



Research Article

# Dietary Nutrients Intake and Type 2 Diabetes in Chinese: Data from China Health and Nutrition Survey (CHNS)

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## Abstract

**Objective:** To identify the differences of dietary nutrients intake and lifestyle among diabetic and healthy people, and dietary risks of type 2 diabetes among Chinese adults. **Methods:** Using data from the China Health and Nutrition Survey (CHNS) in 2009, we selected 246 diabetic patients and 246 healthy people individually matched with patients on gender and age. The basic information, biochemical indicators and consecutive 3 days 24 h records of household food consumption were collected. The intake of nutrients was calculated according to the Chinese Food Composition Table Vol. 1, 2nd Edition. **Results:** Compared with the control group, diabetic patients had poorer glucose and lipid metabolism, liver and kidney function, and higher levels of inflammation. In terms of diet, the intake of fat and protein were higher in diabetic patients but all other nutrients, such as carbohydrate, dietary fiber and vitamins (except for Vitamin A) were lower compared with the control group. **Conclusions:** The changes in diet and behavior of diabetic patients after diagnosis are mainly reflected in reducing carbohydrate intake, smoking and alcohol intake, and relatively increasing fat and protein intake whereas still insufficient dietary fiber and vitamins intake. The overweight/obesity and metabolic syndrome have not been improved, indicating that enhancing the health education of diabetes, especially improving diet structure is of great use in blocking the progress of the disease.

**Keywords:** Diabetes; Nutrients; Lifestyle; Vitamin; Health education

**Abbreviations:** LCD: Low-Carbohydrate Diets; HbA1c: Glycated Haemoglobin; TG: Triglycerides; HDL-C: High-Density Lipoprotein Cholesterol; T2DM: Type 2 Diabetes Mellitus; CHNS: China Health and Nutrition Survey; RNI: Recommended Nutrient

Intake; BMI: Body Mass Index; WHR: Waist-Hip Ratio; 95%CI: 95% Confidence Interval; GLU: Blood Glucose; INS: Insulin; FER: Ferritin; TC: Total Cholesterol; LDL-C: Low Density Lipoprotein-Cholesterol; IGT: Impaired Fasting Glucose; RCT: Randomized Clinical Trial; DSME: Diabetes Self-Management Education

## Introduction

Diabetes is a metabolic disease caused by impaired insulin secretion or its deficient biological function, which may lead to a series of complications [1,2]. According to the diabetes atlas of the International Diabetes Federation in 2021, The global diabetes prevalence in 20-79-year olds in 2021 was estimated to be 536.6 million [3]. The trend in the prevalence of diabetes in China was the same as that in worldwide [4]. Owing to the high prevalence and complex complications, diabetes has become an important public health burden on individuals and health care systems.

However, the factors which affect diabetes are still not fully understood so far. Genetic elements, lifestyle and environmental factors have been proved to be connected with the prevalence of diabetes [5-7]. In traditional concept, diabetes is closely related to a high-intake carbohydrate diet. The project of carbohydrate restriction has been raised to be used for diabetes management. Once carbohydrate intake is less than 130 g/day or 26% of daily energy from carbohydrates can be called “Low-Carbohydrate Diets (LCD)” [8]. Richard et al. cited 12 pieces of evidence to support their argument that adopting LCD could be seen as the preferred method of diabetes management [9]. A systematic review and meta-analysis showed that LCD intervention had a beneficial effect on glycated haemoglobin (HbA1c) level as well as the control of Triglycerides (TG) and High-Density Lipoprotein Cholesterol (HDL-C) concentrations in Type 2 Diabetes Mellitus (T2DM) patients [10]. Besides, exposed to heavy smoking environment was correlated with an increased prevalence of diabetes [11], and there was a negative association between second-hand smoke and glycaemic control [12]. A cross-sectional study in Korea demonstrated that excessive drinking elevated a higher risk of diabetes [13], meanwhile, moderate consumption of alcohol might cut down the risk of diabetes and cardiovascular diseases [14]. Besides the routine clinical medication and lifestyle improvement (no-smoking and limit alcohol consumption), dietary interference is considered to be an effective method with little risk and good compliance.

Former researches were more often revolving around on the causal relationship between influencing factors and diabetes mellitus.

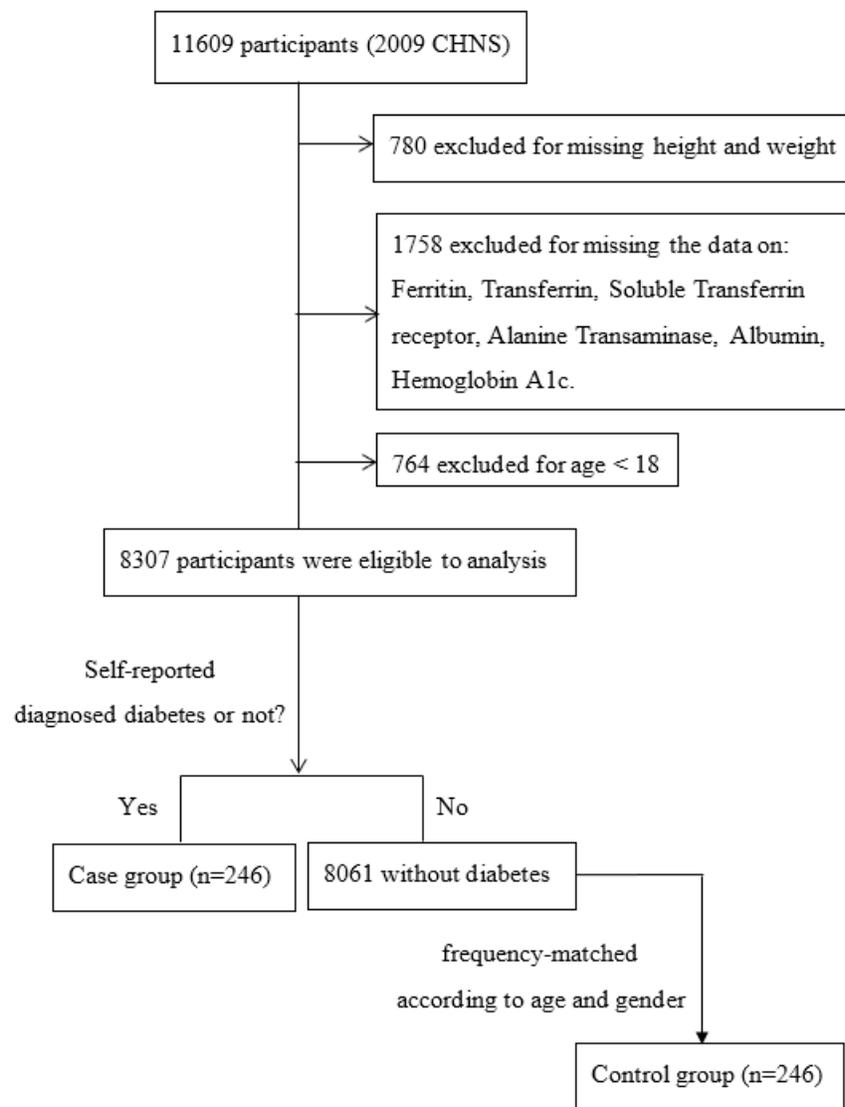
However, our research was to make up for the blank of lifestyle and dietary behaviors after diabetes diagnosis. We planned to investigate the differences in the intake level of comprehensive nutrients and lifestyle among diabetic and healthy people, and to provide evidence for further formulation of diabetes educational strategies.

## Materials and Methods

### Materials

This research used data from China Health and Nutrition Survey (CHNS) <https://www.cpc.unc.edu/projects/china/data/>. CHNS is an ongoing open cohort which conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health at the Chinese Center for Disease Control and Prevention. The CHNS is aimed to establish a multi-level method to collect data from individuals, families and their communities to understand how China’s wide-ranging social and economic changes affect a wide range of nutrition and health-related outcomes. More details on survey methodology and procedures of the CHNS has been published elsewhere [15,16]. The CHNS was approved by the institutional review boards of the University of North Carolina at Chapel Hill and Chinese Center for Disease Control and Prevention. Each participant provided the written informed consent before participating.

In our research, we conducted a case-control study using data of the CHNS. In 2009, there were 11609 participants, of which 780 were excluded for lacking of height and weight; 1758 for missing the data on ferritin, transferrin, soluble transferrin receptor, alanine transaminase, albumin, haemoglobin A1c; 764 for under 18 years old, and finally 8307 met the criteria and were included in the study. Participants with self-reported physician diagnosed diabetes were defined as the case group, a total of 246 cases. Meanwhile, those without diabetes were categorized as the control group. In order to enhance comparability, the case group and the control group were frequency-matched according to age and gender. Finally, 492 participants were included in this analysis (Figure 1).



**Figure 1:** Flow chart of study participants.

### Measurement of Dietary Nutrients Intake

Dietary information was collected by 3-day records of household food consumption. All individuals were asked to report all food consumed away from home on a 24-hour recall basis, and the same daily interview has been used to collect at-home individual consumption. Further, all field workers have accepted three days of specific training in the collection of dietary data for this survey to guarantee the data's quality.

The intake of nutrients was calculated according to the Chinese food composition table Vol.1 2nd Edition. Then, three-day average intakes of dietary macronutrients and micronutrients were calculated. Since total energy intake may have a potential impact on nutrients, it's essential to exclude the impact by residual method when analyzing the association between dietary nutrients and diabetes. Meanwhile, Recommended Nutrient Intake (RNI) followed the health industry standard of the people's Republic of China, WS/T 578—2018.

### Data Collection of Demographic Characteristics, Smoking and Drinking Status

All participants were required to fill in a structured questionnaire, which related to gender, residence, educational level, lifestyle, health status, etc. They were asked their smoking and alcohol status: someone who answered “no” to the question “Have you ever smoked cigarettes?” were classified as never smokers; someone who were reported to have ever smoked would be divided into former smokers and current smokers according to whether they quitted smoking or not. When participants were asked their frequency of alcohol consumption, in addition to “almost every day” and “never”, other options were classified as “often”.

### Anthropometric and Biochemical Indices

As for anthropometric indices, each one received detailed physical examinations that included weight, height, waist and hip circumference. Body Mass Index (BMI) was calculated as weight/height squared (kg/m<sup>2</sup>), Waist-Hip Ratio (WHR) was calculated as waist circumference/hip circumference. Also, blood was collected after an at least 8 h overnight fast and was transported to a national central lab in Beijing for testing. The specific detection methods of biochemical indices in CHNS had been introduced elsewhere [17].

### Statistical Methods

Data were presented as means ± SDs, geometric means (95% confidence intervals, 95% CIs), and n (%) for variables with a normal distribution, variables with a skewed distribution, and categorical variables, respectively. Between-group differences were compared by using the two independent samples t-test for variables with a normal distribution, and the nonparametric rank-sum test for variables with a skewed distribution. Counting data were measured by Chi-square test. SPSS version 26 was used for data analysis, with a level of significance established at 0.05, and all tests were 2-sided.

### Results

#### Baseline Characteristics

The mean age at recruitment of cases and controls was about 61 years and 52.85% were male. Compared to controls, cases were more often living in rural sites, had lower educational level and higher BMI level (Table 1). As for risk factors, the prevalence of diabetes among people with different smoking and drinking status was statistically significant. Concerning the history of diseases, the distributions of myocardial infarction (P=0.02) and asthma (P=0.03) were different between the two groups. No significant difference between the case group and control group was observed for gender, age, WHR, or the history of apoplexy, fracture.

	Cases (N=246)	Controls (N=246)	P value
<b>Demographic characteristics</b>			
Age at blood collection (y)	61.45 ± 10.62	61.33 ± 10.52	0.90
<b>Gender, n (%)</b>			
Men	130 (52.85)	130 (52.85)	1.00
Female	116 (47.15)	116 (47.15)	
<b>Residence, n (%)*</b>			
Urban site	139 (56.50)	179 (72.76)	<0.01
Rural site	107 (43.50)	67 (27.24)	
<b>Educational level, n (%)*</b>			
Uneducated	63 (25.61)	24 (9.76)	<0.01
Graduated from primary	44 (17.89)	67 (27.24)	
Middle school degree	102 (41.46)	101 (41.06)	
Technical degree	20 (8.13)	26 (10.57)	
University degree	17 (6.91)	28 (11.38)	
<b>Behavior factors, n (%)</b>			
Smoking status*			

Never smokers	169 (68.70)	142 (57.72)	<b>0.02</b>
Former smokers	21 (8.54)	19 (7.72)	
Current smokers	56 (22.76)	85 (34.55)	
<b>Drinking status<sup>a</sup></b>			
Never	185 (75.20)	157 (63.82)	<b>0.02</b>
Often	53 (21.54)	77 (31.30)	
Almost everyday	8 (3.25)	12 (4.88)	
<b>Anthropometric indices, n (%)</b>			
BMI (kg/m <sup>2</sup> ) <sup>*</sup>			<b>&lt;0.01</b>
<18.5	3 (1.22)	5 (2.03)	
18.5≤BMI<24.0	74 (30.08)	112 (45.53)	
24.0≤BMI<28.0	110 (44.72)	93 (37.80)	
≥28.0	59 (23.98)	36 (14.63)	
<b>WHR</b>			
<0.9	102 (41.46)	125 (50.81)	0.07
≥0.9	138 (56.10)	121 (49.19)	
<b>History of diseases, n (%)</b>			
Myocardial infarction <sup>c</sup>	14 (5.71)	4 (1.63)	<b>0.02</b>
Apoplexy	11 (4.47)	12 (4.88)	0.83
Fracture	20 (8.13)	25 (10.16)	0.43
Asthma <sup>*</sup>	9 (3.66)	2 (0.81)	<b>0.03</b>
<p><b>Abbreviation:</b> MET: Metabolic Equivalent; BMI: Body Mass Index</p> <p><sup>a</sup>There was significant difference lying between the case group and the control group.</p> <p><sup>a</sup>Data was presented as means ± SDs or n (%) for variables with a normal distribution or categorical variables, respectively.</p> <p><sup>b</sup>Between-group differences were compared using the two independent samples t-test for variables with a normal distribution. Counting data were measured by <i>Chi-square</i> test.</p> <p><sup>c</sup>The data was missing for 1 case.</p>			

**Table 1:** Basic characteristics of participants<sup>a-b</sup>.

### Biochemical Indices and Nutrients Intake

For items with statistically significant differences, glucose (GLU), HbA1c, insulin (INS), TG, and Ferritin (FER) levels in the case group were higher than those in the control group (Table 2). Regarding the intake and energy supply ratio of carbohydrate, fat and protein, all of P values were less than 0.05, represented that the differences between the two group were statistically significant (Table 3). Compared with the control group, people with diabetes had lower carbohydrate intake, higher fat and protein intake, whereas lower total energy intake. Apart from the macronutrients, the same results were found in micronutrients, accompanying statistically significant differences. The intake of insoluble fiber, vitamin E, B1, B2, B3, and in the case group were lower than those in the control group. No significant difference between the case group and control group was observed for concentrations of total cholesterol (TC), HDL-C, low density lipoprotein-cholesterol (LDL-C), vitamin A, etc.

	Cases (N=246)	Controls (N=246)	P
<b>Glucose metabolism</b>			
<b>GLU (mmol/L)*</b>	7.51 (6.16-10.02)	5.09 (4.61-5.71)	<b>&lt;0.01</b>
<b>HbA1C (%)*</b>	7.10 (5.90-8.50)	5.60 (5.30-5.90)	<b>&lt;0.01</b>
<b>INS (IU/ml)*</b>	14.66 (10.03-22.15)	10.82 (6.67-17.30)	<b>&lt;0.01</b>
<b>Lipid metabolism</b>			
<b>TG (mmol/L)*</b>	1.85 (1.24-2.78)	1.55 (1.05-2.29)	<b>&lt;0.01</b>
<b>TC (mmol/L)</b>	5.10 (4.45-5.75)	5.03 (4.47-5.66)	0.46
<b>LP_A (g/L)</b>	82.50 (36.00-179.25)	83.00 (50.00-186.25)	0.19
<b>HDL-C (mmol/L)</b>	1.22 (1.02-1.47)	1.27 (1.06-1.48)	0.19
<b>LDL-C (mmol/L)<sup>c</sup></b>	3.10 (2.50-3.77)	3.18 (2.65-3.81)	0.23
<b>Apo_A (g/L)*</b>	1.08 (0.89-1.30)	1.50 (1.25-1.79)	<b>&lt;0.01</b>
<b>ApoB (g/L)*</b>	1.03 (0.84-1.19)	1.18 (0.99-1.32)	<b>&lt;0.01</b>
<b>Hepatic and renal function</b>			
<b>ALB (g/L)</b>	47.20 (44.60-49.83)	47.50 (45.00-49.03)	0.81
<b>CRE (μmol/L)*</b>	91.00 (79.00-102.00)	86.00 (77.00-97.00)	<b>&lt;0.01</b>
<b>UREA (mmol/L)</b>	5.84 (4.85-7.07)	6.14 (5.15-7.25)	0.11
<b>ALT (U/L) *</b>	20.00 (14.00-30.00)	14.00 (9.75-21.00)	<b>&lt;0.01</b>
<b>Iron metabolism</b>			
<b>FER (ng/ml)*</b>	114.71 (68.29-224.57)	87.06 (52.60-143.62)	<b>&lt;0.01</b>
<b>TRF (g/L)</b>	279.50 (249.50-316.25)	276.00 (245.00-316.25)	0.54
<b>TRF_R (mg/L)</b>	1.42 (1.12-1.76)	1.41 (1.16-1.69)	0.77
<b>Other Protein indexes</b>			
<b>TP (g/L)*</b>	77.70 (74.18-81.1)	78.80 (75.70-83.00)	<b>&lt;0.01</b>
<b>CRP (mg/dL)*</b>	2.00 (1.00-4.00)	1.00 (1.00-3.00)	<b>&lt;0.01</b>
<b>Hemoglobin (g/L)*</b>	140.00 (125.00-154.00)	144.00 (132.00-154.00)	<b>0.02</b>
<p><b>Abbreviations:</b> GLU: Blood Glucose; HbA1c: Glycated Hemoglobin; INS: Insulin; TG: Triglycerides; TC: Total Cholesterol; LP_A: Lipoprotein (a); HDL-C: High-Density Lipoprotein Cholesterol; LDL-C: Low Density Lipoprotein-Cholesterol; Apo_A: Apolipoprotein A-1; ApoB: Apolipoprotein B; ALB: Albumin; CRE: Creatinine; ALT: Alanine Aminotransferase; FER: Ferritin; TRF: Transferrin; TRF_R: Soluble Transferrin Receptor; TP: Total Protein; CRP: C-Reactive Protein</p> <p>*There was significant difference lying between the case group and the control group.</p> <p><sup>a</sup>Data was presented as quantiles for variables with a skewed distribution.</p> <p><sup>b</sup>Between-group differences were compared using the two independent samples t-test for variables with a normal distribution, and the non-parametric rank-sum test for variables with a skewed distribution. Counting data were measured by <i>Chi</i>-square test.</p> <p><sup>c</sup>Data was missing for 1 case.</p>			

**Table 2:** Biochemical indices of participants<sup>a-c</sup>.

	Cases (N=246)	Controls (N=246)	P
<b>Energy supply ratio (%E)</b>			
<b>Energy (kcal)</b>	1438.30 (1126.03-1827.79)	1655.40 (1371.99-1995.75)	<0.01
<b>Protein</b>	16.64 (12.49-21.26)	14.38 (10.78-18.21)	<0.01
<b>Fat</b>	21.75 (14.84-31.28)	17.78 (11.18-24.88)	<0.01
<b>Carbohydrate</b>	62.69 (46.78-78.39)	68.25 (50.88-90.72)	<0.01
<b>Average daily nutrients intake</b>			
<b>Protein (g)</b>	58.00 (51.60-66.20)	56.10 (48.66-64.83)	0.04
<b>Fat (g)</b>	32.93 (24.71-43.72)	30.85 (19.89-43.56)	0.05
<b>Carbohydrate (g)</b>	250.40 (221.41-272.83)	260.42 (228.17-283.93)	0.02
<b>Insoluble fiber (g)</b>	9.06 (7.09-11.52)	11.74 (8.93-15.10)	<0.01
<b>Vitamin A (µgRE)</b>	310.33 (197.96-491.43)	291.65 (170.59-437.96)	0.10
<b>Vitamin E (mg)</b>	10.26 (6.73-14.55)	14.36 (11.36-19.82)	<0.01
<b>Vitamin B<sub>1</sub> (mg)</b>	0.67 (0.54-0.81)	0.79 (0.64-0.96)	<0.01
<b>Vitamin B<sub>2</sub> (mg)</b>	0.73 (0.61-0.84)	0.79 (0.67-0.94)	<0.01
<b>Vitamin B<sub>3</sub> (mg)</b>	12.06 (9.72-14.95)	13.20 (11.56-15.77)	<0.01
<b>Vitamin C (mg)</b>	68.72 (44.37-95.32)	79.50 (58.04-110.57)	<0.01
<p><sup>a</sup>Data was presented as quantiles for variables with a skewed distribution.</p> <p><sup>b</sup>Between-group differences were compared using the two independent samples t-test for variables with a normal distribution, and the non-parametric rank-sum test for variables with a skewed distribution. Counting data were measured by <i>Chi</i>-square test.</p> <p><sup>c</sup>Calculating the energy adjusted nutrient intake.</p>			

**Table 3:** Macronutrients and micronutrients daily intake of participants<sup>a-c</sup>.

### Intake Levels of Macronutrients and Micronutrients

The energy supply ratio of macronutrients was divided into three groups according to the standard: protein recommended nutrient intake (RNI) (10-15%), fat RNI (20-30%), carbohydrate RNI (50-65%). Compared with the normal intake, the risk of diabetes in the high protein-intake group was 1.49 times (95%CI: 1.00-2.22) as much, and the group with low fat intake was 0.66 times (95%CI: 0.43-1.00) as much (Table 4). When generally lower than RNI, the closer the nutrient intake was to RNI, the lower the risk of diabetes. People with insoluble fiber intake “between 8-12g” and “>12g” had the diabetes risks 0.53 times (95%CI: 0.34-0.85) and 0.22 times (95%CI: 0.14-0.36) than that with “<8g”, respectively. The diabetes risk of vitamin B1 intakes of “0.6-0.8mg” and “>0.8mg” were 0.62 times (95%CI: 0.39-0.99) and 0.28 times (95%CI: 0.18-0.45) than that of “<0.6mg”, respectively. As for vitamin B2, the risk of diabetes in the “>0.8mg” group was 0.50 times than that in the “<0.6mg” group (95%CI:0.30-0.82). Vitamin B3, C and E were divided according to RNIs, vitamin B3 (male, 14mg; female, 12mg), vitamin C (100mg), vitamin E (14mg). For vitamin B3, C, and E, the risk of diabetes in the low-level intake group was 1.47 times (95%CI : 0.54-2.97), 0.99 times (95%CI : 0.16-2.41), and 1.16 times (95%CI : 0.21-2.87) higher than that in the normal group, respectively. Both carbohydrate and vitamin A had no significant difference among different subgroups.

Factor	Case N (%)	Control N (%)	Crude OR	Model 1 OR	Model 2 OR	Model 3 OR
<b>Protein (%E)</b>						
<10	27 (10.98)	49 (19.92)	0.64 (0.36-1.12)	0.83 (0.57-1.01)	0.79 (0.57-1.13)	0.75 (0.45-1.04)
10-15	71 (28.86)	82 (33.33)	1.00	1.00	1.00	1.00
>15	148 (60.16)	115 (46.75)	1.49 (1.00-2.22)	1.22 (0.97-1.77)	1.37 (1.11-1.94)	1.33 (1.16-2.01)
	$\chi^2 = 11.30$ $P < 0.01$		$P < 0.01$	$P = 0.21$	$P = 0.04$	$P < 0.01$
<b>Fat (%E)</b>						
<20	106 (43.08)	145 (58.94)	0.66 (0.43-1.00)	0.81 (0.67-1.14)	0.77 (0.45-0.89)	0.69 (0.53-0.92)
20-30	70 (28.46)	63 (25.61)	1.00	1.00	1.00	1.00
>30	70 (28.46)	38 (15.45)	1.66 (0.98-2.79)	1.03 (0.89-1.31)	1.78 (1.21-1.98)	1.52 (1.14-1.76)
			$P < 0.01$	$P = 0.16$	$P = 0.02$	$P < 0.01$
<b>Carbohydrate (%E)</b>						
<50	57 (23.17)	67 (27.24)	1.11 (0.67-1.84)	1.04 (0.53-1.13)	0.89 (0.79-1.02)	0.77 (0.48-1.23)
50-65	52 (21.14)	68 (27.64)	1.00	1.00	1.00	1.00
>65	137 (55.69)	111 (45.12)	1.61 (1.04-2.50)	1.23 (0.89-1.45)	1.29 (1.02-1.52)	1.27 (1.05-1.42)
			$P = 0.59$	$P = 0.68$	$P = 0.45$	$P = 0.18$
<b>Insoluble fiber (g)</b>						
<8	92 (37.40)	43 (17.48)	1.00	1.00	1.00	1.00
8-12	98 (39.84)	86 (34.96)	0.53 (0.34-0.85)	0.67 (0.52-0.89)	0.59 (0.48-0.87)	0.57 (0.46-0.69)
>12	56 (22.76)	117 (47.56)	0.22 (0.14-0.36)	0.53 (0.41-0.68)	0.43 (0.25-0.57)	0.38 (0.29-0.53)
			$P < 0.01$	$P = 0.04$	$P = 0.02$	$P < 0.01$
<b>Vitamin A (ugRE)</b>						
<240	92 (37.40)	102 (41.46)	1.00	1.00	1.00	1.00
240-360	55 (22.36)	55 (22.36)	1.11 (0.69-1.77)	1.25 (0.67-1.32)	1.37 (0.89-1.85)	1.21 (0.93-1.45)
>360	99 (40.24)	89 (36.18)	1.23 (0.83-1.84)	1.47 (0.89-1.71)	1.46 (1.12-1.67)	1.39 (1.02-1.57)
			$P < 0.01$	$P = 0.22$	$P = 0.18$	$P = 0.06$
<b>Vitamin E (mg)</b>						
<13	169 (68.70)	97 (39.43)	2.16 (1.21-3.87)	1.76 (1.32-2.01)	2.22 (1.35-2.78)	2.19 (1.49-2.46)
13-15	25 (10.16)	31 (12.60)	1.00	1.00	1.00	1.00
>15	52 (21.14)	118 (47.97)	0.55 (0.29-1.02)	0.67 (0.43-0.98)	0.59 (0.39-0.95)	0.52 (0.36-0.69)
			$P < 0.01$	$P = 0.03$	$P < 0.01$	$P < 0.01$
<b>Vitamin B<sub>1</sub> (mg)</b>						
<0.6	92 (37.40)	49 (19.92)	1.00	1.00	1.00	1.00
0.6-0.8	90 (36.59)	77 (31.30)	0.62 (0.39-0.99)	0.89 (0.67-1.22)	0.59 (0.22-0.98)	0.47 (0.19-0.78)
>0.8	64 (26.01)	120 (48.78)	0.28 (0.18-0.45)	0.67 (0.33-0.99)	0.32 (0.19-0.61)	0.22 (0.10-0.34)
			$P < 0.01$	$P = 0.05$	$P = 0.02$	$P < 0.01$
<b>Vitamin B<sub>2</sub> (mg)</b>						

<0.6	55 (22.36)	41 (16.67)	1.00	1.00	1.00	1.00
0.6-0.8	112 (45.53)	87 (35.36)	0.96 (0.59-1.57)	0.78 (0.57-1.01)	0.88 (0.57-1.31)	1.02 (0.77-1.43)
>0.8	79 (32.11)	118 (47.97)	0.50 (0.30-0.82)	0.54 (0.32-0.88)	0.43 (0.21-0.78)	0.57(0.23-0.89)
			<i>P</i> < 0.01	<i>P</i> =0.02	<i>P</i> < 0.01	<i>P</i> < 0.01
<b>Vitamin B<sub>3</sub> (mg)</b>						
<12	121 (49.19)	75 (30.49)	2.47 (1.54-3.97)	2.01 (1.01-2.89)	2.45 (1.57-3.23)	2.32 (1.43-2.51)
12-14	45 (18.29)	69 (28.05)	1.00	1.00	1.00	1.00
>14	80 (32.52)	102 (41.46)	1.20 (0.75-1.94)	1.13 (0.79-1.43)	1.23 (0.79-1.45)	1.17 (0.79-1.51)
			<i>P</i> < 0.01	<i>P</i> =0.06	<i>P</i> < 0.01	<i>P</i> < 0.01
<b>Vitamin C (mg)</b>						
<90	179 (72.76)	142 (57.72)	1.99 (1.16-3.41)	2.21 (1.54-2.78)	2.02 (1.67-2.45)	2.14 (1.78-2.49)
90-110	26 (10.57)	41 (16.67)	1.00	1.00	1.00	1.00
>110	41 (16.67)	63 (25.61)	1.03 (0.55-1.93)	0.89 (0.58-1.23)	1.01 (0.65-1.57)	1.04 (0.67-1.54)
			<i>P</i> < 0.01	<i>P</i> < 0.01	<i>P</i> < 0.01	<i>P</i> < 0.01
<p>*There was significant difference between the case group and the control group.</p> <p><sup>a</sup>Data was presented as n (%) for categorical variables.</p> <p><sup>b</sup>Between-group differences were compared using the <i>Chi</i>-square test for counting data</p> <p><sup>c</sup>Calculating the energy adjusted nutrient intake.</p> <p><sup>d</sup>Nutrients were included in the average daily intake.</p>						

**Table 4:** Intake levels of nutrients and the risk of diabetes mellitus<sup>a-d</sup>.

## Discussion

From the results, we could conclude that there are statistically significant differences in dietary nutrients intake and lifestyle between the case group and the control group. These diabetic patients were in the early stage of their clinical practice. The reason was that the case group had relatively higher BMI but with less total energy intake. Obesity (BMI $\geq$ 28.0 kg/m<sup>2</sup>) is associated with diabetes [18]. Patients often lose weight after a period of diabetes. Compared with the control group, diabetics had lower carbohydrate intake, as well as higher fat and protein intake significantly. These results may be related to the diabetics consciously improving their diet structure after diagnosis. It may be beneficial for patients to reduce their carbohydrate intake. In clinical practice, adopting LCD is an active treatment option for diabetic patients [19]. A Case Study in China revealed that ketogenic diets may potentially reverse T2DM [20]. Under a 12-week continuous professional remote care intervention, an overweight T2DM patient restricted carbohydrate intake by ketogenic diets, and adjusted his diabetes medication under monitoring. Related biomarkers became normal after the intervention. It suggested that LCD may have a significant

effect on preventing and treating diabetes in China. Furthermore, LCD can normalize impaired fasting glucose (IGT) patients' blood glucose and prevent them from progressing to become T2DM patients [21].

Nevertheless, its health negative effects also need to be highlighted, including the deficiency of vitamin and dietary fiber, an increased risk of renal dysfunction by high protein intake [22]. Also, our study has shown the deficiency of vitamin and insoluble fiber.

At the same time, diabetic patients in the early stages had also shown a tendency to change their living habits, such as quitted smoking and limited alcohol. The smoking and drinking condition in case group was better than that in control group. Alcohol can affect the secretion of islets, which may lead to an inadequate response of pancreatic cancer  $\beta$  to glucose, finally resulting in insulin resistance and the increased risk of T2DM [23]. Exposed to cigarette smoke can result in pancreatic  $\beta$ -cell dysfunction and impair insulin secretion, too [24]. Even the never-smoking, long-term exposure to second-hand smoke also increases the risk of diabetes. A prospective study conducted by the Japan Public

Health Center illustrated that the never-smoking woman who was in a higher percentage of passive smoking environment from her spouse would have an elevated risk of diabetes. Occupational exposure could also lead to similar outcomes [11]. Therefore, strengthening health education on quitting smoking and limiting alcohol can not only benefit diabetic patients, but also help the surroundings stay healthy.

When people are aware of controlling their illness after diagnosis, their first reaction is to stop smoking and limiting alcohol. However, as for dietary therapy, they just realize to reduce carbohydrate intake, whereas they are at a loss when confronted with the elimination of adverse effects of LCD. It is difficult for them to make some complicated improvements, such as paying attention to the supplement of micronutrients. In our study, the intake of insoluble fiber and vitamins in the case group was relatively lower. Higher intake level of dietary fiber is negatively associated with T2DM [25]. Producing a sense of fullness to delay hunger, disturbing the absorption of carbohydrate to lower blood sugar, and reducing the amount of cholesterol absorbed by the intestine, which are all included in the physiological properties of dietary fiber [26]. Compared with the meaningless pectin fiber, cereal fiber has a protective effect on T2DM, it works through these three pathways: increasing glucose tolerance, decreasing inflammation and changing immune response [27]. In our research, for insoluble fiber and vitamin A, B1, B2, the intake of participants was almost less than RNI. Then, it could be seen that is closer to RNI and has a lower risk of diabetes. For the vitamin B3, C and E which intake roughly reached RNI, the risk of diabetes in the lower-RNI group was significantly higher than that in the RNI group, while no significant difference between the higher group and RNI group. The association between diabetes and vitamin A is still relatively vague. There was a Randomized Clinical Trial (RCT) demonstrating that high intake level of vitamin A, E plus zinc may improve blood glucose control,  $\beta$ -cell function, and insulin secretion in diabetic patients [28]. On the contrary, the other, which contradicted the former one, insisted that further researches were needed to verify whether the deficiency of Vitamin A was positively associated with the pathogenesis of diabetes [29]. Instead, the effect of antioxidant vitamins is clear. RCT proved that the supplement of vitamin C and vitamin E, could benefit T2DM on preventing diabetes, improving clinical conditions and avoiding complications [30]. Adults who were diagnosed with prediabetes or diabetes will have greater demand for vitamin C [31]. In addition to the inherent health concept, it is imperative to carry out a more profound health education of balanced diet on diabetic patients.

In addition to the above nutrients, we can also focus on biochemical indicators. Dyslipidaemia is very common in T2DM and it is associated with increased risk of cardiovascular diseases [32]. Compared with the control group, the level of case group on GLU,

HbA1c, TG, INS and FER was much higher. The results of our research indicated that the TC level in diabetics was 1.85mmol/L, while that in normal people was 1.55mmol/L. A diabetes survey conducted in Mexico City revealed that only less than 5% of patients aware of their illness had achieved treatment targets for LDL-C [33]. The lower rate of diabetes awareness and the poor level of index control highlight the urgent need of strengthening diabetes care, as well as health education. For diabetic patients, lipid-lowering therapy must be considered as a primary measure to prevent coronary heart disease that includes both lifestyle intervention and medical therapy [34]. Nowadays, the NCEP ATP III guidelines recommend that an optimal goal for LDL cholesterol is <70 mg/dl, whereas <100 mg/dl is considered as the lowest target [35].

In our research, the difference of TC level between diabetes group and control group was statistically significant, and so was HbA1C. Besides being a significant diagnostic marker for blood glucose control, HbA1c can also be treated as a positive predicted index of dyslipidaemia in T2DM [36]. Then, Sharen Lee demonstrated that high HbA1c and lipid variability were important predictors of the undesirable outcome in diabetes, such as peripheral vascular disease and ischemic heart disease, as well as atrial fibrillation and heart failure [37]. Therefore, in order to prevent adverse outcomes caused by dyslipidaemia in diabetes, paying attention to routine blood lipid indices, HbA1C can also be monitored.

Iron overload is a known risk factor for T2DM [38]. Our research indicated that the level of FER in case group was significantly higher than that in control group. FER can cause severe damage to the pancreatic cells through excessive oxidative stress, which may lead to the insulin resistance and diabetes complications. For example, it has been confirmed that high dietary iron intake was associated with the presence of diabetic peripheral neuropathy [39]. A Mendelian randomization study demonstrated that a causal relationship lied between increased systemic iron status and increased T2DM risk based on genetic evidence [40]. Meanwhile, with the improvement of people's living standards, the intake of red meat is generally higher, followed by an increase in iron intake. As an additional risk factor for metabolic syndrome, the measurement of serum ferritin concentration determination is essential [41]. From what has been discussed above, early detection can recognize the dangerous signal to prevent further damage to patients.

Finally, we cannot neglect the role played by health education in the prevention and treatment of diabetes. If there was no sufficient action to deal with the pandemic, the estimated number of diabetic patients will be forecasted as 578 million by 2030, and jumping to an alarming 700 million by 2045 [3]. One of the reasons for the higher prevalence may come from the deficient rate of awareness of the diabetes [4]. A population based study in Shanghai, China

showed that among their participants, 28.06% were aware of their diabetes, 25.85% were on medication, and only 12.42% had achieved the glycaemic control [42]. Lower awareness and worse control rate of the diabetes, which may be attributed to lacking of access to health care, has made the diabetes health education looming ahead. Our study had shown that the prevalence of diabetes was higher among people with a lower education level, and among those who lived in rural areas. Both the less educated and rural residents are with inadequate health literacy and deficient access to health services [43], so they seldom know how to improve their lifestyle to control the condition of health indicators and are placed at higher risk for diabetes complications [33]. Nowadays, Diabetes Self-Management Education (DSME) has been used to empower patients to manage their diabetes, which contains healthy eating, self-monitoring of blood glucose, diabetes complications risk decrease behavior, etc. [44]. With the popularity of mobile devices, mobile health can provide better data support for DSME, which means, details of patients' lives can be aggregated on the web and analyzed comprehensively. For example, Frøisland DH developed and tested an app for capturing and visualizing adolescents' nutrients intake [45]. Above all, there remained some shortness in our research. The data of nutrients were collected from the dietary intake, not the serum level. At the same time, the dietary intake was calculated from the recipes recorded by participants and couldn't represent the actual intake level. Further research should focus on the actual dietary intake.

## Conclusions

The changes in diet and behavior of diabetic patients after diagnosis are mainly reflected in reducing carbohydrate intake, smoking and alcohol intake, and relatively increasing fat and protein intake whereas still insufficient dietary fiber and vitamins intake. The overweight/obesity and metabolic syndrome have not been improved, indicating that enhancing the health education of diabetes, including improving lifestyle and diet structure, is of great use not only in preventing the complication, but also in protecting the health of pre-diabetic patients. Early diagnosis and control of diabetes can cut down the premature mortality and disability. Taking early intervention on these people will greatly improve people's health standard and decrease the medical costs.

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## Availability of Data and Materials

Data described in the manuscript, code book, and analytic code will be made available upon request pending application.

## Authors' Contributions

The authors' responsibilities were as follows—XXG, XQL carried out the study design, data analysis and writing of the paper; TYM and XQL provided the original idea of the paper and played a vital role in the revised submission; WYZ collected and organized data from CHNS; FL, DC, PW, SSW, ZRX, ZYH polished the article; All authors were involved in writing the paper and had final approval of the submitted and published versions.

## Competing Interests

The authors declare that they have no competing interests.

**Consent for publication:** Not applicable.

## Ethics Approval and Consent to Participate

The CHNS was approved by the institutional review boards of the University of North Carolina at Chapel Hill and Chinese Center for Disease Control and Prevention. Each participant provided the written informed consent before participating.

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