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Seasonal variation in dietary intake and its association with obesity-related chronic diseases in northeast China

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Abstract

Objective: The objective of this study was to assess seasonal changes in dietary and nutrient intake of residents (18-75 years old) in Northeast China during summer and winter, and to explore the associations between fatty acids, phytosterols, and the prevalence of obesity-related chronic diseases, particularly obesity, hyperlipidemia, and NAFLD. **Methods:** A total of 4773 participants from the Internet-based Dietary Questionnaire for Chinese (IDQC) were included in this study. Dietary intake information was collected using a validated food frequency questionnaire. Student's t-test or Mann-Whitney U-test was used to analyze continuous variables, while Chi-squared tests were used to compare categorical variables. Multivariable logistic regression was employed to assess the relationship between fatty acids, phytosterols, and obesity-related chronic diseases. **Results:** The mean consumption of legumes, vegetables, fruits, nuts, dairy products, fish, condiments, energy, protein, fat, and carbohydrate differed significantly between summer and winter (P < 0.05). Significant inverse associations were found between both fatty acids and phytosterols and obesity-related chronic diseases in multivariate adjusted models. Summer polyunsaturated fatty acid (PUFA) intake was negatively associated with the prevalence of hyperlipidemia (Q4, OR, 0.515; 95%CI, 0.283-0.921; P < 0.05) and non-alcoholic fatty liver disease (NAFLD) (Q4, OR, 0.331; 95%CI, 0.176-0.599; P < 0.001). Phytosterols intake was negatively associated with the prevalence of obesity (Q4, OR, 0.603; 95%CI, 0.414-0.873; P < 0.05), hyperlipidemia (Q4, OR, 0.420; 95%CI, 0.233-0.731; P < 0.001), and NAFLD (Q4, OR, 0.206; 95%CI, 0.111-0.360; P < 0.001) during the summer. **Conclusions:** Higher PUFA intake was associated with a lower prevalence of obesity, hyperlipidemia, and NAFLD. Phytosterol intake was inversely associated with the prevalence of hyperlipidemia and NAFLD. These findings suggest that the associations between PUFA and phytosterols and the prevalence of obesity-related chronic diseases may be influenced by seasonal differences in food intake.

Keywords

obesity-related chronic diseases; polyunsaturated fatty acid; phytosterols

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1 Introduction

Obesity is a recognized risk factor for many complications, including type 2 diabetes, hypertension, dyslipidemia, non-alcoholic fatty liver disease (NAFLD), and cardiovascular disease[1]. According to World Obesity Atlas 2023, more than 2.6 billion people worldwide were considered overweight and obese in 2020, and this number is expected to reach 3 billion by 2025[2]. According to China's obesity classification standard (overweight: body mass index [BMI] 24.0-27.9 kg/m^2; obesity: BMI ≥ 28.0 kg/m^2), the prevalence of overweight and obesity was 34.3% and 16.4%, respectively, among adult residents in 2020, which is more than half of the total population in China[3]. Furthermore, the prevalence of overweight and obesity was higher in Northern China compared to Southern China[1].

Obesity-related chronic diseases are responsible for high percentages of disability and mortality worldwide[4]. It is widely established that diet is a key modifiable factor influencing the prevalence of obesity-related chronic diseases[5-6]. Diet and lifestyle play important roles in the health of the population, and irrational diets contribute to the prevalence of non-communicable diseases such as type 2 diabetes, hypertension, hyperlipidemia, and NAFLD.

Diets are not constant throughout the year and are often highly correlated with the geographical and cultural context of the area. Nutrient and food group intake fluctuates seasonally[7]. There is a significant temperature difference between summer and winter in northeastern China. It is well known that the intake of vegetables and fruits is more likely to vary seasonally due to the cyclical availability of food[8]. Since fat has a lower thermal conductivity than muscle, the thickness of fat in the body is considered to be an effective insulation in winter[9]. Several studies have found differences in protein intake, fat intake, and fat types between seasons[10-12].

Epidemiologic studies have shown increasing evidence of the benefits of n-3 polyunsaturated fatty acid (PUFA) intake and that eating more oily fish reduces dyslipidemia[13-14]. Nuts (except chestnuts) are high in total fat and rich in phytosterols, nearly half of which are derived from monounsaturated fatty acids (MUFAs) and PUFAs. These components are capable of lowering serum low-density lipoprotein concentrations and reducing free radicals[15].

The objective of this study was to assess the changes in dietary and nutrient intake of residents (18-75 years old) in Northeast China during summer and winter. Additionally, we aimed to explore the association between fatty acids, phytosterols, and the prevalence of obesity-related chronic diseases, particularly obesity, hyperlipidemia, and NAFLD.

2 Material and methods

2.1 Study population

The data for this study were obtained from a validated Internet-based dietary questionnaire for Chinese residents (IDQC; www.yyjy365.org/diet), which primarily investigated the dietary habits of northeastern Chinese residents. The recruitment of participants for this survey was conducted in accordance with the Helsinki Declaration, and the study was approved by the Human Research Ethics Committee of Harbin Medical University (ethics number: HMUIRB2019006PRE). All participants provided written informed consent before the questionnaires were administered. This cross-sectional study was conducted from March 2014 to December 2023, with a total of 4911 participants recording their dietary intake during both summer and winter months. We excluded 138 participants who met any of the following criteria: under 18 years old, incomplete IDQC information, implausible daily energy intake levels (< 600 kcal/d for males and females, > 4000 kcal/d for females, and > 4200 kcal/d for males)[16], or had conditions such as hepatitis, diabetes, pregnancy, or other special circumstance. Data from the summer were collected in August, September, and October, while data from the winter were collected in January, February, and March. Ultimately, 4773 participants were included in the final analyses.

2.2 Dietary intake assessment

In the IDQC, common foods were divided into 16 categories (refined grains, potatoes, legumes, vegetables, fungi, fruits, seed and nuts, livestock, poultry, dairy products, egg, fish, fast food, sweets, beverages, and condiments), encompassing 136 food items. Participants could click on the image representing each food to select the appropriate item, the frequency of intake, and the amount consumed. The available intake frequencies for each food item were categorized as: never (less than once a month), 1-3 times a month, once a week, 2-3 times a week, 4-5 times a week, once a day, twice a day, and 3 or more times a day. The total food intake for each category was calculated by summing the intake of all food items within that category. In help participants measure the amount of food more accurately, reference size pictures for each food were provided. Furthermore, based on the Chinese food composition table, the average daily intake of each nutrient was calculated.

2.3 Other covariates

The IDQO table contained data on various covariates: socio-demographic factors including age, gender, BMI, smoking status (never/former/current), drinking status (yes/no), educational level (junior school and below/senior high school or equivalent/college or equivalent/postgraduate or above), work intensity (mild/moderate/severe), and income (< 1000 yuan/1000-2000 yuan/2000-3000 yuan/3000-4000 yuan/ > 4000 yuan per month); dietary intake of nutrient factors including total energy, fat, protein, and carbohydrate.

2.4 Obesity-related chronic diseases

Height, weight, systolic blood pressure (SBP), and diastolic blood pressure (DBP) of participants were measured by trained examiners. Participants wore light clothing and no shoes, with weight and height recorded to the nearest 0.1 kg and 0.1 cm, respectively, using anthropometric methods. BMI is calculated as weight in kilograms divided by the square of height in meters (kg/m^2). For this study, conducted in a Chinese population, obesity was classified as a BMI of 28.0 kg/m^2 or greater. The presence of hyperlipidemia and NAFLD was determined based on self-reports through the IDQC.

2.5 Statistical analysis

We adjusted the intake of 16 food groups and nutrients for total energy intake using the energy density method, which is defined as the ratio of nutrient intake to total energy[17]. We calculated the mean intakes, standard deviations, and differences in percent dietary intakes for 16 dietary categories between summer and winter. The percent difference (% difference) was calculated as (mean winter intake−mean summer intake)/ (mean winter intake+mean summer intake) to illustrate seasonal variations. A positive number indicates greater food consumption in winter than in summer, while a negative number indicates the opposite. Continuous variables were expressed as mean ± SD and analyzed using Student's *t* test or the Kruskal-Wallis test to compare the mean values. Categorical variables were presented as percentages and assessed using Chi-squared tests to evaluate the significance of differences in frequency.

Logistic regression models were used to analyze the association between four quartiles of fatty acids and phytosterols and obesity, hyperlipidemia, and NAFLD. Odds ratios (OR) and 95% confidence intervals (CI) were calculated. The crude model was not adjusted by any potential confounding factors. Model 1 was adjusted for age, and gender (male/female). Model 2 included additional adjustments for drinking status (yes/no) and smoking status (never/former/current). In Model 3, adjustments for educational status (junior school and below/senior high school or equivalent/college or equivalent/postgraduate or above), income (< 1000 yuan/1000-2000 yuan/2000-3000 yuan/3000-4000 yuan/ > 4000 yuan per month), and work intensity (mild/moderate/severe) were added. All analyses were performed with IBM SPSS Statistics version 25.0 and R version 4.3.1. The level of significance was set at two-sided $P < 0.05$.

3 Result

3.1 General characteristics of winter and summer participants

The characteristics of the study population, stratified by summer and winter, are presented in Table 1. The analysis included 2718 summer participants and 2055 winter participants. The mean ages of participants were 40.23 ± 16.29 years in summer and 38.68 ± 14.87 years in winter. Participants in summer tended to be older and had higher BMI, SBP, and DBP. The percentage of participants who reported drinking status was higher in the summer than in the winter. Statistical differences were also observed between summer and winter participants in terms of educational status, work intensity, and income.

3.2 Dietary and nutrients intake of the participants in summer and winter

Table 2 calculates the differences in food and nutrient intakes

Table 1 General characteristics of the participants

	Summer (*N* = 2718)	Winter (*N* = 2055)	*P* Value
Age	40.23 ± 16.29	38.68 ± 14.87	< 0.01
Gender			0.854
Male	1215 (44.70)	925 (45.01)	
Female	1503 (55.30)	1130 (54.99)	
Body mass index, kg/m^2	23.37 ± 3.47	23.090 ± 3.18	< 0.01
Systolic blood pressure, mmHg	121.43 ± 14.71	120.143 ± 12.21	< 0.01
Diastolic blood pressure, mmHg	79.58 ± 9.93	78.665 ± 8.30	< 0.01
Drinking, *N* (% current)	425 (15.64)	219 (10.66)	< 0.01
Smoking, *N* (% current)	364 (13.39)	269 (13.09)	0.729
Educational status			< 0.01
Junior school and below	639 (23.51)	543 (26.42)	
Senior high school or equivalent	579 (21.30)	395 (19.22)	
College or equivalent	1448 (53.27)	964 (46.91)	
Postgraduate or above	52 (1.91)	153 (7.45)	
Work intensity, *N* (%)			< 0.01
Light	1762 (64.83)	1137 (55.33)	
Moderate	765 (28.15)	685 (33.33)	
Heavy	191 (7.03)	233 (11.34)	
Income per month, yuan			< 0.01
< 1000	584 (21.49)	540 (26.28)	
1000-2000	555 (20.42)	302 (14.70)	
2000-3000	753 (27.70)	565 (27.49)	
3000-4000	418 (15.38)	315 (15.33)	
> 4000	408 (15.01)	333 (16.20)	

P Values were determined using Chi-squared test for categorical variables, analysis of Student's *t* test for continuous variables and Mann-Whitney U test for non-normal continuous variables. Data are expressed as mean ± SD, frequencies and percentages as appropriate.

between summer and winter. The larger the absolute value, the greater the difference between winter and summer for the same type of food or nutrient. A negative sign indicates higher intake in summer than in winter, while a positive sign indicates higher intake in winter than in summer. Statistically significant at more than 5% between summer and winter were observed for legumes, vegetables, fruits, nuts, dairy products, fish, and condiments. In summer and winter, the mean daily intake of total energy was 2362.22 ± 819.53 kcal/day and 2094.75 ± 789.09 kcal/day, respectively. The mean daily intake of protein was 89.99 ± 36.51 g/day in summer and 84.35 ± 34.56 g/day in winter. The mean daily intake of fat was 76.13 ± 36.10 g/day in summer and 62.30 ± 30.62 g/day in winter. The mean daily intake of carbohydrate was 345.62 ± 133.51 g/day in summer and 310.04 ± 128.95 g/day in winter. Intakes of the three macronutrients (protein, fat, and carbohydrate) were significantly higher in summer than in winter. Fat showed the highest variation among the three macronutrients at 9.99%. Overall, participants consumed more fish, nuts and seeds, fruits, condiments, vegetables, and legumes in the summer than in winter ($P < 0.05$). Conversely, they consumed more dairy products in winter than in summer ($P < 0.001$). Participants consumed more fat in summer compared to carbohydrate and protein. No significant differences were found for refined grains ($P = 0.09$), potatoes ($P = 0.23$), fungi ($P = 0.22$), poultry ($P = 0.14$), egg ($P = 0.50$), fast food ($P = 0.27$), sweets ($P = 0.14$), and beverages ($P = 0.32$).

3.3 Odds ratios and 95% confidence intervals for obesity-related chronic diseases according to quartiles of fatty acids and phytosterol intake

Table 3 presents the significant associations of fatty acid and phytosterol intake with obesity in summer and winter. In the crude model for summer, higher phytosterol intake was associated with a lower prevalence of obesity (Q4 *vs.* Q1, OR = 0.530, 95%CI = 0.371-0.751; $P < 0.001$). The multivariable-adjusted ORs of obesity across quartiles of phytosterol intake were as follows: Q1 (reference); Q2 0.616 (95%CI = 0.429-0.878); Q3 0.675 (95%CI = 0.471-0.963); and Q4 0.603 (95%CI = 0.414-0.873) (all $P < 0.05$). No significant association was found between different types of fatty acid intake and the prevalence of obesity. In the crude winter model, high levels of phytosterols (Q4) were also significantly associated with a lower prevalence of obesity. However, after multivariate

Table 2 Dietary and nutrients intake of the participants in summer and winter

Groups	Summer (*N* = 2718)	Winter (*N* = 2055)	% difference	*P* Value
Refined grains, g/d	287.67 ± 167.89	296.03 ± 165.91	1.43%	0.087
Potatoes, g/d	55.68 ± 57.91	53.73 ± 52.64	-1.78%	0.232
Legumes, g/d	98.11 ± 100.67	87.18 ± 82.60	-5.89%	< 0.001
Vegetables, g/d	386.81 ± 282.88	333.23 ± 236.60	-7.44%	< 0.001
Fungi, g/d	44.00 ± 49.54	45.87 ± 55.96	2.07%	0.224
Fruits, g/d	281.04 ± 249.78	215.36 ± 182.38	-13.23%	< 0.001
Seed and nuts, g/d	41.83 ± 47.75	29.97 ± 33.27	-16.51%	< 0.001
Livestock, g/d	75.79 ± 61.16	72.44 ± 54.22	-2.26%	0.050
Poultry, g/d	26.37 ± 32.94	27.81 ± 33.15	2.67%	0.135
Dairy products, g/d	96.92 ± 110.78	107.48 ± 112.91	5.16%	0.001
Egg, g/d	27.56 ± 28.85	28.11 ± 26.41	0.98%	0.501
Fish, g/d	66.59 ± 70.85	37.69 ± 37.78	-27.72%	< 0.001
Fast food,g/d	52.36 ± 57.61	50.53 ± 55.29	-1.78%	0.270
Sweets, g/d	3.01 ± 6.80	3.27 ± 5.26	4.25%	0.140
Beverages, mL/d	38.48 ± 96.73	41.27 ± 95.70	3.49%	0.322
Condiments, g/d	10.25 ± 17.67	8.40 ± 19.67	-9.93%	< 0.001
Total energy, kcal/d	2362.22 ± 819.53	2094.75 ± 789.09	-6.00%	< 0.001
Protein, g/d	89.99 ± 36.51	84.34 ± 34.56	-3.24%	< 0.001
Total fat, g/d	76.13 ± 36.10	62.30 ± 30.62	-9.99%	< 0.001
Carbohydrate, g/d	345.62 ± 133.51	310.04 ± 128.95	-5.43%	< 0.001
Fiber, g/d	20.07 ± 10.81	15.51 ± 9.43	-12.83%	< 0.001
Cholesterol, g/d	501.51 ± 322.20	371.76 ± 232.62	-14.86%	< 0.001
Fatty acids, g/d	42.84 ± 24.03	44.20 ± 23.63	1.56%	0.052
Saturated fatty acids, g/d	10.09 ± 5.21	11.62 ± 5.70	7.03%	< 0.001
Monounsaturated fatty acids, g/d	13.93 ± 7.69	16.50 ± 9.50	8.44%	< 0.001
Polyunsaturated fatty acid, g/d	18.39 ± 12.34	15.51 ± 10.02	-8.48%	< 0.001
Phytosterols, mg/d	1326.10 ± 1000.12	503.32 ± 762.50	-44.97%	< 0.001

P Values were determined using Student's *t* test for continuous variables and Mann-Whitney U-test for non-normal continuous variables. Difference in percentage of average summer consumption as it relates to average winter consumption. Data are expressed as mean ± SD.

Table 3 Association of different types of fatty acids and phytosterols with prevalence of obesity in participants during summer and winter

Quartiles	Summer (*N* = 2718)				Winter (*N* = 2055)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fatty acids								
Crude	1	1.421 (0.991-2.048)	1.402 (0.977-2.023)	1.077 (0.736-1.578)	1	1.384 (0.858-2.254)	1.241 (0.761-2.040)	0.728 (0.414-1.262)
Model1	1	1.441 (1.001-2.088)	1.423 (0.987-2.063)	1.047 (0.711-1.543)	1	1.254 (0.767-2.068)	1.041 (0.624-1.747)	0.605 (0.336-1.072)
Model2	1	1.451 (1.006-2.103)*	1.432 (0.992-2.078)	1.056 (0.716-1.560)	1	1.272 (0.776-2.104)	1.081 (0.646-1.819)	0.636 (0.353-1.131)
Model3	1	1.441 (0.996-2.097)	1.371 (0.945-2.000)	1.031 (0.695-1.530)	1	1.239 (0.747-2.069)	1.083 (0.639-1.843)	0.607 (0.333-1.092)
Saturated fatty acids								
Crude	1	1.092 (0.753-1.585)	1.266 (0.883-1.821)	1.264 (0.882-1.818)	1	0.842 (0.502-1.404)	1.286 (0.808-2.064)	0.812 (0.482-1.358)
Model1	1	1.100 (0.756-1.602)	1.335 (0.928-1.928)	1.264 (0.878-1.827)	1	0.753 (0.441-1.275)	1.091 (0.666-1.795)	0.662 (0.382-1.139)
Model2	1	1.107 (0.760-1.614)	1.346 (0.935-1.947)	1.292 (0.896-1.870)	1	0.733 (0.428-1.246)	1.102 (0.670-1.822)	0.675 (0.388-1.164)
Model3	1	1.079 (0.737-1.582)	1.326 (0.915-1.930)	1.234 (0.848-1.802)	1	0.703 (0.405-1.210)	1.062 (0.635-1.782)	0.623 (0.353-1.089)
Monounsaturated fatty acids								
Crude	1	1.229 (0.853-1.775)	1.192 (0.826-1.725)	1.288 (0.897-1.855)	1	1.703 (1.053-2.799)*	1.112 (0.656-1.891)	1.036 (0.606-1.773)
Model1	1	1.332 (0.921-1.935)	1.269 (0.875-1.845)	1.331 (0.923-1.927)	1	1.566 (0.956-2.605)	0.950 (0.548-1.649)	0.862 (0.492-1.511)
Model2	1	1.326 (0.916-1.927)	1.271 (0.875-1.851)	1.333 (0.923-1.932)	1	1.563 (0.950-2.611)	0.968 (0.557-1.686)	0.891 (0.507-1.568)
Model3	1	1.335 (0.919-1.948)	1.236 (0.847-1.810)	1.302 (0.896-1.901)	1	1.557 (0.938-2.619)	0.946 (0.537-1.670)	0.859 (0.483-1.528)
Polyunsaturated fatty acid								
Crude	1	1.209 (0.852-1.721)	1.158 (0.813-1.652)	0.862 (0.591-1.255)	1	1.247 (0.785-1.993)	0.787 (0.468-1.311)	0.787 (0.468-1.311)
Model1	1	1.164 (0.814-1.669)	1.081 (0.754-1.553)	0.796 (0.541-1.168)	1	1.085 (0.676-1.749)	0.650 (0.380-1.100)	0.661 (0.386-1.119)
Model2	1	1.161 (0.811-1.666)	1.088 (0.758-1.565)	0.795 (0.540-1.169)	1	1.116 (0.694-1.803)	0.680 (0.398-1.154)	0.693 (0.404-1.177)
Model3	1	1.163 (0.809-1.675)	1.067 (0.741-1.540)	0.790 (0.533-1.167)	1	1.155 (0.711-1.886)	0.693 (0.399-1.193)	0.688 (0.395-1.186)
Phytosterols								
Crude	1	0.573 (0.404-0.807)*	0.618 (0.438-0.865)*	0.530 (0.371-0.751)**	1	0.841 (0.524-1.343)	0.790 (0.488-1.269)	0.589 (0.348-0.976)*
Model1	1	0.619 (0.434-0.876)*	0.707 (0.498-0.998)	0.609 (0.423-0.871)*	1	0.806 (0.501-1.289)	0.790 (0.487-1.270)	0.738 (0.421-1.274)
Model2	1	0.605 (0.424-0.857)*	0.687 (0.483-0.972)*	0.598 (0.414-0.858)*	1	0.824 (0.511-1.322)	0.811 (0.499-1.308)	0.738 (0.420-1.279)
Model3	1	0.616 (0.429-0.878)*	0.675 (0.471-0.963)*	0.603 (0.414-0.873)*	1	0.815 (0.503-1.315)	0.803 (0.489-1.307)	0.729 (0.408-1.286)

Crude not adjusted for any potential covariates; Model 1adjusted for age, gender; Model 2 adjusted for age, gender, drinking status, smoking status; Model 3 adjusted for age, gender, drinking status, smoking status, educational status, income, work intensity. ** $P < 0.001$; * $P < 0.05$; non letter or symbol, $P > 0.05$.

adjustment (model 4), winter phytosterol intake did not show a significant association with obesity.

Table 4 presents the significant inverse associations of summer PUFA and phytosterols wit the prevalence of hyperlipidemia. The multivariable-adjusted OR for PUFA in Q4 was 0.515 (95%CI = 0.283-0.921, $P < 0.05$). For phytosterol intake in Q4, the OR was 0.420 (95%CI = 0.233-0.731, $P < 0.001$). However, no associations were found between PUFA or phytosterols and obesity-related chronic diseases in winter after multivariate adjustment.

Table 5 presents significant associations of PUFA and phytosterols with the prevalence of NAFLD in summer. In model 4, the OR for PUFA in Q4 was 0.331 (95%CI = 0.176-0.599), while the OR for phytosterol intake in Q4 was 0.206 (95%CI = 0.111-0.360) (all $P < 0.001$). No associations were found between PUFA or phytosterols and obesity-related chronic diseases in winter after multivariate adjustment.

4 Discussion

Our results indicate that residents of northeastern China consume higher amounts of legumes, vegetables, fruits, nuts, fish, and condiments in summer, while dairy products are consumed more in winter. Seasonal differences were observed for legumes, vegetables, fruits, nuts, dairy products, and fish. Notably, fish, vegetables, and fruits are typically considered seasonal foods, with significantly higher intake in summer than in winter, which aligns with findings from several studies[7,10,12]. Some studies have also shown that Spanish men consume fruits, legumes, meat, and dairy products more frequently in summer[10]. However, our study found that intakes of legumes, nuts, and condiments were higher in summer than in winter, whereas dairy products were consumed more in winter, differing from some previous studies. These seasonal differences may be attributed to various factors, including natural conditions, man-made influences, or commercial factors such as pricing[7]. Moreover, inconsistencies in food group findings across studies may stem from differing dietary habits and geographic contexts, particularly influenced by the cold climate and economic development characteristic of northeastern China.

Nutrient intake is closely linked to food consumption, and variations in fat intake can be attributed to differences in food choices between summer and winter. In our study, we found that fat consumption was higher in summer compared to winter.

Table 4 Association of different types of fatty acids and phytosterols with prevalence of hyperlipidemia in participants during summer and winter

Quartiles	Summer (*N* = 2623)				Winter (*N* = 1948)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fatty acids								
Crude	1	1.412 (0.881-2.288)	1.342 (0.833-2.183)	1.100 (0.668-1.820)	1	0.927 (0.426-2.003)	1.222 (0.596-2.546)	0.927 (0.426-2.003)
Model1	1	1.381 (0.851-2.266)	1.310 (0.804-2.156)	0.966 (0.579-1.618)	1	0.735 (0.330-1.624)	0.830 (0.390-1.787)	0.619 (0.274-1.387)
Model2	1	1.490 (0.911-2.464)	1.474 (0.897-2.447)	1.124 (0.667-1.902)	1	0.725 (0.319-1.630)	0.894 (0.415-1.953)	0.712 (0.310-1.626)
Model3	1	1.421 (0.862-2.368)	1.336 (0.804-2.243)	0.996 (0.584-1.704)	1	0.924 (0.397-2.138)	1.174 (0.524-2.678)	0.901 (0.380-2.131)
Saturated fatty acids								
Crude	1	0.885 (0.544-1.433)	0.885 (0.544-1.433)	1.260 (0.807-1.979)	1	1.375 (0.629-3.102)	1.187 (0.526-2.728)	1.661 (0.787-3.666)
Model1	1	0.846 (0.514-1.385)	0.942 (0.574-1.542)	1.180 (0.747-1.874)	1	1.079 (0.479-2.497)	0.812 (0.345-1.935)	1.118 (0.509-2.556)
Model2	1	0.870 (0.527-1.432)	1.025 (0.620-1.689)	1.340 (0.841-2.149)	1	0.942 (0.409-2.222)	0.810 (0.339-1.964)	1.154 (0.515-2.682)
Model3	1	0.814 (0.487-1.355)	0.911 (0.545-1.519)	1.138 (0.704-1.852)	1	1.241 (0.520-3.035)	0.878 (0.354-2.213)	1.232 (0.530-2.974)
Monounsaturated fatty acids								
Crude	1	1.030 (0.629-1.689)	1.289 (0.808-2.074)	1.224 (0.763-1.977)	1	1.519 (0.731-3.271)	1.519 (0.731-3.271)	0.745 (0.302-1.777)
Model1	1	1.135 (0.685-1.884)	1.402 (0.869-2.281)	1.205 (0.742-1.967)	1	1.213 (0.567-2.675)	1.033 (0.477-2.304)	0.488 (0.191-1.204)
Model2	1	1.190 (0.714-1.988)	1.555 (0.955-2.555)	1.333 (0.815-2.197)	1	1.071 (0.488-2.413)	0.971 (0.439-2.207)	0.499 (0.192-1.256)
Model3	1	1.147 (0.683-1.930)	1.436 (0.873-2.383)	1.165 (0.702-1.945)	1	1.286 (0.569-2.997)	1.190 (0.511-2.853)	0.559 (0.208-1.457)
Polyunsaturated fatty acid								
Crude	1	1.540 (0.988-2.428)	1.279 (0.806-2.044)	0.605 (0.342-1.046)	1	0.939 (0.465-1.889)	0.698 (0.322-1.468)	0.698 (0.322-1.468)
Model1	1	1.304 (0.822-2.091)	1.039 (0.645-1.686)	0.465 (0.259-0.815)*	1	0.689 (0.334-1.412)	0.463 (0.209-0.998)	0.476 (0.213-1.030)
Model2	1	1.325 (0.831-2.135)	1.114 (0.688-1.817)	0.520 (0.288-0.920)*	1	0.705 (0.337-1.468)	0.535 (0.238-1.169)	0.526 (0.232-1.161)
Model3	1	1.336 (0.832-2.171)	1.107 (0.678-1.822)	0.515 (0.283-0.921)*	1	0.913 (0.426-1.953)	0.800 (0.344-1.819)	0.824 (0.349-1.906)
Phytosterols								
Crude	1	0.769 (0.508-1.157)	0.513 (0.321-0.804)*	0.319 (0.183-0.533)**	1	0.490 (0.218-1.034)	0.845 (0.432-1.632)	0.490 (0.218-1.034)
Model1	1	0.859 (0.559-1.313)	0.601 (0.370-0.958)*	0.372 (0.210-0.633)**	1	0.444 (0.196-0.944)*	0.857 (0.435-1.671)	0.956 (0.401-2.173)
Model2	1	0.890 (0.577-1.367)	0.644 (0.394-1.037)	0.416 (0.233-0.714)**	1	0.486 (0.212-1.049)	1.029 (0.511-2.058)	1.065 (0.438-2.477)
Model3	1	0.955 (0.613-1.484)	0.674 (0.406-1.101)	0.420 (0.233-0.731)**	1	0.499 (0.214-1.096)	1.089 (0.531-2.221)	1.070 (0.430-2.550)

Crude not adjusted for any potential covariates; Model 1adjusted for age, gender; Model 2 adjusted for age, gender, drinking status, smoking status; Model 3 adjusted for age, gender, drinking status, smoking status, educational status, income, work intensity. **P < 0.001; *P < 0.05; non letter or symbol, P > 0.05.

This may be related to the increased consumption of foods that are naturally rich in fats, such as fish, nuts, legumes, and livestock, which are typically seasonal. Changes in fatty acid intake are particularly noteworthy, with higher levels of PUFA and phytosterols observed in summer. A systematic review indicates that nut, seeds, and legumes are rich sources of healthy MUFA, PUFA, and phytosterol compounds[18]. Additionally, fish serves as a major dietary source of PUFAs. Dairy products, on the other hand, are generally the largest source of saturated fatty acids (SFA), with milk fat containing approximately 70%-75% SFA, 20%-25% MUFA, and a small amount (2%-5%) of PUFA[19]. A study conducted in the UK revealed seasonal variations in the fatty acid composition of milk, with concentrations of SFA being the highest in winter and lowest in summer[20]. Our study also found higher winter intakes of fatty acids, including SFA and MUFA.

Due to the high energy density of nuts and seeds, it is assumed that their consumption will lead to weight gain. However, research suggests that nut consumption does not contribute to weight gain; rather, it helps control satiety, increases thermogenesis, and may prevent or mitigate risk factors associated with chronic diseases, such as alterations in blood sugar and lipid metabolism, oxidative stress, and inflammation[18]. Fish, a rich source of omega-3 PUFA, has been shown to reduce plasma triglyceride concentration plasma triglyceride concentrations[21]. A large observational study involving US adults found a trend toward significantly lower OR for dyslipidemia with increased fish intake and rising PUFA levels[13]. The established association between PUFA and fish intake with hyperlipidemia may partially explain the lower prevalence of hyperlipidemia among participants with higher PUFA intake during the summer.

Regarding phytosterol intake, our study found inverse associations between summer intake and the prevalence of obesity, hyperlipidemia, and NAFLD. Phytosterols are naturally occurring plant compounds known for their beneficial effects on lipid metabolism, such as lowering serum cholesterol, which can help prevent NAFLD[22]. Current international guidelines recommend a daily intake of 2 grams of phytosterols to effectively reduce low-density lipoprotein cholesterol[23]. Animal studies have also demonstrated that that phytosterols may protect against the development and progression of NAFLD in

Table 5 Association of different types of fatty acids and phytosterols with prevalence of NAFLD in participants during summer and winter

Quartiles	Summer (*N* = 2367)				Winter (*N* = 1959)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fatty acids								
Crude	1	1.874 (1.154-3.108)*	1.449 (0.869-2.448)	1.324 (0.786-2.254)	1	0.998 (0.563-1.769)	0.749 (0.402-1.373)	0.708 (0.376-1.308)
Model1	1	1.914 (1.170-3.194)*	1.463 (0.873-2.486)	1.284 (0.758-2.200)	1	0.706 (0.386-1.289)	0.444 (0.230-0.844)*	0.409 (0.209-0.785)*
Model2	1	2.063 (1.252-3.470)*	1.641 (0.972-2.812)	1.468 (0.858-2.542)	1	0.714 (0.384-1.322)	0.470 (0.241-0.903)*	0.447 (0.225-0.871)*
Model3	1	1.871 (1.118-3.195)*	1.383 (0.802-2.416)	1.159 (0.663-2.045)	1	0.954 (0.501-1.818)	0.630 (0.310-1.267)	0.569 (0.278-1.146)
Saturated fatty acids								
Crude	1	1.170 (0.714-1.927)	0.930 (0.551-1.566)	1.594 (1.005-2.564)	1	0.773 (0.407-1.447)	1.043 (0.579-1.884)	0.952 (0.521-1.737)
Model1	1	1.164 (0.706-1.928)	0.991 (0.584-1.677)	1.620 (1.015-2.622)*	1	0.532 (0.270-1.028)	0.627 (0.333-1.178)	0.545 (0.286-1.034)
Model2	1	1.229 (0.741-2.048)	1.092 (0.639-1.862)	1.880 (1.166-3.075)*	1	0.466 (0.232-0.918)*	0.623 (0.325-1.191)	0.536 (0.276-1.034)
Model3	1	1.122 (0.665-1.904)	0.893 (0.513-1.549)	1.405 (0.850-2.350)	1	0.598 (0.287-1.223)	0.698 (0.350-1.391)	0.571 (0.283-1.146)
Monounsaturated fatty acids								
Crude	1	1.292 (0.785-2.145)	1.329 (0.811-2.201)	1.404 (0.862-2.316)	1	1.249 (0.694-2.272)	1.198 (0.662-2.189)	0.704 (0.352-1.374)
Model1	1	1.442 (0.871-2.411)	1.430 (0.867-2.382)	1.449 (0.884-2.404)	1	0.928 (0.500-1.735)	0.732 (0.389-1.385)	0.409 (0.197-0.827)*
Model2	1	1.504 (0.902-2.532)	1.595 (0.959-2.682)	1.591 (0.962-2.663)	1	0.860 (0.454-1.639)	0.691 (0.360-1.332)	0.412 (0.195-0.847)*
Model3	1	1.379 (0.816-2.352)	1.308 (0.771-2.241)	1.213 (0.716-2.076)	1	1.126 (0.576-2.220)	0.906 (0.447-1.850)	0.475 (0.218-1.016)
Polyunsaturated fatty acid								
Crude	1	1.024 (0.658-1.595)	0.998 (0.640-1.558)	0.386 (0.212-0.675)**	1	0.781 (0.441-1.367)	0.535 (0.281-0.986)*	0.640 (0.348-1.149)
Model1	1	0.908 (0.576-1.431)	0.894 (0.567-1.409)	0.329 (0.179-0.580)**	1	0.532 (0.294-0.954)*	0.319 (0.163-0.605)*	0.393 (0.207-0.729)*
Model2	1	0.921 (0.582-1.458)	0.954 (0.603-1.511)	0.360 (0.195-0.640)**	1	0.547 (0.297-0.992)*	0.354 (0.179-0.678)*	0.417 (0.217-0.784)*
Model3	1	0.923 (0.573-1.487)	0.948 (0.588-1.530)	0.331 (0.176-0.599)**	1	0.722 (0.382-1.350)	0.539 (0.264-1.071)	0.658 (0.329-1.293)
Phytosterols								
Crude	1	0.400 (0.258-0.607)**	0.225 (0.130-0.369)**	0.188 (0.105-0.318)**	1	0.679 (0.362-1.248)	1.038 (0.596-1.814)	0.601 (0.312-1.124)
Model1	1	0.440 (0.282-0.673)**	0.259 (0.150-0.429)**	0.216 (0.119-0.369)**	1	0.609 (0.321-1.129)	1.089 (0.618-1.923)	1.340 (0.656-2.688)
Model2	1	0.434 (0.277-0.666)**	0.267 (0.153-0.445)**	0.233 (0.128-0.401)**	1	0.667 (0.348-1.256)	1.265 (0.706-2.279)	1.443 (0.695-2.950)
Model3	1	0.418 (0.262-0.656)**	0.247 (0.139-0.420)**	0.206 (0.111-0.360)**	1	0.700 (0.356-1.353)	1.343 (0.731-2.478)	1.271 (0.595-2.670)

Crude not adjusted for any potential covariates; Model 1adjusted for age, gender; Model 2 adjusted for age, gender, drinking status, smoking status; Model 3 adjusted for age, gender, drinking status, smoking status, educational status, income, work intensity. **P < 0.001; *P < 0.05; non letter or symbol, P > 0.05.

rats[24-25]. Furthermore, a double-blind randomized controlled trial indicated that supplementation with phytosterols and n-3 PUFAs effectively improved metabolic disturbances in patients with NAFLD[26]. The primary food sources of phytosterols include nuts, grains, and vegetables, aligning with our findings that higher phytosterol intake may have a protective effect on the prevalence of NAFLD.

Our study has several limitations. Our study has several limitations. First, like any cross-sectional study design, it may be affected by unmeasured confounders that could influence the results. Second, the reliance on 24-hour dietary recall methods to assess diets and nutrient intake may introduce recall bias. Third, as this study focused on residents of northeastern China, demographic, economic, and geographic factors may have impacted the findings. Future research should aim to include a broader geographic population and more accurate dietary data to enhance the validity of the results.

5 Conclusion

In a representative sample of adult residents from northeastern China, high PUFA intake was associated with a lower prevalence of hyperlipidemia and NAFLD. Additionally, high phytosterol intake was associated with a lower prevalence of obesity, hyperlipidemia, and NAFLD, while no association was found between PUFA intake and obesity prevalence. These findings suggest promoting the consumption of foods rich in PUFAs and phytosterols, such as nuts and seeds, legumes, fish, vegetables, and fruits.

Author contributions

All authors bear public responsibility for the content and have contributed to the concept, research design and data collection of the work described in this paper. Wang C, Li Z C and RF are responsible for literature search and statistical analysis, Wang C, Li Z C writes the draft manuscript, and all authors participate in modifying the vital content. Wang C, Li Z C, Guan D W, Fu H X and Feng R N are responsible for the integrity and accuracy of the data and are the guarantors of this manuscript. All authors have full access to these data and approved the publication of the final version.

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Ethical approval

The recruitment of participants for this survey was conducted in accordance with the Helsinki Declaration, and the study was approved by the Human Research Ethics Committee of Harbin Medical University (ethics number: HMUIRB2019006PRE).

Informed consent

All participants provided written informed consent before the questionnaires were administered.

Conflict of interest

The authors declare no competing interests.

Data availability statement

All data used in the study are available from the corresponding author by request.

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