scientific reports

Check for updates

OPEN

Identification of risk factors for diabetes in Chinese middle-aged and elderly adults

Shuzhen Ma[1,2]✉, Qianqian Sun[3], Yanqi Xu[4], Qiang Tu[5] & Simao Xu[6]✉

This study aimed to identify and analyze the factors associated with the prevalence of diabetes among Chinese adults, using data from the China Health and Retirement Longitudinal Study (CHARLS). Data from the CHARLS cohort, with a mean age of 63.3 years, were analyzed using SPSS software. Descriptive statistics were performed for the overall population, as well as urban and rural subgroups. Logistic regression models were employed to assess the association between diabetes and variables such as age, gender, smoking, alcohol consumption, hypertension, and mental health disorders. Paired-sample t-tests were conducted to evaluate changes in diabetes prevalence across 2015, 2018, and 2020. The average of diabetes increased from 1.08 in 2015 to 1.15 in 2020, with a statistically significant difference (P < 0.001). Paired-sample t-tests showed significant differences between 2020 and 2018, as well as between 2018 and 2015 (P < 0.001). Logistic regression analysis identified hypertension (aOR = 0.447, 95% CI: 0.410–0.488, P < 0.001) and chronic disease (aOR = 0.024, 95% CI: 0.013–0.042, P < 0.001) as key risk factors for diabetes. Mild physical exercise was a protective factor (aOR = 0.813, 95% CI: 0.708–0.935, P < 0.01), while smoking (aOR = 1.220, 95% CI: 1.088–1.369, P < 0.001) and alcohol consumption (aOR = 1.125, 95% CI: 1.020–1.242, P < 0.05) increased the risk. Smoking and alcohol had a greater impact in urban areas, while hypertension and mental health disorders were more influential in rural areas. This study demonstrates that age, gender, smoking, alcohol consumption, hypertension, and mental disorders significantly influence the risk of diabetes among Chinese adults aged 45 and above. Distinct risk factors were identified between urban and rural populations, highlighting the necessity for tailored intervention strategies. The longitudinal analysis from 2015 to 2020 revealed a substantial increase in diabetes prevalence, underscoring the critical need for sustained and targeted public health efforts.

Keywords Diabetes, Risk factor, CHARLS

Background

Accordingto the World Health Organization (WHO), 422 million people worldwide have diabetes[1,2]. Diabetes has become a significant global public health issue, with its impact being especially severe in developing countries like China[3]. Rapid urbanization and substantial lifestyle changes in China have led to a sharp increase in the number of diabetes patients[4–6]. Between 1990 and 2019, the global age-standardized disability-adjusted life years (DALYs) per 100,000 population attributable to type 2 diabetes increased from 628.3 to 801.5, indicating a significant rise in the global burden of type 2 diabetes[7]. In China, these rates rose by 71.5%, from 414 per 100,000 person-years in 1990 to 710 per 100,000 person-years in 2017. With its large population, China has the highest number of diabetes patients worldwide[8]. Furthermore, China's large elderly population exacerbates the burden of elder care[9], contributing to the country's increasing economic strain[6,10].

[1]College of Public Administration, Guilin University of Technology, Guilin 541004, China. [2]Department of Sports Studies, Faculty of Educational Studies, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia. [3]Yantai Affiliated Hospital of Binzhou Medical University, Yantai 264100, China. [4]College of Materials Science and Engineering, Key Laboratory of New Processing Technology for Nonferrous Metals and Materials, Collaborative Innovation Center for Exploration of Nonferrous Metal Deposits and Efficient Utilization of Resources, Ministry of Education, Guilin University of Technology, Guilin 541004, China. [5]Faculty of Medicine and Health, The University of Sydney, Sydney 2006, NSW, Australia. [6]College of Physical Education and Health, Guangxi Normal University, Guilin 541004, China. ✉email: msz20210607@126.com; xusimao666@163.com

If left untreated, diabetes can lead to severe medical complications, including cardiovascular disease, stroke, chronic kidney disease, foot ulcers, eye damage, and long-term renal issues[11]. Currently, there is no permanent cure for diabetes, and patients must rely on a healthy lifestyle and timely medication[12]. Therefore, prevention is crucial. Studies indicate that the severe impact of diabetes can be mitigated through proper management and education; however, awareness remains low, particularly in developing countries[13]. In recent years, substantial advancements have been made in diabetes treatment and prevention, notably with the introduction of novel therapeutic agents such as GLP-1 receptor agonists and SGLT2 inhibitors, alongside the integration of digital health technologies like remote monitoring and mobile health applications[14,15]. These innovations have significantly improved glycemic control and the management of diabetes-related complications, leading to enhanced long-term outcomes and more personalized treatment strategies for high-risk populations. However, despite these advancements, the overall control of diabetes remains a major challenge, particularly among elderly individuals and rural populations in China, where management and prevention efforts are still insufficient[16,17].

Early intervention and comprehensive health education programs have demonstrated significant potential in reducing the risk of complications and improving patient outcomes[18]. These efforts are crucial for addressing the growing burden of diabetes in China and enhancing overall disease management. Previous studies have identified various risk factors associated with diabetes prevalence in the Chinese population, including age, sex, obesity, physical inactivity, unhealthy diet, and genetic predisposition[19–21]. Research utilizing data from large-scale surveys such as the China Health and Nutrition Survey (CHNS) and the China Kadoorie Biobank has provided valuable insights into the epidemiology and risk factors of diabetes in China[22–26]. However, most of these studies are cross-sectional, limiting the ability to infer causal relationships and understand the temporal dynamics of risk factors influencing diabetes prevalence over time.

The China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey initiated in 2011, provides comprehensive health, demographic, and socioeconomic data, making it an ideal source for investigating diabetes risk factors and prevalence trends in China[27]. While some studies have used the CHARLS dataset to explore health outcomes in the aging population, limited research has specifically focused on diabetes risk factors using this longitudinal data[28,29]. There is a critical need for longitudinal analyses to clarify the temporal relationships between risk factors and diabetes development, which can inform more effective prevention and intervention strategies.

Therefore, this study aims to utilize data from CHARLS to identify and analyze risk factors associated with diabetes among middle-aged and elderly Chinese adults. By adopting a longitudinal approach, we will examine trends and changes in diabetes prevalence across different survey waves and explore the relationships between various risk factors and the prevalence of diabetes. The findings of this study are expected to deepen our understanding of diabetes risk factors in the Chinese context and provide robust evidence to inform future public health strategies, including policy reforms, tailored health education programs, and targeted interventions for vulnerable populations. These efforts are crucial for mitigating the growing burden of diabetes in China and improving overall disease management.

Method

Data source

This study utilizes data from CHARLS, a nationally representative survey targeting the Chinese elderly population, which investigates the social, economic, and health status of residents aged 45 and above[30]. CHARLS collects comprehensive data on health, economic, and social factors, tracking individuals over time to provide valuable longitudinal insights into the health dynamics of this population[30]. The CHARLS study employed a multi-stage stratified random sampling method to recruit participants, starting with the selection of 150 county-level units from 28 provinces to capture a diverse range of urban and rural settings with varying economic development levels. Next, 939 primary sampling units (PSUs), including 470 villages and 469 communities, were randomly selected from these counties. In total, the sample included 450 villages, 150 counties, and 28 provinces, involving over 17,000 individuals from approximately 10,000 households[31]. To illustrate the geographic distribution of the sampled areas, a map is provided (as shown in Fig. 1). Map created using CorelDRAW X4 (version 14.0, https://www.coreldraw.com). All residences in each selected PSU were mapped using CHARLS-GIS software on Google Earth, specifically designed for this study[32]. Mappers used GPS devices to collect boundary information for each PSU. Using these boundaries, the research office obtained map images and systematically numbered all buildings, excluding collective living establishments such as military bases, schools, dormitories, or nursing homes. Supervisors used CHARLS-GIS software to randomly select households for field staff to collect information. Based on these data, the final sampling proportions were determined, and the sample units were selected[33]. In the next stage, 24 households were randomly selected from each PSU. Finally, one adult aged 45 or older was randomly chosen from each household for detailed data collection and tracking[34]. All data collection involved in-person interviews and standardized physical health assessments, including measurements of blood pressure, height, weight, and blood samples for laboratory testing. The survey also utilized self-reported questionnaires to gather information on participants' health history, lifestyle factors, and socioeconomic status. Subsequent follow-up assessments were conducted at intervals of two to three years[35]. In this study, diabetes outcomes were assessed during each data collection wave, specifically in 2015, 2018, and 2020. Notably, the 2020 data were publicly released on November 16, 2023. This study specifically analyzes data from the 2015, 2018, and 2020 CHARLS surveys to capture trends and changes in diabetes prevalence and associated risk factors, facilitating a comprehensive longitudinal analysis.

Ethics statement

All participants provided informed consent, and the study, including the collection of anthropometric data, received ethical approval from the Institutional Review Board (IRB) at Peking University (IRB00001052-11015).

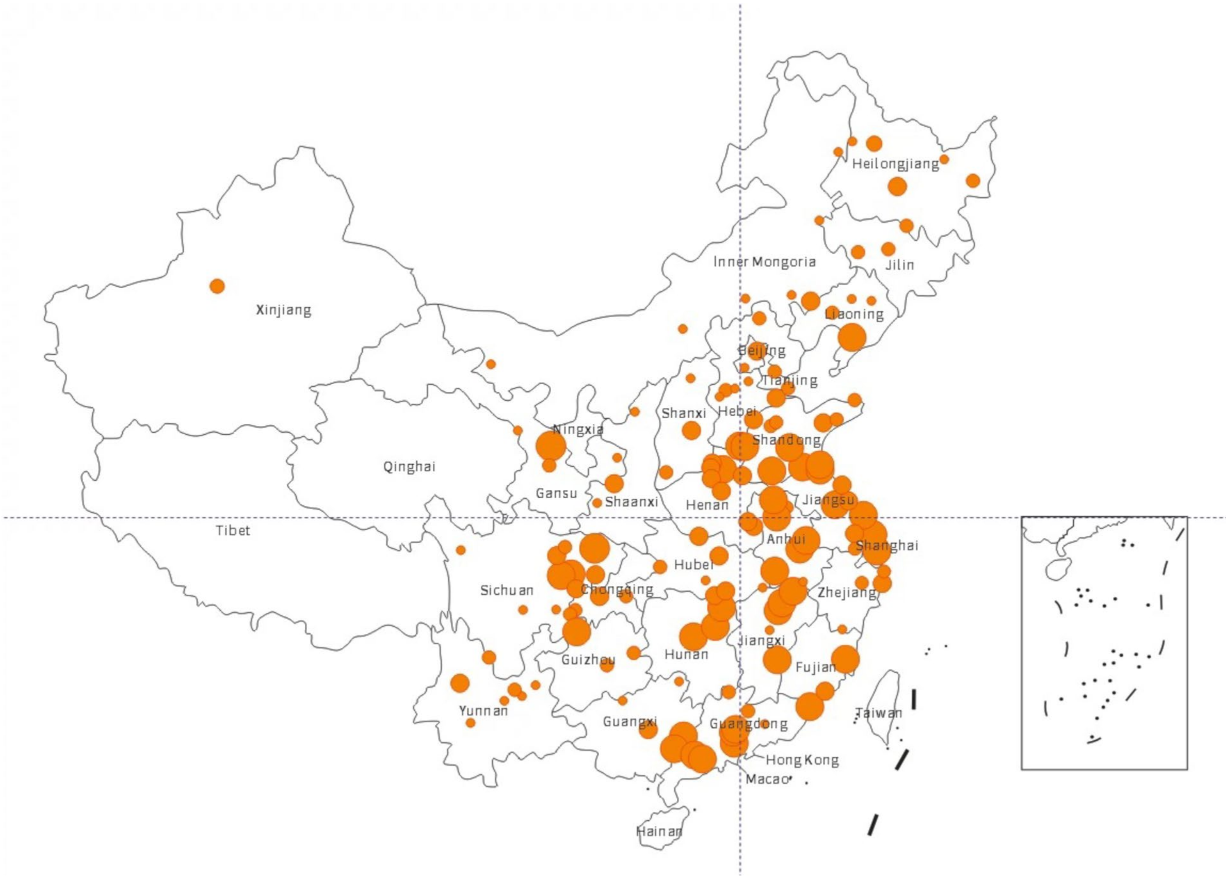

Fig. 1. Geographic distribution of sampled areas (Map created using CorelDRAW X4, version 14.0, https://www.coreldraw.com).

Assessment

In this study, the evaluation of diabetes relies on self-reported data and physical examination results from the CHARLS survey. The criteria for defining diabetes are as follows:

1. Self-reported diagnosis: participants reported having been diagnosed with diabetes by a Doctor.
2. Blood glucose levels: Diabetes status was confirmed based on physical examination results, including fasting blood glucose levels of ≥7.0 mmol/L (126 mg/dL) and glycated hemoglobin (HbA1c) levels of ≥6.5%, in accordance with established guidelines from the World Health Organization (WHO) and the American Diabetes Association (ADA).

Equality, diversity and inclusion

This study emphasizes equality, diversity, and inclusion to ensure a comprehensive analysis and broad applicability of the results across different populations. By employing the multi-stage stratified random sampling method used in CHARLS, the sample achieves wide representativeness across different regions of China. In this study, "geographical background" refers to participants' areas of residence, distinguishing specifically between urban and rural regions. By incorporating this factor, we assessed how geographical differences impact diabetes risk and included it as an important variable in our analysis. The analysis also considers gender and age differences, ensuring that the health status of both male and female participants, as well as various age groups, is adequately accounted for.

Statistical analysis

Based on data from the CHARLS, a logistic regression model was utilized to evaluate the influence of various risk factors on the prevalence of diabetes in China. Descriptive statistical analyses were conducted on the total sample, as well as on urban and rural subgroups. Variables were filtered to remove missing data, and continuous variables were checked for outliers and transformed where necessary. Categorical variables were appropriately coded for analysis to ensure the accuracy of the descriptive statistics. Statistical software SPSS was used for logistic regression analysis and paired-sample t-tests. Specifically, logistic regression was applied to assess the impact of different risk factors on the presence of diabetes. In this analysis, the dependent variable (diabetes) was categorized as 1 (no diabetes) and 2 (diabetes). A binary logistic regression model was employed to explore the risk factors, including gender, age, sleep time, life satisfaction, alcohol consumption, smoking, hypertension, psychiatric disorders, mild exercise, regular exercise, and chronic disease, that influence the risk of having diabetes.

To further compare differences in diabetes prevalence across 2015, 2018, and 2020, paired-sample t-tests were conducted. In these tests, participants with complete data from all three survey waves were selected. A unique identifier for each individual ensured proper matching across the time points, allowing for a within-subject comparison of changes over time. This method ensures that the statistical analysis accurately reflects longitudinal variations within the same cohort.

The selection of variables was based on key risk factors for diabetes confirmed in existing literature[36–40]. Variables such as age, gender, hypertension, chronic disease, smoking, alcohol consumption, exercise, mild exercise, sleep duration, life satisfaction, and psychiatric disorders were included due to their established associations with diabetes prevalence. By controlling for these variables in the logistic regression model, we aimed to mitigate potential confounding effects and clearly identify the specific contribution of each factor to diabetes risk.

Variable interpretation

Table 1 shows the variable names and types used in the empirical analysis of this study.

Results

Descriptive statistics

Table 2 gives descriptive univariate information of all variables which filtered and processed from the 2020 CHARLS data according to the above processing methods and requirements.

In the overall sample ($N = 19{,}395$), the mean age was 63.33 ± 10.105 years. Regarding marital status, 83.9% of participants were married, and 16.1% were classified as "Others." In terms of alcohol consumption, 64.0% of participants reported not drinking alcohol, while 35.9% consumed alcohol. For smoking, 74.4% of participants did not smoke, and 25.5% were smokers. As for mild exercise, 55.7% of participants reported engaging in it, while 44.3% did not. In total, 88.6% of participants reported regular exercise, and 11.3% did not. Regarding participation in social activities, 97.4% of participants did not engage in club activities, and 96.6% did not participate in volunteer activities or charity events. However, 67.9% of participants reported no social activities with friends, while 32.1% engaged in such activities.

For males ($N = 9{,}093$), the mean age was 63.70 ± 9.754 years. A majority (89.3%) were married, 42.5% consumed alcohol, and 49.7% smoked. Regarding exercise, 49.3% engaged in mild exercise, and 89.1% participated in regular exercise. A higher percentage of men (96.8%) did not participate in club activities, and 96.0% did not engage in volunteer activities. For social activities, 68.5% of men did not socialize with friends, while 31.5% did.

For females ($N = 10{,}302$), the mean age was 63.00 ± 10.394 years. A similar proportion of women (79.2%) were married, and a higher percentage (83.1%) did not consume alcohol. Only 4.2% of women smoked, and 61.3% engaged in mild exercise. A similar proportion of women (88.3%) participated in regular exercise, and 97.9% did not participate in club activities. In terms of volunteer activities, 97.2% of women did not participate, and 67.3% reported no social activities with friends, while 32.6% did.

Among the independent variables, age and sleep time are continuous variables, and their descriptive statistics are presented in Table 3. According to Table 3, for the entire sample, the mean age was 63.32 years, and the average sleep time was 5.996 h. For the urban sample, the mean age was 63.28 years, and the average sleep time was 5.988 h. For the rural sample, the mean age was 63.35 years, and the average sleep time was 6.002 h. The distribution differences in age and sleep time between urban, rural, and overall samples are shown in Fig. 2.

Variable type	Variable name	Variable interpretation	Definition
Dependent variable	Diabetes	1 = No; 2 = Yes	Indicates the presence of diabetes in the participant, based on self-report and physical examination
Independent variables	Gender	1 = Female; 2 = Male	Categorical variable representing the participant's gender
	Age	The larger the value, the older the age	Age of the participant in years
	Sleep time	The larger the value, the longer the sleep time	Average hours of sleep per night
	Satisfaction to life	The larger the value, the higher the satisfaction with life	Rated on a scale from 1 (Very Dissatisfied) to 5 (Very Satisfied)
	Currently drink alcohol	1 = No; 2 = Yes	Indicates if the participant currently consumes alcohol
	Currently smoke	1 = No; 2 = Yes	Indicates if the participant currently smokes
	Hypertension	1 = No; 2 = Yes	Indicates if the participant has been diagnosed with hypertension
	Psychiatric disorders	1 = No; 2 = Yes	Indicates if the participant has any diagnosed psychiatric disorders
	Mild exercise	1 = No; 2 = Yes	Defined as engaging in light physical activities (e.g., walking, yoga) at least once a week, lasting at least 30 min per session
	Exercise	1 = No; 2 = Yes	Defined as engaging in moderate to vigorous physical activities (e.g., running, swimming, cycling) at least once a week, lasting at least 30 min per session
	Chronic disease	1 = No; 2 = Yes	Includes long-term health conditions such as heart disease, chronic kidney disease, asthma, and others, based on self-report

Table 1. Variable table.

Factors	All (*N* = 19395)		Male (*N* = 9093)		Female (*N* = 10302)	
Age	63.33 ± 10.105		63.70 ± 9.754		63.00 ± 10.394	
(a) Marital status						
Others	3119	16.1%	977	10.7%	2142	20.8%
Married	16,276	83.9%	8116	89.3%	8160	79.2%
(b) Currently drink alcohol						
No	12,421	64.0%	3860	42.5%	8561	83.1%
Yes	6974	35.9%	5233	57.5%	1741	16.9%
(c) Currently smoke						
No	14,438	74.4%	4575	50.3%	9863	95.7%
Yes	4957	25.5%	4518	49.7%	439	4.2%
(d) Mild exercise						
No	8594	44.3%	4608	50.7%	3986	38.7%
Yes	10,801	55.7%	4485	49.3%	6316	61.3%
(e) Exercise						
No	2200	11.3%	995	10.9%	1205	11.7%
Yes	17,195	88.6%	8098	89.1%	9097	88.3%
(f) Participation in club activities						
No	18,891	97.4%	8804	96.8%	10,087	97.9%
Yes	504	2.6%	289	3.2%	215	2.1%
(g) Participation in volunteer activities or charity events						
No	18,743	96.6%	8733	96.0%	10,010	97.2%
Yes	652	3.3%	360	4.0%	292	2.8%
(h) Social activities with friends						
No	13,165	67.9%	6227	68.5%	6938	67.3%
Yes	6230	32.1%	2866	31.5%	3364	32.6%

Table 2. Descriptive univariate information.

Factors	All (*N* = 19395)				Urban (*N* = 7793)				Rural (*N* = 11602)			
	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation
Age	45	99	63.32	10.088	45	99	63.28	10.127	45	99	63.35	10.063
Sleep time	0.00	24.00	5.996	2.075	0.00	22.00	5.988	1.880	0.00	24.00	6.002	2.196

Table 3. Descriptive univariate information of age and sleep time.

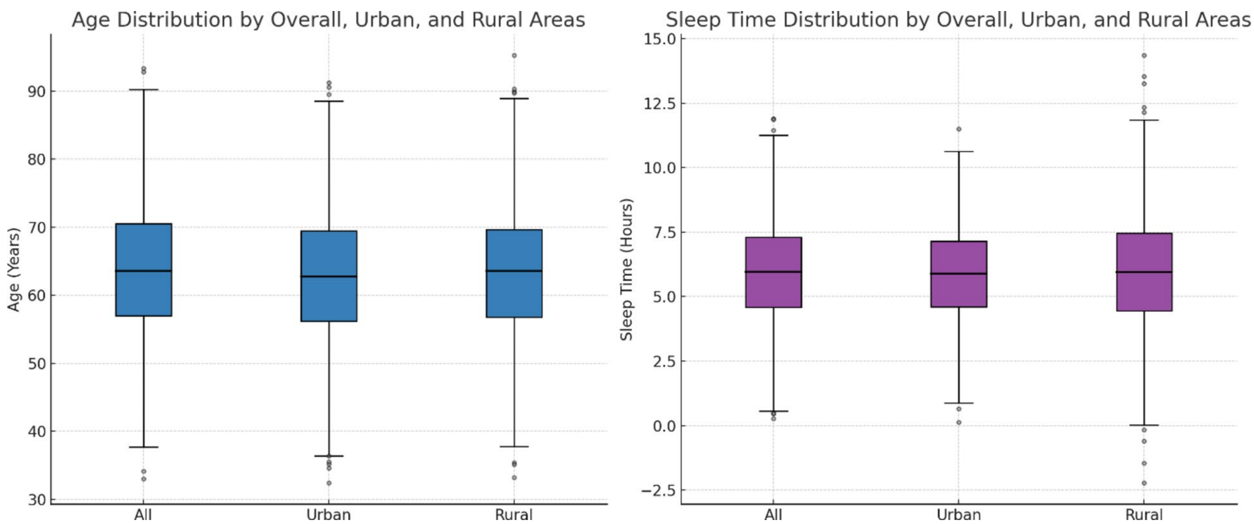

Fig. 2. Distribution differences in age and sleep time among urban, rural, and overall samples.

Logistic regression analysis

In this study, the dependent variable (diabetes) was divided into two categories: no diabetes (coded as 1) and diabetes (coded as 2). A binary logistic regression model was used to explore factors influencing the risk of having diabetes. In the logistic regression analysis, 1 (no diabetes) was the reference category, while 2 (diabetes) represented the outcome of interest. The results are presented in Table 4.

For the overall sample, six independent variables—hypertension, chronic disease, satisfaction with life, mild exercise, alcohol consumption, and smoking—had significant impacts on the likelihood of having diabetes ($p < 0.05$). Participants without hypertension had 55.3% lower odds of having diabetes compared to those with hypertension (β = −0.804, aOR = 0.447, 95% CI = 0.410–0.488, $P < 0.001$). Similarly, individuals without chronic diseases were 97.6% less likely to develop diabetes compared to those with chronic diseases (β = −3.743, aOR = 0.024, 95% CI = 0.013–0.042, $P < 0.001$). For both hypertension and chronic disease, the lower adjusted odds ratios (aORs) (< 1) indicate a decreased likelihood of having diabetes.

Regarding satisfaction with life, all categories showed an increased likelihood of having diabetes compared to those who were "Very satisfied". Specifically, individuals who were very dissatisfied with life had 60.2% higher odds (β = 0.471, aOR = 1.602, 95% CI = 1.173–2.188, $P < 0.01$). Those who were dissatisfied had 38.3% higher odds (β = 0.324, aOR = 1.383, 95% CI = 1.069–1.789, $P < 0.05$), individuals with unclear satisfaction had 29.5% higher odds (β = 0.259, aOR = 1.295, 95% CI = 1.038–1.617, $P < 0.05$), and those who were satisfied had

	All (N = 19395)				Urban (N = 7793)				Rural (N = 11602)			
			95% CI				95% CI				95% CI	
Factors	β	aOR	Lower	Upper	β	aOR	Lower	Upper	β	aOR	Lower	Upper
Gender												
Male (ref:)												
Female	−0.023	0.977	0.883	1.080	−0.088	0.916	0.791	1.060	0.026	1.026	0.892	1.180
Hypertension												
Yes (ref:)												
No	−0.804***	0.447	0.410	0.488	−0.744***	0.475	0.419	0.540	−0.857***	0.425	0.377	0.478
Age												
	0.003	1.003	0.998	1.007	0.005	1.005	0.999	1.012	0.000	1.000	0.994	1.006
Exercise												
Yes (ref:)												
No	0.114	1.121	0.937	1.341	0.297	1.345	0.984	1.840	0.021	1.021	0.819	1.273
Chronic disease												
Yes (ref:)												
No	−3.743***	0.024	0.013	0.042	−3.111***	0.045	0.025	0.079	−18.991	0.000	0.000	.
Sleep time												
	−0.020	0.981	0.962	1.000	0.000	1.000	0.969	1.032	−0.030*	0.971	0.946	0.996
Satisfaction to life												
Very satisfied (ref:)												
Very dissatisfied	0.471**	1.602	1.173	2.188	0.879***	2.409	1.454	3.992	0.278	1.320	0.884	1.971
Dissatisfied	0.324*	1.383	1.069	1.789	0.344	1.411	0.929	2.142	0.333	1.395	1.004	1.938
Unclear	0.259*	1.295	1.038	1.617	0.360*	1.433	1.012	2.031	0.188	1.207	0.905	1.611
Satisfied	0.256*	1.292	1.033	1.617	0.467**	1.595	1.122	2.267	0.086	1.090	0.813	1.460
Mild exercise												
No (ref:)												
Yes	−0.207**	0.813	0.708	0.935	−0.450***	0.638	0.497	0.818	−0.011	0.989	0.834	1.172
Currently drink alcohol												
No (ref:)												
Yes	0.118*	1.125	1.020	1.242	0.138	1.148	0.994	1.326	0.130	1.138	0.993	1.304
Currently smoke												
No (ref:)												
Yes	0.199***	1.220	1.088	1.369	0.128	1.136	0.961	1.343	0.234**	1.263	1.077	1.482
Psychiatric disorders												
No (ref:)												
Yes	−0.418***	0.658	0.544	0.797	−0.401**	0.670	0.501	0.894	−0.424***	0.655	0.506	0.847
Constant	−1.246***	0.288			−1.399***	0.247			−1.145***	0.318		

Table 4. Results of logistic regression analysis. Note: β represents the unstandardized coefficient; aOR represents the adjusted odds ratio; 95% CI refers to the 95% confidence interval; significance levels are indicated as follows: $P < 0.05$ (*); $P < 0.01$ (**); $P < 0.001$ (***).

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Diabe2020	1.15	19,395	0.355	0.003
	Diabe2018	1.13	19,395	0.335	0.002
Pair 2	Diabe2018	1.13	19,816	0.334	0.002
	Diabe2015	1.08	19,816	0.271	0.002

Table 5. The descriptive statistic of diabetes in 2020, 2018 and 2015.

		Paired differences							
					95% Confidence interval of the difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Diabe2020 - Diabe2018	0.019	0.485	0.003	0.012	0.026	5.393	19,394	< 0.001
Pair 2	Diabe2018 - Diabe2015	0.048	0.433	0.003	0.042	0.054	15.732	19,815	< 0.001

Table 6. Paired-samples test of mean of diabetes in 2020, 2018 and 2015.

29.2% higher odds (β = 0.256, aOR = 1.292, 95% CI = 1.033–1.617, $P<0.05$). Participants who engaged in mild exercise were 18.7% less likely to develop diabetes compared to those who did not (β = −0.207, aOR = 0.813, 95% CI = 0.708–0.935, $P<0.01$). People who currently drank alcohol had 12.5% higher odds of having diabetes (β = 0.118, aOR = 1.125, 95% CI = 1.020–1.242, $P<0.05$), while smokers had 22.0% higher odds compared to non-smokers (β = 0.199, aOR = 1.220, 95% CI = 1.088–1.369, $P<0.001$).

For the urban sample, significant factors included hypertension, where individuals without hypertension had 52.5% lower odds of having diabetes compared to those with hypertension (β = −0.744, aOR = 0.475, 95% CI = 0.419–0.540, $P<0.001$). Similarly, individuals without chronic diseases had 95.5% lower odds of having diabetes compared to those with chronic diseases (β = −3.111, aOR = 0.045, 95% CI = 0.025–0.079, $P<0.001$). Participants who were very dissatisfied with life had 140.9% higher odds of having diabetes compared to those who were very satisfied (β = 0.879, aOR = 2.409, 95% CI = 1.454–3.992, $P<0.01$). While dissatisfaction with life (β = 0.344, aOR = 1.411, 95% CI = 0.929–2.142, $P>0.05$) was not statistically significant, individuals with unclear life satisfaction had 43.3% higher odds (β = 0.360, aOR = 1.433, 95% CI = 1.012–2.031, $P<0.05$). Mild exercise also had a significant protective effect, as individuals who engaged in mild exercise were 36.2% less likely to develop diabetes compared to those who did not (β = −0.450, aOR = 0.638, 95% CI = 0.497–0.818, $P<0.001$). Additionally, psychiatric disorders had a protective effect, with individuals without psychiatric disorders being 33.0% less likely to develop diabetes (β = −0.401, aOR = 0.670, 95% CI = 0.501–0.894, $P<0.01$).

For the rural sample, significant factors included hypertension, where individuals without hypertension were 57.5% less likely to develop diabetes compared to those with hypertension (β = −0.857, aOR = 0.425, 95% CI = 0.377–0.478, $P<0.001$). Sleep time had a small protective effect, with longer sleep being associated with 2.9% lower odds of having diabetes (β = −0.030, aOR = 0.971, 95% CI = 0.946–0.996, $P<0.05$). Smokers were 26.3% more likely to develop diabetes compared to non-smokers (β = 0.234, aOR = 1.263, 95% CI = 1.077–1.482, $P<0.01$). As in the overall and urban samples, psychiatric disorders had a protective effect, with individuals without psychiatric disorders being 34.5% less likely to develop diabetes (β = −0.424, aOR = 0.655, 95% CI = 0.506–0.847, $P<0.001$). Across all samples, lower aORs (< 1) consistently indicate a decreased likelihood of having diabetes for certain variables, reinforcing their protective roles.

Paired-samples T test

Paired-samples T Test of dependent variable

As can be seen from Table 5, in three years, the average of diabetes in 2020 is the highest, 1.15; The average for 2018 was in the middle, at 1.13; The minimum average in 2015 was 1.08.

To further test whether these differences are significant, a paired-sample t-test was conducted. The results are presented in Table 6. For Pair 1, the significance level (P) of the t-test statistic was less than 0.001, indicating a significant difference between the diabetes means for 2020 and 2018 at the 1% significance level. Similarly, for Pair 2, the significance level (P) was less than 0.001, indicating a significant difference between the diabetes means for 2018 and 2015 at the 1% significance level.

Paired-samples T test of independent variables

As shown in Table 7, the mean values of the independent variables exhibit variations across the years. Specifically, variables such as hypertension, age, and life satisfaction demonstrate a year-on-year increase, whereas variables like gender and psychological status remain relatively stable between 2015, 2018, and 2020.

As indicated in Table 8, the p-values for the t-test statistics of most independent variables are below 0.05, demonstrating statistically significant differences in mean scores between 2020 and 2018, as well as between 2018 and 2015, at the 5% significance level. However, for variables such as gender and psychological status, the

		Mean	*N*	Std. Deviation	Std. Error Mean
Pair 1	Gender2020	1.48	19,395	0.499	0.004
	Gender2018	1.47	19,395	0.499	0.004
Pair 2	Gender2018	1.47	19,812	0.499	0.004
	Gender2015	1.47	19,812	0.499	0.004
Pair 3	Hypert2020	1.40	19,395	0.490	0.004
	Hypert2018	1.38	19,395	0.486	0.003
Pair 4	Hypert2018	1.38	19,816	0.486	0.003
	Hypert2015	1.27	19,816	0.446	0.003
Pair 5	Age2020	63.32	19,381	10.088	0.072
	Age2018	61.80	19,381	10.407	0.075
Pair 6	Age2018	61.82	19,759	10.417	0.074
	Age2015	59.58	19,759	10.692	0.076
Pair 7	Exercise2020	1.90	19,395	0.317	0.002
	Exercise2018	1.89	19,395	0.305	0.002
Pair 8	Exercise2018	1.89	19,816	0.305	0.002
	Exercise2015	1.42	19,816	0.494	0.004
Pair 9	Chronic2020	1.81	19,378	0.396	0.003
	Chronic2018	1.79	19,378	0.406	0.003
Pair 10	Chronic2018	1.79	16,507	0.406	0.003
	Chronic2015	1.80	16,507	0.399	0.003
Pair 11	Sleep2020	5.99	19,322	2.074	0.015
	Sleep2018	6.24	19,322	2.016	0.015
Pair 12	Sleep2018	6.24	18,308	2.019	0.015
	Sleep2015	6.40	18,308	1.924	0.014
Pair 13	Satlife2020	3.33	19,395	0.785	0.006
	Satlife2018	3.06	19,395	0.992	0.007
Pair 14	Satlife2018	3.06	19,816	0.991	0.007
	Satlife2015	3.23	19,816	0.969	0.007
Pair 15	Mildex2020	1.77	19,395	0.421	0.003
	Mildex2018	1.82	19,395	0.383	0.003
Pair 16	Mildex2018	1.82	19,816	0.383	0.003
	Mildex2015	1.37	19,816	0.484	0.003
Pair 17	Drinkl2020	1.36	19,316	0.480	0.003
	Drinkl2018	1.35	19,316	0.472	0.003
Pair 18	Drinkl2018	1.35	19,577	0.472	0.003
	Drinkl2015	1.34	19,577	0.478	0.003
Pair 19	Smoken2020	1.28	19,316	0.436	0.003
	Smoken2018	1.27	19,316	0.442	0.003
Pair 20	Smoken2018	1.27	19,585	0.443	0.003
	Smoken2015	1.26	19,585	0.449	0.003
Pair 21	Psyche2020	1.03	19,395	0.175	0.001
	Psyche2018	1.03	19,395	0.179	0.001
Pair 22	Psyche2018	1.03	19,816	0.178	0.001
	Psyche2015	1.02	19,816	0.137	0.001

Table 7. The descriptive statistic of independent variables in 2020, 2018 and 2015.

P-values exceed 0.05, indicating no statistically significant differences in mean scores across these time periods. The trends in these variables are further illustrated in Fig. 3.

Discussion

The findings of this study offer valuable insights into the risk factors contributing to diabetes among Chinese adults aged 45 and above using data from the China Health and Retirement Longitudinal Study (CHARLS). By analyzing these factors, we gain a deeper understanding of diabetes epidemiology in this population and identify potential areas for targeted public health interventions. A significant innovation of this study is the utilization of longitudinal data from the 2015, 2018, and 2020 CHARLS datasets. This dataset offers a unique opportunity to examine a large, nationally representative sample of middle-aged and elderly Chinese adults. It allows for an

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Gender2020 - Gender2018	0.003	0.706	0.005	−0.013	0.007	−0.549	19,394	0.583
Pair 2	Gender2018 - Gender2015	0.002	0.704	0.005	−0.012	0.008	−0.444	19,811	0.657
Pair 3	Hypert2020 - Hypert2018	0.019	0.684	0.005	0.009	0.028	3.788	19,394	< 0.001
Pair 4	Hypert2018 - Hypert2015	0.107	0.660	0.005	0.098	0.116	22.787	19,815	< 0.001
Pair 5	Age2020 - Age2018	1.519	14.410	0.104	1.316	1.722	14.676	19,380	< 0.001
Pair 6	Age2018 - Age2015	2.240	14.869	0.106	2.033	2.448	21.179	19,758	< 0.001
Pair 7	Exercise2020 - Exercise2018	0.009	0.439	0.003	−0.016	−0.003	−2.978	19,394	0.003
Pair 8	Exercise2018 - Exercise2015	0.474	0.580	0.004	0.465	0.482	114.920	19,815	< 0.001
Pair 9	Chronic2020 - Chronic2018	0.014	0.562	0.004	0.006	0.021	3.349	19,377	0.001
Pair 10	Chronic2018 - Chronic2015	0.008	0.568	0.004	−0.017	0.000	−1.906	16,506	0.057
Pair 11	Sleep2020 - Sleep2018	0.247	2.886	0.021	−0.288	−0.206	−11.889	19,321	< 0.001
Pair 12	Sleep2018 - Sleep2015	0.155	2.771	0.020	−0.196	−0.115	−7.591	18,307	< 0.001
Pair 13	Satlife2020 - Satlife2018	0.274	1.258	0.009	0.257	0.292	30.373	19,394	< 0.001
Pair 14	Satlife2018 - Satlife2015	0.174	1.389	0.010	−0.194	−0.155	−17.654	19,815	< 0.001
Pair 15	Mildex2020 - Mildex2018	0.052	0.564	0.004	−0.059	−0.044	−12.716	19,394	< 0.001
Pair 16	Mildex2018 - Mildex2015	0.448	0.617	0.004	0.439	0.456	102.245	19,815	< 0.001
Pair 17	Drinkl2020 - Drinkl2018	0.025	0.669	0.005	0.015	0.034	5.140	19,315	< 0.001
Pair 18	Drinkl2018 - Drinkl2015	0.018	0.668	0.005	−0.027	−0.008	−3.715	19,576	< 0.001
Pair 19	Smoken2020 - Smoken2018	0.011	0.620	0.004	−0.020	−0.002	−2.438	19,315	0.015
Pair 20	Smoken2018 - Smoken2015	0.013	0.632	0.005	−0.022	−0.004	−2.927	19,584	0.003
Pair 21	Psyche2020 - Psyche2018	0.001	0.250	0.002	−0.005	0.002	− 0.717	19,394	0.473
Pair 22	Psyche2018 - Psyche2015	0.014	0.224	0.002	0.010	0.017	8.516	19,815	< 0.001

Table 8. Paired-samples test of means of independent variables in 2020, 2018 and 2015.

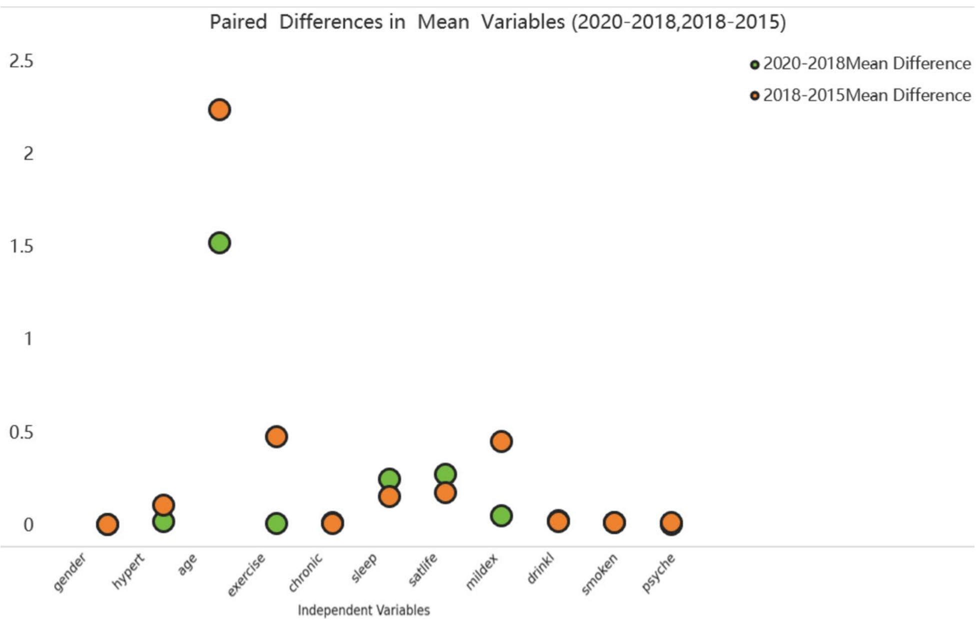

Fig. 3. Trend of Mean Changes for Independent Variables.

in-depth exploration of the socio-economic and demographic factors influencing diabetes risk. Additionally, our research reveals new relationships between lifestyle behaviors and diabetes prevalence, thereby expanding the existing body of knowledge with a specific focus on this age group in China.

Key risk factors and their associations

Although existing literature consistently identifies age as a significant risk factor for diabetes[41,42], the results of this study did not find age to be a statistically significant predictor in the logistic regression analysis ($P > 0.05$). This discrepancy may be due to the confounding influence of other more dominant factors in the sample, such as hypertension and lifestyle-related variables, which may have overshadowed the independent effect of age[43]. Additionally, potential interactions between age and other variables may have mitigated its effect on diabetes risk[44]. Previous studies have also suggested that aging is associated with a natural decline in insulin sensitivity and beta-cell function, which contributes to the increased risk of having diabetes in older populations; however, these effects may be less pronounced when controlling for other risk factors[45,46].

The logistic regression analysis in this study revealed that gender was not a statistically significant predictor of diabetes ($P > 0.05$). However, gender has been widely discussed as a risk factor for diabetes in the existing literature, with men generally exhibiting a higher risk compared to women[45]. This disparity may result from differences in hormones, lifestyle, and fat distribution between genders[47]. Additionally, men are more prone to accumulating visceral fat, which has been strongly associated with insulin resistance and an increased risk of diabetes[48]. In our analysis, the influence of gender may have been overshadowed by other dominant variables, such as hypertension and lifestyle factors, thus reducing its statistical significance. This finding aligns with other studies that suggest the independent effect of gender can diminish when controlling for these confounding factors[49]. Despite the lack of statistical significance in our model, the role of gender as a risk factor remains important within the broader epidemiological context, which is why it was included in the discussion.

Lifestyle factors, including smoking and alcohol consumption, significantly impact diabetes risk. The study found that life satisfaction was significantly associated with diabetes status, particularly for participants who reported being 'very dissatisfied' or 'unclear' about their life satisfaction, highlighting the critical role of emotional and psychological well-being in diabetes management. Our results are consistent with previous research, emphasizing the detrimental effects of these behaviors on metabolic health. Studies have shown that obesity is the most significant modifiable risk factor for non-insulin-dependent diabetes[50–52]. However, smoking and alcohol consumption may also play important roles, either indirectly through their impact on obesity[53–55]or directly through physiological factors related to insulin secretion or insulin resistance[56–58].Independent of body size, smokers experience a higher transient increase in blood glucose concentration after an oral glucose challenge[59,60]compared to non-smokers and have higher insulin resistance[56], suggesting a potential increased risk of diabetes[61]. Based on previous evidence, smoking may be an independent, modifiable risk factor for non-insulin-dependent diabetes[62]. On the other hand, regular alcohol consumption is primarily associated with adverse metabolic characteristics, although it has an independent beneficial association with high-density lipoprotein cholesterol[63].

Pre-existing health conditions, such as hypertension and psychiatric disorders, have also been identified as significant risk factors for diabetes. The relationship between hypertension and diabetes is well-established, with studies indicating that 50–80% of individuals with type 2 diabetes develop hypertension, accounting for over 90% of the diabetic population, while approximately 30% of individuals with type 1 diabetes develop hypertension[64]. On the other hand, anxiety and depression can lead to hormonal imbalances in the body, severely affecting blood sugar control[65]. Interestingly, the results of this study indicated a protective effect of psychiatric disorders on the risk of having diabetes, which may be related to increased healthcare access and monitoring for individuals with mental health conditions.

Urban vs. rural disparities

Analysis of urban and rural populations reveals significant differences in diabetes risk factors between these groups. Increased socioeconomic status has been identified as an independent risk factor for impaired glucose tolerance in both areas[66]. Despite having similar body mass index (BMI), the prevalence of diabetes (DM) is higher in urban populations compared to rural ones[67]. This discrepancy may be attributed to unhealthy lifestyle habits, which are more prevalent among urban residents[68,69]. Conversely, in rural populations, factors such as healthcare disparities, socioeconomic status, and health literacy significantly affect diabetes mortality[70].

Temporal trends and public health implications

Longitudinal analysis of data from 2015, 2018, and 2020 reveals trends in diabetes risk factors over time, indicating a gradual increase in the number of diabetes patients. This observation aligns with previous research showing a progressive increase in the estimated effects of diabetes during the periods 1992–2005, 2006–2010, and 2011–2017 [73]. While increased public awareness and preventive measures may have positively influenced some risk factors, others have deteriorated due to lifestyle and socioeconomic changes. This perspective highlights the need for ongoing monitoring and adjustments to public health strategies.

Epidemiological studies suggest that approximately 11% of the population has diabetes, with a significant portion remaining undiagnosed[71]. Early and sustained interventions are crucial for delaying the onset of diabetes, improving blood glucose levels, and reducing cardiovascular risks in diagnosed patients, thereby lowering morbidity and mortality rates[72]. Consequently, effective diabetes prevention and management require ongoing policy evaluation and adaptation. Greater efforts are needed to understand the underlying drivers of this epidemic and to develop preventive strategies to address the escalating global public health "tsunami"[73].

The findings of this study provide a foundation for enhancing current diabetes management guidelines by emphasizing the role of lifestyle modifications, particularly in high-risk urban populations where unhealthy lifestyle behaviors are more prevalent. Integrating targeted educational programs that promote psychological well-being and encourage healthier lifestyle choices could be crucial. Furthermore, these findings highlight the need for adaptive public health policies that address the unique challenges of urban and rural settings, enabling the development of region-specific diabetes prevention strategies and improved access to healthcare for both urban and rural residents.

Future directions

In summary, this study enhances our understanding of diabetes risk factors in China and underscores the need for targeted public health interventions that address both individual and contextual factors. By considering the diverse needs of urban and rural populations and adapting to evolving trends, we can improve diabetes prevention and management strategies. While this study identified several risk factors associated with diabetes, it did not assess multicollinearity among the predictor variables. High correlations between variables may affect the stability and interpretability of regression coefficients. Additionally, future work could apply clustering techniques to explore patterns of diabetes burden across regions, particularly in urban and rural settings, to identify high-risk areas and inform targeted interventions[74]. Future studies should also employ methods such as the Variance Inflation Factor (VIF) or Condition Index (CI) to assess multicollinearity, thereby improving the robustness of the models and the results.

Limitations

This study has several limitations that must be acknowledged. First, the data were derived from the 2020 CHARLS dataset, which is based on self-reported information, potentially introducing reporting bias due to inaccuracies in how participants disclose their health status. Additionally, the study lacks qualitative insights into the socio-cultural factors influencing diabetes risk, which could provide a more comprehensive understanding of the disease's underlying determinants. Future research should integrate qualitative methods to address this gap. Moreover, multicollinearity among the predictor variables was not assessed, which is crucial for ensuring the stability and interpretability of regression coefficients. Future analyses should evaluate multicollinearity using techniques such as the Variance Inflation Factor (VIF) or Condition Index (CI) to improve the robustness of the findings. Furthermore, diagnostic checks and goodness-of-fit tests (e.g., AIC, BIC, or Hosmer-Lemeshow test) were not performed for the logistic regression models, which could limit the evaluation of model robustness and fit. These tests should be incorporated in future work to enhance the credibility and interpretability of the results. Finally, the use of paired t-tests in this study may not fully account for the correlation structure inherent in longitudinal data, potentially leading to biased estimates. The use of multiple paired t-tests also increases the risk of Type I errors, which could undermine the robustness of the findings.

Conclusion

This study investigates the factors associated with the prevalence of diabetes among Chinese adults aged 45 and above using data from the CHARLS. The findings indicate that smoking, alcohol consumption, hypertension, and mental disorders significantly influence the risk of diabetes, while age and gender do not show a significant association within the overall population. Additionally, distinct risk factors were identified between urban and rural populations, underscoring the need for tailored intervention strategies that address the specific needs of each demographic group. The longitudinal analysis from 2015 to 2020 reveals a substantial increase in diabetes prevalence, highlighting the urgent need for sustained and targeted public health efforts. Developing region-specific preventive measures and enhancing diabetes management programs are essential to effectively curb the growing diabetes epidemic in China and improve health outcomes among its aging population.

Data availability

All data results and analysis methods for this study are included in the article or supplementary information. To support reproducibility, the raw data is also available upon reasonable request. The authors are open to addressing any remaining questions to further research in this field. Please contact the corresponding author if needed.

Received: 7 August 2024; Accepted: 24 March 2025
Published online: 12 April 2025

References

1. Molina, R. T. et al. Predictors of diabetes risk in urban and rural areas in Colombia. *Heliyon* **8**, e01234. https://doi.org/10.1016/j.heliyon.2021.e08653 (2022).
2. Oparaji, N. A. Non-invasive blood glucose monitoring: A new approach for diabetic patients. *Afr. J. Psychol. Stud. Soc.* **27**, 72–85 (2024).
3. Foos, V. et al. Assessing the burden of type 2 diabetes in China considering the current status-quo management and implications of improved management using a modeling approach. *Value Health Reg.* **18**, 36–46 (2019).
4. Federation, I. D. I. D. F. & Diabetes Atlas Tenth. *International Diabetes* (2021).
5. Luo, D. & Kuo, W. C. Great leap forward famine exposure and urban-rural migration convolute the modern prevalence of diabetes in China. *J. Health Popul. Nutr.* **43**, 109–110 (2024).
6. Liu, J. et al. Projected rapid growth in diabetes disease burden and economic burden in China: A spatio-temporal study from 2020 to 2030. *Lancet Reg. Health–West Pac.* **33**, 100700 (2023).
7. Liu, J. et al. Low- and middle-income countries demonstrate rapid growth of type 2 diabetes: an analysis based on global burden of disease 1990–2019 data. *Diabetologia* **65**, 1339–1352 (2022).
8. Yan, Z., Cai, M., Han, X., Chen, Q. & Lu, H. The interaction between age and risk factors for diabetes and prediabetes: A community-based cross-sectional study. *Diabetes Metab. Syndr. Obes.* **16**, 85–93 (2023).

9. Gong, J. et al. Nowcasting and forecasting the care needs of the older population in China: analysis of data from the China health and retirement longitudinal study (CHARLS). *Lancet Public. Health*. **7**, e1005–e1013. https://doi.org/10.1016/S2468-2667(22)00203-1 (2022).
10. Sun, D. et al. Cancer burden in China: trends, risk factors and prevention. *Cancer Biol. Med.* **17**, 879–895 (2020).
11. Ismail, L., Materwala, H. & Al Kaabi, J. Association of risk factors with type 2 diabetes: A systematic review. *Comput. Struct. Biotechnol. J.* **19**, 1759–1785 (2021).
12. Härner, S. & Ekman, D. Comparing ensemble methods with individual classifiers in machine learning for diabetes detection. (2022).
13. Bai, A. et al. Prevalence and risk factors of diabetes among adults aged 45 years or older in China: A National cross-sectional study. *Endocrinol. Diabetes Metab.* **4**, e00265. https://doi.org/10.1002/edm2.265 (2021).
14. Pop, G. N. et al. Bridging the Gap: A literature review of advancements in obesity and diabetes mellitus management. *Appl. Sci.* **14**, 6565 (2024).
15. Caturano, A. et al. Modern challenges in type 2 diabetes: balancing new medications with multifactorial care. *Biomedicines* **12**, 2039 (2024).
16. Dong, C., Wu, G., Li, H., Qiao, Y. & Gao, S. Type 1 and type 2 diabetes mortality burden: predictions for 2030 based on bayesian age-period-cohort analysis of China and global mortality burden from 1990 to 2019. *J. Diabetes Investig*. **15**, 623–633 (2024).
17. Peng, M., Li, L., Shi, X. & Wang, Z. Does integrated health management within a County medical consortium improve rural type 2 diabetic patients' self-management behavior and quality of life? An empirical analysis from Eastern China. *BMC Public. Health*. **24**, 1439 (2024).
18. Francis, A. et al. Chronic kidney disease and the global public health agenda: an international consensus. *Nat. Rev. Nephrol.* **20**, 473–485 (2024).
19. Duan, H. et al. Association of unhealthy lifestyle and genetic risk factors with mild cognitive impairment in Chinese older adults. *JAMA Netw. Open*. **6**, e2324031. https://doi.org/10.1001/jamanetworkopen.2023.24031 (2023).
20. Zhang, K. et al. Metabolic diseases and healthy aging: identifying environmental and behavioral risk factors and promoting public health. *Front. Public. Health*. **11**, 1253506 (2023).
21. Carter, N. et al. Lifestyle behaviours and associated factors among people with type 2 diabetes attending a diabetes clinic in Ningbo, China: A cross-sectional study. *PLoS One*. **18**, e0294245. https://doi.org/10.1371/journal.pone.0294245 (2023).
22. Liu, M. et al. Trajectories of meat intake and risk of type 2 diabetes: findings from the China health and nutrition survey (1997–2018). *Nutrients* **15**, 3277 (2023).
23. Writing Committee of the Annual Report on Cardiovascular Health and Diseases in China Interpretation of the annual report on cardiovascular health and diseases in China 2021. *Cardiol. Discovery*. **3**, 277–300 (2023).
24. Xue, L., Liu, M., Ying, X. & Wu, S. Trends and regional variations in chronic diseases and their risk factors in China: an observational study based on National health service surveys. *Int. J. Equity Health*. **22**, 120 (2023).
25. The Writing Committee of the Report on Cardiovascular Health and Diseases in China. Report on cardiovascular health and diseases in China 2021: an updated summary. *Biomed. Environ. Sci.* **35**, 573–603 (2022).
26. Hu, S. S. Influencing factors on cardiovascular health in China. *J. Geriatr. Cardiol.* **21**, 4 (2024).
27. Zhou, Z. et al. Evaluation of social-economic inequality in the high CVD risk population with or without diabetes in China. *Res. Square*. https://doi.org/10.21203/rs.3.rs-1793719/v1 (2022).
28. Lu, Q. et al. Relationship between social isolation and glycaemic control of people previously diagnosed with diabetes: secondary analysis from the CHARLS. *BMJ Open*. **14**, e076106. https://doi.org/10.1136/bmjopen-2023-076106 (2024).
29. Bu, F. et al. Development and validation of a risk prediction model for frailty in patients with diabetes. *BMC Geriatr.* **23**, 172 (2023).
30. Chen, C. L. et al. Association between triglyceride glucose index and risk of new-onset diabetes among Chinese adults: findings from the China health and retirement longitudinal study. *Front. Cardiovasc. Med.* **7**, 610322 (2020).
31. Hu, Y. et al. Sarcopenia and mild cognitive impairment among elderly adults: the first longitudinal evidence from CHARLS. *J. Cachexia Sarcopenia Muscle*. **13**, 2944–2952 (2022).
32. Song, H. et al. Urban-rural disparity in the utilization of national community-based hypertension monitoring service-results from the China Health and Retirement Longitudinal Study, 2015. *PeerJ* 7, e7842; (2019). (2019) https://doi.org/10.7717/peerj.7842. eCollection.
33. Zhao, Y. et al. China health and retirement longitudinal study–2011–2012 National baseline users' guide. *Natl. Sch. Dev. Peking Univ.* **2**, 1–56 (2013).
34. Ma, X., He, Y. & Xu, J. Urban-rural disparity in prevalence of Multimorbidity in China: A cross-sectional nationally representative study. *BMJ Open*. **10**, e038404. https://doi.org/10.1136/bmjopen-2020-038404 (2020).
35. Gao, Y., Jia, Z., Zhao, L. & Han, S. The effect of activity participation in middle-aged and older people on the trajectory of depression in later life: National cohort study. *JMIR Public. Hlth Sur*. **9**, e44682 (2023).
36. Bishwajit, G., Tang, S., Yaya, S., He, Z. & Feng, Z. Lifestyle behaviors, subjective health, and quality of life among Chinese men living with type 2 diabetes. *Am. J. Men's Health*. **11**, 357–364 (2017).
37. Shim, E. J. et al. Trajectories of depressive symptoms in Korean adults with diabetes: individual differences and associations with life satisfaction and mortality. *Br. J. Health Psychol.* **29**, 1000–1016 (2024).
38. Brückner, R. M., Schönenberg, A., Wientzek, R., Schreiber, M. & Prell, T. Exploring factors associated with self-rated health in individuals with diabetes and its impact on quality of life: evidence from the survey of health, ageing, and retirement in Europe. *J. Diabetes*. **16**, e13522. https://doi.org/10.1111/1753-0407.13522 (2024).
39. Kim, J., Lee, M. & Dan, H. Gender differences in factors affecting life satisfaction of the elderly with Multimorbidity in Korea. *Nurs. Rep.* **11**, 54–63 (2021).
40. Jafari, A., Moshki, M., Ghelichi-Ghojogh, M. & Nejatian, M. Role of diabetes health literacy, psychological status, self-care behaviors, and life satisfaction in predicting quality of life in type 2 diabetes. *Sci. Rep.* **14**, 1635 (2024).
41. Tudurí, E. et al. The pancreatic β-cell in ageing: implications in age-related diabetes. *Ageing Res. Rev.* **80**, 101674 (2022).
42. Janssen, J. A. Hyperinsulinemia and its pivotal role in aging, obesity, type 2 diabetes, cardiovascular disease and cancer. *Int. J. Mol. Sci.* **22**, 7797 (2021).
43. Rostosky, S. S. & Travis, C. B. Menopause research and the dominance of the biomedical model 1984–1994. *Psychol. Women Q.* **20**, 285–312 (1996).
44. Wray, L. A., Ofstedal, M. B., Langa, K. M. & Blaum, C. S. The effect of diabetes on disability in middle-aged and older adults. *J. Gerontol. B Psychol. Sci. Soc. Sci.* **60**, 1206–1211 (2005).
45. Wild, S., Roglic, G., Green, A., Sicree, R. & King, H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care*. **27**, 1047–1053 (2004).
46. Boyle, J. P. et al. Projection of the year 2050 burden of diabetes in the US adult population: dynamic modeling of incidence, mortality, and prediabetes prevalence. *Popul. Health Metr.* **8**, 1–12 (2010).
47. Kautzky-Willer, A., Harreiter, J. & Pacini, G. Sex and gender differences in risk, pathophysiology and complications of type 2 diabetes mellitus. *Endocr. Rev.* **37**, 278–316 (2016).
48. Huxley, R., Barzi, F. & Woodward, M. Excess risk of fatal coronary heart disease associated with diabetes in men and women: Meta-analysis of 37 prospective cohort studies. *Lancet* **332**, 73–78 (2006).
49. Ginter, E. & Simko, V. Type 2 diabetes mellitus, pandemic in 21st century. *Adv. Exp. Med. Biol.* **771**, 42–50 (2012).
50. Barrett-Connor, E. Epidemiology, obesity, and non-insulin-dependent diabetes mellitus. *Epidemiol. Rev.* **11**, 172–181 (1989).

51. Colditz, G. A. et al. Weight as a risk factor for clinical diabetes in women. *Am. J. Epidemiol.* **132**, 501–513 (1990).
52. Chan, J. M., Rimm, E. B., Colditz, G. A., Stampfer, M. J. & Willett, W. C. Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. *Diabetes Care*. **17**, 961–969 (1994).
53. Shimokata, H., Muller, D. C. & Andres, R. Studies in the distribution of body fat. III. Effects of cigarette smoking. *JAMA* **261**, 1169–1173 (1989).
54. Seidell, J. C. et al. Body fat distribution in relation to physical activity and smoking habits in 38-year-old European men. The European fat distribution study. *Am. J. Epidemiol.* **133**, 257–265 (1991).
55. Eisen, S. A., Lyons, M. J., Goldberg, J. & True, W. R. The impact of cigarette and alcohol consumption on weight and obesity. An analysis of 1911 monozygotic male twin pairs. *Arch. Intern. Med.* **153**, 2457–2463 (1993).
56. Facchini, F. S., Hollenbeck, C. B., Jeppesen, J., Chen, Y. D. & Reaven, G. M. Insulin resistance and cigarette smoking. *Lancet* **339**, 1128–1130 (1992).
57. Facchini, F., Chen, Y. I. & Reaven, G. M. Light-to-moderate alcohol intake is associated with enhanced insulin sensitivity. *Diabetes Care*. **17**, 115–119 (1994).
58. Mayer, E. J., Newman, B., Quesenberry, C. Jr, Friedman, P., Selby, J. V. & G. D. & Alcohol consumption and insulin concentrations. Role of insulin in associations of alcohol intake with high-density lipoprotein cholesterol and triglycerides. *Circulation* **88**, 2190–2197 (1993).
59. Janzon, L. et al. Glucose tolerance and smoking: A population study of oral and intravenous glucose tolerance tests in middle-aged men. *Diabetologia* **25**, 86–88 (1983).
60. Pyörälä, K., Savolainen, E., Kaukola, S. & Haapakoski, J. Plasma insulin as coronary heart disease risk factor: relationship to other risk factors and predictive value during 9 1/2-year follow-up of the Helsinki policemen study population. *Acta Med. Scand.* **701**, 38–52 (1985).
61. Reaven, G. M. Role of insulin resistance in human disease. *Diabetes* **37**, 1595–1607 (1988).
62. Rimm, E. B., Chan, J., Stampfer, M. J., Colditz, G. A. & Willett, W. C. Prospective study of cigarette smoking, alcohol use, and the risk of diabetes in men. *BMJ* **310**, 555–559 (1995).
63. Godsland, I., Leyva, F., Walton, C., Worthington, M. & Stevenson, J. C. Associations of smoking, alcohol and physical activity with risk factors for coronary heart disease and diabetes in the first follow-up cohort of the heart disease and diabetes risk indicators in a screened cohort study (HDDRISC-1). *J. Intern. Med.* **243**, 33–41 (1998).
64. Jia, G. & Sowers, J. R. Hypertension in diabetes: an update of basic mechanisms and clinical disease. *Hypertension* **78**, 1197–1205 (2021).
65. Chien, I. C. & Lin, C. H. Increased risk of diabetes in patients with anxiety disorders: A population-based study. *J. Psychosom. Res.* **86**, 47–52 (2016).
66. Sayeed, M. A. et al. Effect of socioeconomic risk factors on the difference in prevalence of diabetes between rural and urban populations in Bangladesh. *Diabetes Care*. **20**, 551–555 (1997).
67. Hussain, A., Rahim, M. A., Azad Khan, A. K., Ali, S. M. K. & Vaaler, S. Type 2 diabetes in rural and urban population: diverse prevalence and associated risk factors in Bangladesh. *Diabet. Med.* **22**, 931–936 (2005).
68. Guevara-Romero, E., Flórez-García, V., Egede, L. E. & Yan, A. Factors associated with the double burden of malnutrition at the household level: A scoping review. *Crit. Rev. Food Sci. Nutr.* **62**, 6961–6972 (2022).
69. Aschner, P. Epidemiology of diabetes in Colombia. *Av. Diabetol.* **26**, 95–100 (2010).
70. Yu, D. et al. Ethnic differences in mortality and hospital admission rates between Māori, Pacific, and European new Zealanders with type 2 diabetes between 1994 and 2018: A retrospective, population-based, longitudinal cohort study. *Lancet Glob Health*. **9**, e209–e217. https://doi.org/10.1016/S2214-109X(20)30412-5 (2021).
71. Ma, R. C. Epidemiology of diabetes and diabetic complications in China. *Diabetologia* **61**, 1249–1260 (2018).
72. Nanayakkara, N. et al. Impact of age at type 2 diabetes mellitus diagnosis on mortality and vascular complications: systematic review and meta-analyses. *Diabetologia* **64**, 275–287 (2021).
73. Nanditha, A. et al. Diabetes in Asia and the Pacific: implications for the global epidemic. *Diabetes Care*. **39**, 472–485 (2016).
74. Ganasegeran, K. et al. How socio-economic inequalities cluster people with diabetes in Malaysia: geographic evaluation of area disparities using a non-parameterized unsupervised learning method. *Epidemiol. Glob Health*. **14**, 169–183 (2024).

Acknowledgements
This study thanks all authors for their contributions.

Author contributions
Conceptualization: Shuzhen MaData curation: Shuzhen MaInvestigation: Shuzhen MaMethodology: Shuzhen MaSupervision: Qianqian Sun, Yanqi Xu, Qiang TuWriting – original draft: Shuzhen Ma Writing – review & editing: Shuzhen Ma，Simao Xu.

Funding
The authors received no specific funding for this work.

Declarations

Competing interests
The authors declare no competing interests.

Patient and public involvement
Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication
Not applicable.

Provenance and peer review
Not commissioned, externally peer reviewed.

Additional information

Correspondence and requests for materials should be addressed to S.M. or S.X.

Reprints and permissions information is available at www.nature.com/reprints.