fasting plasma glucose and 2-hour postprandial glucose) (P for trend $<.0001$, calculated by chi-square test after standardizing for the study population for age with the Chinese population data in 2010) (Fig. 1).

Similarly, the prevalence of undiagnosed DM increased: 1.6% in 1994, 4.2% in 2001, 5.9% in 2007, and 8.1% in 2010. In contrast, the proportion of the undiagnosed population among individuals with diabetes is stable at ~70%, relative to 27.8% in the U.S. (9). The higher ratio of undiagnosed to diagnosed cases may be due to the lack of population-based screening programs, as well as a relatively rapid and recent increase in the incidence of diabetes (8).

Because individuals with uncontrolled hyperglycemia are prone to various complications, such as stroke, heart failure, acute myocardial infarction, renal disorders, and retinopathy (1,10), undiagnosed prediabetes and diabetes represent a hidden healthcare burden that is growing rapidly.

The prevalence of impaired glucose regulation (IGR, including impaired fasting glucose, or impaired glucose tolerance, IGT) (Fig. 1) was first reported in the survey conducted in 1994 (2.1%, diagnosed by 2-hour postprandial glucose and OGTT). As suggested by later studies, the general trend has been increasing dramatically and rose to 27.2% in the latest study in 2010 (diagnosed by fasting plasma glucose). Of note, in the 2010 survey, glycated hemoglobin and 2-hour plasma glucose were also tested, and the overall prevalence of prediabetes was 50.1%. Because prediabetes is an important risk factor for the development of overt diabetes and cardiovascular disease (11), this large prevalence of IGR is alarming and indicates a much larger segment of the population is at risk for developing long-term complications of hyperglycemia.

The overall prevalence of DM and IGR increased rapidly with increased age, as suggested by all surveys (Fig. 2 *A* and *B*). It is worth noting that in the young age groups (20 to 39 years), although the prevalence of diabetes was relatively low, IGR was high in these groups, suggesting that a large proportion of these young adults were at risk of developing DM in the future. One Chinese study showed that the progression rates from IGT to diabetes reached 8.8% per year (12).

The results regarding gender difference in DM prevalence was inconsistent. In the first four studies conducted between 1981 and 2001, a similar prevalence of DM and IGR were observed in men and women. However, the 2007 study reported significantly higher prevalence of IGR among men but similar prevalence of DM by sex, and the most recent study (2010) found a higher prevalence of DM and IGR among men than women (Fig. 3).

In China, rapid economic and social development and increasing urbanization over the last 2 decades have contributed to significant changes in lifestyle and living environments. It has been consistently reported that living in urban areas is associated with a higher prevalence of diabetes, relative to rural areas, throughout the world (4,6,13). This observation could be explained by the fact that urbanization is associated with several risk factors for diabetes, such as physical inactivity, a dietary pattern with high consumption of fat and sodium and

low consumption of fruits and vegetables, and work-related stress (1,14). Consistently, similar patterns for DM prevalence were observed in Chinese studies (Fig. 4). In contrast, the prevalence of IGR was higher in the rural populations than urban groups in the 2007 study (Fig. 4). More studies are needed to understand this discrepancy.

INCIDENCE OF DM IN CHINA

Several prospective cohort studies have reported on the incidence of DM in mainland China. The first study was conducted in Daqing, in which 36,471 adults aged 24 to 47 years (18,801 men and 17,670 women) were followed from 1986 to 1990, and DM was diagnosed by 2-hour postprandial glucose and OGTT (15). In this study, the incidence of DM was 1.31 per 1,000 person-years (1.37 per 1,000 person-years in men and 1.25 per 1,000 person-years in women). In 2012 (16), data from the Shanghai Women's Health Study and Shanghai Men's Health Study showed the incidence of physician diagnosis of type 2 diabetes (T2D), based on self-reported questionnaire, was 3.61 per 1,000 person-years in 69,385 Chinese women aged 40 to 70 years and 2.70 per 1,000 person-years in 55,311 men aged 40 to 74 years living in urban communities of Shanghai. Participants in this study were followed for a mean of 7.3 years for women, starting from 1997 to 2000, and 3.6 years for men, starting from 2002 to 2006. In 2013, an incident rate of 9.5 per 1000 person-years was reported based on a cohort of 10,704 adults aged 18 to 59 years (8,238 men and 2,466 women) living in Qingdao, a city in north China, which was followed from 2000 to 2011 (17). Very recently, in 2016 (18), a cohort study reported that the age-standardized incidence of T2D was 9.6 and 9.2 per 1,000 person-years in men and women, respectively, in a sample of 15,684 Chinese adults aged 35 to 74 years from the China Multicenter Collaborative Study of Cardiovascular Epidemiology (ChinaMUCA) and the China Cardiovascular Health Study, followed from 2000–2001 to 2007–2008.

The reported incidence varied among the above studies. The possible reasons for this variance include the different populations from different locations, different duration of follow-up, age ranges, and diagnosis criteria. Nationally representative samples should be included and standard methods should be used to estimate the incidence of T2D in the future in China. The incidence of diabetes was also examined in another large-scale prospective study, the Kailuan cohort, including 73,357 participants, age 18 years or older, living in Tangshan city. Fasting blood glucose concentrations and information on lifestyle, social economic status, and medical status were assessed every 2 years since 2006 among the entire cohort of participants. The incidence of T2D was 15.8 per 1,000 person-years from 2006 to 2010 (19). All 5 studies are summarized in Table 2.

RISK FACTORS OF DM IN CHINA

Obesity

Obesity has been well recognized as a central risk factor for diabetes (20,21). Except for the 1995 study, the aforementioned 6 Chinese national DM surveys reported that obesity was strongly associated with the prevalence of DM and IGF. In parallel with the increase in DM prevalence, the prevalence of overweight or obesity (body mass index [BMI] ≥ 25 kg/m²)

among Chinese adults aged 18 years or older increased from 14.6 to 35.1% between 1992 and 2010 (10).

BMI has been widely used in these population-based studies to classify overweight and obesity in adults (22) and has been demonstrated to be an independent risk factor for type 2 DM, as well as the indexes of insulin resistance and β -cell function (23). Although Asians generally have lower prevalence rates of overweight and obesity (as assessed by BMI) than their Western counterparts, the absolute risk of diabetes tends to be higher among Asians for any given level of BMI (24,25). This leads to a similar or even higher prevalence of diabetes in some Asian countries (e.g., China) relative to Western countries (24–26). One study showed that for a fixed body fat percentage, Asians had a 3 to 4 unit (i.e., kg/m²) lower BMI than Europeans (27). Furthermore, the body fat percentage for fixed BMI also differs between Asian groups. For example, in one study, Singapore Chinese were found to have lower body fat than Indians and Malays (28).

Due to differences in body composition across populations, many researchers studied the association between central obesity, as measured by waist circumference (WC) or waist-to-hip ratio (WHR), and DM risk. A recent study compared the association of diabetes with WC or WHR, relative to that with BMI, and found that BMI and WC/WHR could predict diabetes risk, independent of each other (20). The Multi-Ethnic Study of Atherosclerosis, funded by the National Institutes of Health and initiated in 2000 among approximately 7,000 U.S. men and women aged 45 to 84 years showed that for a given WC, Chinese Americans have the highest incidence of diabetes, followed by Hispanic, African, and European ancestry individuals (29), which may be explained by higher levels of visceral adipose tissue in Chinese Americans when compared with Europeans for a fixed WC (30). Furthermore, higher central adiposity was also associated with prediabetes in a recent Chinese study (31).

Diet

In the last 30 years, the Chinese dietary pattern has been shifting towards a high-fat, high-energy-density, and low-fiber diet (32). For example, between 1992 and 2002, the proportion of energy intake obtained from animal foods increased from 9.3 to 13.7% (10). Several U.S. cohorts have consistently shown that diet plays an important role in the development of diabetes, independent of BMI (33,34). A diet high in cereal fiber and polyunsaturated fat and low in saturated and trans fats and glycemic load are associated with a lower risk of DM (33,34). Data from the 2002 China National Nutrition and Health Survey also demonstrated that dietary patterns characterized by high fat and low carbohydrate, which is different from traditional Chinese diets, were associated with a higher risk of having diabetes in the Chinese population (35). Dietary patterns were associated with the presence of glucose-tolerance abnormalities, even independent of obesity. A new affluence diet (mainly well-to-do individuals) was considered as an important modifiable risk factor (36). Refined cereals form the basis of Chinese diets with high glycemic index and glycemic load values. In a prospective cohort study of middle-aged Chinese women in Shanghai, a high intake of foods with a high glycemic index or glycemic load, especially rice, was associated with a 2-fold (the highest vs. the lowest quintiles of rice intake) increased risk of diabetes (37). The same ongoing Chinese cohort also reported that a dietary pattern low in staple foods (i.e., rice,

noodle, steamed bread, and bread) and high in dairy milk was associated with lower risk of DM (38). In addition, glycemic response to glucose and rice in people of Chinese ethnicity was 60% greater than in Europeans (39). Very recently, results from the China Health and Nutrition Survey reconfirmed the association between dietary patterns and diabetes or insulin resistance among Chinese adults, using both principal component analysis and reduced rank regression (40).

Both the quantity and quality of dietary fat and fatty acids may have an effect on health outcome. In the Shanghai Women/Men Health Study, women in the highest quintile of intake of long-chain n-3 fatty acids had 16% lower risk of T2D compared with those in the lowest quintile after 9 years of follow-up, and shellfish intake was significantly associated with a lower risk of T2D in both women and men (41).

Sugar-sweetened beverages were reported to be associated with a higher risk of T2D; however, national consumption data for sugar-sweetened beverages and its association with T2D are not presently available for China.

Early Life Nutrition and the Great Famine of the 1960s

Early nutrition has a persistent effect on the risk of diabetes in later life. Li et al (42) examined the association between famine exposure in fetal life between 1959 and 1961 and adult hyperglycemia in the Chinese National Nutrition and Health Survey. They found that participants with fetal exposure to severe famine who followed an affluent/Western dietary pattern or who had a higher economic status in later life experienced a substantially higher risk of hyperglycemia, compared with relatively unexposed subjects or those who had a traditional dietary pattern. These findings indicate that undernutrition during early life increases the risk of hyperglycemia in adulthood, and this association is markedly exaggerated when facing overnutrition in later life. A more recent population-based study (data from the Kailuan Health Study [42]) on the association between experiences of famine during early life and DM prevalence in later life had the same conclusions. Many Chinese adults who experienced undernutrition in early life are now adapting Westernized diets and lifestyles; this is one of the important risk factors for the elevated diabetes prevalence in China (43).

Lifestyle (Physical Activity, Smoking, Alcohol Consumption)

A strong relationship between lifestyle factors and the risk of developing diabetes has been well documented. Physical inactivity, smoking, and heavy alcohol drinking have been shown to be independent risk factors for increased DM risk (33,44). A large shift towards increased inactivity has been observed in China (32). Between 1991 and 2006, average physical activity among Chinese adults declined by 32% (45), which could be due to decreases in occupational activities as a result of urbanization (45). Urbanization factors, such as efficient housing infrastructure and increased use of automobiles, predict more than 80% of the decline in occupational physical activity over the 1991–2006 period for men and nearly two-thirds of the decline for women (45,46). The Da Qing Lifestyle Intervention Study showed that lifestyle modification by diet and/or exercise were beneficial for diabetes prevention. In this study, subjects with IGT aged 24 to 74 years were randomly assigned to control, diet,

exercise, and diet plus exercise treatment groups. After 6 years intervention, all of the treatments were effective at reducing the incidence of diabetes, and exercise and diet plus exercise were more beneficial than the diet treatment only (47).

China has become the largest producer and consumer of tobacco in the world; one-third of all cigarettes manufactured are consumed in China (48). For example, in a study including 51,464 Chinese men in urban Shanghai aged 40 to 74 years, 61.8% were current smokers and 30.5% were current regular alcohol drinkers (32.9%) (44). With 5.4 years of follow-up among all the participants, smoking more than 20 cigarettes per day and more than 40 packs per year were associated with a 25 to 28% increased risk of DM (44).

A meta-analysis found that active smoking is positively associated with an increased risk of diabetes, with a dose-response relationship between the number of cigarettes smoked and diabetes risk; heavy smokers (20+ cigarettes/day) had a 61% higher risk of DM (risk ratio, 1.61; 95% confidence interval, 1.43–1.80) compared with nonsmokers (49).

Air Pollution

As a consequence of rapid economic and technologic advances in combination with overpopulation, air pollution has become a major health risk factor in many metropolitan cities in China. Several epidemiologic studies have demonstrated a positive association between particulate matter or traffic-related air pollutants and increased risk of DM (50,51). Inflammation in response to particulate matter exposure in air pollution represents a common mechanism that may interact with other pro-inflammatory influences in diet and lifestyle to modulate susceptibility to DM (50,51). The first study regarding air pollution and fasting blood glucose (FBG) was published in 2016 (52); the researchers estimated the association between air pollutants (particles with diameters of 10 μm or less [PM10], sulfur dioxide [SO₂], and nitrogen dioxide [NO₂]) and FBG in 27,685 participants followed from 2006 to 2008 in the Kailuan study, which was conducted in Tangshan city in China. They found that greater exposure to SO₂, NO₂, and PM10 was associated with elevated FBG levels; the effect of air pollutants on FBG level was stronger in young, elderly, and overweight people. Vulnerable individuals should pay more attention to ambient air pollution to prevent related diseases.

Genetic Factors

Recent genome-wide association studies (GWASs) have observed that many genes confer an increased risk for T2D. GWAS have been used to identify genetic loci which are associated with T2D by searching susceptibility variants across the entire genome. Most of the earlier GWASs were conducted in Caucasian populations and identified numerous loci (53). To validate whether these Caucasian-derived loci also affect the susceptibility to DM in Han Chinese, several replication studies have been performed (53), and most of the susceptibility loci have not been replicated in Chinese populations. For some of the replicated susceptibility loci, the location, the frequency of these risk alleles, as well as the strength of their association with DM, differ from Caucasians. Some common genetic variants, like the *TCF7L2* gene, that are significantly associated with diabetes in Caucasian populations are not common in China (53).

Several Chinese-based GWASs have been conducted (54–58) and have identified several novel loci which have not been reported in previous Caucasian-based studies. GWAS-identified genetic loci in Chinese populations are listed in Table 3. Of note, consistent with the finding from Caucasian genetic studies, most diabetes susceptibility loci identified in Chinese populations are also related to impaired β -cell function, whereas only a few are associated with insulin resistance or fasting insulin, which may suggest a differing pathophysiologic basis of DM in Chinese individuals. It is worth noting that like any other GWAS findings of a complex disease, all the known genetic variations identified explain only a small proportion of the heritability of diabetes (59). The clinical implications of GWAS genetic information remains controversial. Prediction models within the American Framingham Heart Study showed no meaningful improvement in diabetes prediction when genetic information was added to standard clinical predictors (60). Similarly, subjects with high- or low-risk genotypes benefited from lifestyle prevention in the American Diabetes Prevention Program (61). A systematic review and meta-analysis focused on gene polymorphisms in the Inter-East populations indicated that behavior and environmental risk factors had a more significant impact on ethnic difference in East Asian patients with T2D compared with genetic predispositions (62). Therefore, like other multifactorial diseases, diabetes is a product of the interplay between genetic and environmental factors. More research is needed to explore the interaction of genetic and environmental risk factors for T2D.

Socioeconomic Factors

Urbanization was consistently demonstrated as a major risk factor in the aforementioned national studies. Education level was also associated with risk of DM in China. An 11-year follow-up cohort of 10,704 participants aged 18 to 59 years in Qingdao of China showed that low education level was adversely associated with a higher incidence of diabetes, independent of BMI (17). More research is needed to explore other potential possible socioeconomic risk factors in Chinese population such as ethnic groups, culture, and religions.

DIABETES COMPLICATIONS

Approximately one-third of newly diagnosed DM patients in China have some diabetes-related complications (63). However, initiation of diabetic treatment and glycemic control has not been satisfactory at preventing complications. The recent national Chinese DM study showed that only 25.8% of DM patients received treatment for diabetes, and among those treated patients, only 39.7% had adequate glycemic control (2). As a result, diabetic macro- or microvascular complications are common in Chinese DM patients. In 2002, the Chinese Diabetes Society conducted a nationwide retrospective analysis on chronic diabetes-related complications and related macrovascular diseases of inpatients with DM between 1991 and 2000 (64). They found that 73.2% Chinese DM patients had chronic diabetes-related complications and macrovascular diseases. In 2013, another national survey reported similar results. In this national representative sample including 25,817 Chinese outpatients with type 2 DM, 72% had either hypertension, dyslipidemia, or both (65). In contrast, only 5.6% of patients had good control of blood glucose, blood pressure, and blood lipids (65).

STRENGTHS AND LIMITATIONS

In this review, we included the most relevant and recent publications, in both English and Chinese languages. We collected data from 7 nationwide diabetes surveys to show the prevalence changes over recent decades and data from large cohort studies to show the incidence of diabetes in China. We also reviewed the risk factors for diabetes that have been found or confirmed specifically in the Chinese population.

However, the methodology of sampling differed across these 7 national surveys, and the 1994 study used convenience samples rather than representative ones. The 1980 and 1995 studies chose nonrandom, representative provinces on the basis of the geographic distribution. The age groups also varied in all 7 surveys; in the 2001 InterASIA study, age ranged from 35 to 74 years, which may have overestimated the prevalence. This does raise the concern that results across studies are not directly comparable. This is further suggested by the facts that different screening methods and diagnostic criteria for DM were used across studies (Table 1). For example, the cut-off point for FBG in the American Diabetes Association criteria changed from 7.8 to 7.0 mmol/L in 1997 (66), which leads to an underestimation of DM prevalence for studies conducted before 1997. In contrast, the latest study, conducted in 2010, may result in a higher estimation of the prevalence, relative to previous studies, because hemoglobin A1c was for the first time included as an additional screening method, as recommended by the 2010 American Diabetes Association diagnosis criteria.

China has 56 ethnic groups all over the country, and Han are the largest population. In all 7 national diabetes surveys, only the 2002 study reported that the prevalence of diabetes in the Han was higher than in minorities in both men and women in all age groups (7). The 1981 study compared the prevalence between Han and other minorities in the population of the same province, but the results differed across provinces (3). It will be valuable to conduct more studies to focus on the differences in prevalence of diabetes among different ethnicities in China in the future.

CONCLUSION

The prevalence of diabetes has been increasing significantly during the past 30 years and has reached epidemic proportions in China. The prevalence of prediabetes is concomitantly exponentially rising, and the number of individuals with undiagnosed DM or prediabetes is particularly alarming. Implementation of effective steps to suppress the conversion from prediabetes to DM and the recognition and efficient treatment of those with DM are desperately needed in China.

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Abbreviations

BMI	body mass index
DM	diabetes mellitus
FBG	fasting blood glucose
GWAS	genome-wide association study
IGR	impaired glucose regulation
IGT	impaired glucose tolerance
OGTT	oral glucose tolerance test
T2D	type 2 diabetes
WC	waist circumference
WHR	waist-hip ratio

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Figure 1.

Prevalence and its 95% confidence interval of diabetes mellitus (DM) and impaired glucose regulation (IGR) of China. IGR referred impaired glucose tolerance by WHO criteria (in the 1994, 1995 and 2007 surveys) or impaired fasting glucose by ADA criteria (in the 2001, 2002, 2010 surveys) (Note: the detailed diagnosis criteria of DM and IGR used in the 7 studies were described in table 2)

Figure 2. Prevalence trend for diabetes mellitus (DM) (panel A) and impaired glucose regulation (IGR) (Panel B) in China, in each age group (Note: the detailed diagnosis criteria of DM and IGR used in the 7 studies were described in table 2)

Figure 3. Prevalence of diabetes mellitus (DM) (panel A) and impaired glucose regulation (IGR) (Panel B) in China, according to sex (Note: the detailed diagnosis criteria of DM and IGR used in the 7 studies were described in table 2)

Figure 4. Prevalence of diabetes mellitus (DM) and impaired glucose regulation (IGR) in urban and rural area (Note: the detailed diagnosis criteria of DM and IGR used in the 7 studies were described in table 2)

Table 1

National studies of prevalence of diabetes in China

Author, study & start year	Sample size	Age range (years)	Diagnosis method	Glycemic thresholds for DM diagnosis	Diagnosis criteria	Age adjusted	BMI (kg/m ²)
National Diabetes Research Group, 1980 National DM survey (3)	314,895	all	Urine glucose/2-h PG/OGTT	FPG 7.2mmol/L; or 2-h PG 11.1 mmol/L;	Lanzhou criteria (3)	Yes	-
Pan, 1994 National DM survey (4)	213,515	25–64	2-h PG/OGTT	FPG 7.8 mmol/L; or 2hPG 11.1 mmol/L;	WHO 1985	Yes	25.2 (for DM) 23.8 (for normal ^a)
Wang, 1995 National DM survey (5)	42,751	20–74	FPG ³ /OGTT	FPG 7.8 mmol/L; or 2-h PG 11.1 mmol/L	WHO 1985	Yes	-
Gu, 2001 InterASIA (6)	15,236	35–74	FPG	FPG 7.0 mmol/L	ADA 2002	Yes	24.3 (for urban) 23.3 (for rural)
Liu, 2002 National Nutrition and Health Survey (7)	47,729	20-	FPG	FPG 7.0 mmol/L	ADA 2009	Yes	-
Yang, 2007 The China National Diabetes and Metabolic Disorders Study (8)	46,239	20-	OGTT	FPG 7.0 mmol/L; 2-h PG 11.1 mmol/L	WHO 1999	Yes	23.6 (for normal ^a men) 26.6 (for T2D men) 22.0 (for normal ^a women) 25.9 (for T2D women)
Xu, 2010 China Noncommunicable Disease Surveillance (2)	98,658	18-	FPG/2-h PG/HbA1c	FPG 7.0 mmol/L; or 2-h PG 11.1 mmol/L; or HbA1c 6.5% (48mmol/mol)	ADA 2010	Yes	23.7

Abbreviations: ADA = American Diabetes Association; BMI = body mass index; DM = diabetes mellitus; FPG = fasting plasma glucose; HbA1c = glycated hemoglobin; OGTT = oral glucose tolerance test; PG = postprandial glucose; T2D = type 2 diabetes; WHO = World Health Organization.

^aBlood glucose is in normal range.

Table 2

Large Cohort Studies of Incidence of Diabetes in China

Study	Daqing (15)	Shanghai Women's Health Study (16)	Shanghai Men's Health Study (16)	Qingdao Port Health Study (17)	ChinaMUA and the China Cardiovascular Health Study (18)	Kailuan Study (19)
Sample size	36,471 (18,801 M; 17,670 F)	69,385 F	55,311 M	10,704 (8,238 M; 2,466 F)	15,684 (7,277 M; 8,407 F)	73,357 (57,719 M; 20,400 F)
Follow-up years (start year)	4 (1986)	7.3 (1997–2000)	3.6 (2002–2006)	11 (2000)	8 (2000–2001)	4 (2006–2010)
Age range (years)	25–74	40–70	40–74	18–59	35–74	18
Diagnosis method	Urine glucose/2-h PG/OGTT	FPG/OGTT	FPG/OGTT	FPG	FPG	FPG
Glycemic thresholds for DM diagnosis		FPG 7.0 mmol/L; 2-h PG 11.1 mmol/L	FPG 7.0 mmol/L; 2-h PG 11.1 mmol/L	FPG 7.0 mmol/L	FPG 7.0 mmol/L	FPG 7.0 mmol/L
Diagnosis criteria	WHO 1985			WHO 1999	ADA	ADA
Location	Daqing	Shanghai city	Shanghai city	Qingdao city	14 provinces	Kailuan community in Tangshan city
Incidence (per 1,000 person-years)	1.31	3.61	2.7	9.5	9.6 (men) 9.2 (women)	15.8

Abbreviations: ADA = American Diabetes Association; DM = diabetes mellitus; F = female; FPG = fasting plasma glucose; M = male; OGTT = oral glucose tolerance test; PG = postprandial glucose; WHO = World Health Organization.

Table 3

Type 2 Diabetes Genes Identified by GWASs in Han Chinese

Gene	SNP	Risk allele	RAF (case)	RAF (control)	Odds ratio	Reference
<i>SRR</i>	rs391300	G	0.68	0.62	1.28	(54)
<i>SRR</i>	rs4523957	T	0.68	0.63	1.27	(54)
<i>PTPRD</i>	rs17584499	T	0.09	0.06	1.57	(54)
<i>KCNQ1</i>	rs231361	T	0.83	0.79	1.30	(54)
<i>KCNQ1</i>	rs231359	A	0.84	0.80	1.33	(54)
<i>KCNQ1</i>	rs2237895 ^a	C	0.39	0.33	1.29	(54)
<i>KCNQ1</i>	rs163182	C	0.40	0.33	1.305	(55)
<i>C2CD4A/B</i>	rs1370176	C	0.73	0.69	1.115	(55)
<i>C2CD4A/B</i>	rs1436953	G	0.67	0.62	1.187	(55)
<i>C2CD4A/B</i>	rs7172432 ^a	A	0.64	0.58	1.137	(55)
<i>MGLL</i>	rs3773159	T	0.18	0.11	1.137	(55)
<i>GRK5</i>	rs10886471	C	NA	NA	1.12	(56)
<i>RASGRP1</i>	rs7403531	T	NA	NA	1.10	(56)
<i>CDKAL1</i>	rs2206734	A	NA	NA	1.37	(56)
<i>GLIS3</i>	rs10814916	C	NA	NA	1.11	(56)
<i>CDKN2B</i>	rs2383208 ^b	A	NA	NA	1.22	(56)
<i>CDC123</i>	rs11257655 ^b	T	NA	NA	1.15	(56)
<i>KCNQ1</i>	rs2299620	G	NA	NA	1.37	(56)
<i>HNF1B</i>	rs4430796	G	NA	NA	1.19	(56)
<i>FAM58A</i>	rs12010175	G	NA	NA	1.21	(56)
<i>DUSP9</i>	rs5945326 ^a	A	NA	NA	1.18	(56)
<i>PAX4</i>	rs10229583 ^a		0.87	0.78	1.66	(57)
13q31.1	rs1359790	G	0.75	0.71	1.15	(58)
10p13	rs10906115	A	0.65	0.62	1.13	(58)
15q22.2	rs1436955	C	0.79	0.75	1.13	(58)

Abbreviations: RAF = risk allele frequency; SNP = single-nucleotide polymorphism.

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^aGene variants confirmed in Caucasians: rs2237895 in KCNQ1 (67); rs7172432 in C2CD4A/B (68); rs5945326 in DUSP9 (59); rs10229583 in PAX4 (57).
^bGene variants reported in Caucasians with same gene but different SNPs (56).