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ORIGINAL RESEARCH

Prevalence and Associated Factors of Type 2 Diabetes Mellitus Among Chinese Hakka Individuals Aged 35–65 Years: A Cross-Sectional Study

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Purpose: The prevalence of diabetes in China is increasing, influenced by economic and genetic factors, with varying rates across regions. The Hakka population in Ganzhou city has unique exposures compared to surrounding districts, while limited research reported the epidemiological characteristics of type 2 diabetes mellitus (T2DM) in this population. This study aims to investigate the prevalence and influencing factors of T2DM among the population, thereby establishing a robust foundation for disease prevention and control measures.

Patients and Methods: In 2017, a multistage random sampling method selected 3028 individuals from Ganzhou City's permanent resident population. Physical examinations, blood tests, and questionnaire surveys were conducted for data collection, with binary logistic regression analysis used to examine factors affecting T2DM prevalence.

Results: A total of 2978 valid samples were included in this study. The average age of the surveyed population was 52.83±7.88 years, comprising 966 males and 2012 females. The prevalence rates of T2DM were 11.8% and 12.9% in males and females, respectively, while the standardized prevalence rate was recorded as 9.1%. Logistic regression analysis revealed that age (Odds Ratio[*OR*]=1.05, *95%* Confidence Interval [*CI*]:1.03–1.06), hypertension (*OR*=2.22, *95% CI*:1.71–2.93), family history of diabetes (*OR*= 3.54, *95% CI*: 2.58–4.85), overweight (*OR*=1.73, *95% CI*: 1.20–2.48), high total cholesterol (*OR*=1.17, *95% CI*:1.09–1.27), elevated low-density lipoprotein cholesterol (*OR*=1.19, *95% CI*:1.00–1.40) and serum insulin (*OR*=1.05, *95% CI*:1.03–1.06) were identified as significant risk factors for T2DM, Conversely, a higher level of high-density lipoprotein cholesterol (*OR*=0.55, *95% CI*:0.36–0.84) was found to be inversely related to T2DM development.

Conclusion: The prevalence of T2DM in Ganzhou city has significantly increased. The effective implementation of comprehensive management strategies aimed at addressing hypertension, overweight, dyslipidemia, and abnormal serum insulin level is essential for promoting overall well-being and efficiently controlling the prevalence of T2DM.

Keywords: type 2 diabetes mellitus, cross-sectional studies, epidemiology, influence factors

Introduction

Diabetes presents a significant global public health challenge, with the International Diabetes Federation (IDF) projecting that the number of cases of type 2 diabetes mellitus will surge to 783 million by 2045.[1] Approximately three-quarters of individuals diagnosed with diabetes reside in low-income countries,[2] and among them, approximately 240 million cases remain undiagnosed. The prevalence of diabetes among Chinese adults has shown an upward trend over time, as indicated by the IDF2021 diabetes map data. Specifically, the age-adjusted comparative prevalence of diabetes in the

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population aged 20–79 in China was 8.8% in 2011 and increased to 10.6% in 2021.[1] The prevalence rate of diabetes among Chinese adults was found to be 12.8% in another domestic study.[3] The current prevalence of diabetes in China stands at approximately 140.9 million individuals, with projections indicating a rise to 174.4 million by the year 2045[1]. Regional variations in diabetes prevalence within China are significant and potentially influenced by economic and hereditary factors,[3–5] but the etiology of diabetes remains incompletely understood.[2,6]

Hakkas is the descendants of the Central Plains in ancient China who fled to the South to avoid wars, and Ganzhou was their first settlement in the course. The city of Ganzhou has emerged as a prominent hub for the Hakka community while also serving as a historic revolutionary stronghold. However, its economic development lags behind that of its neighboring provinces. The dietary habits in this region clearly differ from those in its neighboring provinces, characterized by a predominant combination of “freshness, spiciness, sourness, and saltiness”. Additionally, Ganzhou city is a significant rare earth production hub in China. The unregulated mining practices of the past have resulted in environmental degradation and adverse health effects.[7,8] However, there is limited literature reporting on the prevalence of diabetes and its influencing factors in this region. The purpose of this study was to investigate the prevalence of T2DM and its influencing factors in this region, aiming to provide data support for diabetes prevention and control efforts.

Materials and Methods

Sampling and Study Population

The participants among the permanent residents aged 35–65 in Ganzhou city were selected using a multistage random sampling method. The formula being employed for sample volume determining was $n = \frac{z_{1-\frac{a}{2}} P(1-P)}{d^2} Deff$, where P is the prevalence of T2DM, d is allowable errors and Deff is the design effect. In the study, P was estimated at 14.3% (According to the 2017 IDF Diabetes Atlas, there were approximately 79.5 million cases of diabetes among individuals aged 35 to 65 in China, while the same age group consisted of around 555.5 million people according to the 2017 Chinese Census data), d was 0.1P, deff was 2, Considering an expected response rate of ≥85%, a sample size of 2764 participants was deemed necessary. The first step involved categorizing 18 counties and districts into high, medium, and low economic classifications based on administrative divisions and levels of economic development. Subsequently, a random selection process was employed to choose 1–3 counties or districts from each category, resulting in the selection of 7 counties and districts in the initial stage. In the second stage, a similar random selection method was used to choose 1–3 communities or streets within each county or district, leading to a total of 21 sampling units. Finally, approximately 400–500 participants were selected from each second sampling unit. The study adhered to the principles outlined in the Declaration of Helsinki, and the protocol received approval from the medical ethics committee of Gannan Medical University (Ethics Committee Number: NO.2016032). All participants willingly volunteered to participate in this study and provided signed informed consent.

Investigation Contents and Methods

The study was conducted from July to September 2017, employing questionnaires, blood biochemical tests, and physical examinations as data collection methods. A self-designed questionnaire was utilized by trained interviewers to gather data on general demographic information, smoking and alcohol consumption history, family history of chronic diseases, personal medical history, physical exercise and sleep patterns (assessed by self-reported sleep duration and quality), and dietary habits.

The quality of the survey was ensured through the implementation of several measures. (1) Prior to the formal investigation, the questionnaire underwent refinement through a pre-investigation process. (2) Researchers received comprehensive training in all aspects of data collection procedures, including questionnaires, physical examinations, profiling, and testing of biological samples. (3) Any issues encountered during investigations were promptly identified and rectified through our morning meetings and evening meeting system. (4) Calibration of all devices was performed daily before conducting the survey. (5) Following thorough data verification, entry into the system was carried out using a double-entry method.

Anthropometric and Clinical Assessment

Height, body weight, and blood pressure were measured by staff members who had undergone standardized training and followed established protocols. The body mass index (BMI) is calculated by dividing the weight in kilograms by the square of the height in meters. BMI was utilized for categorizing different body types based on the Guidelines for the Prevention and Control of Overweight and Obesity in Chinese Adults: BMI <18.5 kg /m^2 was considered as underweight, 18.5 ~23.9 kg /m^2 as normal, and 24 ~27.9 kg /m^2 as overweight, and ≥28 kg /m^2 as obese.[9]

The blood pressure data were obtained using Omron electronic blood pressure monitors (HEM-8102K) following a five-minute rest period. In the case of abnormal blood pressure readings, a second measurement was conducted after 10 minutes, and the average blood pressure was recorded. Primary hypertension was defined as a blood pressure of 140/90 mmHg or higher or having a history of primary hypertension according to the Chinese hypertension guidelines of the 2017 edition.[10]

All instruments were calibrated prior to the measurements. Throughout the study, quality control personnel supervised the entire process to ensure data collection quality.

Biochemical Assessment

Blood samples were collected from all participants after an overnight fasting period. The levels of total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG), hemoglobin A1c (HbA1c), blood uric acid, and serum insulin were measured using the Beckman AU5800 automatic biochemical analyzer.

Correlation Criterion

Diagnostic Criteria of T2DM

According to the 2017 Chinese Guidelines for the Prevention and Treatment of T2DM,[11] individuals with a fasting blood glucose (FBG) level ≥7.0 mmol/L were categorized as patients. Moreover, individuals who had received a medical diagnosis of T2DM or were currently undergoing treatment with hypoglycemic medication were also considered to have T2DM.

Criteria for Determining Behavior Indicators

In this study, nondrinkers were defined as individuals who consumed minimal or negligible amounts of alcohol within a six-month period. Alcohol abstainers referred to those who previously had a regular drinking habit but had refrained from consuming alcohol for more than six months. Drinkers were classified as individuals who regularly consumed alcohol with an intake of 50 g or more per occasion. The definition of smokers in this study refers to individuals who consume at least one cigarette per day and have maintained this habit for a minimum duration of six months or longer. On the other hand, ex-smokers are former tobacco users who have successfully abstained from smoking for a period of three months or more. Physical activity in the study denotes engagement in sustained physical exertion lasting over 30 minutes.

Statistical Methods

The data-entry and analysis were conducted using EpiData3.1 (double-record) and SPSS 14 0.0 statistical software packages. Continuous data were presented as mean ± standard deviation ($\bar{x} \pm s$) or median (lower quartile, upper quartile) [M (P25, P75)], and comparison between groups was conducted using *t*-test or rank sum test. Categorical data were analyzed by the χ^2 test. A binomial Logistic regression model was employed to investigate the influencing factors associated with T2DM. Statistical significance was defined as a P value less than 0.05.

Results

Basic Information

A total of 3028 participants were enrolled in the study, yielding a response rate of 98.4%. After excluding individuals with missing key information, a total of 2978 participants were included in the analysis. The mean age of the subjects was 52.83±7.88 years old, with women comprising 67.6% (2012/2987) of the sample population. The majority of participants exhibited characteristics such as being married, farmers, and having a low level of education (refer to Table 1 for detailed information).

The prevalence rate of T2DM was found to be 11.8% (95% CI: 10.6–12.9%), with rates among men and women being recorded at 12.9% and 11.2%, respectively. The prevalence rate of diabetes based on data from China's national census conducted in 2010 was estimated to be approximately 9.1%.

Comparison of Demographic Variables, History of Diabetes Disease, and Presence of Hypertension Between Patients with and without T2DM

The population was divided into two groups based on the presence or absence of T2DM, and significant differences were observed in the age distribution, occupational composition, family history of diabetes, and between the two groups ($P<0.05$). The T2DM group exhibited a higher mean age in comparison to the non-patient group, whereas the prevalence of T2DM among hypertensive patients (19.0%) was significantly greater than that observed among non-patients (7.4%). The distribution of other factors between the two groups did not exhibit any statistically significant differences (P>0.05), as presented in Tables 1 and 2.

Comparison of Behavior and Lifestyle, Mental Stress and BMI Between T2DM Patients and Non-Patients

The results of the rank sum test showed significant disparities in the prevalence of smoking, alcohol consumption, fresh fruit consumption, sweet food consumption, daily sleep duration, and BMI between individuals with and without T2DM (P<0.05). The trend chi-square test revealed a significant inverse association between the prevalence of T2DM and fruit (χ^2_{trend} =7.69, P=0.006) and sweet food intake frequency (χ^2_{trend} =104.05, P=0.000) and daily sleep time (χ^2_{trend} =5.99, P=0.014), while a positive correlation was observed between the prevalence of T2DM and BMI (χ^2_{trend} =12.45, P=0.000). No other factors were found to be correlated with T2DM in the population. See Table 2 for details.

Table 1 Comparison of Demographic Data and Family History of Diabetes and Hypertension Between Patients with and without T2DM

Variable	**T2DM (*n*)**	**Non-T2DM (n)**	***P***
Age ($\bar{x} \pm s$)	55.833±6.837	52.424±7.922	0.000
Gender			
Male	125	841	0.176
Female	226	1786	
Marital status			
Unmarried	1	13	0.446
Married	328	2489	
Divorced	4	14	
Widowed	13	80	
Occupation			
Worker	38	390	0.000
Farmer	130	1005	
Managerial staff	28	236	
Retired	76	338	
Others*	76	612	

(*Continued*)

Table 1 (Continued).

Variable	T2DM (*n*)	Non-T2DM (n)	*P*
Education level			
Primary school and below	126	815	0.195
Middle school	189	1520	
Above college	34	268	
Family history of diabetes			
Unknown	31	156	0.000
No	232	2203	
Yes	88	268	
Hypertension			
No	138	1724	0.000
Yes	213	903	

Note: *Others refer to those not included in the above items, such as the unemployed, freelancers, etc.

Table 2 Comparison of Behavioral Lifestyle, Mental Stress and BMI Between Individuals with and without T2DM

Variable	T2DM (n)	Non-T2DM (n)	*P*
Smoking status			
Never	263	2080	0.002
Former	29	109	
Current	48	359	
Passive smoker			
Yes	155	1231	0.375
No	186	1333	
Weekly fresh fruits intake			
≥3 times	208	1722	0.019
1–2 times	114	747	
Almost none	24	113	
Weekly sweets intake			
≥3 times	24	482	0.000
1–2 times	86	1168	
<1 time	234	919	

(*Continued*)

Table 2 (Continued).

Variable	T2DM (n)	Non-T2DM (n)	*P*
Drinking status			
Never	221	1545	0.005
Former	23	99	
Current	107	976	
Salt intake level (self-reported)			
Less	104	655	0.136
Medium	159	1231	
More	86	727	
Weekly frequency of physical activity			
Almost none	89	719	0.159
1–2 times	54	481	
≥3times	201	1396	
Sleep duration			
<6 h	114	736	0.040
6–8 h	202	1517	
>8 h	33	359	
Self-reported sleep quality			
Good	114	869	0.346
Medium	141	1138	
Bad	91	597	
BMI (*n*, kg/m^2)			
<18.5	9	114	0.000
18.5 ~23.9	142	1330	
24 ~28	130	731	
≥28	70	452	

Abbreviation: BMI, body mass index.

Comparison of Blood Biochemical Indexes Among People with or Without T2DM

The results of *t*-test and rank sum test demonstrated statistically significant differences in the levels of TC, TG, LDL-C and serum insulin between T2DM patients and non-patients. Specifically, the levels of TC, TG, LDL-C and serum insulin were higher in T2DM patients compared to non-patients, while the level of HDL-C was lower inT2DM Patients than in non-patients ($P<0.05$). There was no statistically significant disparity observed in blood uric acid level between the two groups ($P>0.05$), as shown in Table 3.

Analysis of Multivariate Logistic Regression

Before conducting multiple logistic regression, this study initially assessed the assumptions of multiple logistic regression. Refer to Appendices 1 to 3 for further details. The dependent variable in the study was T2DM, while the

Table 3 Comparison of Blood Biochemical Indexes in People with or Without T2DM

Variable	T2DM (n=351)	Non-T2DM (n=2627)	*P*
Blood uric acid ($\bar{x} \pm s$)	313.32±84.99	304.42±91.17	0.083
TC ($\bar{x} \pm s$)	5.52±1.18	5.32±1.01	0.001
HDL-C ($\bar{x} \pm s$)	1.50±0.34	1.63±0.37	0.000
LDL-C ($\bar{x} \pm s$)	2.80±0.83	2.70±0.74	0.026
HbA1c ($\bar{x} \pm s$)	7.71±2.72	5.42±0.82	0.000
FBG [M (P_{25}, P_{75})]	7.48 (6.190 9.63)	5.00 (4.64, 5.38)	0.000*
Serum insulin [M (P_{25}, P_{75})]	12.77 (6.00, 17.10)	11.41 (5.01, 14.28)	0.000*
TG[M (P_{25}, P_{75})]	1.70 (1.30, 2.70)	1.30 (1.00, 1.90)	0.000*

Note: *The data did not conform to a normal distribution; thus, the rank sum test was employed for intergroup comparison.

Abbreviations: TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; HbA1c, glycated hemoglobin; FBG, Fasting blood glucose; TG, Triglyceride.

independent variables included those with $P<0.1$ in univariate analysis (excluding FBG and HbA1c). Unconditional Logistic regression analysis was conducted using these variables. The results of multiple logistic regression analysis indicated that age, hypertension, family history of diabetes, overweight, high TG, high LDL-C, and serum insulin were positively associated with T2DM (P<0.05). Conversely, sweet food intake, high uric acid levels, and high HDL-C levels were found to be negatively correlated with T2DM (P<0.05). See Figure 1 for details.

Discussion

The findings of this study revealed that the prevalence rate of T2DM in Ganzhou City was 11.8%, surpassing the prevalence of individuals aged between 40–69 years old (10.6%) in Ganzhou City in 2013,[12] and also exceeding the rate reported by IDF among people aged 20–79 years old in 2021 in China, which stood at 10.6%.[1] The prevalence rate of 11.2% among individuals aged 40 and above in Fujian, China in 2013[13] is comparable to our findings, while the prevalence rate of 17.5% in American Chinese population in 2022[14] exceeds our results. The economic development level of Ganzhou City may have an impact on various aspects. Additionally, being a hub for Hakka culture, Ganzhou City showcases unique cultural customs, eating habits, and lifestyles distinct from other regions in the country. The prevalent

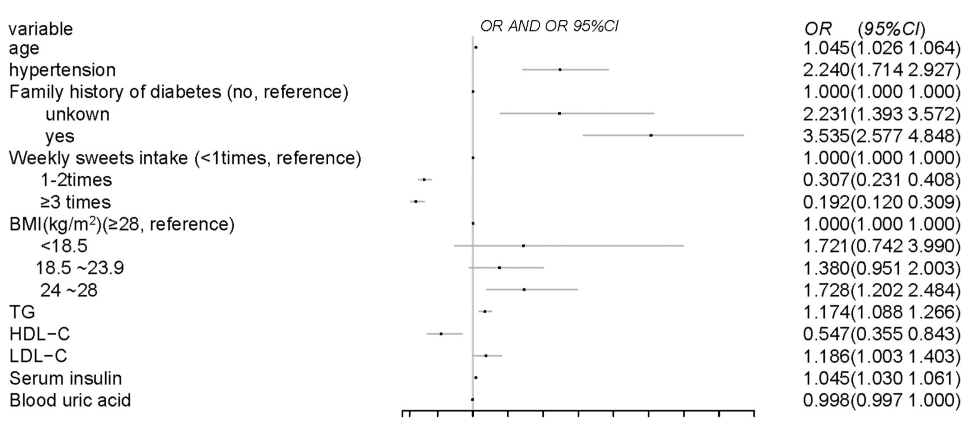

Figure 1 The findings of non-conditional logistic regression analysis on the determinants of T2DM.

consumption of bacon and high-salt diets in southern Ganzhou could potentially be linked to the increased risk of diabetes. The challenge of diabetes prevention and control in Ganzhou City is quite significant, necessitating the implementation of effective strategies to address this issue.

Additionally, the results of this study revealed significant associations between age, hypertension, family history of diabetes, sweet food intake, obesity and overweight, TG, HDL-C, LDL-C, serum insulin and blood uric acid the development of T2DM. Age, hypertension, family history of diabetes, elevated BMI, increased TG levels, higher serum insulin and LDL-C levels were identified as risk factors for T2DM. Conversely, sweet food intake, higher HDL-C and blood uric acid levels were found to be protective factors against T2DM. However, these findings contradict the conclusions drawn by several previous studies regarding the role of sweet food consumption and blood uric acid as protective factors.[2,15,16] This could be attributed to the modification of certain maladaptive behaviors in current patients, thereby reducing their exposure rate, or it could be associated with medication aimed at lowering uric acid levels in insulin-resistant patients with T2DM who often suffered from impaired uric acid excretion. The presence of alternative factors may be attributable to the diagnostic criteria for diabetes, resulting in the inclusion of some undiagnosed patients within the non-diabetic category. As a result, this could potentially diminish or even reverse the observable disparities between individuals with and without diabetes.

The univariate analysis results of this study indicated a significant association between occupation and T2DM, with workers demonstrating a lower prevalence while retirees exhibited a higher prevalence. However, upon adjusting for other confounding factors, occupation did not emerge as a significant predictor in the regression equation, potentially due to its indirect correlation with age, which tends to be lower among workers compared to retirees. Furthermore, although there was a slightly higher prevalence of T2DM among men than women in this study, no statistically significant difference was observed between the sexes (P=0.176). The gender trend observed in Yang's 2010 study (10.6% in males, 8.8% in females) and the IDF report of 2019 on Chinese individuals (9.6% in males, 9.0% in females) is consistent with the findings presented here.[2,3]

The present study revealed a strong association between a family history of hypertension and diabetes with the development of T2DM. It is well-established that individuals with T2DM commonly exhibit a high prevalence of hypertension[17,18] which in turn serves as a significant risk factor for cardiovascular diseases.[19] Notably, cardiovascular diseases represent the leading cause of mortality among patients with T2DM.[20] However, it should be acknowledged that various studies have presented divergent perspectives on the sequential relationship between hypertension and diabetes, suggesting that hyperglycemia and hypertension may coexist.[21] Although this study could not determine a causal relationship between hypertension and T2DM, control of blood glucose and blood pressure is important for the prevention of cardiovascular accidents in people with T2DM. In this study, individuals with a family history of diabetes had a 3.535 times higher risk of developing the disease compared to those without such a history (OR 95% CI: 2.58–4.85), indicating a genetic predisposition to diabetes. Genetic factors play a significant role in the risk of T2DM, evident through familial clustering and ethnic disparities, with susceptibility genes being the underlying determinants.[22] Results of a domestic meta-analysis showed that the risk of diabetes in those with a family history of diabetes was 2.48 times that of those without a family history (*OR95% CI*: 2.41–2.55).[6] The current lack of effective interventions targeting genetic factors necessitates the strengthening of public awareness and education among individuals with a family history, in order to enhance their self-care consciousness.

Dyslipidemia and overweight are common risk factors for diabetes and hypertension. The findings of this study demonstrate that elevated levels of TG, LDC-C and reduced HDC-C all contribute to an increased risk of T2DM. Some studies have indicated that abnormal blood lipid levels in patients can disrupt the binding of insulin to receptors on target organs, leading to insulin resistance and ultimately causing an increase in the patient's blood sugar levels.[23] Additionally, this study reveals a relationship between BMI and T2DM, indicating that obesity carries the lowest risk (OR=1.000), followed by normal weight individuals with a slightly higher risk (OR=1.380). Conversely, underweight individuals exhibit a greater risk (OR=1.721), and while overweight individuals face the highest risk (OR=1.728). The observed discrepancy from previous studies[6,24] lies in the dissimilar association between BMI and T2DM risk. This disparity may be attributed to a higher prevalence of diabetes cases within the subjects under investigation, with 268 instances accounting for 76.4% of all cases. Generally, patients diagnosed with diabetes tend to modify their behaviors by controlling their diet and increasing physical activity, which may result in weight loss. According to some studies, individuals with diabetes can lose up to 2.3kg within two years of diagnosis,[25] potentially leading to changes in BMI and different conclusions from other research. Compared to genetic factors, the variability of diet, exercise, obesity management, disease control and other factors in the population is higher and thus more amenable to intervention. Numerous domestic and foreign studies have confirmed the significance of enhancing health interventions aimed at improving dietary habits, promoting physical activity, maintaining normal weight and blood lipid levels for diabetes prevention.[26–30]

Conclusion

The prevalence of T2DM in Ganzhou City has exhibited a significant increase, with age, overweight, family history of diabetes, and abnormal lipid metabolism emerging as crucial influencing factors. With the aging of society, improvement in living standards, and changes in dietary habits in Ganzhou City, the impact of diabetes on population health is becoming increasingly severe. The provision of health education on hypertension and metabolic diseases management, coupled with the promotion of a healthy lifestyle, is therefore imperative in order to mitigate the health risks associated with T2DM.

Ethic Statement

The study adhered to the principles outlined in the Declaration of Helsinki, and the protocol received approval from the medical ethics committee of Gannan Medical University (Ethics Committee Number: NO.2016032).

Informed Consent

All participants willingly volunteered to participate in this study and provided signed informed consent.

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Disclosure

The authors declare no conflicts of interest in this work.

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