Original Article

Comparison of the dietary intakes of individuals with and without type 1 diabetes in China

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Background and Objectives: The objective was to compare the dietary intakes of individuals with type 1 diabetes (T1D) to individuals without diabetes in China. **Methods and Study Design**: Data are from 1) the 3C Nutrition Ancillary Study, a cross-sectional study of individuals with T1D in China, and 2) the China Health and Nutrition Survey. Dietary intake in both samples was assessed using three 24-hour recalls. ANCOVA and multivariable logistic regression, adjusted for sex, age, and urban-rural residence, were used to assess differences in nutrient and food group intake between participants without diabetes (n=1059) and participants with T1D (n=97), who were stratified by insulin regimen (basal-bolus, n=49, versus fixed, n=48). **Results**: Participants with T1D had a lower percentage of energy from carbohydrates, higher vegetable intake, and were more likely to consume low-fat cakes and fungi/sea weed compared to participants without diabetes (all $p<0.05$). Distinguishing characteristics of insulin regimen groups also emerged. Participants on fixed regimens had higher intakes of wheat and were less likely to consume fruit and more likely to consume high-fat cakes and dairy compared to participants without diabetes (all $p<0.05$). Participants on basal-bolus regimens were less likely to consume fried foods and more likely to consume fish/shellfish compared to participants without diabetes (all $p<0.05$). **Conclusions**: Differences in dietary intake between participants with and without T1D in China suggest that dietary modifications are common and reflect carbohydrate-conscious nutrition recommendations for individuals with T1D. Future research should focus on the health effects of these modifications.

Key Words: human nutrition, carbohydrate, epidemiology, type 1 diabetes, China

INTRODUCTION

Modifications to dietary intake have consistently been an essential component of type 1 diabetes (T1D) treatment. In a considerable shift from the prescriptive diets characteristic of much of the 20th century,[1-3] in 1994, the American Diabetes Association (ADA) published nutrition recommendations emphasizing individualization of dietary advice with a focus on the effects of nutrition therapy on metabolic control.[4] The most recent ADA recommendations reiterate that there is no "one-size-fits-all" diet for individuals with diabetes and that food choices should only be limited when supported by scientific evidence.[5]

There is a dearth of information on the dietary intakes of individuals with T1D from low- and middle-income countries where economic development and urbanization have resulted in a transition from traditional foods to foods high in saturated fat and sugar, and low in fiber.[6,7] Whether this nutrition transition has also affected the dietary intakes and self-management practices of individuals with T1D in these countries has yet to be explored.

A recent study conducted in Shanghai reported a mean annual increase in the incidence rate of T1D of 14.2% between 1997 and 2011, suggesting that the burden of T1D in China is increasing.[8] China has also undergone dramatic changes in diet over the past 20 years.[9-12] The objective of this study was to compare the dietary intakes of individuals with T1D in China to those of individuals without diabetes in China. Such a comparison will improve our understanding of how patients with T1D are modifying their diet relative to the general population in order to manage their condition and will inform future

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interventions to improve the lives of individuals with T1D in China.

METHODS

Study samples

The 3C Study was an epidemiological study of the coverage, cost, and care of T1D in China.[13] The 3C Nutrition Ancillary Study (3CNAS) was conducted between February and August 2013, on average, 1.6±0.2 years (range: 1.2-2.0 years) after the 3C Study, and expanded the 3C Study to include comprehensive information on dietary intake. 3C Study participants who met the following criteria were eligible for 3CNAS: Beijing resident, ≥12 years old, no severe diabetes complications (i.e. advanced micro- and macrovascular complications, including nephropathy and stroke), and in-service telephone number available. A total of *n*=195 3C Study participants met these criteria. Of these, *n*=72 (37%) refused to participate and *n*=23 (12%) dropped out before the 3CNAS visit. The final sample size was *n*=100. There were no differences in diabetes duration, sex, education, or residence status between those who participated and those who refused or dropped out (all *p*>0.05). However, those who participated tended to be older (*p*=0.001), have higher household incomes (*p*=0.05), and be retired/unemployed (*p*=0.06) and married/cohabitating (*p*=0.02).

Data on individuals without T1D residing in Beijing came from the most recent (2011) China Health and Nutrition Survey (CHNS). CHNS is an ongoing open cohort of the health and nutritional status of the Chinese population.[14] For the first time in 2011, 24 communities from Beijing were included in the survey. CHNS participants who met the following criteria were eligible for this analysis: Beijing resident, ≥12 years old, no diagnosed diabetes, and dietary data available. The final sample size was *n*=1059.

All procedures were approved by The University of North Carolina Office of Human Research Ethics (study number 12-2408) and for 3CNAS, the Peking University Biomedical Institutional Review Board (study number IRB00001052-13007), and for CHNS, the China National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention (study number 201524). All participants provided informed consent (≥18 years old) or parent permission and participant assent (12 to <18 years old).

Dietary intake assessment

Dietary intake in 3CNAS was assessed using three (two weekdays and one weekend day) telephone administered 24-hour recalls assisted by food records. Telephone administration was used to overcome the cultural stigma associated with T1D in China, which precluded visiting the homes of participants. This method was validated against in-person administration in a subset of participants.[15] At the end of the 3CNAS visit, participants were trained by dietitians to record their dietary intake on food records provided in an introductory packet. Emphasis was placed on estimating portion sizes using food samples, an electronic scale, and a culturally appropriate portion size picture guide. On average, beginning 3.0±2.8 days after this visit, participants completed the three 24-hour recalls.

Dietary intake in CHNS was assessed using three consecutive in-person administered 24-hour recalls randomly allocated to start between Monday and Sunday in combination with a household food inventory conducted over the same 3-day period.[10] Food models and picture aids were used by trained interviewers to assist with estimating portion sizes. For dishes prepared at home, the recipe components were taken from the household food inventory and portion sizes were based on the proportion of the dish reportedly consumed by the participant.

For both 3CNAS and CHNS, the 24-hour recall food lists were converted into nutrients using the Chinese Food Composition Tables.[16,17] Nutritionally meaningful food groups were derived by a collaborative working group that included researchers at The University of North Carolina, Chapel Hill, and the China National Institute of Nutrition and Food Safety.[10] Nutrients were specified continuously as energy densities.[18] Due to the non-normal distribution of some food groups largely stemming from large proportions of non-consumers, food groups were specified as binary variables. Food groups with ≥80% consumers were dichotomized as below versus above the median of the corresponding food group distribution in g/1000 kcal among participants without diabetes, and food groups with <80% consumers were dichotomized as non-consumers versus consumers.

Covariate assessment

Self-reported demographic data were collected via interviewer-administered questionnaires during the 3C Study visit and the CHNS visit. Both studies used standardized protocols to measure weight and height. Underweight and overweight for adults (≥18 years) were defined according to the WHO's recommendation as underweight, BMI <18.5 kg/m^2, and overweight, BMI ≥25 kg/m^2,[19] and for adolescents (12 to <18 years) using the sex- and age-specific cut-points recommended by the International Obesity Task Force.[20,21]

Information on insulin administration was collected during the 3CNAS visit. Two insulin regimens were defined as follows: (1) "basal-bolus," including continuous subcutaneous infusion and regimens with ≥3 daily injections that included glargine or detemir, and (2) "fixed," including regimens with ≥3 daily injections with any insulin types excluding glargine and detemir and regimens with 1-2 injections per day of any insulin types.

Statistical analysis

Descriptive statistics were used to summarize sample characteristics, and differences between participants with and without diabetes were evaluated using ANOVA for continuous variables and chi-square tests for categorical variables.

Potential confounders, including age, sex, marital status, household income, residence status, education, occupation, medical insurance coverage, smoking status, and BMI status, were explored using a directed acyclic graph[22] and formally evaluated by estimating their associations with both the exposure (diabetes status) and outcomes (nutrients and food groups). We found that BMI status was a collider in the directed acyclic graph analysis, being both the result of diabetes status and dietary intake. We therefore did not include BMI status in our final models as adjustment for colliders results in biased estimates.[23,24] The final adjustment set included sex, age (<22 years versus ≥22 years), and residence status (urban versus rural) as these factors were associated with the exposure (Table 1) and the outcomes (data not shown). Because *n*=3 participants with T1D were missing residence status, the final sample size for this analysis was *n*=1059 without diabetes and *n*=97 with T1D (*n*=49 on basal-bolus insulin regimens and *n*=48 on fixed insulin regimens).

Confounder-adjusted differences were calculated using ANCOVA for continuous variables (nutrients) and multivariable logistic regression for binary variables (food groups). Given that dietary recommendations for T1D management are specific to an individual's insulin regimen and differ between flexible, basal-bolus regimens and fixed regimens,[25] analyses were conducted with 1) all participants with T1D combined and 2) participants with T1D stratified by insulin regimen (basal-bolus versus fixed).

All statistical analyses were conducted using SAS 9.2 (SAS Institute, Cary, North Carolina). Values presented are mean±SD or percentage (*n*) unless otherwise indicated.

RESULTS

Participants with T1D were more likely to be <22 years old (p=0.04) and single/divorced/widowed (p<0.0001), had higher incomes (p=0.002) and education (p=0.01), and were more likely to be underweight and less likely to be overweight (p<0.0001) compared to participants without diabetes (Table 1). Participants with T1D on fixed insulin regimens were more likely to be male compared to the other two groups (p=0.04), and participants with T1D on basal-bolus insulin regimens were more likely to be urban residents compared to the other two groups (p=0.008).

The macronutrient composition of the diets of participants with and without T1D differed substantially (Table 2). Participants with T1D had a significantly (p=0.01) lower adjusted mean percentage of energy from carbohydrates compared to participants without diabetes: approximately 47% of calories from carbohydrates in those with T1D versus 50% in those without diabetes. Consistent with this observation, participants with T1D had a significantly higher adjusted mean percentage of energy from fat (p=0.04) and protein (p=0.02) compared to participants without diabetes. Stratification by insulin regimen revealed that the differences in carbohydrate and fat were stronger among participants on fixed insulin regimens, while the difference in protein was more evident in participants on basal-bolus insulin regimens. No statistically significant differences were observed in adjusted mean fiber intake.

Participants with T1D in both insulin regimen groups were more likely to be consumers of low-fat cakes (adjusted OR [95% CI], 3.19 [1.99, 5.10]) and fungi/seaweed (adjusted OR [95% CI], 2.69 [1.76, 4.12]) compared to participants without diabetes (Table 3). They were also significantly more likely to be above the median intake for vegetables (adjusted OR [95% CI], 8.33 [4.37, 15.86]) compared to participants without diabetes.

Participants with T1D on basal-bolus insulin regimens had several distinct dietary modifications (Table 3): they were less likely to be consumers of fried foods (adjusted OR [95% CI], 0.48 [0.23, 1.00]) and more likely to be consumers of fish/shellfish (adjusted OR [95% CI], 1.95 [1.08, 3.52]) compared to participants without diabetes.

Participants with T1D on fixed insulin regimens also had several distinct dietary modifications (Table 3): they were more likely to be above the median intake for wheat products (adjusted OR [95% CI], 2.03 [1.08, 3.81]), and they were more likely to be consumers of high-fat cakes (adjusted OR [95% CI], 2.73 [1.25, 5.95]) and milk/milk products (adjusted OR [95% CI], 2.57 [1.19, 5.53]). Furthermore, they were less likely to be consumers of fruit (adjusted OR [95% CI], 0.47 [0.26, 0.87]).

DISCUSSION

Individuals with T1D in China had a lower mean percentage of energy from carbohydrates compared to individuals without diabetes. In addition, they had higher intakes of vegetables, fungi/seaweed, and low-fat cakes. Several distinguishing characteristics of insulin regimen groups also emerged: participants on fixed regimens had higher intakes of wheat products and were less likely to consume fruit and more likely to consume high-fat cakes and dairy compared to participants without diabetes. In contrast, participants on basal-bolus regimens were less likely to consume fried foods and more likely to consume fish/shellfish compared to participants without diabetes. Together, these observations suggest that dietary modifications are common among individuals with T1D in China and reflect carbohydrate-conscious nutrition recommendations.

Few studies have systematically compared the dietary intakes of individuals with T1D and the general population. One study conducted in the United States found similar results to our study, reporting that adults with T1D had a higher mean percentage of energy from fat and protein and a lower mean percentage of energy from carbohydrates compared to controls.[26] A similarly higher mean percentage of energy from fat compared to controls has also been observed in several small samples of youth with T1D in Europe.[27,28]

In contrast to the aforementioned studies, a small study conducted in Australia did not find any statistically significant differences in dietary intake between adults with newly diagnosed T1D and controls despite the fact that all of the T1D participants were reportedly following fixed insulin regimens matched to a set diet.[29] Two other studies, both conducted in youth with T1D in Europe, also did not find significant differences in the macronutrient composition of the diet between participants with T1D and controls.[30,31] In our study, most participants with T1D were on fixed insulin regimens matched to a rigid diet with respect to timing and amount of food,[15] and we observed substantial differences in dietary intake between participants with T1D and those without diabetes despite previously reporting limited nutrition education in this group of participants.[15] This

Table 1. Comparison of demographic and clinical characteristics between participants without diabetes and those with type 1 diabetes, combined and stratified by insulin regimen

	No diabetes (n=1059)	T1D (n=97)	T1D		*p* combined T1D†	*p* stratified T1D‡
			Basal-bolus insulin (n=49)	Fixed insulin (n=48)		
Age (years)	43.1±15.3	41.3±16.3	41.9±17.4	40.7±15.3	0.28	0.52
<22	8.3 (88)	14.4 (14)	16.3 (8)	12.5 (6)	0.04	0.10
≥22	91.7 (971)	85.6 (83)	83.7 (41)	87.5 (42)		
Diabetes duration (years)	N/A	11.6±9.3	13.6±10.9	9.5±6.9	N/A	0.03
Sex						
Men	53.2 (563)	46.4 (45)	57.1 (28)	35.4 (17)	0.20	0.04
Women	46.8 (496)	53.6 (52)	42.9 (21)	64.6 (31)		
Marital status						
Married/cohabitating	88.0 (871)	59.6 (56)	52.2 (24)	66.7 (32)	<0.001	<0.001
Single/divorced/widowed	12.0 (119)	40.4 (38)	47.8 (22)	33.3 (16)		
Household income (RMB/month)						
<3000	22.4 (234)	19.0 (18)	12.8 (6)	25.0 (12)	0.002	0.009
3000 - <5000	25.3 (264)	23.2 (22)	23.4 (11)	22.9 (11)		
5000 - <10,000	39.9 (417)	31.6 (30)	34.0 (16)	29.2 (14)		
≥10,000	12.4 (130)	26.3 (25)	29.8 (14)	22.9 (11)		
Residence						
Urban	78.9 (836)	84.5 (82)	95.9 (47)	72.9 (35)	0.19	0.008
Rural	21.1 (223)	15.5 (15)	4.1 (2)	27.1 (13)		
Highest attained level of education						
<University	48.0 (506)	32.3 (31)	25.0 (12)	39.6 (19)	0.01	0.02
Junior college	12.4 (131)	14.6 (14)	14.6 (7)	14.6 (7)		
≥University	39.6 (417)	53.1 (51)	60.4 (29)	45.8 (22)		
Occupation						
Non-government worker	37.5 (364)	30.9 (30)	28.6 (14)	33.3 (16)	<0.001	<0.001
Government worker	22.8 (221)	17.5 (17)	16.3 (8)	18.8 (9)		
Student	1.8 (17)	17.5 (17)	16.3 (8)	18.8 (9)		
Farmer	1.4 (14)	7.2 (7)	4.1 (2)	10.4 (5)		
Retired or not working	36.5 (354)	26.8 (26)	34.7 (17)	18.8 (9)		
Medical insurance coverage						
Yes	94.7 (1000)	95.9 (93)	95.9 (47)	95.8 (46)	0.62	0.88
No	5.3 (56)	4.1 (4)	4.1 (2)	4.2 (2)		

T1D: type 1 diabetes. Values are given as mean±SD or percentage (n).
†*p* from chi-square test for categorical variables and ANOVA for continuous variables comparing participants without diabetes and participants with type 1 diabetes.
‡*p* from chi-square test for categorical variables and ANOVA for continuous variables comparing participants without diabetes, participants with type 1 diabetes on basal-bolus insulin regimens, and participants with type 1 diabetes on fixed insulin regimens.
§Underweight and overweight for adults (≥18 years) were defined according to the World Health Organization's recommendation as underweight, BMI <18.5 kg/m^2, and overweight, BMI ≥25 kg/m^2, and for adolescents (12 to <18 years) using the sex- and age-specific cut-points recommended by the International Obesity Task Force.

Table 1. Comparison of demographic and clinical characteristics between participants without diabetes and those with type 1 diabetes, combined and stratified by insulin regimen (cont.)

	No diabetes (n=1059)	T1D (n=97)	T1D		*p* combined T1D†	*p* stratified T1D‡
			Basal-bolus insulin (n=49)	Fixed insulin (n=48)		
Smoking status						
Non-smoker	79.1 (834)	80.4 (78)	85.7 (42)	75.0 (36)	0.77	0.41
Smoker	20.9 (220)	19.6 (19)	14.3 (7)	25.0 (12)		
BMI Status§						
Underweight	3.1 (33)	16.5 (16)	14.3 (7)	18.8 (9)	<0.001	<0.001
Normal weight	55.0 (580)	73.2 (71)	67.4 (33)	79.2 (38)		
Overweight	41.8 (441)	10.3 (10)	18.4 (9)	2.1 (1)		

T1D: type 1 diabetes. Values are given as mean±SD or percentage (n).
†*p* from chi-square test for categorical variables and ANOVA for continuous variables comparing participants without diabetes and participants with type 1 diabetes.
‡*p* from chi-square test for categorical variables and ANOVA for continuous variables comparing participants without diabetes, participants with type 1 diabetes on basal-bolus insulin regimens, and participants with type 1 diabetes on fixed insulin regimens.
§Underweight and overweight for adults (≥18 years) were defined according to the World Health Organization's recommendation as underweight, BMI <18.5 kg/m^2, and overweight, BMI ≥25 kg/m^2, and for adolescents (12 to <18 years) using the sex- and age-specific cut-points recommended by the International Obesity Task Force.

Table 2. Comparison of nutrient intake between participants without diabetes and those with type 1 diabetes, combined and stratified by insulin regimen

	No diabetes (n=1059)	T1D (n=97)	T1D		*p* T1D vs no diabetes†	*p* basal-bolus vs no diabetes‡	*p* fixed vs no diabetes‡
			Basal-bolus insulin (n=49)	Fixed insulin (n=48)			
Energy intake (kcal/day)	1769±18	1560±60.4	1543±85	1578±86	0.001	0.01	0.03
Fat (% kcal)	33.8±0.3	36.0±1.0	35.7±1.5	36.4±1.5	0.04	0.21	0.08
Carbohydrate (% kcal)	49.9±0.3	47.2±1.0	47.5±1.4	46.8±1.4	0.01	0.10	0.04
Protein (% kcal)	15.3±0.1	16.2±0.4	16.3±0.5	16.1±0.5	0.02	0.06	0.15
Fiber (g/1000 kcal)	8.2±0.1	7.4±0.5	7.4±0.7	7.4±0.7	0.13	0.27	0.27

T1D: type 1 diabetes.
Values are given as least square (LS) mean±SD from analysis of covariance, adjusted for sex (male versus female), age (< 22 years versus ≥ 22 years), and residence status (urban versus rural).
†*p* from pair-wise comparison of LS means from analysis of covariance. *p*> |t| for H_0: LS mean (type 1 diabetes) = LS mean (no diabetes).
‡*p* from pair-wise comparison of LS means from analysis of covariance. *p*> |t| for H_0: LS mean (basal-bolus or fixed insulin) = LS mean (no diabetes).

Table 3. Comparison of food group intake between participants without diabetes and those with type 1 diabetes, combined and stratified by insulin regimen

	No diabetes (n=1059)	T1D (n=97)	T1D		OR (95% CI)		
			Basal-bolus insulin (n=49)	Fixed insulin (n=48)	T1D vs no diabetes (ref)‡	Basal-bolus vs no diabetes (ref)‡	Fixed vs no diabetes (ref)‡
Rice							
≤Median† (ref)	50.1 (530)	56.7 (55)	55.1 (27)	58.3 (28)	0.74	0.81	0.68
>Median	50.0 (529)	43.3 (42)	44.9 (22)	41.7 (20)	(0.49, 1.13)	(0.45, 1.45)	(0.38, 1.23)
Wheat products							
≤Median† (ref)	50.1 (530)	38.1 (37)	44.9 (22)	31.3 (15)	1.66	1.39	2.03
>Median	50.0 (529)	61.9 (60)	55.1 (27)	68.8 (33)	(1.08, 2.56)	(0.78, 2.49)	(1.08, 3.81)
Low-fat cakes							
Non-consumer (ref)	87.0 (921)	68.0 (66)	65.3 (32)	70.8 (34)	3.19	3.25	3.12
Consumer	13.0 (138)	32.0 (31)	34.7 (17)	29.2 (14)	(1.99, 5.10)	(1.74, 6.06)	(1.62, 6.03)
High-fat cakes							
Non-consumer (ref)	90.9 (963)	81.4 (79)	81.6 (40)	81.3 (39)	2.25	1.91	2.73
Consumer	9.1 (96)	18.6 (18)	18.4 (9)	18.8 (9)	(1.28, 3.95)	(0.89, 4.09)	(1.25, 5.95)
Fried foods							
Non-consumer (ref)	69.3 (734)	76.3 (74)	81.6 (40)	70.8 (34)	0.68	0.48	0.93
Consumer	30.7 (325)	23.7 (23)	18.4 (9)	29.2 (14)	(0.42, 1.11)	(0.23, 1.00)	(0.49, 1.77)
Fast food							
Non-consumer (ref)	42.5 (450)	41.2 (40)	44.9 (22)	37.5 (18)	1.03	0.87	1.23
Consumer	57.5 (609)	58.8 (57)	55.1 (27)	62.5 (30)	(0.68, 1.58)	(0.49, 1.55)	(0.68, 2.25)
Vegetables							
≤Median† (ref)	50.1 (530)	11.3 (11)	8.2 (4)	14.6 (7)	8.33	11.45	6.53
>Median	50.0 (529)	88.7 (86)	91.8 (45)	85.4 (41)	(4.37, 15.86)	(4.06, 32.26)	(2.88, 14.78)
Fruit							
Non-consumer (ref)	26.0 (275)	32.0 (31)	18.4 (9)	45.8 (22)	0.70	1.20	0.47
Consumer	74.0 (784)	68.0 (66)	81.6 (40)	54.2 (26)	(0.44, 1.13)	(0.56, 2.57)	(0.26, 0.87)
Fungi & seaweed							
Non-consumer (ref)	65.3 (692)	41.2 (40)	34.7 (17)	47.9 (23)	2.69	3.47	2.10
Consumer	34.7 (367)	58.8 (57)	65.3 (32)	52.1 (25)	(1.76, 4.12)	(1.89, 6.36)	(1.17, 3.77)
Nuts & seeds							
Non-consumer (ref)	66.3 (702)	56.7 (55)	57.1 (28)	56.3 (27)	1.49	1.31	1.71
Consumer	33.7 (357)	43.3 (42)	42.9 (21)	43.8 (21)	(0.97, 2.29)	(0.73, 2.36)	(0.94, 3.11)

T1D: type 1 diabetes; ref: referent.
Values are given as percentage (n) or OR (95% CI).
†Median defined according to distribution in g/1000 kcal among participants without diabetes.
‡OR (95% CI) from multivariable logistic regression, adjusted for sex (male versus female), age (< 22 years versus ≥ 22 years), and residence status (urban versus rural).

Table 3. Comparison of food group intake between participants without diabetes and those with type 1 diabetes, combined and stratified by insulin regimen (cont.)

	No diabetes (n=1059)	T1D (n=97)	T1D		OR (95% CI)		
			Basal-bolus insulin (n=49)	Fixed insulin (n=48)	T1D vs no diabetes (ref)‡	Basal-bolus vs no diabetes (ref)‡	Fixed vs no diabetes (ref)‡
Beans & bean products							
Non-consumer (ref)	25.4 (269)	19.6 (19)	14.3 (7)	25.0 (12)	1.40	2.10	1.00
Consumer	74.6 (790)	80.4 (78)	85.7 (42)	75.0 (36)	(0.83, 2.36)	(0.93, 4.74)	(0.51, 1.96)
Red meat							
≤Median† (ref)	50.0 (529)	42.3 (41)	42.9 (21)	41.7 (20)	1.32	1.24	1.40
>Median	50.1 (530)	57.7 (56)	57.1 (28)	58.3 (28)	(0.86, 2.02)	(0.69, 2.23)	(0.77, 2.54)
Poultry							
Non-consumer (ref)	64.4 (682)	69.1 (67)	65.3 (32)	72.9 (35)	0.72	0.79	0.65
Consumer	35.6 (377)	30.9 (30)	34.7 (17)	27.1 (13)	(0.46, 1.14)	(0.43, 1.46)	(0.34, 1.26)
Fish & shellfish							
Non-consumer (ref)	59.1 (626)	48.5 (47)	40.8 (20)	56.3 (27)	1.52	1.95	1.18
Consumer	40.9 (433)	51.6 (50)	59.2 (29)	43.8 (21)	(1.00, 2.32)	(1.08, 3.52)	(0.65, 2.13)
Eggs							
≤Median† (ref)	50.1 (530)	39.2 (38)	34.7 (17)	43.8 (21)	1.55	1.76	1.38
>Median	50.0 (529)	60.8 (59)	65.3 (32)	56.3 (27)	(1.01, 2.38)	(0.96, 3.21)	(0.77, 2.48)
Milk & milk products							
Non-consumer (ref)	34.0 (360)	17.5 (17)	14.3 (7)	20.8 (10)	2.39	2.19	2.57
Consumer	66.0 (699)	82.5 (80)	85.7 (42)	79.2 (38)	(1.35, 4.25)	(0.95, 5.05)	(1.19, 5.53)
Sugar-sweetened beverages							
Non-consumer (ref)	89.9 (952)	90.7 (88)	85.7 (42)	95.8 (46)	0.85	1.24	0.40
Consumer	10.1 (107)	9.3 (9)	14.3 (7)	4.2 (2)	(0.41, 1.74)	(0.54, 2.87)	(0.10, 1.70)

T1D: type 1 diabetes; ref: referent.
Values are given as percentage (n) or OR (95% CI).
†Median defined according to distribution in g/1000 kcal among participants without diabetes.
‡OR (95% CI) from multivariable logistic regression, adjusted for sex (male versus female), age (< 22 years versus ≥ 22 years), and residence status (urban versus rural).

result may partially stem from the fact that our sample, relative to the aforementioned samples, was older and had longer disease durations. More research is needed to identify the underlying factors contributing to the observed dietary modifications of individuals with T1D in China.

The mean fiber intakes of participants with T1D and those without diabetes were well below the recommended level of 14 g/1000 kcal.[5] While there was no statistically significant difference between these means after adjustment for confounders, the fiber intake of participants with T1D was, on average, approximately 0.8 g/1000 kcal lower than that of participants without diabetes. Given that fiber intake is inversely associated with all-cause mortality and cardiovascular disease risk among individuals with diabetes,[32,33] identifying strategies for improving dietary fiber intake should be an important goal of future research.

Individuals with T1D in both insulin regimen groups had higher intakes of vegetables, fungi/seaweed, and low-fat cakes compared to individuals without diabetes. The observation that they were more likely to consume fungi/seaweed may be the result of recommendations during diabetes education courses to eat more sugar-free foods, of which fungi are used as an example. The increased intake of low-fat cakes, which includes biscuits/crackers, likely reflects the common use of these food items to treat hypoglycemia in China.

We observed that individuals with T1D on fixed insulin regimens were increasing their wheat product intake relative to individuals without diabetes. They also restricted their rice intake relative to individuals without diabetes, though it was not statistically significant. These observations may reflect the fact that physicians in China, when discussing the effects of carbohydrates on blood glucose, often use rice as an example. In the absence of additional nutrition education, we hypothesize that patients may subsequently equate rice with high blood glucose and replace rice with wheat products for their staple food. Similarly, we observed that individuals with T1D on fixed insulin regimens were more likely to consume high-fat cakes compared to individuals without diabetes, perhaps because sugar-free cakes tend to be higher in fat and patients focus on low-sugar, low-carbohydrate foods rather than the totality of nutritional information. Finally, individuals with T1D on fixed insulin regimens (but not those on basal-bolus insulin regimens) restricted fruit intake, a phenomenon also reported in the United States,[34] and again, likely the result of a carbohydrate focus rather than a healthy diet focus. Overall, the lack of physician time and dietitian involvement in T1D care in China may be contributing to patient misconceptions relating to nutrition. In-depth, qualitative research into this phenomenon may prove to be informative for future nutrition interventions in this population.

Participants with T1D on basal-bolus insulin regimens had a generally healthier diet than the other groups, consuming fewer fried foods and more fish/shellfish. They also had higher intakes of beans and eggs relative to individuals without diabetes, though these differences were not statistically significant. These observations are consistent with the higher protein intake found in this group. Together, these results suggest that individuals with T1D in China who are on basal-bolus insulin regimens may be more motivated and/or have higher adherence to self-management relating to nutrition.

Participants with T1D in both insulin regimen groups had significantly lower energy intake compared to participants without diabetes. They were also more likely to be underweight and less likely to be overweight compared to individuals without diabetes. This observation is consistent with a study conducted in Guangdong in southern China, which reported underweight and overweight prevalences of 19.6% and 11.8%, respectively, among individuals with T1D.[35] Several factors may be underlying these results including the fact that most participants with T1D in 3CNAS reported a rigid diet with respect to timing and amount of food, including those on basal-bolus insulin regimens,[15] and this may prevent overeating and weight gain. Furthermore, the diabetes duration in this sample was relatively long and though 3C Study participants with self-reported advanced micro- and macrovascular complications were not eligible for 3CNAS, it is possible that the natural progression of T1D and undiagnosed complications contributed to the relatively high prevalence of underweight.

This study focused on individuals with T1D in a large urban area in northern China. Therefore, results may not be generalizable to more rural areas or southern China where the diet differs substantially from the north. Additional challenges of this study were differences in dietary assessment methods between 3CNAS and CHNS. While interviewers from both studies were trained by staff from the China Center for Disease Control and Prevention, and the 24-hour recall questionnaire and food composition tables were the same between studies, we cannot rule out that some of the differences observed between individuals with and without diabetes were the result of slight differences in dietary assessment methods rather than true differences between these populations. Related to this, dietary intake was self-reported and therefore subject to differential misclassification as individuals with T1D may be more accustomed to reporting dietary intake. Finally, participants with T1D on basal-bolus insulin regimens were more urban and therefore may have more modern lifestyles than the other two groups. Although we controlled for residence status in the analysis, we cannot rule out residual confounding by unmeasured correlates of a more urbanized, modern lifestyle.

The substantial differences in macronutrient content, particularly carbohydrates, and food groups between individuals with T1D in China and those without diabetes suggest that dietary modifications are common and reflect carbohydrate-conscious nutrition recommendations for individuals with T1D. Future research should focus on the effects of these modifications on quality of life and health outcomes.

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AUTHOR DISCLOSURES

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REFERENCES

1. Leeds AR. The dietary management of diabetes in adults. Proc Nutr Soc. 1979;38:365-71. doi: 10.1079/PNS19790061.
2. Joslin E. The diabetic diet. J Am Diet Assoc. 1927;3:89-92.
3. Caso EK. Calculation of diabetic diets. J Am Diet Assoc. 1950;26:575-83.
4. Franz MJ, Horton ES S, Bantle JP, Beebe CA, Brunzell JD, Coulston AM, Henry RR, Hoogwerf BJ, Stacpoole PW. Nutrition principles for the management of diabetes and related complications. Diabetes Care. 1994;17:490-518. doi: 10.2337/diacare.17.5.490.
5. Evert AB, Boucher JL, Cypress M, Dunbar SA, Franz MJ, Mayer-Davis EJ et al. Nutrition therapy recommendations for the management of adults with diabetes. Diabetes Care. 2013;36:3821-42. doi: 10.2337/dc13-2042.
6. Popkin B. Nutritional patterns and transitions. Popul Dev Rev. 1993;19:138-57.
7. Popkin BM. The nutrition transition in low-income countries: an emerging crisis. Nutr Rev. 1994;52:285-98. doi: 10.1111/j.1753-4887.1994.tb01460.x.
8. Zhao Z, Sun C, Wang C, Li P, Wang W, Ye J et al. Rapidly rising incidence of childhood type 1 diabetes in Chinese population: epidemiology in Shanghai during 1997-2011. Acta Diabetol. 2014;51:947-53. doi: 10.1007/s00592-014-0590-2.
9. Popkin BM, Keyou G, Zhai F, Guo X, Ma H, Zohoori N. The nutrition transition in China: a cross-sectional analysis. Eur J Clin Nutr. 1993;47:333-46.
10. Popkin BM, Lu B, Zhai F. Understanding the nutrition transition: measuring rapid dietary changes in transitional countries. Public Health Nutr. 2002;5:947-53. doi: 10.1079/PHN2002370.
11. Du S, Lu B, Zhai F, Popkin BM. A new stage of the nutrition transition in China. Public Health Nutr. 2002;5:169-74. doi: 10.1079/PHN2001290.
12. Zhai F, Wang H, Du S, He Y, Wang Z, Ge K, Popkin BM. Prospective study on nutrition transition in China. Nutr Rev. 2009;67:S56-61. doi: 10.1111/j.1753-4887.2009.00160.x.
13. McGuire H, Kissimova-Skarbek K, Whiting D, Ji L. The 3C Study: coverage cost and care of type 1 diabetes in China—study design and implementation. Diabetes Res Clin Pract. 2011;94:307-10. doi: 10.1016/j.diabres.2011.10.016.
14. Popkin BM, Du S, Zhai F, Zhang B. Cohort Profile: the China Health and Nutrition Survey—monitoring and understanding socio-economic and health change in China, 1989-2011. Int J Epidemiol. 2010;39:1435-40. doi: 10.1093/ije/dyp322.
15. Jaacks LM, Liu W, Ji L, Mendez M, Du S, Crandell J, Rosamond W, Mayer-Davis EJ. Diabetes nutrition therapy and dietary intake among individuals with type 1 diabetes in China. Diabet Med. 2015;32:399-406. doi: 10.1111/dme.12634.
16. Institute of Nutrition and Food Hygiene, ed. Chinese Food Composition Tables, Book 1, 2nd Edition. Beijing: People's Medical Publishing House; 2009.
17. Institute of Nutrition and Food Hygiene, ed. Chinese Food Composition Tables, Book 2, 1st Edition. Beijing: People's Medical Publishing House; 2004.
18. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. Am J Clin Nutr. 1997;65:S1220-8.
19. World Health Organization and Food and Agriculture Organization. Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation, Geneva, 28 January-1 February 2002. World Health Organ Tech Rep Ser. 2003;916:1-149.
20. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320:1240-3. doi: 10.1136/bmj.320.7244.1240.
21. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ. 2007;335:194-201. doi: 10.1136/bmj.39238.399444.55.
22. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. Epidemiology. 1999;10:37-48. doi: 10.1097/00001648-199901000-00008.
23. Howards PP, Schisterman EF, Poole C, Kaufman JS, Weinberg CR. "Toward a clearer definition of confounding" revisited with directed acyclic graphs. Am J Epidemiol. 2012;176:506-11. doi: 10.1093/aje/kws127.
24. Weinberg CR. Toward a clearer definition of confounding. Am J Epidemiol. 1993;137:1-8.
25. Smart CC. Nutritional management in children and adolescents with diabetes. Pediatr Diabetes. 2009;10:100-17. doi: 10.1111/j.1399-5448.2009.00572.x.
26. Snell-Bergeon JK, Chartier-Logan C, Maahs DM, Ogden LG, Hokanson JE, Kinney GL, Eckel RH, Ehrlich J, Rewers M. Adults with type 1 diabetes eat a high-fat atherogenic diet that is associated with coronary artery calcium. Diabetologia. 2009;52:801-9. doi: 10.1007/s00125-009-1280-4.
27. Overby NC, Flaaten V, Veierod MB, Bergstad I, Margeirsdottir HD, Dahl-Jorgensen K, Andersen LF. Children and adolescents with type 1 diabetes eat a more atherosclerosis-prone diet than healthy control subjects. Diabetologia. 2007;50:307-16. doi: 10.1007/s00125-006-0540-9.
28. Lodefalk M, Aman J. Food habits, energy and nutrient intake in adolescents with type 1 diabetes mellitus. Diabet Med. 2006;23:1225-32. doi: 10.1111/j.1464-5491.2006.01971.x.
29. Tahbaz F, Kreis I, Calvert D. An audit of diabetes control, dietary management and quality of life in adults with type 1 diabetes mellitus, and a comparison with nondiabetic subjects. J Hum Nutr Diet. 2006;19:3-11. doi: 10.1111/j.1365-277X.2006.00668.x.
30. Pietiläinen KH, Virtanen SM, Rissanen A, Rita H, Mäenpää J. Diet, obesity, and metabolic control in girls with insulin dependent diabetes mellitus. Arch Dis Child. 1995;73:398-402. doi: 10.1136/adc.73.5.398.
31. Schober E, Langergraber B, Rupprecht G, Rami B. Dietary intake of Austrian diabetic children 10 to 14 years of age. J Pediatr Gastroenterol Nutr. 1999;29:144-7. doi: 10.1097/00005176-199908000-00009.
32. Slavin JL. Position of the American Dietetic Association:

health implications of dietary fiber. J Am Diet Assoc. 2008; 108:1716-31. doi: 10.1016/j.jada.2008.08.007.
33. Wheeler ML, Dunbar SA, Jaacks LM, Karmally W, Mayer-Davis EJ, Wylie-Rosett J, Yancy WS Jr. Macronutrients, food groups, and eating patterns in the management of diabetes: a systematic review of the literature, 2010. Diabetes Care. 2012;35:434-45. doi: 10.2337/dc11-2216.
34. Mehta SN, Haynie DL, Higgins LA, Bucey NN, Rovner AJ, Volkening LK, Nansel TR, Laffel LM. Emphasis on carbohydrates may negatively influence dietary patterns in youth with type 1 diabetes. Diabetes Care. 2009;32:2174-6. doi: 10.2337/dc09-1302.
35. Li J, Yang D, Yan J, Huang B, Zhang Y, Weng J. Secondary Diabetic ketoacidosis and severe hypoglycaemia in patients with established type 1 diabetes mellitus in China: a multicentre registration study. Diabetes Metab Res Rev. 2014;30:497-504. doi: 10.1002/dmrr.2547.

Original Article

Comparison of the dietary intakes of individuals with and without type 1 diabetes in China

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中国 1 型糖尿病患者与正常人群的膳食摄入比较研究

背景与目的：比较中国 1 型糖尿病患者与正常人群的膳食摄入之间的差异。**方法与研究设计**：数据来源于 3C 营养辅助研究（中国 1 型糖尿病横断面研究）及中国健康与营养调查，两项研究均的膳食摄入量是采用 3 天 24 小时回顾法评估的。本研究经调整年龄、性别及城乡差异，应用协方差分析和多因素 Logistic 回归分析比较 1 型糖尿病患者（n=97）及正常人群（n=1059）营养素和食物组分摄入之间的差异，并对 1 型糖尿病患者根据胰岛素治疗方式进行分层分析（基础餐食方案，n=49；固定剂量方案，n=48）。**结果**：与正常人群相比，1 型糖尿病患者能量摄入中碳水化合物占的比例较低，蔬菜类较高，更倾向于摄入低脂点心、木耳、海带类食物（$p<0.05$）。不同胰岛素治疗组之间亦存在差异。与正常人群相比，使用固定剂量胰岛素方案的 1 型糖尿病患者摄入小麦制品、高脂点心及奶制品较多，而水果类较少（$p<0.05$），使用基础餐食胰岛素方案的 1 型糖尿病患者摄入油炸食品较少而鱼类及海鲜类食品较多（$p<0.05$）。**结论**：中国 1 型糖尿病患者与正常人群之间膳食摄入的差异提示 1 型糖尿病患者膳食调整比较常见，更关注碳水化合物摄入的饮食指导建议。未来需要进一步研究这种膳食调整对健康的影响。

关键词：人类营养、碳水化合物、流行病学、1 型糖尿病、中国