Garlic consumption and risk of diabetes mellitus in Chinese older individuals: A population-based cohort study

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ABSTRACT

Background and Objectives: Diabetes mellitus (DM) is a major public health problem worldwide. Numerous traditional plants are used for preventing DM. However, limited evidence supports the association between garlic consumption and DM. **Methods:** Data came from the 2008-2018 Chinese Longitudinal Healthy Longevity Survey. Garlic consumption was obtained by questionnaire, and DM was self-reported diagnosis. A multivariate adjusted Cox regression model was used to estimate hazard ratios (HR) and 95% confidence intervals (CI) to determine the incidence of DM. **Results:** There were 1927 participants in our sample, of which 24.08% consumed garlic daily; and 20.08% developed DM. The HR for daily garlic consumption decreased by 42%, relative to rare or no garlic consumption. Our subgroup analyses revealed that daily garlic consumption significantly reduced the risk of DM in older adults aged 65-79, rural, non-drinkers informal education, financial dependence, and working in agriculture (aged 65-79: HR = 0.54, 95% CI: 0.36–0.80; rural area: HR = 0.48, 95% CI: 0.29–0.77; non-drinkers: HR = 0.60, 95% CI: 0.41–0.86; informal education: HR = 0.46, 95% CI: 0.29–0.74; financial dependence: HR = 0.39, 95% CI: 0.23–0.65; agricultural work: HR = 0.49, 95% CI: 0.32–0.76). **Conclusion:** Garlic consumption can reduce the risk of having DM in older adults in China, and this benefits varies by age, current residence, drinking status, education level, occupation, and economic source. Future efforts are required to make potential dietary intervention strategies that take into account demographic and educational disparities, as well as financial source and occupational factors to effectively prevent diabetes among older population.

Key Words: garlic consumption, diabetes, older adults, epidemiology, China

INTRODUCTION

Diabetes mellitus (DM) is a major public health problem. In 2021, the global prevalence of DM was 10.5% (536.6 million people), and the incidence of DM was highest among people aged 75–79 years. The International Diabetes Federation estimated that the prevalence of DM will rise to 12.2% (783.2 million) by 2045.[1] The global prevalence of DM is increasing faster than ever before.[2] China is one of the countries with the highest prevalence of DM in the world. The prevalence of DM among Chinese adults rose from 0.67% in 1980, as determined using the World Health Organization standards, to 10.9% in 2013, as determined using the American Diabetes Association standards.[3,4]

DM, a complex metabolic disorder characterized by β-cell dysfunction, hyperglycemia, and insulin resistance,[5] causes severe complications, including myocardial infarction, stroke, diabetic foot amputation, and chronic kidney disease,[6] all of which considerably contribute to the high DM-associated mortality rate. Furthermore, DM imposes a substantial financial burden on individuals, families, and health-care systems. The health-care cost associated with DM was US$966 billion in 2021, with this figure expected to rise to US$1054 billion by 2045.[1]

The onset of DM is linked to numerous factors, including lifestyle, environmental, and genetic factors.[7] For example, individuals with low socioeconomic status, a smoking habit, a sedentary lifestyle, rare physical activity, and poor eating habits are more likely to develop DM.[8,9] DM is still regarded as a life-threatening disease, despite recent scientific advancements in its management and treatment.[10] In addition, most antidiabetic drugs have side effects, such as hypoglycemia, weight gain, nutritional disorders, allergic reactions, and liver disease.[11] Therefore, exploring antidiabetic drugs with fewer side effects is necessary, especially for individuals who experience severe side effects from clinical drugs or individuals of low socioeconomic status.

Traditional plants and herbs are used in many nations to cure common diseases.[12] Garlic (*Allium sativum*), a perennial herb species in the Amaryllidaceae family, was consumed and used in ancient civilizations worldwide, including Rome, India, Greece, Egypt, and China.[13-15] Garlic is commonly used for flavoring, in functional foods, and in traditional medicine for nutritional and medical purposes.[16,17] Garlic or its bioactive components have been associated with considerable health benefits. A population-based study reported that garlic is effective in preventing cardiovascular disease.[18] Furthermore, case–control studies have indicated that garlic can protect against colorectal cancer, gastric cancer, prostate cancer, lung cancer, and head and neck cancer.[19-22] A meta-analysis of 11 studies showed that garlic is beneficial for the treatment of hypertension.[23] At present, the research of garlic and DM mainly focuses on the animal experiment and clinical cell research of garlic and its extract and DM, DM complication or DM related index. However, the analytical epidemiological study on the relationship between garlic intake and DM is limited.[24,25] Accordingly, we conducted this population-based cohort study with the aim of investigating the causal association between garlic consumption and DM in Chinese older adults.

METHODS

Study participants

We retrieved study data from the China Longitudinal Health and Longevity Survey (CLHLS), a nationwide prospective cohort study aimed at identifying individual, family, and social factors related to the health and longevity of older adults. This survey applied stratified multistage sampling in 23 of the 31 provinces of mainland China. All survey information was obtained through face-to-face interviews by specially trained interviewers from local Centers for Disease Prevention and Control. Detailed information regarding the CLHLS can be found elsewhere.[26] The survey was approved by the Ethics Committee of Peking University. Informed consent was obtained from all participants.

For the present study, we used CLHLS data for the period from 2008 to 2018. Among the total of 16,954 respondents in 2008, 15,799 was remained after excluding those younger than 65 years of age (391), missing data on garlic (10), missing data on diabetes (332), and those who already had diabetes at the 2008 baseline survey (422). In addition, we excluded 13872 respondents due to loss to follow-up during the three follow-up surveys, death, and incomplete diabetes data. Therefore, 1927 individuals were finally included in our study, as shown in Figure 1 for the screening process.

Assessment of garlic consumption

A short food frequency questionnaire—which was demonstrated to be effective in assessing functional performance[27]—was used in the CLHLS to assess garlic ion habits were determined according to participants' responses to the following question: "How often do you eat garlic at present?" We classified the frequency of garlic consumption into three categories: daily, occasionally, and never or rarely.[28]

Assessment of DM

DM was determined according to participants' responses to the following question: "Are you currently suffering from DM?" Older adults who had DM before death were also included in the study analysis.

Assessment of covariates

Demographic variables included sex (female or male), age group (65–79 or ≥80 years), marital status (married and living with spouse or others), and residence (urban and rural). We used dietary diversity scores (DDS) rather than nutritional adjustments alone to account for the potential confounding effect of dietary diversity in the association between garlic consumption and DM risk. The participants completed a food frequency questionnaire involving 12 major food groups: eggs, beans, milk or dairy products, meat, fish, mushrooms or algae, tea, nuts, sugar, fruit, preserved vegetables， and fresh vegetables. The frequency of consumption was used to determine the scores for each food group.[29] The DDS was derived as the sum of the scores of the 12 food groups, with a higher DDS indicating higher dietary diversity. Lifestyle habits included exercise status (yes or no), drinking status (yes or no), and smoking status (yes or no). Socioeconomic status included education level, income source, and occupation. Education level was classified as formal if the participants attended school and as informal if they did not. Income source was determined according to the participants' responses to the following question: "What are your main sources of financial support?" On the basis of the responses, income source was classified as financially dependent or financially independent. Occupation before the age of 60 was classified as non-agricultural work or agricultural work. Health conditions included a history of chronic diseases and body mass index (BMI; underweight, normal, overweight, or obese). Participants who did not report heart disease, hypertension, cancer, dyslipidemia, stroke, or cerebrovascular disease were determined to not have a history of chronic diseases (i.e., "No"); by contrast, those who reported any of the listed diseases were determined to have a history of chronic diseases (i.e., "Yes").

Statistical analysis

Categorical variables are presented as numbers and percentages, and average age and DDS are presented as mean and standard deviation. The variables were compared at baseline by using a chi-square test and an analysis of variance (ANOVA). The Cox proportional hazards model was used to assess the association between garlic consumption and DM risk. This model provided estimates of hazard ratios (HR) along with 95% confidence intervals (CI). The final model was adjusted for sex, age, residence location, education level, BMI, DDS, drinking status, smoking status, exercise status, marital status, income source, occupation, and history of chronic disease. Also, we further conducted subgroup analyses by stratified by age, residence, drinking status, education level, occupation, income source and BMI to assess the association between garlic consumption and the incidence of DM. All statistical analyses were conducted using SPSS software. Statistical significance was defined as a two-sided *p* value of 0.05.

RESULTS

Participant characteristics

Table 1 lists the basic characteristics of the participants. There were 1927 participants in the sample, of which 1328 (68.92%) were aged 65–79 years and 898 (46.60%) were men. Of the participants, 49.27% had no formal education, 41.83% were financially dependent, 26.48% worked in agriculture, 77.89% did not smoke, 77.69% did not consume alcohol, and 63.67% did not exercise. We observed that the characteristics of the three garlic consumption groups (i.e., participants who never consumed garlic, consumed garlic occasionally, and consumed garlic every day) differed in the sample. 20.81% of the participants never consumed garlic, 55.11% consumed garlic occasionally, and 24.08% consumed garlic every day, participants who consumed garlic daily were younger, had a higher DDS, and were mostly economically independent with a normal body mass index.

The prevalence of DM was 20.08%, and was higher in older adults who were male, lived in the urban area, were farmers, did not smoke, did not drink alcohol, exercised, were overweight or obese, and had a history of chronic disease. (Table 2)

Garlic consumption and incidence of DM

As presented in Table 3, the unadjusted model revealed that the HR for DM was 0.61 (95% CI: 0.44-0.82) for those who consumed garlic daily compared with those who never or rarely consumed garlic. The model adjusted only for age, sex and residence and adjusted for demographic characteristics, lifestyle habits, dietary habits, socioeconomic status, and health conditions showed that, the association between garlic consumption and DM risk persisted (Model 2 daily garlic consumption: HR = 0.62, 95% CI: 0.45–0.84; Model 3 daily garlic consumption: HR = 0.58, 95% CI: 0.42–0.80), the HR for daily garlic consumption decreased by 42%, relative to rare or no garlic consumption.

Subgroup analysis and interaction analysis

Figure 2 presents the results of our subgroup analyses stratified by age, sex, residence location, smoking status, drinking status, exercise status and socioeconomic status. Daily garlic consumption significantly reduced the risk of DM in 65-79 year old (HR = 0.54, 95% CI: 0.36–0.80) but not in those over 80 years of age (HR = 0.74, 95% CI: 0.41–1.32); reduced it in rural older adults (HR = 0.48, 95% CI: 0.29-0.77) but not in urban older adults (HR = 0.67, 95% CI: 0.42-1.06); reduced it in non-drinkers (HR = 0.60, 95% CI: 0.41-0.86) but not in current drinkers (HR = 0.53, 95% CI: 0.24-1.16); reduced it in older adults with informal education (HR = 0.46, 95% CI: 0.29-0.74) but not in older adults with formal education (HR = 0.73, 95% CI: 0.45-1.17); and reduced it in financially dependent older adults (HR = 0.49, 95% CI: 0.32-0.76) but not in financially independent older adults (HR = 0.62, 95% CI: 0.36-1.06); and reduced it in agricultural work (HR = 0.39, 95% CI: 0.23-0.65) but not in non-agricultural work (HR = 0.73, 95% CI: 0.46-1.16). However, daily consumption of garlic reduced the risk of DM in older adults across gender, smoking status, and exercise status.

The results of the interaction showed that older adults who consumed garlic daily and were financially independent had a lower risk of DM compared with older adults who consumed garlic rarely and were financially dependent; no significant interactions were found among the other variables.

DISCUSSION

We conducted a 10-year population-based longitudinal study to examine the effect of garlic consumption on DM risk among older Chinese adults. Findings showed that about 1 in 5 older adults in China developed DM during 10-year follow-up and about 1 in 4 regularly consume garlic. After controlling for potential confounders and baseline DM, daily garlic consumption showed an inverse association with DM risk, suggesting that regular garlic consumption may be an effective way to reduce DM risk.

Our findings are consistent with those of previous studies revealing beneficial effects of garlic consumption. Garlic is used clinically as a hypoglycemic drug.[30] In most cases, reduced insulin sensitivity and insulin secretion are associated with the development of DM.[31] Evidence suggests that garlic may exert its hypoglycemic effects by influencing both mechanisms. Liu reported that garlic oil significantly increased the concentration of basal insulin in rats with DM.[32] Padiya revealed that applying garlic treatment to glucose-fed rats significantly reduced blood glucose and increased insulin sensitivity.[33] Mathew et al. reported an increase in peripheral insulin activity in alloxan-induced diabetic rabbits treated with allicin, suggesting that the most likely mechanism underlying the action of allicin is its activity against insulin-inactivating sulfhydryl group compounds, which can prevent insulin inactivation.[34] Recent studies have proposed a new mechanism underlying the action of garlic: that is, garlic can inhibit dipeptidyl peptidase-4 (a protease-regulating glucose metabolism), thereby inhibiting the secretion of postprandial glucagon, improving the function of pancreatic cells, and promoting insulin production.[35] In addition, lipid metabolism disorder is one of the key factors for DM.[36] Garlic is used as an antidiabetic nutrient because it reduces plasma levels of triglycerides, cholesterol, and low-density lipoprotein cholesterol.[30]

Oxidative stress plays a major role in the pathogenesis of DM. High levels of free radicals and a decrease in endogenous antioxidants may be contributing factors to the development of insulin resistance.[37] Garlic contains phenolic compounds, which have strong antioxidant properties.[38] Human studies have shown that 2 weeks of garlic powder supplementation reduced the oxidative sensitivity of apolipoprotein B by 34%.[39]

A recent meta-analysis showed that garlic supplementation could regulate oxidative stress markers, including malondialdehyde and total antioxidant capacity.[40] In addition, inflammation can induce insulin resistance.[41] Previous studies have also suggested that hyperglycemia is a proinflammatory state.[42] Garlic enhances insulin sensitivity by activating AMP-activated protein kinase (AMPK). AMPK activation inhibits several inflammatory factors and sterol regulatory element-binding protein 1c, thereby suppressing chronic inflammation in adipocytes.[43] Garlic has anti-inflammatory and antioxidant properties that are helpful for both DM prevention and treatment. Nonenzymatic glycosylation is among the mechanisms underlying diabetic complications.[44] Several sulfur compounds in garlic can protect low-density lipoprotein from glycosylation in healthy individuals or patients with diabetes.[45,46] Garlic's antiglycative properties may also prevent DM.

Our subgroup analyses revealed that the protective effect of garlic consumption against DM varied across age, residence location, drinking status and socioeconomic status (occupation, education level, and financial source**)**. The highest prevalence of diabetes was in 65-79 years of age group.[47] Daily consumption of garlic may be able to effectively reduce the risk of diabetes for these older people; however, the mortality rate of diabetes has also increased with age,[48] and those who survive beyond the age of 80 had relatively good health in general. This study did not find that garlic consumption was effective in lowering the risk of diabetes mellitus in those over 80 years of age. The prevalence of DM in urban areas is significantly higher than in rural areas,[49] but the prevalence of DM as a whole is showing a rapid growth trend,[50] DM is characterized by a high prevalence and a low rate of awareness, treatment and control[51] in rural areas of China, and therefore consuming garlic every day might reduce the risk of DM effectively, while the urban areas had relatively good health care resources and clinical capacity,[52] the effect of consuming garlic on a reduced risk of DM became relatively weak. A previous study reported that up to 9 out of 10 new cases of DM can be attributed to modifiable lifestyle habits such as alcohol consumption.[53] Alcohol consumption is harmful to the pancreas, resulting in defective insulin secretion in animals.[54,55] Furthermore, alcohol consumption can reduce glucose production in healthy people, engendering insulin resistance.[56] Alcohol consumption may influence the effects of garlic on DM. The present study did not reveal protective effects of garlic among older adults who were drinkers. Notably, the findings of existing studies on alcohol consumption and DM risk are inconsistent. Some studies have reported that moderate alcohol consumption can reduce the risk of DM; however, the definition of "moderate" in these studies is unclear. In addition, one of the aims of the elderly to adhere to the lifestyle of not drinking is to keep healthy. This health awareness may encourage them to choose garlic as an affordable and healthy vegetable. Therefore, the benefits of garlic may increase in these groups of older adults.

Our results reveal that garlic consumption can significantly reduce the risk of DM in older adults who work in agriculture, receive informal education, and are financially dependent; and that economic independence and daily garlic consumption synergistically reduce the risk of DM. Some epidemiological studies have shown that the prevalence of DM is higher in individuals of low socioeconomic status than in those of high socioeconomic status.[57,58] The precise mechanism underlying the association between low socioeconomic status and an increased risk of DM is currently being researched, with key modifiable DM factors such as obesity, diet, and physical activity accounting for 33% to 50% of the association;[59] other factors, including hopelessness, psychosocial stress, a lack of autonomy, limited access to exercise facilities, limited access to healthy food, and limited access to medical services, may account for the remainder of the association.[59-61] Socioeconomic factors can influence dietary habits and quality.[62] A healthy diet should include garlic. These findings corroborate our findings that older adults of relatively low socioeconomic status should consume garlic to prevent DM.

Our study is an epidemiologic study based on a representative, prospective, large-sample national sample of older adults investigating the association between garlic consumption and risk of DM. However, it has some limitations. First, our findings were based on a questionnaire on garlic consumption, which included information on garlic consumption frequency but did not include specific garlic intake information. Second, DM was self-reported by the participants, instead of being identified from medical records, which may have led to information bias. Finally, this study lacked diabetes-related information on metabolic biochemical indicators that might affect our results.

Conclusion

The prevalence of DM is high in China, and garlic consumption is associated with a reduced risk of DM in older Chinese adults, and this benefits varies by age, residence location, drinking status and education, financial source, and occupation. Therefore, older adults, especially those with informal education, financial dependence and agricultural work, should consume garlic and adopt healthy lifestyle habits, such as abstaining from alcohol, to prevent DM.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare that they have no competing interests.

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Table 1. Basic characteristics of the participants with different garlic consumptions

Characteristics	N(%)	Garlic consumption, n%		
		Rarely or never	Occasionally	Daily
Total	1927 (100)	401 (20.81)	1062 (55.11)	464 (24.08)
Age group				
65-79	1328 (68.92)	253 (19.05)	733 (55.2)	342 (25.75)
≥80	599 (31.08)	148(24.71)	329 (54.92)	122 (20.37)
Sex				
Male	898 (46.60)	188 (20.94)	485 (54.01)	255 (28.4)
Famale	1029 (53.40)	213 (20.70)	577 (56.07)	239 (23.23)
Residence location				
Town or city area	703 (36.48)	151 (21.48)	386 (54.91)	166 (23.61)
Rural area	1224 (63.52)	250 (20.42)	676 (55.23)	298 (24.35)
Education level				
Informal education	948 (49.27)	203 (21.41)	528 (55.7)	217 (22.89)
Formal education	976 (50.73)	198 (20.29)	532 (54.51)	246 (25.20)
Financial source				
Financial dependence	1121 (58.17)	244 (21.77)	653 (58.25)	224 (19.98)
Financial independence	806 (41.83)	157 (19.48)	409 (50.74)	240 (29.78)
Occupation				
Non-agricultural work	1352 (73.52)	277 (20.49)	770 (56.95)	305 (22.56)
Agricultural work	487 (26.48)	105 (21.56)	252 (51.75)	130 (26.69)
Marital status				
Married and living with spouse	1107 (57.45)	219 (19.78)	623 (56.28)	265 (23.94)
others	820 (42.55)	182 (22.20)	439 (53.54)	199 (24.27)
Smoking status				
No	1501 (77.89)	312 (20.79)	840 (55.96)	349 (23.25)
Yes	426 (22.11)	89 (20.89)	222 (52.11)	115 (27.00)
Drinking status				
No	1497 (77.69)	319 (21.31)	830 (55.44)	348 (23.25)
Yes	430 (22.31)	82 (19.07)	232 (53.95)	116 (26.98)
Exercise status				
No	1227 (63.67)	273 (22.25)	700 (57.05)	254 (20.70)
Yes	700 (36.33)	128 (18.29)	362 (51.71)	210 (30.00)
BMI, kg/m2				
Underweight (< 18.5)	402 (20.98)	106 (26.37)	217 (53.98)	79 (19.65)
Normal (18.5–23.99)	1082 (56.47)	227 (20.98)	591 (54.62)	264 (24.4)
Overweight (24–27.99)	339 (17.69)	55 (16.22)	205 (60.47)	79 (23.30)
Obese (≥28)	93 (4.85)	12 (12.90)	42 (45.16)	39 (41.94)
History of chronic diseases				
No	1343 (69.69)	269 (20.03)	763 (56.81)	311 (23.16)
Yes	584 (30.31)	132 (22.6)	299 (51.2)	153 (26.2)
DDS, M (SD)	5.42 (2.43)	5.04 (2.25)	5.27 (2.44)	6.11 (2.42)

M (SD) mean (stand deviation).

Table 2. Univariate analysis of covariates and diabetes prevalence

Characteristics	N (%)	DM, n%		χ2
		No	Yes	
Total	1927 (100)	1540 (79.92)	387 (20.08)	
Age group,				0.21
65-79	1328 (68.92)	1065 (80.20)	263 (19.8)	
≥80	59 (31.08)	475 (79.30)	124 (20.70)	
Sex				13.59***
Male	898 (46.60)	750 (83.52)	148 (16.48)	
Female	1029 (53.40)	790 (76.77)	239 (23.23)	
Residence location				41.93***
Urban area	703 (36.48)	507 (72.12)	196 (27.88)	
Rural area	1224 (63.52)	1033 (84.40)	191 (15.60)	
Education level				0.52
Informal education	948 (49.27)	751 (79.22)	197 (20.78)	
Formal education	976 (50.73)	786 (80.53)	190 (19.47)	
Financial source				1.36
Financial dependence	1121 (58.17)	906 (80.82)	215 (19.18)	
Financial independence	806 (41.83)	634 (78.66)	172 (21.34)	
Occupation				21.07***
Non-agricultural work	1352 (73.52)	356 (73.10)	131 (9.69)	
Agricultural work	487 (26.48)	1119 (82.77)	233 (47.84)	
Marital status				0.37
Married and living with spouse	1107 (57.45)	890 (80.40)	217 (19.60)	
Others	820 (42.55)	650 (79.27)	170 (20.73)	
Smoking status				4.54*
No	1501 (77.89)	1184 (78.88)	317 (21.12)	
Yes	426 (22.11)	356 (83.57)	70 (16.43)	
Drinking status				6.99**
No	1497 (77.69)	1177 (78.62)	320 (21.38)	
Yes	430 (22.31)	363 (84.42)	67 (15.58)	
Exercise status				4.24*
No	1227 (63.67)	998 (81.34)	229 (18.66)	
Yes	700 (36.33)	542 (77.43)	158 (22.57)	
BMI, kg/m2				30.53***
Underweight (< 18.5)	402 (20.98)	348 (86.57)	54 (13.43)	
Normal (18.5–23.99)	1082 (56.47)	874 (80.78)	208 (19.22)	
Overweight (24–27.99)	339 (17.69)	243 (71.68)	96 (28.32)	
Obese (≥28)	93 (4.85)	66 (70.97)	27 (29.03)	
History of chronic diseases				36.33***
No	1343 (69.69)	1122 (83.54)	221 (16.46)	
Yes	584 (30.31)	418 (71.58)	166 (28.42)	
DDS, M (SD)	5.42 (2.43)	5.40 (2.39)	5.50 (2.58)	0.54a

M (SD) mean (stand deviation).
a indicates the statistical value in variance analysis.
*p < 0.05, **p < 0.01, ***p < 0.001.

Table 3. Association between garlic consumption and incidence of DM

Characteristics	Model 1	Model 2	Model 3
	HR (95% CI)	HR (95% CI)	HR (95% CI)
Rarely or never	Reference		
Occasionally	0.86(0.67-1.09)	0.86(0.68-1.09)	0.88(0.69-1.13)
Daily	0.61(0.44-0.82)**	0.62(0.45-0.84)**	0.58(0.42-0.80)**

HR: hazard ratio, CI: confidence interval.
Model 1: No adjustment.
Model 2: Adjustment for age, sex and residence.
Model 3: Adjustment for age, sex, residence, education level, BMI, DDS, drinking status, smoking status, exercise status, marital status, income source, occupation, and history of chronic diseases.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.