Association between plant dietary fiber intake and hyperuricemia risk in Chinese children aged 6-17 years

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ABSTRACT

Background and Objectives: The increasing prevalence of hyperuricemia in children is a global health concern. Plant dietary fiber may influence uric acid levels by improving gut health and lowering blood glucose and lipid levels. This study aims to examine the relationship between plant-based dietary fiber intake and hyperuricemia risk in Chinese children aged 6-17 years. **Methods and Study Design:** This study analyzed dietary fiber intake data from 11,423 children (aged 6-17 years) from the China Children and Lactating Women Nutrition and Health Surveillance (CCLWNHS) conducted between 2016 and 2019. Plant dietary fiber intake was assessed using a food frequency questionnaire. Logistic regression was performed, adjusting for age, sex, body mass index (BMI), smoking, alcohol consumption, physical activity, and energy intake. Restricted cubic splines (RCS) and receiver operating characteristic (ROC) curves were utilized to explore nonlinear relationships and identify cut-off values for dietary fiber intake. **Results:** Among the 11,423 children, 1,730 (15.14%) were diagnosed with hyperuricemia. The average daily fiber intake was 8.28 ± 5.90g, with cereal fiber accounting for 56.10%-57.84%. A significant negative correlation was found between cereal dietary fiber intake and hyperuricemia risk ($p = 0.0004$). Stratified analysis indicated that overweight/obesity status modified this relationship. ROC curve analysis identified optimal intake cut-off values: 8.35 g/day for boys and 11.13 g/day for girls. **Conclusions:** Cereal fiber intake was inversely associated with hyperuricemia risk in children. The recommended intake is >8.35 g/day for boys and >11.13 g/day for girls. Increasing cereal fiber intake may be associated with a reduced risk of hyperuricemia in children.

Key Words: hyperuricemia, dietary fiber, cereals dietary fiber, children, consumption

INTRODUCTION

Hyperuricemia is a condition in which the concentration of uric acid in the serum is elevated. Long-term hyperuricemia is closely associated with the development of gout, metabolic syndrome, and cardiovascular disease.[1] In recent years, the incidence of hyperuricemia in children has increased and has become a global public health issue.[2] The estimated overall prevalence of hyperuricaemia was 23.3% in Chinese children.[3] The formation of hyperuricemia is affected by a variety of factors, among which dietary factors are particularly critical.[4] Although dietary fiber, as an important nutrient, has been widely studied in relation to metabolic diseases in adults, especially in terms of weight management, blood sugar, and blood lipid control,[5, 6] research on the relationship between dietary fiber and hyperuricemia, especially in children, is still relatively scarce.

Dietary fiber, especially dietary fiber from plant sources, has been shown to have a variety of health benefits, including improving intestinal health and lowering blood sugar and lipid levels.[7] Fiber from plant sources, particularly cereals, plays a crucial role in children's health by promoting healthy digestion, supporting gut microbiota balance, and influencing metabolic processes that are key to preventing conditions like hyperuricemia. Previous studies have shown that there may be a relationship between dietary fiber intake and uric acid metabolism, especially by affecting intestinal flora and kidney function to regulate uric acid levels.[8, 9] However, the role of dietary fiber in children, especially the relationship between plant dietary fiber and uric acid concentration, has not been fully supported by empirical evidence.

This study aims to explore the relationship between plant dietary fiber intake and the risk of hyperuricemia in children aged 6-17 years using cross-sectional data from the Chinese Children and Mothers Nutrition and Health Surveillance Program. This study is novel in focusing on the relationship between cereal fiber intake and hyperuricemia in children aged 6-17, a group not well explored in previous research. It provides new empirical evidence on the role of plant dietary fiber in uric acid metabolism in children. We hypothesized that a high intake of cereal dietary fiber may be associated with a lower risk of hyperuricemia. The core goal of this study is to fill the research gap on the relationship between dietary fiber and hyperuricemia in children, provide a scientific basis to help develop effective dietary intervention measures for children, and provide data support for the optimization of public health policies.

MATERIALS AND METHODS

Data source

CCLWNHS project collected between 2016 and 2019 to analyze the nutritional health status of children aged 6 to 17 years.[10] A multi-stage stratified cluster random sampling method was adopted in Shandong, Jiangsu, Hebei and Guizhou provinces of China. The final valid sample included in the analysis was 11,423 children, all of whom provided valid data and met the inclusion criteria. Inclusion criteria: Children included in this study were participants aged 6 to 17 years in the CCLWNHS project.[11] All participants participated voluntarily, and their parents or guardians signed informed consent. Exclusion criteria: The following children were excluded from the analysis: 1) suffering from serious chronic diseases (such as diabetes, kidney disease, etc.); 2) receiving medication that affects uric acid levels; 3) with serious missing data, especially missing key variables (such as dietary intake or uric acid levels). The detailed inclusion and exclusion process is shown in Figure 1.

The study adhered to the Declaration of Helsinki guidelines and received approval from the Ethics Committee of the National Institute of Nutrition and Health and the Chinese CDC (approval number: 201614). All participants provided written informed consent and voluntarily joined the study, fully understanding the consent form.

Variable definition

Dietary fiber intake: Dietary fiber intake was assessed using a dietary frequency questionnaire for the past 1 month.[12] During the survey, a reliable and validated food frequency questionnaire (FFQ) was used to collect participants' dietary data from the past month. Developed by experts from the NINH and the Chinese CDC, it is a standardized tool widely used in large-scale dietary studies of Chinese children. Participants or their guardians were asked to recall all food intake in the past 1 month, and the investigators calculated the children's plant dietary fiber intake (in grams per day) based on this information and a food composition table. Plant dietary fiber refers to non-digestible carbohydrates found in plant-based foods that aid in digestive health and metabolic regulation. In this study, the primary sources of plant dietary fiber were classified into cereals (such as rice, wheat, and oats), beans (including soybeans and lentils), vegetables, and fruits, all of which are rich in various types of fiber beneficial for children's health.

Hyperuricemia: The diagnostic criteria for hyperuricemia are serum uric acid concentrations ≥420 μmol/L (boys) or ≥360 μmol/L (girls) in children.[3,13] Blood sample collection: Venous blood samples (6 mL) were collected from all participating children in the fasting state, stored at -80℃ after serum separation, and transported to the central laboratory of the Chinese Center for Disease Control and Prevention via a cold chain for standardized quantitative analysis. Serum uric acid was determined using a standard enzymatic method (Cat#: 05185121160, Roche Diagnostics, Jinan, China) (CV ≤ 5.0%) .

Confounding factors: To control potential confounders, the following variables were considered: age, gender, BMI, passive smoking status, drinking alcohol status, outdoor physical activity time, energy intake, etc. All variables were measured by standardized methods and strict quality control measures were taken. Macronutrients were excluded from the final models due to multicollinearity with other dietary factors, which could distort results.

Socioeconomic factors were not included as their incomplete assessment limited their consideration as confounders.

Data collection

Dietary data collection: Dietary data were collected by trained nutrition interviewers using food frequency tables. Interviewers used standardized interview methods and auxiliary tools to ensure the accuracy and completeness of the data. Each participant received only one dietary recall survey. Other variables: weight and height were obtained using standardized measurement procedures, and BMI was calculated by dividing weight (kg) by height (m) squared.[14] Physical activity, passive smoking, and alcohol consumption were collected using self-report questionnaires. Missing data were handled using listwise deletion. Specifically, after the initial selection of 23,301 participants from the 2016-2019 CCLWNHS, participants who were unable to participate were replaced. After narrowing the sample to 13,087 children aged 5-20, 198 subjects aged 6-17 were excluded, along with 1,466 subjects with serious chronic diseases or significant missing data. Only the remaining 11,423 subjects with complete data were included in the final analysis, ensuring the accuracy and consistency of the results.

Statistical analysis

A descriptive statistical analysis was conducted on the sample's demographic characteristics, such as age and gender, using Sankey plots and histograms. Quantitative data were reported as mean±standard deviation, with independent sample t-tests for group comparisons. Percentages represented count data, analyzed with chi-square tests for correlations. Hyperuricemia served as a binary dependent variable, while dietary fiber intake was the independent variable. Logistic regression assessed the link between dietary fiber intake and hyperuricemia risk, adjusting for confounders like age, gender, BMI, passive smoking, alcohol consumption, physical activity, and energy intake. Initially, protein, carbohydrate, and fat intake were considered confounders, but multicollinearity was detected among these variables. Given that total energy intake can adequately represent the overall dietary intake level, we decided to retain only total energy intake as the adjustment factor. Stratified analysis and interaction analysis were used for sensitivity analysis. Restricted cubic splines (RCS) were used to depict the nonlinear relationship between dietary fiber intake and the risk of hyperuricemia.[15] The Youden index was calculated by ROC analysis to determine the optimal cut-off value of dietary fiber intake.16 All statistical analyses were performed using R software (version 4.3.1), and the significance level was set at $p < 0.05$.

RESULTS

Baseline characteristics

A total of 11,423 children aged 6-17 years (mean age 11.04 ± 3.15 years, mean BMI 18.81 ± 4.58 kg/m²) were included in the study , with 5,627 boys (49.26%) and 5,796 girls (50.74%). Of these children, 1,730 (15.14%) were diagnosed with hyperuricemia. The average daily intake of plant dietary fiber was 8.28±5.90 g. Among the participants, 1,145 (10.02%) were classified as overweight or obese.

The hyperuricemia group was significantly older and had a higher BMI than the non-hyperuricemia group ($p < 0.0001$). There was no significant difference in the gender distribution between the two groups ($p = 0.5499$). The rate of overweight and obesity was significantly higher in the hyperuricemia group compared to the non-hyperuricemia group. Additionally, the prevalence of passive smoking and alcohol consumption was higher in the hyperuricemia group ($p = 0.0004$, < 0.0001, respectively). Energy intake was also higher in the hyperuricemia group ($p = 0.0086$). Notably, total fiber intake, plant dietary fiber and vegetable fiber intake was higher in the hyperuricemia group than in the non-hyperuricemia group ($p < 0.05$). Detailed characteristics are summarized in Table 1, with sample distribution illustrated in Figure 2.

Association between plant fiber and hyperuricemia risk

Table 2 presents the odds ratios (OR) for the association between different types of plant fiber intake and the risk of hyperuricemia. After adjusting for potential confounders, including age, gender, BMI, passive smoking status, alcohol consumption, outdoor physical activity time, and energy intake, total dietary fiber and cereal fiber intake were significantly associated with a reduced risk of hyperuricemia ($p < 0.05$). Figure 2 shows the distribution of cereal fiber intake as a histogram, with the non-hyperuricemia group showing a rightward skew compared to the hyperuricemia group. Figure 3 shows the source of plant dietary fiber. Cereal fiber is the main source of plant dietary fiber in all age groups or gender groups, accounting for 56.10-57.84%. Associations are not only seen after adjustment. In Model 1 (unadjusted), some fiber types (e.g., total fiber, plant dietary fiber) showed significant associations with hyperuricemia. However, after adjustment for covariates in Model 2 and further adjustment in Model 3, the significance of associations changed—some persisted, some emerged, and some disappeared. This shows associations exist in unadjusted models but are refined/modified by covariate adjustment, highlighting the role of accounting for confounders in interpreting these relationships.

Stratified analysis of total and cereal fiber intake

Table 3 presents the stratified analysis of total dietary fiber and cereal fiber intake in relation to hyperuricemia risk. The relationship between total dietary fiber intake and hyperuricemia risk was significantly influenced by gender and overweight/obesity status (p for interaction < 0.05). Similarly, cereal fiber intake had a significant interaction with overweight/obesity status in its association with hyperuricemia risk (p for interaction < 0.05).

Figure 3 illustrates the dose-response relationship between cereal fiber intake and hyperuricemia risk using restricted cubic splines. A general downward trend in hyperuricemia risk was observed with increasing cereal fiber intake. In the female subgroup, a U-shaped relationship was noted, where moderate Cereal fiber intake was associated with the lowest hyperuricemia risk, but higher intake still appeared protective against hyperuricemia.

Cereal fiber intake cut-off values

Receiver operating characteristic (ROC) curve analysis identified the optimal cut-off values for cereal fiber intake to distinguish individuals at risk for hyperuricemia. For boys, the cut-off was 8.35 g/day, and for girls, it was 11.13 g/day . In this sample, 80.87% of boys (4,544 individuals) and 91.47% of girls (5,296 individuals) had cereal fiber intake below the respective cut-off values. (Figure 3).

DISCUSSION

Based on CCLWNHS data, this study explored the relationship between plant dietary fiber intake and the risk of hyperuricemia in children. Cereal fiber is the main source of plant dietary fiber in all age groups or gender groups, accounting for 56.10-57.84%. Cereal dietary fiber intake was negatively correlated with the risk of hyperuricemia, that is, with the increase in cereal dietary fiber intake, the risk of hyperuricemia in children decreased significantly. Further stratified analysis showed that the relationship between total dietary fiber and cereal intake and hyperuricemia was affected by whether they were overweight/obese. In addition, we obtained the critical value of cereal dietary fiber for preventing hyperuricemia through ROC curve analysis, which was 8.35g/day for boys and 11.13g/day for girls.

Studies have shown that dietary fiber has a certain impact on metabolic health, especially in weight management, blood sugar control and cardiovascular health.[17-19] Our study found that the negative correlation between cereal dietary fiber and the risk of hyperuricemia is consistent with the results of studies in some previous countries. These studies also showed that dietary fiber may reduce the risk of hyperuricemia by improving intestinal microecology, increasing uric acid excretion or reducing insulin resistance.[8, 9, 20, 21] However, similar studies on Chinese children are relatively scarce, especially those exploring the relationship between cereal dietary fiber intake and hyperuricemia. Our findings fill this research gap and suggest the potential role of dietary fiber in preventing hyperuricemia, which is of great significance, especially in Chinese children. The apparent contradiction between higher fiber intake in hyperuricemia cases (Table 1) and the protective association in adjusted models can be explained by two main factors: Table 1 does not adjust for confounders such as age, gender, BMI, and other lifestyle factors, whereas the adjusted models do. Additionally, reverse causality may be at play, where individuals with hyperuricemia may increase fiber intake in response to the condition, creating an association in Table 1 that disappears after adjustments.

Dietary fiber, especially cereal fiber, may reduce the risk of hyperuricemia through multiple mechanisms.[22] First, dietary fiber can indirectly promote the excretion of uric acid by improving the intestinal microecology and increasing the excretion function of the intestine.[23] Studies have shown that dietary fiber can improve the structure of the intestinal flora, increase the proportion of beneficial bacteria, and thus affect the production and excretion of metabolites.[24-26] In addition, dietary fiber intake helps improve insulin sensitivity and reduce the accumulation of body fat,[27-29] which may help reduce excessive uric acid caused by metabolic disorders. Our study also found that the relationship between cereal dietary fiber intake and the risk of hyperuricemia is affected by overweight and obesity, which may indicate that there are differences in the metabolic effects of dietary fiber on people with different weight states.[29,30]

The findings of this study have important implications for public health and clinical practice. With changes in lifestyle, overweight and obesity in children are becoming increasingly serious,[31-33] and the incidence of hyperuricemia is also increasing year by year.[34,35] Therefore, increasing dietary fiber intake, especially cereal fiber, may become an effective intervention strategy to reduce the risk of hyperuricemia in children.[36, 37] Based on our study, it is recommended that children increase their intake of cereal foods, especially high-fiber cereals, in their daily diet, which may have a positive effect on preventing hyperuricemia. Considering the moderating effects of gender and overweight/obesity on the relationship between dietary fiber and hyperuricemia, future studies can further explore the effects of different subgroups to develop more personalized dietary intervention strategies. At the same time, exploring the mechanism of action of dietary fiber in children of different ages, especially in terms of intestinal microorganisms and metabolic pathways, may provide a deeper theoretical basis for public health policies.

This study has limitations. It used a cross-sectional design, revealing a correlation between dietary fiber and hyperuricemia but not causation. While cereal fiber intake was negatively correlated with hyperuricemia, we can't conclude it reduces risk. Future longitudinal studies and intervention trials are needed to confirm this. Additionally, recall bias may affect the accuracy of self-reported dietary data, and unmeasured factors like genetics or lifestyle could influence the results. These limitations should be considered when interpreting the findings, as they may impact the conclusions.

Conclusion This study found that cereal fiber is the main source of plant dietary fiber. Cereal fiber intake is negatively correlated with the risk of hyperuricemia, especially in normal-weight children. This finding provides new perspectives on dietary intervention and the prevention of hyperuricemia, with certain public health significance, although the causal relationship requires further research validation.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflicts of interest.

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Table 1. Sample characteristics of participants with or without hyperuricemia

	Non-Hyperuricemia (n=9693)	Hyperuricemia (n=1730)	t/χ^2	*p*
Age (years)	10.72±3.10	12.83±2.81	14.17	<0.0001
Male, n(%)	4762(49.13)	865(50.00)	0.3575	0.5499
BMI(kg/m^2)	18.33±4.25	21.51±5.35	11.7	<0.0001
Overweight & obesity, n (%)	838(8.65)	307(17.75)	134.796	<0.0001
Passive smoking status (yes), n (%)	3843(39.65)	764(44.16)	12.4334	0.0004
Drinking alcohol status (yes), n (%)	816(8.42)	301(17.40)	134.1938	<0.0001
Outdoor physical activity time (h)	1.80±1.99	1.87±2.27	-0.23	0.816
Energy intake (kcal/day)	1894.79±806.26	2096±824.36	2.63	0.0086
Protein intake (g/day)	106.91±51.68	115.22	-6.157	<0.001
Fat intake (g/day)	36.65±25.97	40.54	-5.704	<0.001
Carbohydrate intake (g/day)	323.70±140.59	358.79	-9.517	<0.001
Total fiber (g/day)	10.77±8.26	11.34±8.56	-2.60	0.0094
Plant dietary fiber (g/day)	8.18±5.79	8.82±6.45	-4.10	<0.0001
Cereal fiber (g/day)	5.10±4.31	5.26±4.48	0.93	0.355
Legume fiber (g/day)	0.91±1.98	1.12±3.32	0.53	0.5959
Vegetable fiber (g/day)	2.14±2.33	2.49±2.91	2.41	0.0159
Fruit fiber (g/day)	0.72±2.28	0.82±2.63	-1.27	0.2049

BMI, body mass index.
Continuous variables are described as means±standard deviation; categorical variables are described as participants (percentage). *p* values were calculated by t test for continuous variables, and chi-square test for categorical variables.

Table 2. Multivariate-adjusted ORs (95% CIs) of hyperuricemia according to plant dietary fiber intake

	Model 1†		Model 2‡		Model 3§	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Total fiber (g/day)	1.082 (1.019,1.148)	0.0095	0.969 (0.907,1.035)	0.3481	0.897 (0.827,0.827)	0.0085
Plant dietary fiber (g/day)	1.184 (1.092,1.283)	<0.0001	0.986 (0.902,1.078)	0.7597	0.909 (0.818,1.011)	0.0795
Cereal fiber (g/day)	1.083 (0.965,1.215)	0.1761	0.867 (0.765,0.983)	0.0253	0.776 (0.675,0.893)	0.0004
Legume fiber (g/day)	1.389 (1.114,.1.733)	0.0036	1.134 (0.900,1.428)	0.287	1.084 (0.855,1.375)	0.5035
Vegetable fiber (g/day)	1.606 (1.345,1.917)	<0.0001	1.207 (0.991,1.472)	0.0617	1.144 (0.932,1.405)	0.1983
Fruit fiber (g/day)	1.183 (0.854,1.639)	0.3114	1.314 (0.935,1.845)	0.1154	1.306 (0.927,1.840)	0.1262

CI, confidence interval

†Model 1 unadjusted. ‡Model 2 adjusted for age, gender, and BMI. §Model 3 adjusted for age, gender, BMI, passive smoking status, drinking alcohol status, outdoor physical activity time, energy intake. In these models, fiber intake units were adjusted to 10 g/day.

Table 3. Multivariate stratified analyses of the association between Cereal fiber consumption and ORs of hyperuricemia

	Model 1†		Model 2‡		Model 3§		*p* for interaction
	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*	
Total fiber (g/day)							
Gender							0.0576
Male	1.145(1.056,1.241)	0.0010	0.970(0.882,1.068)	0.5369	0.887(0.791,0.994)	0.0391	
Female	1.015(0.929,1.109)	0.7390	0.943(0.858,1.035)	0.2148	0.901(0.801,1.013)	0.0818	
Age							0.3507
6-11 years	0.983(0.876,1.103)	0.7693	0.905(0.801,1.023)	0.1098	0.799(0.682,0.937)	0.0058	
12-17 years	1.006(0.931,1.086)	0.8875	0.971(0.896,1.052)	0.4769	0.925(0.840,1.019)	0.1150	
Obesity							0.0120
Normal weight	1.095(1.026,1.168)	0.0062	0.970(0.903,1.043)	0.4107	0.898(0.822,0.981)	0.0173	
Overweight & obesity	0.965(0.827,1.126)	0.6532	0.934(0.796,1.096)	0.4038	0.888(0.726,1.087)	0.2494	
Cereal fiber (g/day)							
Gender							0.2772
Male	1.166(0.998,1.361)	0.0523	0.815(0.683,0.973)	0.0238	0.697(0.572,0.850)	0.0003	
Female	0.987(0.830,1.175)	0.8863	0.860(0.717,1.031)	0.1037	0.818(0.666,1.004)	0.0543	
Age							0.3327
6-11 years	1.031(0.824,1.289)	0.7896	0.924(0.729,1.170)	0.5121	0.842(0.645,1.100)	0.2084	
12-17 years	0.879(0.762,1.013)	0.0753	0.798(0.687,0.926)	0.003	0.716(0.606,0.846)	<0.0001	
Obesity							0.0391
Normal weight	1.115(0.983,1.264)	0.0906	0.864(0.753,0.990)	0.035	0.767(0.658,0.894)	0.0007	
Overweight & obesity	0.906(0.673,1.219)	0.5136	0.838(0.616,1.142)	0.2631	0.802(0.568,1.131)	0.2084	

CI, confidence interval

†Model 1 unadjusted. ‡Model 2 adjusted for age, gender, and BMI. §Model 3 adjusted for age, gender, BMI, passive smoking status, drinking alcohol status, outdoor physical activity time, energy intake. In these models, fiber intake units were adjusted to 10 g/day.

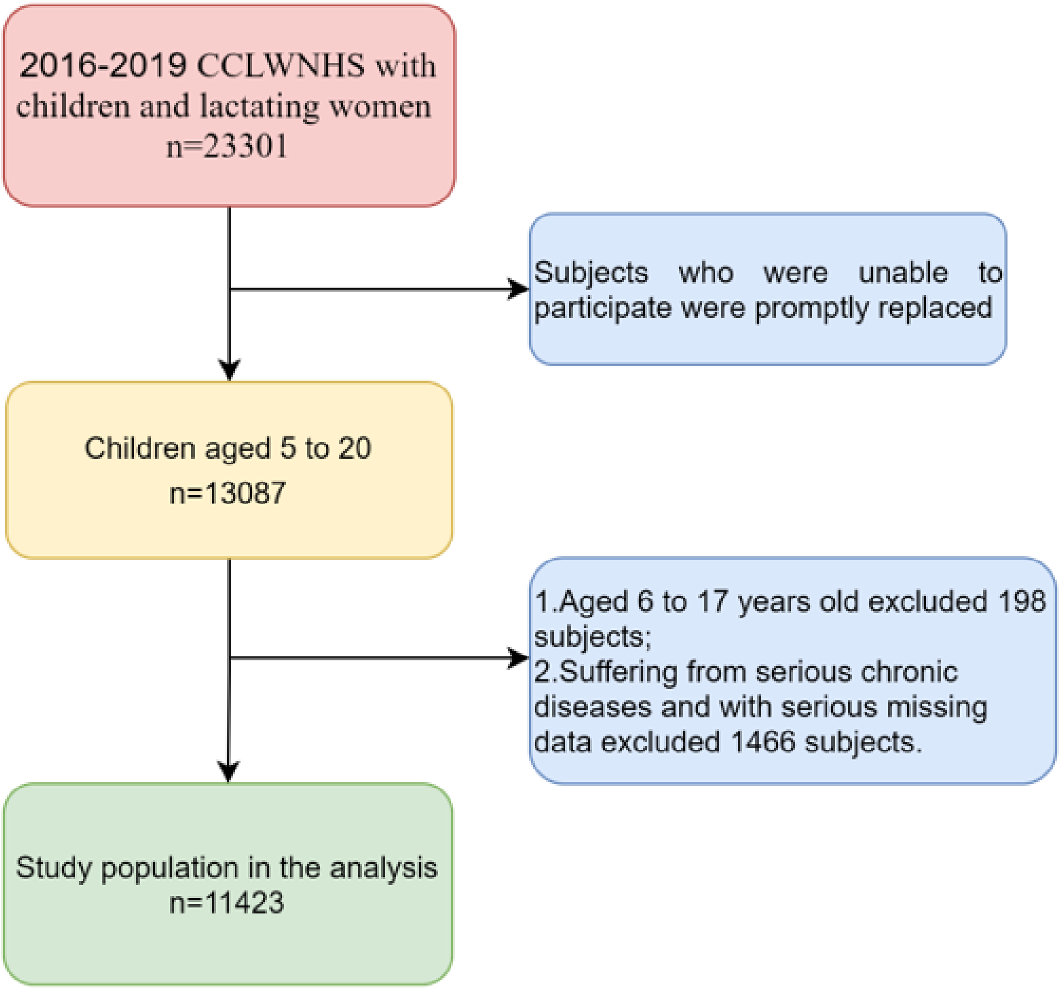

Figure 1. Inclusion and exclusion flowchart

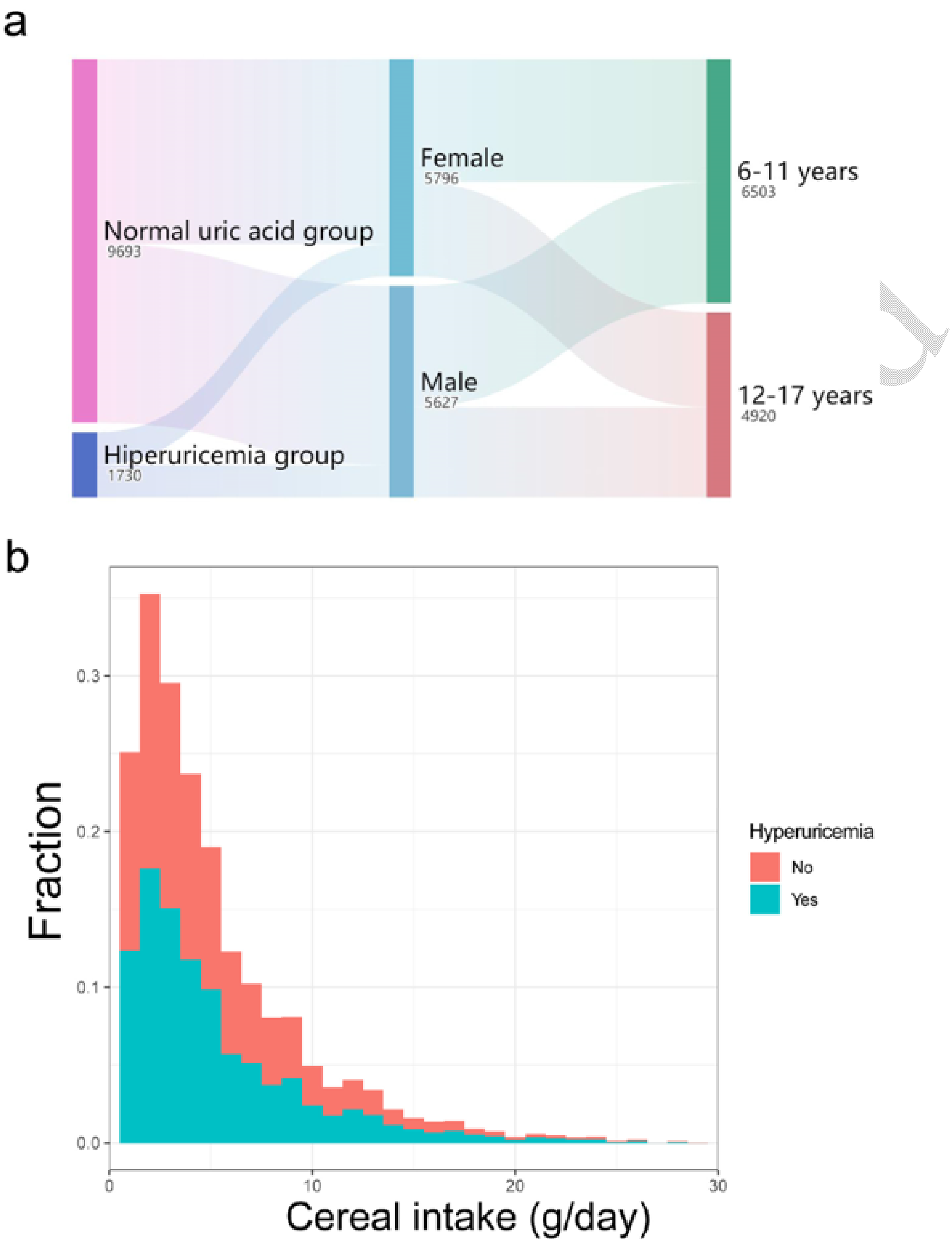

Figure 2. (A) The characteristics of hyperuricemia, sex and age distribution of participants. (B) Distribution characteristics of cereal dietary fiber in hyperuricemia group and non-hyperuricemia group

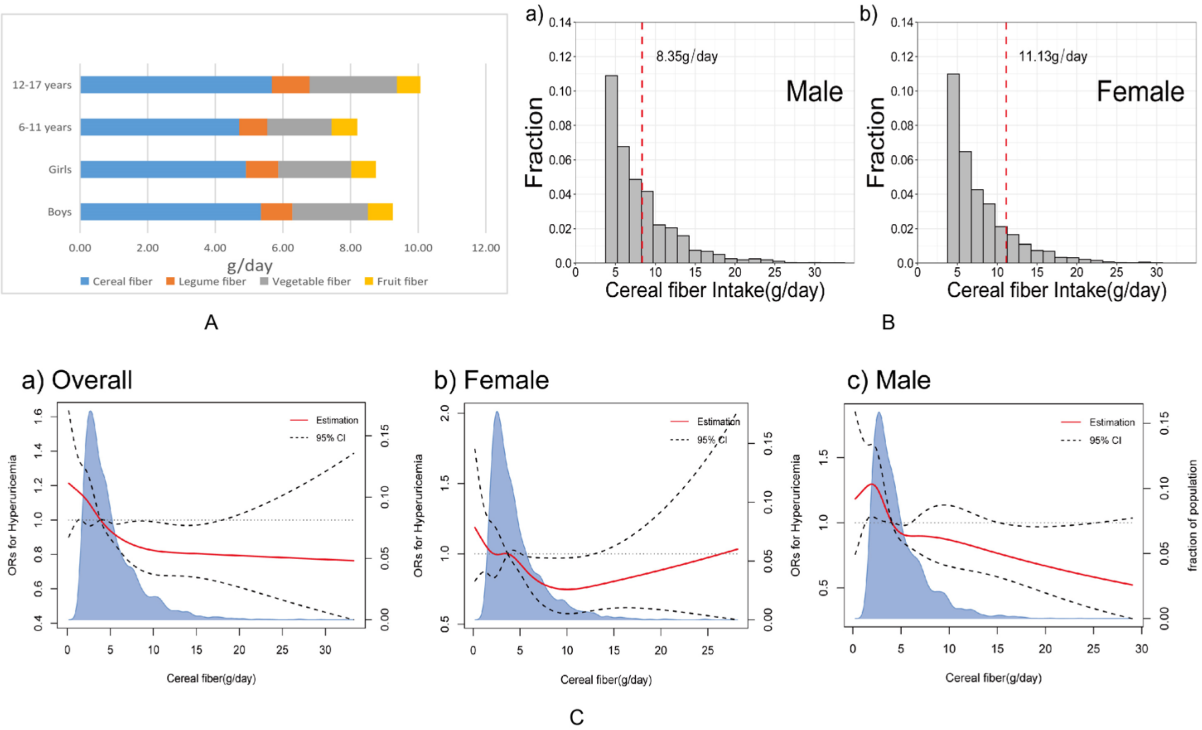

Figure 3. (A) Sources of plant dietary fiber different age and gender groups. (B) Distribution of cereal fiber consumption of different genders and cut-off values for cereal fiber distinguish the minimal risk hyperuricemia. (C) Representation of restricted cubic spline logistic regression models for cereal fiber and risk of hyperuricemia. The models were adjusted for age, gender, BMI, passive smoking status, drinking alcohol status, outdoor physical activity time, energy intake