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Association Between the Korean Healthy Eating Index and Hyperuricemia Among Korean Adults

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ABSTRACT

Background: Hyperuricemia is an emerging public health concern associated with gout and metabolic diseases. While numerous studies have examined associations between individual dietary factors and hyperuricemia, comprehensive assessments of overall diet quality and their impact on hyperuricemia are lacking. This study aimed to investigate the association between overall diet quality, as measured by the Korean Healthy Eating Index (KHEI), and the prevalence of hyperuricemia among Korean adults using nationally representative data.

Methods: We analyzed data from 27,149 Korean adults aged ≥ 20 years from the Korea National Health and Nutrition Examination Survey (2016–2021). The KHEI assesses dietary quality based on adherence to Korean dietary guidelines, encompassing adequacy, moderation, and balance of intake. Hyperuricemia was defined as serum uric acid ≥ 7.0 mg/dL in men and ≥ 6.0 mg/dL in women. Logistic regression was performed, adjusting for sociodemographic, lifestyle, and health-related factors.

Results: Higher total KHEI scores were significantly associated with a lower prevalence of hyperuricemia (10.6% vs. 15.5%; $P < 0.001$). After adjustment, participants with high KHEI scores exhibited 22% lower odds of hyperuricemia compared to those with low scores (odds ratio, 0.78; 95% confidence interval, 0.72–0.84). Specifically, higher consumption of breakfast, whole grains, fruits, vegetables, and balanced energy intake were inversely associated with hyperuricemia risk. However, higher intake of purine-rich foods (meat, fish, eggs, beans) was positively associated with hyperuricemia. An unexpected finding was observed regarding sodium: lower sodium intake correlated with increased hyperuricemia risk, possibly related to renal uric acid reabsorption mechanisms or confounding by medications.

Conclusion: Our findings demonstrate a significant inverse relationship between overall dietary quality, assessed using the KHEI, and hyperuricemia risk among Korean adults. The results emphasize the protective effects of balanced dietary habits, highlighting the benefits of regular breakfast consumption, increased fruit and vegetable intake, and balanced energy distribution. These insights underscore the importance of adopting holistic dietary strategies for the prevention and management of hyperuricemia, moving beyond traditional recommendations focused on individual nutrients. Further longitudinal studies are required to clarify causality and mechanisms underlying these associations.

Disclosure

The authors have no potential conflicts of interest to disclose.

Data Availability Statement

The datasets analyzed during the current study are publicly available from the Korea National Health and Nutrition Examination Survey (KNHANES) website at <https://knhanes.kdca.go.kr/knhanes/eng/main.do> (accessed on October 9, 2024).

Author Contributions

Conceptualization: Son H. Data curation: Son H, Lee HS, Lee SY, Lee W. Formal analysis: Son H. Investigation: Son H, Lee HS, Lee SY, Lee W. Methodology: Son H, Lee HS. Project administration: Lee SY, Lee W. Supervision: Lee SY, Lee W. Visualization: Son H, Lee HS, Lee W. Writing - original draft: Son H, Lee HS. Writing - review & editing: Lee SY, Lee W.

Keywords: Hyperuricemia; Uric Acid; Gout; Nutrition; Korean Healthy Eating Index (KHEI); KNHANES

INTRODUCTION

Hyperuricemia is a metabolic disorder characterized by elevated serum uric acid (SUA) levels, which results from either excessive production or impaired excretion of uric acid.¹ Hyperuricemia is a known risk factor for various chronic diseases, including gout, chronic kidney disease, hypertension, and cardiovascular diseases.²⁻⁴ With the increasing prevalence of hyperuricemia worldwide, it has emerged as a significant public health concern.

While genetic predisposition contributes to the risk of hyperuricemia,⁵ extensive evidence has long established that dietary factors play a critical role in modulating SUA levels and disease progression of related conditions, such as gout.⁶ For instance, a large population-based longitudinal study showed that adherence to healthy lifestyle practices can counteract the genetic risk of gout, suggesting the potential of preventive strategies even among high-risk individuals.⁷ Specific dietary patterns have also been implicated in increasing the risk of disease.⁸ A comprehensive meta-analysis and systemic review identified high consumption of red meat, seafood, alcohol, and fructose as being positively associated with an increased likelihood of hyperuricemia and gout, underscoring the role of dietary choices in disease pathogenesis.⁹ More recent large-scale prospective studies further reinforce these findings, emphasizing that adherence to a balanced diet and other healthy lifestyle factors can substantially lower the risk of hyperuricemia, even among those with elevated genetic susceptibility study reported that promoting such lifestyle habits could reduce gout risk by up to 30% in genetically predisposed individuals, offering a promising avenue for intervention.¹⁰ These insights highlight the critical interplay between genetics and lifestyle, setting the stage for targeted approaches to prevent and manage hyperuricemia and gout.

Historically, much of the research on dietary influences has centered on individual nutrients or specific foods—such as sodium, purine-rich items, or alcohol, rather than assessing overall dietary quality. For example, studies have often examined isolated associations between nutrients, like vitamin C, fiber, or protein, and hyperuricemia risk, overlooking the synergistic effects of combined dietary patterns. This narrow, fragmented approach may fail to capture the broader context of dietary habits, which better reflect the complex interplay of nutrients in real-world settings and their combined effects on hyperuricemia risk. Consequently, focusing solely on individual nutrients or foods can offer an incomplete picture, constraining our understanding of how overall eating patterns influence hyperuricemia risk.

To overcome these shortcomings, the Korean Healthy Eating Index (KHEI) was developed as a comprehensive tool to assess overall diet quality based on adherence to the Korean dietary guidelines. The KHEI evaluates various aspects of dietary intake, including adequacy, moderation, and balance, providing a holistic measure of an individual's eating habits. It is considered superior to single-nutrient approaches for reflecting real-world dietary behavior and has been validated as a useful indicator for assessing chronic disease risk in Korean populations; however, its application to hyperuricemia remains underexplored.

Given the growing prevalence and health burden of hyperuricemia, investigating the role of overall diet quality, as measured by KHEI, is both timely and essential. Therefore, this study aims to explore the association between KHEI and hyperuricemia, providing valuable evidence for dietary interventions to prevent hyperuricemia and related metabolic diseases in the Korean population.

METHODS

Data collection and study participants

The present study analyzed data from the 2016–2021 Korea National Health and Nutrition Examination Survey (KNHANES), conducted by the Korea Centers for Disease Control and Prevention (KCDC). KNHANES employs a multi-stage, stratified cluster sampling method to select households from the non-institutionalized population in South Korea. The survey comprises three main components: a health interview, a health examination, and a nutritional assessment. In KNHANES, the sample design and size are estimated to represent the entire Korean population, so that the results can be employed to represent the overall population in Korea in each survey year.¹ Fig. 1 presents the exclusion process for the final 27,149 participants.

Exposure

The primary exposure variable in this study was diet quality, assessed using the KHEI. The KHEI is a validated dietary assessment tool designed^{11,12} to evaluate adherence to national dietary guidelines, with scores ranging from 0 to 100, where higher scores indicate better diet quality. To examine the association between diet quality and hyperuricemia, participants were categorized into two groups based on their KHEI scores: low diet quality (Q1: 0–50), and high diet quality (Q2: 50–100). The KHEI comprises 14 components categorized into three main domains: adequacy, moderation, and balance. The first domain evaluates the adequacy of intake for recommended foods and nutrients, consisting of eight subcomponents: breakfast consumption, whole grain intake, total fruit intake, fresh fruit intake (excluding fruit juice), total vegetable intake, vegetable intake (excluding kimchi and pickled vegetables), intake of meat, fish, eggs, and beans, and milk and dairy product consumption. Higher consumption results in higher scores. For instance, breakfast consumption is assessed based on whether individuals report eating breakfast five or more days per week, which reflects a key indicator of regular dietary patterns. The second domain assesses moderation in the consumption of foods and nutrients recommended for limited intake, including three subcomponents: the percentage of energy from saturated fatty acids,

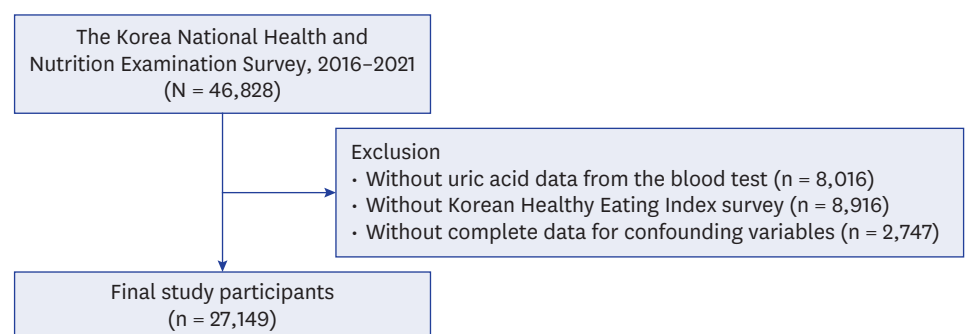


Fig. 1. Schematic diagram depicting study participants.

sodium intake, and the percentage of energy from sugars and beverages. Lower consumption results in higher scores. Sodium intake is calculated using 24-hour dietary recall data, and scoring is based on alignment with World Health Organization (WHO) recommendations ($< 2,000$ mg/day), with lower intake corresponding to higher scores. The third domain focuses on the balance of energy intake, comprising three subcomponents: the percentage of energy from carbohydrates, the percentage of energy from fats, and appropriate energy intake, with scores increasing as intake aligns with optimal ratios. Energy balance scoring reflects the degree to which an individual's intake aligns with the acceptable macronutrient distribution ranges, as defined in the Dietary Reference Intakes for Koreans, typically 55–65% carbohydrates and 15–30% fat. KHEI scores were calculated based on dietary recall data collected in KNHANES, following the guidelines established by KCDC.¹¹ The categorized KHEI groups were then used to investigate their association with hyperuricemia prevalence.

Outcome

The primary outcome of this study was hyperuricemia, which was determined based on SUA levels. Hyperuricemia was defined as a SUA level of ≥ 7.0 mg/dL in men and ≥ 6.0 mg/dL in women, following established clinical guidelines.^{13–15} SUA levels were measured using enzymatic colorimetric methods, with slight variations in equipment and reagents depending on the survey year. From 2016 to 2018, uric acid levels were measured using the Cobas 8000 analyzer (Roche, Mannheim, Germany) and the UA2 reagent (Roche).¹⁶ From 2019 to 2021, measurements were conducted using the Labospect 008AS analyzer (Hitachi, Tokyo, Japan) with the Qualigent UA reagent (Sekisui, Tokyo, Japan), based on the uricase method.¹⁷ Both measurement instruments utilize enzymatic colorimetric methods, and their analytical performances are similar in terms of precision (coefficient of variation $\leq 1.5\%$) and linearity range (Cobas 8000: 0.6–20.0 mg/dL; Labospect 008AS: 0.2–25.0 mg/dL).

Covariates

A previous study reported that hyperuricemia is associated with health behavioral factors such as smoking and alcohol consumption, body mass index (BMI), and dietary factors. Additionally, socioeconomic factors including education level and household income, as well as physical activity, have been considered relevant covariates in previous research.^{18,19} Although marital status has not been widely reported as a risk factor for hyperuricemia in previous studies, our analysis showed that unmarried individuals had a significantly higher prevalence of hyperuricemia compared to married individuals. Based on these findings and our backward stepwise selection, we included sex, age, education level, household income, marital status, smoking, drinking, physical activity, BMI, and dietary quality (KHEI) as covariates in this study. Several covariates were included in the analysis to adjust for potential confounding factors influencing both diet quality and hyperuricemia. The covariates were categorized into demographic, lifestyle, and health-related factors.^{12,20} Demographic variables include age group (≤ 20 , 21–40, 41–60, ≥ 61 years), sex (male, female), education level (elementary school, middle school, high school or above), household income (low, middle-low, middle-high, high), and marital status (unmarried, married). Lifestyle variables include smoking status (smoker, non-smoker), alcohol consumption (yes, no), and physical activity (engagement in aerobic exercise or not). Health-related variables include BMI, categorized as underweight (< 18.5 kg/m²), normal weight (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), obesity (≥ 25.0 kg/m²). General obesity was defined as a BMI ≥ 25.0 kg/m² in accordance with the WHO recommendations for Asian populations.²¹ All covariates were included in the logistic regression model to adjust for their potential impact on the association between diet quality (KHEI) and hyperuricemia prevalence.

Statistical analyses

All statistical analyses were conducted using SAS software version 9.4 (SAS Institute, Cary, NC, USA). To account for the complex survey design of the KNHANES study, primary sampling units, stratification, and sampling weights were applied in all analyses. Statistical significance was set at $P < 0.05$, and all probability tests were two-sided. Baseline characteristics of the study participants were analyzed according to hyperuricemia status. Categorical variables, including age group, sex, education level, household income, marital status, alcohol consumption, smoking status, physical activity, and BMI, were expressed as frequencies and percentages. Associations between hyperuricemia and categorical covariates, including each component of the KHEI, were examined using χ^2 tests. To further investigate the relationship between diet quality and hyperuricemia, a logistic regression analysis was performed. Covariates included age group, sex, education level, household income, marital status, smoking, alcohol consumption, physical activity, and BMI. Also, we conducted sensitivity analysis between SUA and each score of KHEI items using distribution visualization and linear regression model.

Ethics statement

The current study used research approved by the Institutional Review Board (IRB) of the Korea Centers for Disease Control and Prevention (IRB No. 2016–2018: 2018-01-03-P-A and 2018-01-03-C-A). Written informed consent was obtained from all participants involved in the KNHANES.

RESULTS

Table 1 presents the prevalence of hyperuricemia according to various demographic, lifestyle, and health-related covariates, with significant differences observed across most variables. The analysis included 27,149 participants, of whom 3,543 (13.1%) were identified as having hyperuricemia. Prevalence was notably higher in males (20.5%) than in females (7.3%). By age group, those aged 20–39 years exhibited the highest prevalence (16.5%), followed by individuals under 20 years (14.8%), those aged 60 years and older (12.3%), and those aged 40–59 years (11.1%). Regarding education, participants with a high school education or above showed a slightly higher prevalence (13.4%) compared to those with middle school (11.4%) or elementary school education (12.5%). Household income was inversely associated with hyperuricemia; the lowest income quartile had the highest prevalence (14.5%), with a decreasing trend as income levels rose. Unmarried individuals had a higher prevalence (18.2%) than their married counterparts (12.0%). Lifestyle factors also influenced prevalence: drinkers had a higher rate (15.4%) than non-drinkers (10.4%), and smokers showed a markedly elevated prevalence (20.2%) compared to non-smokers (11.6%). Participants engaging in physical activity had a slightly higher prevalence (13.6%) than those who did not (12.7%). Obesity was strongly linked to hyperuricemia, with a prevalence of 21.0% in the obese group compared to 3.7% in the underweight group. Lastly, individuals with low KHEI scores had a higher prevalence (15.5%) than those with high scores (10.6%). The distribution of KHEI scores according to general characteristics is presented in **Supplementary Table 1**, providing additional information on the variation of diet quality across demographic and lifestyle factors.

Table 2 presents the prevalence of hyperuricemia according to total KHEI score and its subcomponents. Participants in the high KHEI group had a significantly lower prevalence

Table 1. Prevalence of hyperuricemia according to general characteristics and KHEI total score

Characteristics	Overall	Hyperuricemia		P value
		No	Yes	
Sex				< 0.001
Male	11,810 (43.5)	9,386 (79.5)	2,424 (20.5)	
Female	15,339 (56.5)	14,220 (92.7)	1,119 (7.3)	
Age, yr				< 0.001
< 20	495 (1.8)	422 (85.2)	73 (14.8)	
20–39	7,472 (27.5)	6,238 (83.5)	1,234 (16.5)	
40–59	10,346 (38.1)	9,197 (88.9)	1,149 (11.1)	
≥ 60	8,836 (32.6)	7,749 (87.7)	1,087 (12.3)	
Education level				0.008
Elementary school	3,894 (14.3)	3,407 (87.5)	487 (12.5)	
Middle school	2,953 (10.9)	2,615 (88.6)	338 (11.4)	
High school or above	20,302 (74.8)	17,584 (86.6)	2,718 (13.4)	
Household income quartile				0.008
Low	4,657 (17.2)	3,980 (85.5)	677 (14.5)	
Middle low	6,694 (24.7)	5,826 (87.0)	868 (13.0)	
Middle high	7,557 (27.8)	6,614 (87.5)	943 (12.5)	
High	8,241 (30.3)	7,186 (87.2)	1,055 (12.8)	
Marital status				< 0.001
Unmarried	4,774 (17.6)	3,904 (81.8)	870 (18.2)	
Married	22,375 (82.4)	19,702 (88.0)	2,673 (12.0)	
Drinking experience				< 0.001
No	12,734 (46.9)	11,416 (89.6)	1,318 (10.4)	
Yes	14,415 (53.1)	12,190 (84.6)	2,225 (15.4)	
Smoking experience				< 0.001
No	22,659 (83.5)	20,021 (88.4)	2,638 (11.6)	
Yes	4,490 (16.5)	3,585 (79.8)	905 (20.2)	
Physical activity				0.029
No	15,334 (56.5)	13,393 (87.3)	1,941 (12.7)	
Yes	11,815 (43.5)	10,213 (86.4)	1,602 (13.6)	
BMI, kg/m ²				< 0.001
Underweight	1,061 (3.9)	1,022 (96.3)	39 (3.7)	
Normal	10,339 (38.1)	9,627 (93.1)	712 (6.9)	
Overweight	6,248 (23.0)	5,448 (87.2)	800 (12.8)	
Obesity	9,501 (35.0)	7,509 (79.0)	1,992 (21.0)	
KHEI				< 0.001
Low score	13,574 (50.0)	11,475 (84.5)	2,099 (15.5)	
High score	13,575 (50.0)	12,131 (89.4)	1,444 (10.6)	

Values are presented as number (%).

KHEI = Korean Healthy Eating Index, BMI = body mass index.

of hyperuricemia compared to those in the low KHEI group (10.6% vs. 15.5%, $P < 0.001$). Across the adequacy domain, higher intakes of breakfast, whole grains, total fruits, and fresh fruits were all significantly associated with lower hyperuricemia prevalence ($P < 0.001$ for all). In contrast, vegetable intake—both total and excluding kimchi and pickled vegetables—did not show a significant association. Notably, higher milk and dairy intake was linked to a lower prevalence of hyperuricemia (12.1% vs. 13.7%, $P < 0.001$), while higher intake of meat, fish, eggs, and beans was associated with increased prevalence ($P = 0.017$). In the moderation domain, individuals with higher moderation scores (indicating lower intake of sodium and saturated fat) had significantly lower hyperuricemia prevalence ($P < 0.001$ for both). However, the intake of sweets and beverages was not significantly associated with hyperuricemia ($P = 0.102$). Within the balance domain, a well-balanced total energy intake was significantly associated with a lower prevalence of hyperuricemia (12.2% vs. 13.9%, $P < 0.001$). Other balance subcomponents, such as carbohydrate and fat intake distribution, showed no statistically significant associations.

Table 2. Prevalence of hyperuricemia according to domains of KHEI scores

KHEI	Score	Hyperuricemia		P value
		No	Yes	
Total	Low	11,475 (84.5)	2,099 (15.5)	< 0.001
	High	12,131 (89.4)	1,444 (10.6)	
Adequacy				
Adequacy total	Low	11,505 (84.8)	2,069 (15.2)	< 0.001
	High	12,101 (89.1)	1,474 (10.9)	
Breakfast	Low	8,412 (84.7)	1,524 (15.3)	< 0.001
	High	15,194 (88.3)	2,019 (11.7)	
Whole grains	Low	11,576 (85.3)	1,998 (14.7)	< 0.001
	High	12,030 (88.6)	1,545 (11.4)	
Total fruits	Low	11,472 (84.5)	2,102 (15.5)	< 0.001
	High	12,134 (89.4)	1,441 (10.6)	
Fresh fruits (excluding fruit juice)	Low	11,454 (84.4)	2,119 (15.6)	< 0.001
	High	12,152 (89.5)	1,424 (10.5)	
Total vegetable	Low	11,789 (86.9)	1,785 (13.2)	0.625
	High	11,817 (87.1)	1,758 (13.0)	
Vegetable (excluding kimchi and pickle)	Low	11,750 (86.6)	1,824 (13.4)	0.058
	High	11,856 (87.3)	1,719 (12.7)	
Meat, fish, eggs, and beans	Low	11,869 (87.4)	1,705 (12.6)	0.017
	High	11,737 (86.5)	1,838 (13.5)	
Milk and dairy	Low	13,674 (86.3)	2,178 (13.7)	< 0.001
	High	9,932 (87.9)	1,365 (12.1)	
Moderation				
Moderation total	Low	11,644 (85.8)	1,930 (14.2)	< 0.001
	High	11,962 (88.1)	1,613 (11.9)	
Saturated fatty acid intake	Low	9,241 (85.9)	1,510 (14.1)	< 0.001
	High	14,365 (87.6)	2,033 (12.4)	
Sodium intake	Low	11,651 (85.8)	1,923 (14.2)	< 0.001
	High	11,955 (88.1)	1,620 (11.9)	
Sweets and beverages intake	Low	9,241 (87.4)	1,336 (12.6)	0.102
	High	14,365 (86.7)	2,207 (13.3)	
Balance of energy intake				
Balance total	Low	11,703 (86.6)	1,816 (13.4)	0.062
	High	11,903 (87.3)	1,727 (12.7)	
Carbohydrate intake	Low	11,767 (86.7)	1,807 (13.3)	0.200
	High	11,839 (87.2)	1,736 (12.8)	
Energy intake from fat	Low	10,905 (86.5)	1,698 (13.5)	0.054
	High	12,701 (87.3)	1,845 (12.7)	
Energy intake	Low	11,694 (86.1)	1,880 (13.9)	< 0.001
	High	11,912 (87.8)	1,663 (12.2)	

Values are presented as number (%).

KHEI = Korean Healthy Eating Index.

Table 3 presents adjusted odds ratios (ORs) for hyperuricemia according to total KHEI scores and its subcomponents. After adjusting for sociodemographic lifestyle, and health-related covariates, participants with high total KHEI scores had significantly lower odds of hyperuricemia compared to those with low scores (OR, 0.78; 95% confidence interval [CI], 0.72–0.84). In the adequacy domain, higher scores in total adequacy (OR, 0.81; 95% CI, 0.75–0.88), breakfast consumption (OR, 0.82; 95% CI, 0.75–0.89), whole grains (OR, 0.81; 95% CI, 0.75–0.87), total fruits (OR, 0.88; 95% CI, 0.81–0.95), fresh fruits (OR, 0.85; 95% CI, 0.78–0.91), total vegetable (OR, 0.86; 95% CI, 0.80–0.93), and non-pickled vegetable (OR, 0.91; 95% CI, 0.84–0.98) were all significantly associated with a reduced risk of hyperuricemia. In contrast, meat, fish, eggs, and beans intake and milk and dairy intake showed no significant associations. In the moderation domain, higher scores in total moderation (OR, 0.93; 95% CI, 0.86–1.00) and saturated fatty acid intake (OR, 0.92; 95% CI, 0.85–1.00) were marginally associated with lower odds of hyperuricemia. Notably, higher

Table 3. Odds ratios and 95% confidence interval for having hyperuricemia according to domains of KHEI

KHEI	Score	Odds ratio (95% confidence interval)
Total	Low	Reference
	High	0.78 (0.72–0.84)
Adequacy		
Adequacy total	Low	Reference
	High	0.81 (0.75–0.88)
Breakfast	Low	Reference
	High	0.82 (0.75–0.89)
Whole grains	Low	Reference
	High	0.81 (0.75–0.87)
Total fruits	Low	Reference
	High	0.88 (0.81–0.95)
Fresh fruits (excluding fruit juice)	Low	Reference
	High	0.85 (0.78–0.91)
Total vegetable	Low	Reference
	High	0.86 (0.80–0.93)
Vegetable (excluding kimchi and pickle)	Low	Reference
	High	0.91 (0.84–0.98)
Meat, fish, eggs, and beans	Low	Reference
	High	1.02 (0.95–1.10)
Milk and dairy	Low	Reference
	High	0.99 (0.92–1.07)
Moderation		
Moderation total	Low	Reference
	High	0.93 (0.86–1.00)
Saturated fatty acid	Low	Reference
	High	0.92 (0.85–1.00)
Sodium	Low	Reference
	High	1.18 (1.09–1.28)
Sweets and beverages	Low	Reference
	High	0.97 (0.90–1.05)
Balance of energy intake		
Balance total	Low	Reference
	High	0.93 (0.86–1.00)
Carbohydrate	Low	Reference
	High	0.94 (0.87–1.01)
Fat	Low	Reference
	High	0.91 (0.85–0.99)
Total energy	Low	Reference
	High	0.89 (0.82–0.95)

Bold indicated statistical significance (P value < 0.05). Adjusted for sex, age, educational level, household income quartile, marital status, drinking experience, smoking experience, physical activity, body mass index and KHEI. KHEI = Korean Healthy Eating Index.

sodium score (indicating lower sodium intake) was associated with increased odds (OR, 1.18; 95% CI, 1.09–1.28). Sweets and beverage intake were not significantly associated. In the balance domain, high total balance score (OR, 0.93; 95% CI, 0.86–1.00), balanced fat intake (OR, 0.91; 95% CI, 0.85–0.99), and appropriate energy intake (OR, 0.89; 95% CI, 0.82–0.95) were significantly associated with lower odds of hyperuricemia. Carbohydrate intake balance did not show a significant association.

Fig. 2 illustrates the linear regression trends between serum urea acid levels and KHEI scores. Significant inverse associations were observed between SUA levels and total KHEI scores, as well as the adequacy, moderation, and balance of energy intake.

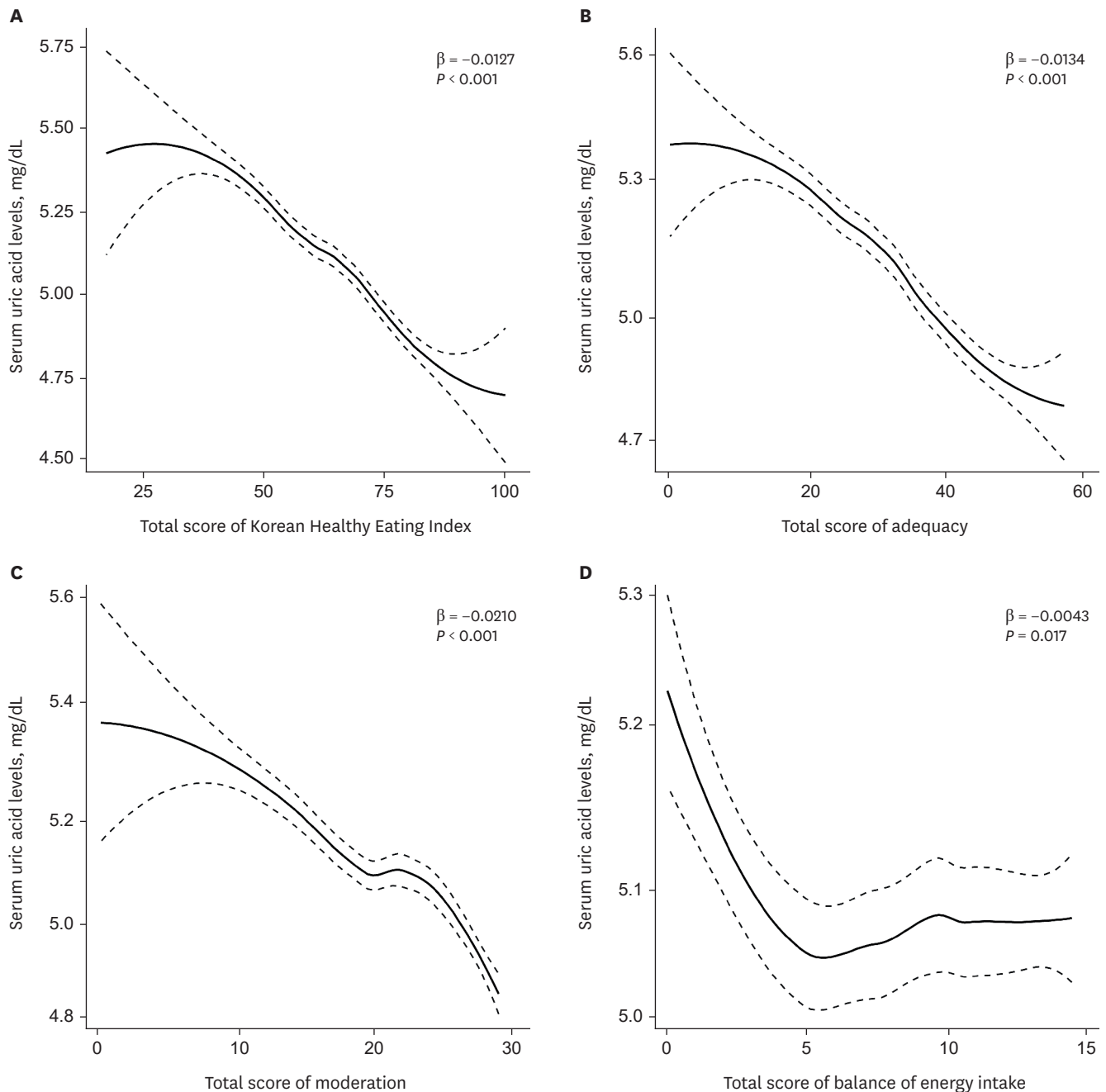


Fig. 2. Trends and linear regression for serum uric acid levels according to Korean Healthy Eating Index scores. (A) Total score of Korean Healthy Eating Index; (B) Total score of adequacy; (C) Total score of moderation; (D) Total score of balance of energy intake.

DISCUSSION

This study investigated the association between overall diet quality, as measured by the KHEI, and the prevalence of hyperuricemia in a nationally representative Korean adult population. Our findings showed that higher KHEI scores were significantly associated with lower odds of hyperuricemia, even after adjusting for demographic, lifestyle, and health-related covariates.

This supports the role of comprehensive dietary quality, beyond individual nutrients, in uric acid metabolism and metabolic health.

Participants with higher total KHEI scores had a significantly lower prevalence and adjusted odds of hyperuricemia. The inverse association was observed across the three KHEI domains—adequacy, moderation, and balance—highlighting the importance of not only consuming beneficial foods but also limiting intake of less healthy dietary components and maintaining energy and macronutrient balance.

Higher scores in the KHEI adequacy domain, including total adequacy, breakfast consumption, mixed grain intake, and total and fresh fruit intake, were significantly associated with a lower prevalence of hyperuricemia. Individuals who regularly consumed breakfast and had greater intake of whole grains and fruits exhibited a lower risk of hyperuricemia, emphasizing the protective role of plant-based, fiber-rich foods and consistent eating patterns. Importantly, higher intake of total vegetables and non-pickled vegetables was also significantly associated with reduced hyperuricemia risk, reinforcing the benefits of vegetable consumption in uric acid metabolism. These findings align with previous studies suggesting that diets rich in antioxidants such as vitamin C and polyphenols enhance renal uric acid excretion and reduce oxidative stress.^{22,23} Additionally, high dietary fiber intake may improve insulin sensitivity, thereby decreasing URAT1-mediated urate reabsorption in the proximal tubules.²⁴ Increased consumption of whole grains, fruits, and vegetables also promotes gut microbiota diversity, facilitating alternative uric acid degradation pathways via microbial uricase-like enzymes.²⁵ Furthermore, plant-based diets contribute to a more alkaline systemic pH, improving uric acid solubility and enhancing its renal elimination.²⁶

Higher moderation scores, reflecting lower intake of saturated fat and sodium, were generally associated with a lower prevalence of hyperuricemia. In particular, the reduced saturated fat intake appeared beneficial. However, an unexpected finding was that individuals with lower sodium intake had a higher prevalence of hyperuricemia. This paradoxical result may be explained by several plausible mechanisms. First, from a physiological perspective, low sodium intake may increase uric acid reabsorption in the proximal renal tubules, leading to decreased renal excretion and elevated SUA levels.²⁷ Additionally, sodium restriction may also impair nitric oxide synthesis, resulting in reduced renal blood flow and further limiting uric acid clearance.²⁸ Second, comorbid conditions such as chronic kidney disease and diabetes mellitus, which often necessitate sodium-restricted diets, are themselves associated with impaired uric acid metabolism.²⁹ These underlying conditions may act as confounders in the relationship between sodium intake and SUA levels.^{25,30} Third, potential confounding by medication use should be considered. Thiazide and loop diuretics—commonly prescribed to patients with hypertension or cardiovascular disease—are known to increase SUA levels by promoting renal tubular reabsorption and decreasing uric acid excretion.³¹ Individuals who follow low-sodium diets are often those with such comorbidities and may be more likely to use these medications, which could contribute to the observed elevation in uric acid despite reduced sodium intake. These factors collectively underscore the complex interplay between sodium intake, medication use, and comorbid conditions in regulating uric acid homeostasis. Future studies are needed to disentangle these influences through more detailed dietary, clinical, and pharmacologic data.

Better balance of energy and macronutrient intake was associated with a lower prevalence of hyperuricemia. In particular, the balanced fat intake and appropriate total energy

consumption were protective, whereas carbohydrate balance showed no significant association. Maintaining a balanced macronutrient distribution may help preserve insulin sensitivity, which is crucial for regulating renal uric acid handling.²⁴ Adequate fat intake may also reduce systemic inflammation and preserve endothelial function, supporting efficient renal uric acid excretion.^{32,33}

In the multivariable-adjusted analysis, several components across all three domains of the KHEI—adequacy, moderation, and balance of energy intake—did not exhibit statistically significant associations with hyperuricemia. Specifically, meat, fish, eggs, and beans and milk and dairy (adequacy domain); Saturated fatty acid and sweets and beverages (moderation domain); and carbohydrate (balance of energy intake domain) showed null associations. These null findings may be attributable to several factors. Although milk, dairy products, and protein-rich foods are often considered protective against hyperuricemia,³⁴ variability in portion size, cooking methods, and individual metabolic responses could attenuate their measurable effects. Similarly, while added sugars and refined carbohydrates have been linked to hyperuricemia in previous studies,^{35,36} the combined “sweets and beverages” component may dilute the distinct impact of highly sweetened items, limiting the detection of significant associations. Regarding carbohydrate intake, the scoring method used may not adequately reflect carbohydrate quality (e.g., refined vs. whole grains), which could differentially influence uric acid metabolism.³⁷ These results highlight the limitations of using composite dietary indices and suggest that future studies may benefit from examining specific food items or nutrient subtypes to clarify their individual contributions to hyperuricemia risk.

Consistent with previous epidemiological studies, hyperuricemia was more prevalent among males (20.5%) compared to females (7.3%), likely reflecting the role of sex hormones such as estrogen in promoting uric acid excretion.³⁸ Interestingly, the highest prevalence of hyperuricemia was observed in young adults aged 20–39 years, contrasting with Western studies where prevalence typically increases with age.²⁷ Socioeconomic disparities were evident, with lower education and income levels associated with higher hyperuricemia risk.³⁹ Lifestyle factors, including alcohol consumption and smoking, were also significantly associated with increased hyperuricemia prevalence, consistent with previous findings on the impact of these behaviors on uric acid metabolism and renal function.^{40,41}

Several limitations should be considered when interpreting our findings. First, the cross-sectional design of this study limits the ability to establish a causal relationship between dietary quality and hyperuricemia. While our findings demonstrate significant associations, they cannot establish whether poor diet leads to elevated uric acid levels or vice versa. To better understand the directionality and underlying mechanisms, future longitudinal cohort studies are needed to track changes in dietary quality over time and assess their subsequent impact on the development and progression of hyperuricemia. Additionally, intervention studies targeting dietary improvement could provide stronger evidence for causative effects and offer practical strategies for hyperuricemia prevention. Second, dietary intake was assessed using self-reported data, which may be subject to recall bias. However, KHEI is a validated and promising dietary assessment tool with growing recognition for its reliability in public health research. Third, although we adjusted for a wide range of demographic, lifestyle, and health-related covariates, residual confounding by unmeasured genetic factors cannot be ruled out. Previous genome-wide association studies have identified several genetic variants such as *SLC2A9*, *ABCG2*, and *SLC22A12* that significantly

influence SUA levels.⁴²⁻⁴⁴ These variants regulate renal urate transport and excretion and may predispose individuals to hyperuricemia independently of their dietary habits or lifestyle.⁴⁵ The absence of genetic information in our dataset limits our ability to fully account for individual susceptibility, which may have influenced the observed associations. In addition, unmeasured lifestyle behaviors and the potential for reverse causality should be considered. Nevertheless, we incorporated nearly all key demographic, behavioral, and health-related variables that are typically accounted for in KHEI-based studies, thereby minimizing the impact of major confounding factors. Given the possibility of residual confounding, future research should explore the mechanisms underlying the observed associations between specific dietary components and hyperuricemia. Longitudinal and interventional studies incorporating genetic data are warranted to clarify causal relationships, evaluate the effectiveness of dietary modifications, and guide the development of personalized dietary strategies based on gene–diet interactions. Lastly, participants excluded due to incomplete data might have introduced potential selection bias, although sensitivity analyses indicated no substantial bias. Future prospective studies with minimal missing data are required to confirm our findings.

Despite these limitations, our study has several strengths. Notably, few studies have comprehensively evaluated the association between hyperuricemia and overall diet quality using the KHEI in a nationally representative Korean population. While previous studies have investigated the relationship between individual dietary components (e.g., purine-rich foods, dairy intake) and hyperuricemia, our study provides novel insights by assessing the cumulative effects of multiple dietary factors through a validated dietary quality index. These findings highlight the importance of an overall healthy diet in hyperuricemia prevention and suggest that dietary guidelines should emphasize a well-balanced nutrient intake rather than focusing solely on specific food restrictions. Moreover, the use of KNHANES data ensured robust methodology with standardized biochemical measures and diet recall protocols. The findings provide actionable insights for public health nutrition and clinical dietary counseling aimed at preventing hyperuricemia. Another key strength of our study is the use of a multidimensional dietary quality index, which integrates not only the quantity but also the quality and distribution of various food groups and nutrients. This holistic approach captures dietary behaviors more realistically than nutrient-based analyses. Furthermore, our study included a wide range of demographic, lifestyle, and metabolic covariates in the analysis, allowing for a more precise estimation of the independent effect of diet quality on hyperuricemia. The large sample size also enhanced statistical power and the generalizability of findings across the Korean population.

Our study demonstrates a significant association between hyperuricemia and overall diet quality using the KHEI. Higher KHEI scores were linked to a lower prevalence of hyperuricemia, highlighting the importance of a balanced and nutrient-rich diet in managing SUA levels. Regular breakfast consumption and increased fruit intake were particularly protective, whereas imbalanced energy intake and high consumption of purine-rich foods were associated with increased risk. These findings suggest that improving overall diet quality may be an effective strategy for hyperuricemia prevention. Further research is needed to explore underlying mechanisms and assess the long-term effects of dietary modifications on hyperuricemia risk.

SUPPLEMENTARY MATERIAL

Supplementary Table 1

Distribution of Korean Healthy Eating Index (KHEI) Score by general characteristics

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