Soy product consumption and type 2 diabetes among adults in Beijing, China

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ABSTRACT

Background and Objectives: To examine the association between the frequency of soy products consumption and type 2 diabetes or impaired fasting glucose. **Methods and Study Design:** A cross-sectional study of 3,314 subjects aged 18-79 years was conducted in Beijing, China in 2016. Consumption of soy products was assessed by a validated food-frequency questionnaire and examined with type 2 diabetes or impaired fasting glucose risk using multiple logistic regression. **Results:** 509 of the 3,314 participants (15.4%) included in the current analyses had diabetes, and among them 453 were diabetes uncontrolled. The prevalence of impaired fasting glucose was 11.9%. After adjustment for demographic variables, smoke, alcohol, physical activity and BMI, soy products consumption was inversely associated with type 2 diabetes risk and impaired fasting glucose. ORs and 95% CI for diabetes uncontrolled across soy products consumption frequencies (monthly, weekly, daily) were 1 (reference), 0.819 (0.627-1.070), 0.605 (0.387, 0.944) respectively (p_{trend}=0.033). ORs (95% CI) for impaired fasting glucose across soy products consumption frequencies were 1 (reference), 0.873 (0.661-1.152), 0.616 (0.385, 0.985) respectively (p_{trend}=0.046). **Conclusions:** Consuming soy products daily may decrease the risk of diabetes and impaired fasting glucose.

Key Words: soy products, type 2 diabetes, impaired fasting glucose, cross-sectional study, Chinese

INTRODUCTION

Type 2 diabetes has become a major public health issue. In 2015, the global number of diabetic case was estimated to be 415 million, 60% occurring in Asia.[1] The number of diabetic cases increase year by year in China, and the prevalence of diabetes increased by 5 times from 1979 to 1996. The prevalence of diabetes among Chinese residents aged 18 and over reached 9.7% in 2012.[2] Therefore, it is important to study the knowledge of risk factors and protective factors associated with type 2 diabetes in order to prevent it.

Healthy diet is known to be a modifiable protective factor for type 2 diabetes.[3] Soy products, a low-energy, nutrient-dense and low glycemic index food, have shown beneficial effects on glycemic control and adiposity.[4] However, the association between soy products consumption and type 2 diabetes is not well documented, and the results are inconsistent. Some epidemiologic studies showed inverse association between soy products and diabetes.[5-8] However, some studies didn't find that there is an association between soy consumption and type 2 diabetes.[9-11] Reasons for the different results were not found out. In China, one study indicated the inverse association between soy products and diabetes in Shanghai adults.[8]

In this paper, we aimed to assess whether the frequency of soy products consumption is associated with the risk of diabetes among Beijing adults.

MATERIALS AND METHODS

Ethical consideration

The survey received ethical approval from Peking University Biomedical Ethics Committee and the approval number was IRB00001052. Prior informed consent was obtained from each respondent. The analysis presented in the survey was based on secondary analysis of existing survey data with all identifying information removed.

Study population

Data used were from the 2016 survey of chronic diseases and risk factors in Mentougou District of Beijing adult population aged 18-79 years. The subjects were the residents who have lived in Mentougou for 6 months or more in the past year, and 3314 participants were included in this analysis. This cross-sectional survey used a stratified multistage probability proportional to size sampling design. The first stage involved a random selection of administrative villages or neighborhood committees. The second stage involved a random selection of natural villages or residents groups of each administrative villages or neighborhood committees. In the third stage, the stratified random sampling method was used to determine the subjects in the family. Not less than 100 households were investigated in each natural village or residents groups. Each household was randomly selected to investigate.

Data collection

Questionnaire interview. Data collection was performed in physical examination centers at local health stations or community clinics in the participants' residential area. A standardized questionnaire was administered by trained research staffs to obtain information on demographic, diets and other covariates. The questionnaire was used to collect information on demographic factors such as gender, age and education level, smoking, and alcohol consumption. The status of physical activity was assessed by IPAQ including the leisure-time physical activity.

Dietary consumption was assessed through an in-person interview with the use of a validated food-frequency questionnaire (FFQ). During the interview, the respondents were shown accompanying photographs that listed four food-frequency categories (including "never", "monthly", "weekly", "daily"), times and quantities each time. The survey asked several questions relating to the current health status of the respondents, including the question, "Have you ever been diagnosed with diabetes in community or hospitals (except gestational diabetes)?" which aimed to ensure whether the respondents had the history of diabetes.

Laboratory and anthropometric measurement. Standing height and weight were measured by research staffs. Height was measured without shoes and hat in an upright position with a vertical height gauge to the nearest 0.1 cm. Weight was measured using an electronic scale to the nearest 0.1 kg after removal of shoes, hat, heavier clothing and pocket contents. BMI (kg/m^2) was calculated as weight in kilograms divided by height in meters squared. According to the Chinese BMI classifications, we divided the subjects into two groups ($<24 kg/m^2$, $\geq 24 kg/m^2$). The laboratory test were performed to obtain fasting plasma glucose. According the results of laboratory test, the participants were divided into different groups.

Definitions and groups

The diagnostic criteria for diabetes mellitus in Chinese Diabetes Prevention and Treatment Guideline (2013): fasting plasma glucose (FPG) ≥7.0 mmol/L (diabetes), 6. 1mmol/L≤FPG<7.0 mmol/L (impaired fasting glucose, IFG), FPG <6.1 mmol/L (normal).[12] According to fasting plasma glucose obtaining from the laboratory tests and the subjects self-reported whether they had the history of diabetes, the survey subjects were divided into 4 groups (Figure 1): diabetes uncontrolled, diabetes controlled, IFG and normal. The group of diabetes uncontrolled indicates that FPGs was equal or greater than 7.0 mmol/L this time. The group of IFG means that FPG was between 6.1 mmol/L and 6.9 mmol/L this time. The group of diabetes controlled means that the subjects self-reported that they had the history of diabetes but their fasting plasma glucose were less than 6.1 mmol/L this time. Some subjects, whose fasting plasma glucose was less than 6.1 mmol/L this time, didn't have the history of diabetes and they were classified to the group of normal.

Statistical analysis

Epi data 3.0 software was used for data entry and verification and SPSS 23.0 software was used for data analysis. Two-tailed $p<0.05$ was considered to be statistically significant. χ^2 test was used to compare the differences between the frequency of soy products consumption in different gender, age groups, education levels and other confounders. Multiple logistic regression models were used to estimate the odds ratios (ORs) of different frequencies of soy products consumption on the risk of diabetes and IFG, including unadjusted model and another 3 models. The dependent variable was the groups of diabetes status: diabetes uncontrolled, diabetes controlled, impaired fasting glucose and normal (reference).The independent variable was the frequency of soy products consumption. Unadjusted model only present the unadjusted association between the frequency and diabetes or IFG. Model 1 presents results adjusted for gender, age and education levels. Model 2 adjusted smoking, alcohol consumption and leisure-time physical activity on the basis of Model 1. Model 3 adjusted cereal and tuber and vegetables on the basis of Model 2. Chinese dietary guideline gave the standard amount of each kinds of food. The recommended amount of cereal and tuber consumption is between 250 and 400 g daily and of vegetables consumption is between 300 and 500 g. According this guideline, the participants were divided into three groups (below, normal, above). The amounts of soy products consumption were considered in this analysis. Tests for trends were performed by using median consumption value for each frequency of soy products consumption and modeling them as continuous variables.

RESULTS

A total of 3314 subjects were studied, including 1,426 men (43.0%) and 1,888 women (57.0%). The average age was 49.4±14.0. There are 1,490 (45.0%) under 50 years old and 1,824 (55.0%) equal to and greater than 50 years old.

Soy products consumption

3,314 subjects all ingest soy products at different frequencies. The monthly, weekly, and daily consumption were 628 (18.9%), 2379 (71.8%), and 307 (9.3%) respectively. Most of the people ingest soy products weekly. For each frequency of soy products intake (monthly, weekly, daily), the median amounts of soy products were 6.67, 28.57, 100.00 g/day. Baseline characteristics are shown in Table 1. Participants consuming more frequently were more likely to be women, young people, secondary educated and non-smokers. They also had an engage in some level of leisure-time physical activity. Soy products consumption was positively associated with cereal and tuber and vegetable.

The prevalence of diabetes

During the survey, 509 participants had type 2 diabetes (15.4%). Among them, 453 (13.7%) people were diabetes uncontrolled and 56 (1.7%) people were diabetes controlled. Because the number of diabetes controlled is small and they may have changed actions, especially lifestyles, to reduce the level of blood sugar, we didn't study this group of people. The prevalence rate of IFG was 11.9%.

The sample distribution was shown in Table 2. Participants who had IFG or diabetes were more likely to be men, old people, no formal education or elementary school, current smoker, infrequent alcohol consumption, high BMI index (p<0.01). Participants who had IFG were likely to have a small amount of vegetables but who had diabetes would rather have more vegetables (p=0.033).

Association between soy products consumption and diabetes, IFG

The prevalence rate of diabetes uncontrolled for monthly, weekly, daily was 15.9%, 13.7% and 10.7%. Multiple logistic regression was used to analyze the association between soy products consumption and diabetes and the results were shown in Table 2. The frequency of soy products consumption was used as an independent variable and the reference is monthly. Unadjusted odds of suffering from diabetes are 35.2% (OR: 0.648; 95% CI: 0.423-0.993) and 10.4% (OR: 0.896; 95% CI: 0.696-1.152) lower among those who consumed soy products daily or weekly respectively compared to those who consumed monthly (p_{trend}=0.046). After controlling for demographic variables including gender, age, and education level in Model 1, the risks of diabetes when they consumed soy products daily and weekly are also lower than the risk when they consumed soy products monthly (p_{trend}=0.024). On the basis of Model 1, Model 2 adjusted for smoking, alcohol consumption, physical activity, and BMI. The frequency of soy products consumption is associated with risk of diabetes (p_{trend}=0.033) and daily soy products consumption (OR: 0.605, 95% CI: 0.38-0,944) was associated with the significantly reduced prevalence of diabetes among adults. Considering cereal, tuber and vegetable, on the basis of Model 2, Model 3 adjusted these confounders. ORs and 95% CI for diabetes uncontrolled across soy products consumption frequencies (monthly, weekly, daily) were 1 (reference), 0.857 (0.652-1.126), 0.609 (0.385, 0.963) respectively (p_{trend}=0.037).

The prevalence rate of impaired fasting glucose for monthly, weekly, daily was 12.7%, 12.1% and 9.1%. Unadjusted odds of suffering from impaired fasting glucose are 35.4% (OR: 0.646; 95%CI: 0.711-1.216) and 7.0% (OR: 0.930; 95% CI: 0.409-1.022) lower among those who consumed soy products daily or weekly respectively compared to those who consumed monthly (p_{trend}=0.057). Daily (OR:0.598, 95% CI: 0.375-0.953, Model 1) (OR: 0.616, 95%CI: 0.385-0.985, Model 2) soy products consumption were associated with the significantly reduced prevalence of IFG among men in both Model 1 and Model 2.The trend of the risk is statistically significant both in Model 1 and Model 2. (p_{trend}=0.034, p_{trend}=0.046). However, non-significant association were observed in Model 3. ORs (95% CI) for impaired fasting glucose risk across soy products consumption frequencies (monthly, weekly, daily) were 1 (reference), 0.856 (0.646-1.134), 0.627 (0.388, 1.011) respectively (p_{trend}=0.061).

DISCUSSION

Soy products consumption is ubiquitous in Chinese diets and all of the study population reported consuming some soy products either daily, weekly or monthly. We found that daily soy products consumption were associated with a significantly reduced prevalence of type 2 diabetes among adults. There is a significant trend between soy products consumption and the risk of diabetes. The higher the frequency of soy products consumption, the lower the risk of diabetes. Therefore, consuming soy products daily is the protective factor for diabetes. Soy products consumption daily may also decrease the risk of impaired fasting glucose. For the subjects who were used to have diabetes but this time had a normal fasting glucose, we think they may have change their lifestyle, especially diets, and the number of this group is small, so we exclude them.

To date there has been some observational studies focusing on the link between soy products and diabetes. Several animal studies have shown that soy-based diet could increase insulin sensitivity and lower insulin requirement.[13-15] Besides, clinical trials have been conducted to examine the effects of soy foods on glucose homeostasis, and the results have suggested that soy food and soy-rich diets may lower blood glucose.[16-19] Some epidemiologic studies showed inverse association between soy products and diabetes. In the Singapore Chinese health study, it was documented that consumption of unsweetened soy products but not sugar-sweetened soy foods, were associated with a lower type 2 diabetes.[7] The result of Shanghai Women's Health Study revealed the consumption of total soy products including soybeans was associated with a reduced risk of type 2 diabetes incidence.[8]

Soy products has the ability to improve glucose tolerance and insulin homeostasis.[20-22] Soy products, rich in plant protein, dietary fiber, vitamins, polyunsaturated fatty acids and phytoestrogens, is already widely consumed in many Asian countries.[20] Plant proteins seem to be higher in l-arginine, which could improve insulin sensitivity in individuals with type 2 diabetes.[22] Soy products also contain significant amounts of calcium, potassium and magnesium, minerals which consumption has been inversely related to type 2 diabetes risk.[23-26] It was also said that the reduction in body iron stores may be another possible mechanism because the iron could damage the pancreatic b-cells.[27] Soy products contribute to reduced risk of mortality because of their benefits against major chronic diseases, cancer, obesity and gut health. In addition, soy products have enormous but largely untapped potential for sustainable agriculture, plant diversity and enhancement of primary production with reduced fertilizer use, however, soy products lag behind cereals in terms of area expansion and productivity gains because of the lack of inputs. Hence, the increased public perception for health and wellbeing advantages of a grain-legume-rich diet may be an important driver of culture change in considering soy products as a key to food security.[28]

In fact, some epidemiological studies are contrary to ours. No significant association between soy consumption and diabetes occurrence was showed in studies.[9-11] Reasons for the different results were not found out. We think the studies were conducted in different places where people have different constitutions and lifestyles. Although the studies including our study control other risk factors such as demographic variables, bias still existed in different studies. A validated FFQ was used to assess diet, measurement errors are inevitable. Responses from the participants would inevitably incur some recall error which might impact on the estimation of consumption. In order to reduce the prevalence-incidence bias, we divide diabetes into two groups, diabetes controlled and diabetes uncontrolled according the result of laboratory tests and self-report. In addition, the cross-sectional design precludes causal inferences and we were limited to the questions used to elicit lifestyles and dietary. The association between soy products consumption and diabetes should be checked with the amount of different kinds of soy products.

Conclusions

In this study, daily consumption of soy products decreased the risk of diabetes among adults. Daily soy products consumption were associated with the significantly reduced prevalence of type 2 diabetes uncontrolled and impaired fasting glucose. Further studies are needed to elucidate the frequency and amount of different kinds of soy products consumption and active compounds and fasting glucose levels.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflict of interest. The funding was supported by Mentougou District of Beijing Center for Disease Control and Prevention, Beijing, China.

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Table 1. Baseline characteristics according to the frequency of soy products intake (%)

Characteristics	Monthly (N=628)	Weekly (N=2379)	Daily (N=307)	χ^2	p†
Gender				9.143	0.010
Men	21.3	69.7	9.0		
Women	17.2	73.4	9.5		
Age(years)				9.129	0.010
<50	21.1	69.4	9.5		
≥50	17.2	73.7	9.1		
Education				14.850	0.005
No formal education or elementary school	16.7	76.0	7.3		
Middle school or high school	17.7	72.7	9.6		
College and above	22.8	67.9	9.4		
Current smoker				13.313	0.001
yes	23.3	69.1	7.5		
no	17.7	72.5	9.7		
Alcohol consumption (d/wk)				4.704	0.095
<1	22.1	69.8	8.2		
≥1	18.3	72.2	9.5		
Leisure-time physical activity (d/wk)				7.733	0.021
<1	21.5	71.8	6.7		
≥1	18.4	71.8	9.8		
BMI(kg/m^2)				1.012	0.603
<24	18.1	72.6	9.3		
≥24	19.5	71.2	9.3		
Cereal and tuber(g/d)				10.576	0.032
<250	20.2	72.2	7.6		
250-400	19.0	72.7	8.3		
>400	18.7	69.9	11.5		
Vegetables(g/d)				18.770	0.001
<300	17.2	74.1	8.7		
300-500	19.0	72.1	8.8		
>500	23.7	62.8	13.5		

†*p*-value is the result of a simple Chi-square test for independence. Pearson test is used to examine whether association between the frequency of soy products intake and variables was statistically significant.

Table 2. Sample distribution and prevalence of impaired fasting glucose (IFG), diabetes uncontrolled (%)

Characteristics	IFG (N=396)	Diabetes uncontrolled (N=453)	χ^2	$p^{\dagger}$
Gender			13.738	0.003
Men	13.3	14.9		
Women	10.9	12.7		
Age(years)			277.298	＜0.001
<50	7.5	5.4		
≥50	15.6	20.4		
Education			163.283	＜0.001
No formal education or elementary school	15.1	22.7		
Middle school or high school	14.0	15.9		
College and above	6.2	4.8		
Current smoker			16.525	0.001
yes	13.9	17.4		
no	11.4	12.6		
Alcohol consumption(d/wk)			34.736	＜0.001
<1	17.4	17.4		
≥1	10.8	12.9		
Leisure-time physical activity (d/wk)			7.067	0.070
<1	13.8	12.0		
≥1	11.5	14.1		
BMI(kg/m^2)			64.446	＜0.001
＜24	8.5	9.5		
≥24	14.0	16.1		
Cereal and tuber(g/d)			7.983	0.239
<250	11.5	11.5		
250-400	12.5	13.7		
>400	11.2	14.6		
Vegetables(g/d)			13.718	0.033
<300	13.6	14.0		
300-500	11.5	13.1		
>500	8.7	15.8		

$^{\dagger}p$-value is the result of a simple Chi-square test for independence. Pearson test is used to examine whether association between the frequency of soy products intake and variables was statistically significant

Table 3. ORs and 95% CI for association between soy products intake and diabetes uncontrolled risk, impaired fasting glucose risk

Soy products intake	Monthly (N=628)	Weekly (N=2379)	Daily (N=307)	p_{trend}[†]
Prevalence of diabetes uncontrolled, %	15.0	13.7	10.7	
Unadjusted model	1.00 (reference)	0.896 (0.696, 1.152)	0.648 (0.423, 0.993)	0.046
Adjusted model 1[‡]	1.00 (reference)	0.789 (0.606, 1.028)	0.584 (0.375, 0.909)	0.024
Adjusted model 2[§]	1.00 (reference)	0.819 (0.627, 1.070)	0.605 (0.387, 0.944)	0.033
Adjusted model 3[¶]	1.00 (reference)	0.857 (0.652, 1.126)	0.609 (0.385, 0.963)	0.037
Prevalence of IFG, %	12.7	12.1	9.1	
Unadjusted model	1.00 (reference)	0.930 (0.409, 1.022)	0.646 (0.711, 1.216)	0.057
Adjusted model 1[‡]	1.00 (reference)	0.851 (0.646, 1.121)	0.598 (0.375, 0.953)	0.034
Adjusted model 2[§]	1.00 (reference)	0.873 (0.661, 1.152)	0.616 (0.385, 0.985)	0.046
Adjusted model 3[¶]	1.00 (reference)	0.856 (0.646, 1.134)	0.627 (0.388, 1.011)	0.061

[†]Tests for trends were performed by using median intake value for each frequency of soy products intake and modeling them as continuous variables. For each frequency of soy products intake (monthly, weekly, daily), the median amounts of soy products were 6.67, 28.57, 100.00 g/day.

[‡]Model 1 adjusted gender (men, women), age (<50, ≥50) and education level (no formal education or elementary school, middle school or high school, college and above).

[§]Model 2 adjusted current smoker (yes, no), alcohol consumption (<1 day/week, ≥1 day/week), leisure-time physical activity (<1 day/week, ≥1 day/week) and BMI (<24 kg/m^2, ≥24 kg/m^2) on the basis of Model 1.

[¶]Model 3 adjusted cereal and tuber (<250 g/d, 250-400 g/d, >400g/d), vegetable (<300 g/d, 300-500 g/d, >500 g/d).

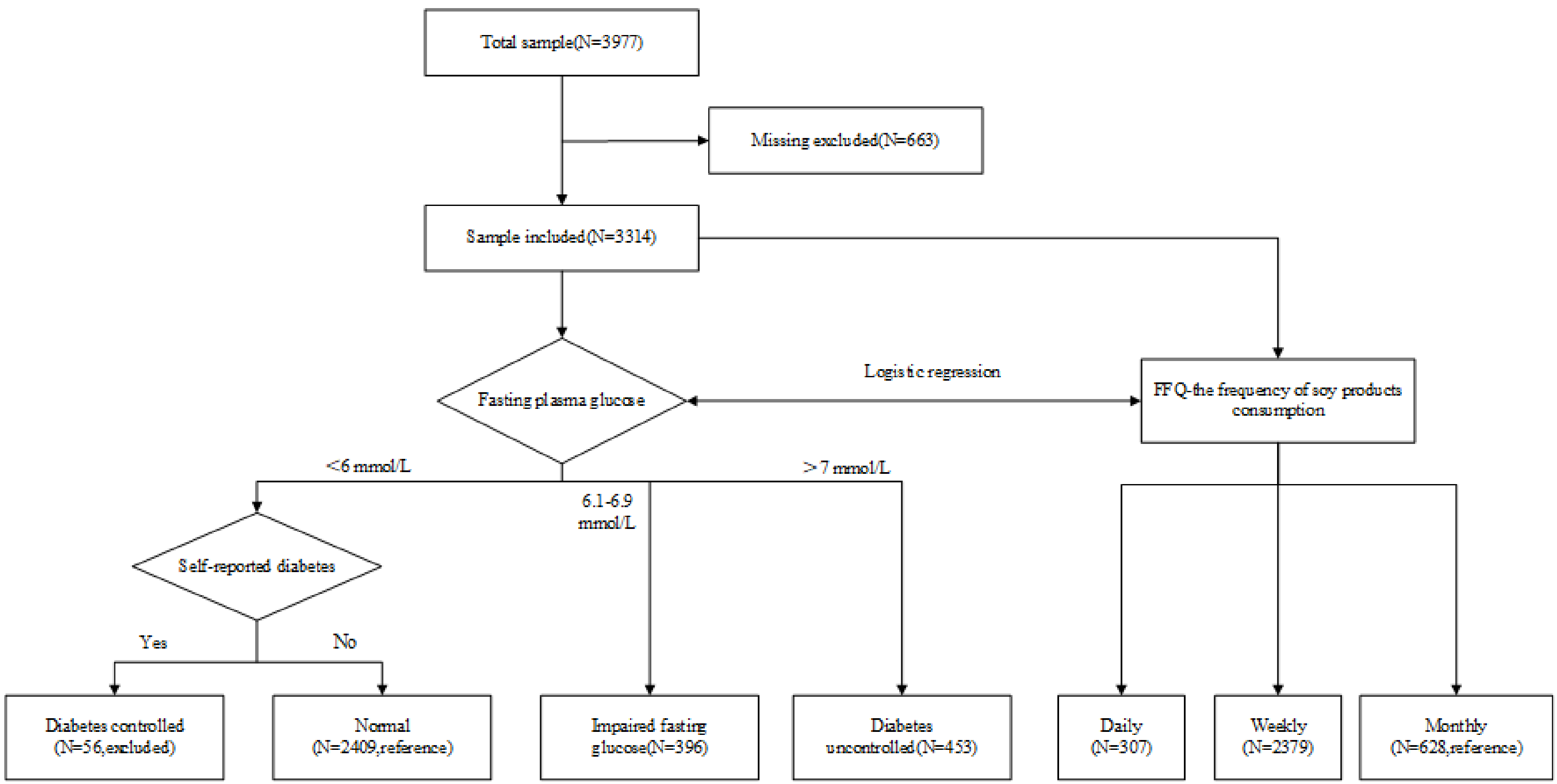

Figure 1. Diagram of grouping and analysis