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Association between dietary coenzyme Q10 intake and hyperuricemia in Chinese adults: a nationwide cross-sectional study

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Abstract

Background The association of food-sourced Coenzyme Q10(CoQ10) intake with hyperuricemia (HUA) remains unclear. We aimed to investigate the association between dietary CoQ10 intake and HUA among Chinese adults.

Methods A total of 7953 Chinese adults from the 2009 China Health and Nutrition Survey (CHNS) were included in the present cross-sectional. Dietary CoQ10 was assessed by 3 consecutive 24-h dietary recall interviews combined with a household food inventory. Multivariable logistic regression models and restricted cubic spline models were used to explore the associations between dietary CoQ10 and HUA.

Results In an adjusted logistic regression model, the multivariable odds ratio (OR) and 95% confidence interval (CI) for HUA in the highest versus the lowest quartile of total, animal-based, and plant-based CoQ10 intake were 1.40 (95% CI: 1.15 to 1.70), 1.46 (95% CI: 1.20 to 1.78), and 0.80 (95% CI: 0.65 to 0.97), respectively. Dose-response analyses revealed similar linear patterns, with the exception of plant-derived CoQ10, which did not reach statistical significance (p for nonlinearity = 0.09). In stratified analysis, there were no significant interactions between sex, age, BMI, smoking status, drinking status and total dietary CoQ10 intake in relation to the HUA (All p for interaction > 0.05).

Conclusions Our study documented a novel positive association between total dietary CoQ10 intake and HUA, with similar trends for animal-derived CoQ10 and an inverse trend for plant-derived CoQ10.

Keywords Hyperuricemia, Coenzyme Q10, Uric acid, Cross-sectional studies

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Background

Hyperuricemia (HUA) is a metabolic disorder characterized by impaired uric acid metabolism, mainly due to overproduction of uric acid or impaired uric acid excretion by the kidneys and gut [1]. Emerging data indicated that HUA is a precursor of gout, which presents as intermittent episodes of severe painful arthritis [2]. Nowadays, the prevalence of HUA is still increasing worldwide [3, 4], affecting approximately 14% of the Chinese population [5]. It has become the second most common metabolic disorder following diabetes [6]. Therefore, it is essential to identify potentially modifiable factors for the prevention of HUA.

In recent decades, modifiable lifestyle factors, such as alcohol consumption, smoking, and a sedentary lifestyle, are associated with an increased risk of HUA [7, 8]. High-purine diets and the intake of red meat, seafood and fructose, which promote the breakdown of purine nucleotides, elevate serum urate levels and the likelihood of developing HUA [9, 10]. Adherence to the Mediterranean and Dietary Approaches to Stop Hypertension (DASH) dietary patterns may serve as potent prophylactic measures against the emergence of HUA [11]. Adopting a vegetarian diet and ensuring adequate consumption of nuts, and vegetables may help reduce the risk of HUA [12–14]. The intake of probiotics has been observed to possibly diminish uric acid concentrations through the elimination of pathogenic microorganisms or their by-products [15]. Additionally, studies have validated the therapeutic potential of bioactive substances, such as polyphenols, peptides, and alkaloids, in the mitigation of HUA [16]. Therefore, targeting dietary modifications deserves greater focus in strategies to combat the widespread prevalence of HUA.

Epidemiological studies have provided substantial evidence suggesting that a healthy diet can prevent the development or mitigate HUA, possibly through mechanisms involving oxidative stress [17]. Coenzyme Q10 (CoQ10) is a lipid-soluble molecule that acts as an electron carrier in the mitochondria and is a coenzyme for mitochondrial enzymes, also known as an effective natural antioxidant [18]. Typically, CoQ10 can be endogenously synthesized by the human body. It can also be acquired exogenously from CoQ10 supplements or dietary sources such as animal offal (beef heart, chicken liver), beef, sardines, dragonfish, vegetable oils and other foods [19]. Previous well-designed randomized-controlled trials (RCTs) have investigated the relationship between CoQ10 supplementation and intermediate outcome of serum uric acid levels [20, 21], and although the results vary, these studies provide reasonable evidence of a potential link between CoQ10 and uric acid levels. Nevertheless, the high cost of CoQ10 supplementation poses a challenge to its widespread adoption among the general public. Considering that dietary sources provide a more accessible route for obtaining CoQ10, investigating the influence of dietary CoQ10 on HUA is of significant public health importance. However, no research to date has explored the relationship between dietary CoQ10 intake and HUA in the Chinese general adult population.

Therefore, we conducted a cross-sectional study from the nationwide China Health and Nutrition Survey (CHNS) to investigate the associations between the intake of dietary total CoQ10, animal- and plant-derived CoQ10 and the prevalence of HUA among Chinese general adults.

Materials and methods

Study design and population

This cross-sectional study used data from the CHNS. The CHNS is an ongoing open cohort covering 15 provinces and cities, which can reflect the diet and health status of the Chinese people [22]. The research was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill, the China-Japan Friendship Hospital and the Chinese Centre for Disease Control and Prevention. All subjects signed an informed consent form before the investigation. In our study, we used data from the 2009 survey because data on biomarkers and serum uric acid were first collected in 2009.

A total of 18,805 participants were included in the 2009 CHNS survey, and we excluded participants who were <18 years, pregnant, or had incomplete dietary information and missing serum uric acid data. Participants with implausible total energy intake data (< 800 or > 4000 kcal/d) [23], cancer and myocardial infarction were also excluded. In total, 7953 participants were included in this study (Fig. 1).

Definition of hyperuricemia

Serum uric acid was analyzed by enzymatic colorimetric method (Redox, UK kit) on a Hitachi 7600 automated biochemical analyzer (Hitachi, Tokyo, Japan). HUA was defined as serum uric acid ≥ 420 μmol/L (7 mg/dL) in men and ≥ 360 μmol/L (6 mg/dL) in women [24].

Dietary nutrients intakes

Individual dietary intake data were collected using the 3-day, 24-hour food recall method, and consumption of cooking oil and spices was collected using a weighing and measuring technique over the same 3 days. Household consumption of cooking oil and spices was allocated to individuals according to the proportion of individual energy consumption in the household. Total energy intake was calculated using the China Food Composition Tables Standard Edition (CFCTSD). Dietary intakes of CoQ10 were calculated based on the consumption of various foods and their respective CoQ10 content. Foods

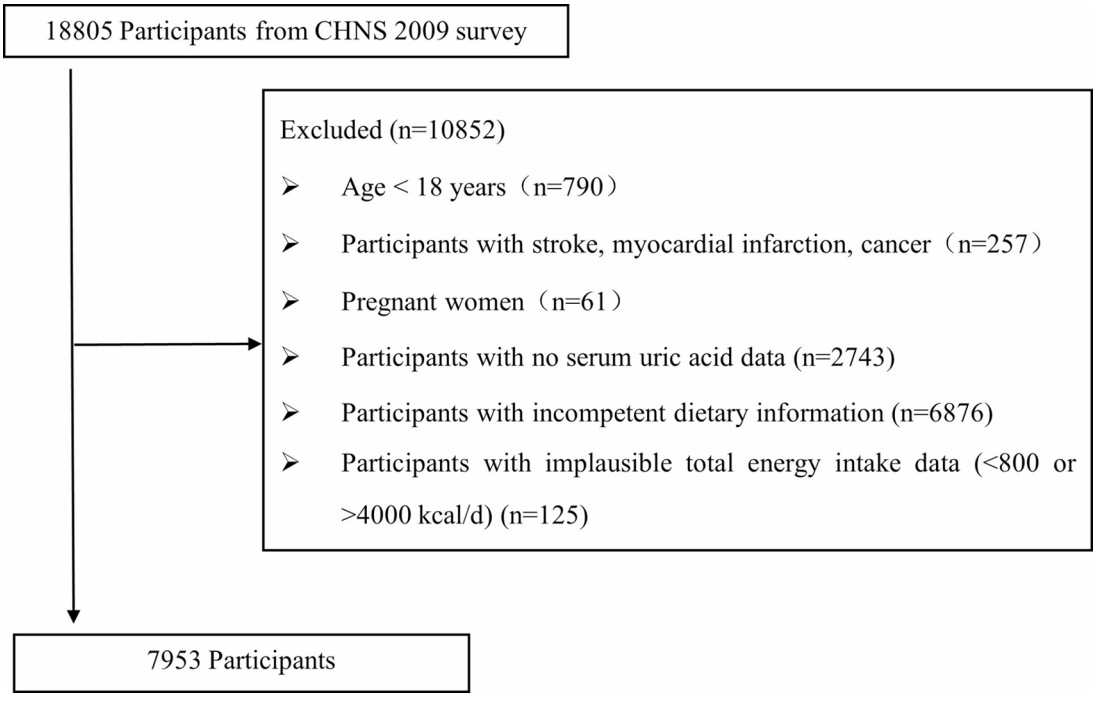

Fig. 1 Flow chart for inclusion and exclusion of eligible subjects

high in CoQ10 were pinpointed from the literature [19, 25, 26]. They were grouped into eight categories based on nutrition, culinary applications, and CoQ10 levels. The categories included a range of animal-based foods, such as meats and processed meat products, fish and shellfish, eggs, and dairy products, as well as plant-based foods, which included plant cooking oils, nuts and seeds, vegetables and their derivatives, and fruits and fruit products [27]. The average intake of CoQ10 from animal-based sources is likely higher than from plant-based sources. Comprehensive procedures for assessing diet in the CHNS have been previously described [28].

Assessment of covariates

In addition to diet, demographic characteristics, behavior and lifestyle information was also obtained by the questionnaire and physical examination, including age, sex, education level, region, physical activity, drinking status, smoking status, body mass index (BMI), total energy intake, hypertension, diabetes mellitus, total cholesterol (TC), triglyceride (TG), high density lipoprotein cholesterol (HDL-C). The types of physical activities encompassed work, home chores, leisure sports, and commuting [29]. The overall physical activity level was determined by adding up the duration of each activity, each weighted by its respective metabolic equivalent for task (MET) score [30]. The resulting aggregate score was then classified as 'Low', 'Moderate', or 'High', according to the distribution of total MET scores into thirds [31]. Hypertension was defined as a mean systolic blood pressure ≥ 140 mmHg or a mean diastolic blood pressure ≥ 90 mmHg, or a self-reported diagnosis of hypertension, or currently taking antihypertensive medication [32]. Diabetes mellitus was defined as fasting blood glucose ≥ 7.0 mmol/L, or the glycohemoglobin level ≥ 6.5%, or self-reported diagnosis of diabetes, or taking diabetes pills or insulin [33]. BMI was calculated as weight (kg) divided by height squared (m^2).

Statistical analysis

The general characteristics of the participants are presented as mean (standard deviation) for continuous variables, and categorical variables were presented as frequency and percentage. Chi-square test or student's t-test was applied to analyze the differences of participant characteristics between hyperuricemia group and non-hyperuricemia group. Multivariable logistic regression analysis was used to calculate odds ratios (ORs) and 95% confidence intervals (95% CIs) for the associations between intakes of dietary total dietary CoQ10, animal-derived CoQ10 and plant-derived CoQ10 and odds of having HUA. For these analyses, dietary coenzyme Q10 intake was categorized based on quartiles (quartile 1: <25th percentile, quartile 2: ≥25th to 50th percentile, quartile 3: ≥50th to 75th percentile, quartile 4: ≥75th percentile) with the lowest quartile as a reference. Two models were conducted in the study: model 1 was adjusted for age (continuous), sex, BMI (continuous), educational level (middle school or below, high school or college or above), region (urban or rural), smoking status (yes or

no), drinking status (yes or no), physical activity (low, medium and high), and total energy intake (continuous); model 2 was further adjusted for hypertension status (yes or no), diabetes status (yes or no), TC, TG and HDL-C levels (continuous). In addition, we used restricted cubic spline (RCS) functions with four knots to assess the dose-response relationships between the intake of dietary CoQ10 and HUA. Furthermore, the likelihood ratio test of the cross-product terms between dietary CoQ10 intake and effect modifiers was used to test the significance of interactions. Then, stratified analyses were conducted by sex (male or female), age (< 60 or ≥ 60 years), BMI (< 24 or ≥ 24 kg/m^2), smoking status (no or yes) and drinking status (no or yes) to determine the associations between dietary CoQ10 intake and HUA. Finally, sensitivity analyses have been carried out to examined whether the results would be different if CoQ10 consumption and serum uric acid were continuous variables. In this analysis, multivariable linear regression was utilized to examined the impact of dietary CoQ10 intake on serum uric acid levels with the correlation index (β) and its 95% confidence interval (CI). In addition, the OR may seriously overestimate the effect of exposure on outcomes if the prevalence of HUA is high (≥ 10%) [34]. We therefore performed log-binomial analyses to calculate prevalence ratios (PRs) with 95% CIs to examine the association between dietary CoQ10 and HUA [35]. In these analyses, all adjustments were treated as categorical variables: age (< 60 or ≥ 60 years), sex, BMI (< 24 or ≥ 24 kg/m^2), educational level (middle school or below, high school or college or above), region (urban or rural), smoking status (yes or no), drinking status (yes or no), physical activity, total energy intake (quartile 1: <25th percentile, quartile 2: ≥25th to 50th percentile, quartile 3: ≥50th to 75th percentile, quartile 4: ≥75th percentile), hypertension status (yes or no), diabetes status (yes or no), TC (< 5.2 or ≥ 5.2mmol/L), TG (<1.7or ≥ 1.7mmol/L) and HDL-C (< 0.91or ≥ 0.91mmol/L).

All data analyses were performed using R software version 4.2.1(http://www.R-project.org). All p-values are two-tailed and $p \leq 0.05$ was considered statistically significant.

Result

Baseline characteristics

According to the status of HUA, the comparisons of the baseline characteristics of the participants are shown in Table 1. A total of 7953 adult participants were eventually enrolled in this study, including 3712 (46.7%) men and 4241 (53.3%) women. The average age of the study population was 50.4 (SD, 14.9) years. Among these included subjects, the overall prevalence of HUA was 15.4% (20.2% in men; 11.3% in women). Overall, participants with HUA were older, more likely to be men, smokers and drinkers, have a higher prevalence of hypertension and diabetes. They also tended to have higher levels of education, BMI, TC, TG, along with greater dietary intakes of total and animal-derived CoQ10 when contrasted with participants without HUA (all p-values < 0.05). Furthermore, subjects with HUA exhibited a significant lower in physical activity, and serum HDL-C levels.

Association between dietary CoQ10 intake and HUA

The correlation between dietary CoQ10 intake and HUA was examined according to quartiles of dietary intakes of total, animal- and plant-derived CoQ10, as is presented in Table 2. In model 2, for the highest quartile compared to the lowest quartile, total CoQ10 (OR 1.40, 95%CI 1.15–1.70) and animal CoQ10 (OR 1.46, 95%CI 1.20–1.78) intake were positively associated with HUA, whereas plant-derived CoQ10 (OR 0.80, 95%CI 0.65–0.97) intake was inversely associated with HUA after adjustment for age, sex, BMI, education level, region, smoking status, alcohol consumption, total energy intake, physical activity, hypertension, diabetes, and total energy intake, TC, TG and HDL-C.

The non-linear relationship between dietary CoQ10 and HUA

The RCS analysis of the relationship between dietary CoQ10 and HUA was shown in Fig. 2. We observed a linear positive dose-response relationship (p overall < 0.001, p for nonlinearity = 0.950) between total dietary CoQ10 and HUA (Fig. 2A). Similarly, animal-derived CoQ10 intake was positively associated with the risk of HUA in a linear manner (p overall < 0.001, p for nonlinearity = 0.810, Fig. 2B). However, no significant association (Fig. 2C) was observed between plant-derived CoQ10 intake and the risk of HUA (p overall = 0.110, p for nonlinearity = 0.090).

Subgroup and sensitivity analyses

The results of stratified analyses based on potential risk factors for the association between total dietary CoQ10 intake and HUA are shown in (Table S1). We found that there were no significant interactions between sex, age, BMI, smoking status and hypertension and total dietary CoQ10 intake in relation to the HUA (p for interaction > 0.05 for all).

The results of sensitivity analysis are shown in (Table S2). Similar findings were obtained when we employed multiple linear regression to investigate the impact of dietary CoQ10 intake on serum uric acid levels as a continuous variable. Additionally, log-binomial analyses were utilized to explore the association between dietary CoQ10 and HUA, and the findings remained largely consistent (Table S3).

Table 1 Baseline characteristics of participants according to HUA status

Characteristic	Total	Hyperuricemia		*P* value
		No	Yes	
Participants (n, %)	7953	6725(84.5)	1228(15.4)	
Age, year	50.4 ±14.9	49.9±14.8	53.0 ±15.0	< 0.001
Sex, (n, %)				
male	3712(46.7)	2963 (79.8)	749 (20.2)	
female	4241(53.3)	3762 (88.7)	479 (11.3)	
BMI, kg/m^2	23.4 ± 3.47	23.1 ± 3.38	24.8 ± 3.60	0.001
Region (n, %)				< 0.001
Urban	2612 (32.8)	2129 (81.5)	483 (18.5)	
Rural	5341(67.2)	4596 (86.1)	745 (13.9)	
Education level (n, %)				< 0.001
Middle school or below	6064 (76.2)	5177 (85.4)	887 (14.6)	
High school	931 (11.7)	777 (83.5)	154 (16.5)	
College or above	958 (12.0)	771 (80.5)	187 (19.5)	
Physical activity level (n, %)				< 0.001
Low	2286 (28.7)	1908 (83.5)	378 (16.5)	
Medium	2715 (34.1)	2260 (83.2)	455 (16.8)	
High	2952 (37.1)	2557 (86.6)	395 (13.4)	
Drinking (n, %)				< 0.001
Yes	2623 (33.0)	2082 (79.4)	541 (20.6)	
No	5530(67.0)	4643 (87.1)	687 (12.9)	
Smoking (n, %)				< 0.001
Yes	2465 (31.0)	1993 (80.9)	472 (19.1)	
No	5488(69.0)	4732 (86.2)	756 (13.8)	
Hypertension (n, %)				< 0.001
Yes	2370 (29.8)	1831 (77.3)	539 (22.7)	
No	5583(70.2)	4894 (87.7)	689 (12.3)	
Diabetes (n, %)				< 0.001
Yes	867 (10.9)	635 (73.2)	232 (26.8)	
No	7086(89.1)	6090 (85.9)	2996 (14.1)	
TC (mg/dl)	187.8 ± 38.9	185.0 ± 37.8	203.0 ± 42.1	< 0.001
TG (mg/dl)	147.5 ± 131.3	127.0 ± 99.6	258.0 ± 207.0	< 0.001
HDL-C (mg/dl)	55.52 ± 18.8	56.6 ± 17.7	49.7 ± 23.3	< 0.001
Energy, kcal/day	2126 ± 608	2113± 606	2194± 616	< 0.001
Total dietary CoQ10 intake (mg/d)	2.42 ± 2.02	2.37 ± 1.96	2.74 ± 2.29	< 0.001
Animal-derived CoQ10 intake (mg/d)	2.01 ± 1.94	1.95 ± 1.89	2.31 ± 2.20	< 0.001
Plant-derived CoQ10 intake (mg/d)	0.42 ± 0.42	0.42 ± 0.41	0.43 ± 0.45	0.282

Continuous variables are presented as the mean ± standard deviation (SD), and categorical variables are presented as participants (percentage)

Abbreviations: BMI, body mass index; TC, total cholesterol; TG, triglyceride; HDL-C, high density lipoprotein cholesterol

Discussion

In this nationwide cross-sectional study, we extended evidence that a positive association between dietary CoQ10 intake and HUA after adjusting for major confounders in general Chinese adults. In detail, animal-sourced dietary CoQ10 positively associated with HUA, while plant-sourced dietary CoQ10 inversely associated with HUA. Notably, dose-response analyses showed similar largely linear relationships for dietary CoQ10 intake and HUA. In addition, this association was particularly pronounced in males, overweight population and alcohol consumers.

To our knowledge, this is the first study to explore the association between daily intake of dietary-derived CoQ10 and HUA. Population-based research has only investigated the impact of CoQ10 supplementation on serum uric acid in a limited number of small but well-designed trials. One RCT demonstrated that an 8-week regimen of 90 mg/day CoQ10 had no effect on the serum uric acid levels in moderately trained healthy men ($n = 12$) [21]. Contrarily, a study involving 23 chronic heart failure patients, conducted as a double-blind, placebo-controlled, cross-over factorial trial, demonstrated that a 100 mg/day CoQ10 supplement significantly decreased plasma uric acid levels compared to placebo after 16 weeks [20]. While plausible evidence has been established regarding the association between CoQ10 and uric

Table 2 The relationship of dietary CoQ10 intake with HUA

Dietary CoQ10 intake, mg/d	Case/Participants	Crude OR (95% CI)	Model 1[a] OR (95% CI)	Model 2[b] OR (95% CI)
Total intake				
Q1 (< 0.91)	267/1990	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Q2 (0.92 to < 2.03)	282/1987	1.07 (0.89,1.28)	1.11 (0.92,1.33)	1.07 (0.88,1.3)
Q3 (2.04 to < 3.45)	300/1988	1.15 (0.96,1.37)	1.12 (0.93,1.35)	1.08 (0.88,1.32)
Q4 (≥3.45)	379/1988	1.52 (1.28,1.80) **	1.43 (1.19,1.72) **	1.40 (1.15,1.70) **
P trend		< 0.001	< 0.001	0.001
Animal food derived				
Q1 (< 0.44)	255/1990	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Q2 (0.44 to < 1.64)	299/2007	1.19 (0.99,1.43)	1.21 (1.01,1.46) *	1.15 (0.94,1.4)
Q3 (1.64 to < 2.95)	307/1968	1.26 (1.05,1.50) *	1.26 (1.04,1.52) *	1.19 (0.97,1.45)
Q4 (≥2.95)	367/1988	1.54 (1.30,1.83) **	1.47 (1.22,1.77) **	1.46 (1.20,1.78) **
P trend		< 0.001	< 0.001	< 0.001
Plant food derived				
Q1 (< 0.13)	302/1992	1.00 (Ref.)	1.00 (Ref.)	1.00 (Ref.)
Q2 (0.44 to < 0.32)	314/1985	1.05 (0.89,1.25)	0.99 (0.83,1.18)	0.96 (0.79,1.15)
Q3 (0.32 to < 0.58)	299/1988	0.99 (0.83,1.18)	0.88 (0.74,1.06)	0.84 (0.70,1.02)
Q4 (≥0.58)	313/1988	1.05 (0.88,1.24)	0.85 (0.71,1.02)	0.80 (0.65,0.97) *
P trend		0.253	0.302	0.009

Model 1 was adjusted for age, gender, BMI, region, education background, physical activity level, smoking status, drinking status, and total energy intake

Model 2 was further adjusted for hypertension status, diabetes status, TC, TG and HDL-C

P trends were assessed by entering the dietary CoQ10 as a continuous variable

Abbreviations: OR, odds ratio; CI, confidence interval. $^{*}p < 0.05$; $^{**}p < 0.01$

acid. It should be noted that the studies employed CoQ10 doses much higher than those commonly consumed by the general public. Additionally, the high cost of CoQ10 supplementation poses a barrier to its widespread adoption. Considering that dietary sources provide a more accessible way to obtain CoQ10, researching the effects of dietary intake on HUA is crucial for public health.

Our study extend these findings by demonstrating a positive association of total dietary CoQ10 intake with the endpoint of HUA in general population. Moreover, in line with the positive associations observed in the current study, we previously showed in this population that individuals with higher dietary CoQ10 were positively correlated with triglycerides levels. These results might be partly due to the food sources of CoQ10. Typically, dietary CoQ10 was found higher concentrations in animal-based foods, such as animal viscera (beef, pork and chicken heart and liver), exceeding 50 mg/kg [19]. Notably, the most purine-rich foods are also found in meat products, such as seafood and fish [10, 36], especially animal viscera, which have purine concentrations that exceed 1,000 mg/100 g (with beef liver approximately 2706.0 mg/kg, pork liver 2752.1 mg/kg, and chicken liver 3170.0 mg/kg purine) [37]. This implies that an increase in dietary CoQ10 intake may be accompanied by an increase in purine consumption. Consequently, overconsumption purine-rich foods may lead to higher serum uric acid levels, making individuals more vulnerable to developing HUA [38]. Therefore, the deleterious effects of purines in foods of animal origin may, to some extent, counteract the protective effects of CoQ10 in the diet.

Interestingly, an inverse association between plant-derived CoQ10 intake and HUA was observed in our present study. Similar to our study, a previous cross-sectional study demonstrated that long-term adherence to the plant-based Mediterranean diet reduced the prevalence of HUA in older adults [39]. The Mediterranean diet exerts its beneficial effects may through its antioxidant-rich components, which can reduce the concentrations of pro-inflammatory cytokines, increase those of anti-inflammatory cytokines and attenuate oxidative stress caused by disordered purine metabolism [40]. Hence, it is plausible that HUA benefits may be partly derived from CoQ10 from plant-based dietary sources. We have also conducted an analysis of CoQ10 from various food categories, which warrants further investigation in our future studies.

Although the precise mechanisms by which CoQ10 intake modulates uric acid levels remain unclear, it is proposed that CoQ10 may exert its effects by influencing anti-inflammatory cytokines and reducing oxidative stress, both of which are key factors in the development and progression of HUA [41–44]. A meta-analysis indicates that CoQ10 supplementation significantly decreases MDA levels, and enhances total antioxidant capacity as well as the activity of antioxidant defense system enzymes [45]. Additionally, lipopolysaccharide (LPS) triggers cytokines like IFN-γ and IL-1β,

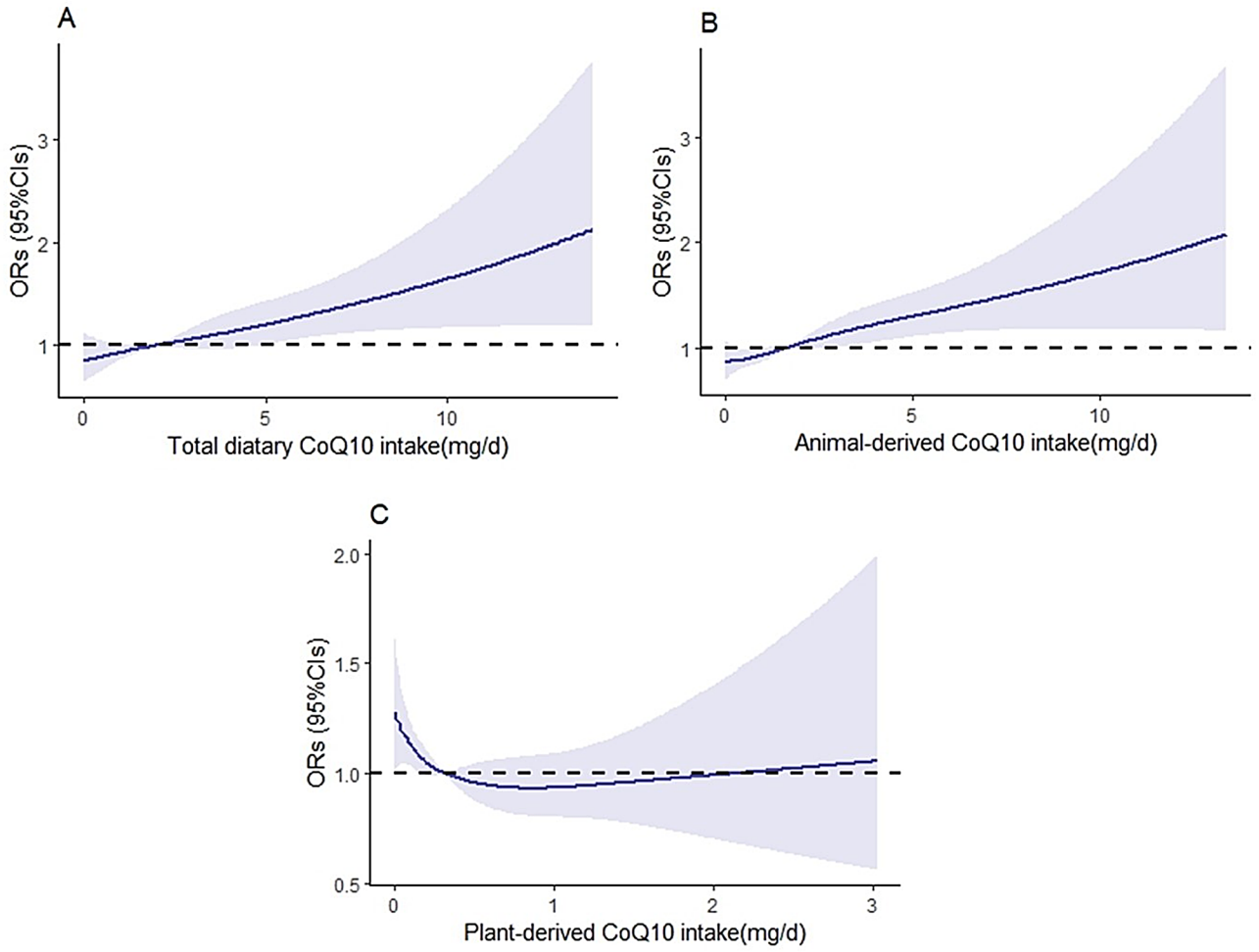

Fig. 2 Dose–response relationship between dietary CoQ10 intake and HUA by the restricted cubic spline model. (**A**) Total dietary CoQ10; (**B**) Animal-derived CoQ10; (**C**) Plant-derived CoQ10. The models were adjusted for age, gender, BMI, region, education background, physical activity level, smoking status, drinking status, and total energy intake, hypertension status, diabetes status, TC, TG and HDL-C. Solid lines represent point estimates and ribbons represent 95% CIs

boosting xanthine oxidase activity and uric acid production [46]. It has been observed that CoQ10 can alleviate LPS-induced oxidative stress and inflammation, processes that are regulated by the NLRP3 pathway [47]. In addition, prior studies indicated CoQ10 could potentially lower uric acid by modulating gut microbiota absorbs purine and adenine [48]. For example, *Lactobacillus* species facilitate the reduction of purine absorption in the intestine by producing enzymes such as uricase, allantoinase, and allantoicase [49]. Furthermore, gut microbiota metabolites promote uric acid excretion by providing energy for intestinal epithelial cells [50].

The present study has several strengths. Firstly, this study is the first to directly examine the relationship between dietary CoQ10 intake and HUA in general Chinese adults through a large, nationally representative longitudinal survey. Secondly, in contrast to previous studies that focused on supplements, we concentrated on dietary-derived CoQ10, exploring the dose-response association and providing the first recommendations for selecting CoQ10 dietary sources to prevent HUA. Lastly, sensitivity analyses were conducted to assess the robustness of our findings.

There are several limitations to consider when interpreting the results of our study. As this study was an observational study, we cannot exclude the possibility that unmeasured factors might contribute to the observed associations. Therefore, to establish a causal relationship between dietary CoQ10 and HUA, further prospective studies and intervention trials should be conducted. Another limitation is that our study was restricted to people of Chinese ancestry, and it is unknown whether our findings can be generalized to other demographic or ethnic groups. Finally, further studies are needed to investigate the mechanism of this association.

Conclusions

The results showed that dietary intake of total and animal-derived CoQ10 was positively associated with HUA, whereas plant-derived CoQ10 was negatively associated with HUA in the Chinese general adults. While a diet rich in plant-based foods may seem like a strategic approach for those at higher risk of HUA to increase CoQ10 intake, the relatively low levels of CoQ10 in such foods suggest that dietary sources alone may be insufficient. Consequently, isolated CoQ10 supplements could potentially offer a more effective means of supplementation. However, further investigation and research are needed to verify the efficacy of CoQ10 supplements in preventing HUA.

Abbreviations

HUA	Hyperuricemia
CoQ10	Coenzyme Q10
BMI	Body mass index
TC	total cholesterol
TG	triglyceride
HDL-C	high density lipoprotein cholesterol
CHNS	China Health and Nutrition Survey
RCT	randomized-controlled trials
RCS	restricted cubic spline
PR	prevalence ratios
OR	odds ratio
CI	confidence interval
DASH	Dietary Approaches to Stop Hypertension
LPS	lipopolysaccharide
IFN-γ	interferon-γ
IL-1β	interleukin-1β
NLRP3	NOD-like receptor protein 3
MDA	Malondialdehyde

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-21041-3.

Supplementary Material 1

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Author contributions

Y.Y. and Y.Z. designed the study. H.K. and D.Z. performed the data analysis and wrote the initial draft of the manuscript. Z.T., Y.L., Z.L., S.D., Y.Z., Z.Z. and L.L. contributed to the data cleaning. Y.Y. and Y.Z. contributed to the critical revision of the manuscript for important intellectual content and approved the final version of the manuscript. All authors critically reviewed the manuscript for important intellectual content. All authors have read and agreed to the published version of the manuscript.

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Data availability

All data used during the study are publicly available online from the China Health and Nutrition Survey (https://www.cpc.unc.edu/projects/china, accessed on 5th February, 2022).

Declarations

Ethics approval and consent to participate

This cross-sectional study used data from the CHNS. The research was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill, the China-Japan Friendship Hospital and the Chinese Centre for Disease Control and Prevention. All CHNS participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Ichida K, Matsuo H, Takada T, Nakayama A, Murakami K, Shimizu T, Yamanashi Y, Kasuga H, Nakashima H, Nakamura T, et al. Decreased extra-renal urate excretion is a common cause of hyperuricemia. Nat Commun. 2012;3:764.
2. Dalbeth N, Gosling AL, Gaffo A, Abhishek A. Gout. Lancet. 2021;397(10287):1843–55.
3. Singh G, Lingala B, Mithal A. Gout and hyperuricaemia in the USA: prevalence and trends. Rheumatology (Oxford). 2019;58(12):2177–80.
4. Trifirò G, Morabito P, Cavagna L, Ferrajolo C, Pecchioli S, Simonetti M, Bianchini E, Medea G, Cricelli C, Caputi AP, et al. Epidemiology of gout and hyperuricaemia in Italy during the years 2005–2009: a nationwide population-based study. Ann Rheum Dis. 2013;72(5):694–700.
5. Zhang M, Zhu X, Wu J, Huang Z, Zhao Z, Zhang X, Xue Y, Wan W, Li C, Zhang W, et al. Prevalence of Hyperuricemia Among Chinese Adults: Findings From Two Nationally Representative Cross-Sectional Surveys in 2015-16 and 2018-19. Front Immunol. 2021;12:791983.
6. [Chinese multi-disciplinary consensus. on the diagnosis and treatment of hyperuricemia and its related diseases]. Zhonghua nei ke za zhi. 2017;56(3):235–48.
7. He H, Guo P, He J, Zhang J, Niu Y, Chen S, Guo F, Liu F, Zhang R, Li Q, et al. Prevalence of hyperuricemia and the population attributable fraction of modifiable risk factors: Evidence from a general population cohort in China. Front Public Health. 2022;10:936717.
8. Zhu B, Li Y, Shi Y, Song N, Fang Y, Ding X. Long-term drinking behavior change patterns and its association with hyperuricemia in chinese adults: evidence from China Health and Nutrition Survey. BMC Public Health. 2022;22(1):1230.
9. Choi JWJ, Ford ES, Gao X, Choi HK. Sugar-sweetened soft drinks, diet soft drinks, and serum uric acid level: the Third National Health and Nutrition Examination Survey. Arthritis Rheum. 2008;59(1):109–16.
10. Choi HK, Atkinson K, Karlson EW, Willett W, Curhan G. Purine-rich foods, dairy and protein intake, and the risk of gout in men. N Engl J Med. 2004;350(11):1093–103.
11. Yokose C, McCormick N, Choi HK. Dietary and Lifestyle-Centered Approach in Gout Care and Prevention. Curr Rheumatol Rep. 2021;23(7):51.
12. Piao W, Li S, Guo Q, Cheng X, Xu X, Zhao L, Yu D. Bean and Nut Intake Were Protective Factors for Comorbid Hypertension and Hyperuricemia in Chinese Adults: Results from China Nutrition and Health Surveillance (2015–2017). Nutrients 2024, 16(2).
13. Piao W, Zhao L, Yang Y, Fang H, Ju L, Cai S, Yu D. The Prevalence of Hyperuricemia and Its Correlates among Adults in China: Results from CNHS 2015–2017. *Nutrients* 2022, 14(19).
14. Major TJ, Topless RK, Dalbeth N, Merriman TR. Evaluation of the diet wide contribution to serum urate levels: meta-analysis of population based cohorts. BMJ. 2018;363:k3951.

15. Guo Z, Zhang J, Wang Z, Ang KY, Huang S, Hou Q, Su X, Qiao J, Zheng Y, Wang L, et al. Intestinal Microbiota Distinguish Gout Patients from Healthy Humans. Sci Rep. 2016;6:20602.
16. Sun L, Ni C, Zhao J, Wang G, Chen W. Probiotics, bioactive compounds and dietary patterns for the effective management of hyperuricemia: a review. Crit Rev Food Sci Nutr. 2024;64(7):2016–31.
17. Danve A, Sehra ST, Neogi T. Role of diet in hyperuricemia and gout. Best Pract Res Clin Rheumatol. 2021;35(4):101723.
18. Cirilli I, Damiani E, Dludla PV, Hargreaves I, Marcheggiani F, Millichap LE, Orlando P, Silvestri S, Tiano L. Role of Coenzyme Q in Health and Disease: An Update on the Last 10 Years (2010–2020). Antioxid (Basel) 2021, 10(8).
19. Pravst I, Zmitek K, Zmitek J. Coenzyme Q10 contents in foods and fortification strategies. Crit Rev Food Sci Nutr. 2010;50(4):269–80.
20. Belardinelli R, Muçaj A, Lacalaprice F, Solenghi M, Seddaiu G, Principi F, Tiano L, Littarru GP. Coenzyme Q10 and exercise training in chronic heart failure. Eur Heart J. 2006;27(22):2675–81.
21. Ostman B, Sjödin A, Michaëlsson K, Byberg L. Coenzyme Q10 supplementation and exercise-induced oxidative stress in humans. Nutrition. 2012;28(4):403–17.
22. Zhang B, Zhai FY, Du SF, Popkin BM. The China Health and Nutrition Survey, 1989–2011. Obes Rev. 2014;15(Suppl 1):2–7.
23. Moliterno P, Donangelo CM, Borgarello L, Pécora M, Olascoaga A, Noboa O, Boggia J. Association of Dietary Patterns with Cardiovascular and Kidney Phenotypes in an Uruguayan Population Cohort. Nutrients 2021, 13(7).
24. Schlesinger N, Schumacher HR. Update on gout. Arthritis Rheum. 2002;47(5):563–5.
25. Weber C, Bysted A, Hølmer G. Coenzyme Q10 in the diet–daily intake and relative bioavailability. Mol Aspects Med. 1997;18(Suppl):S251–4.
26. Weber C, Bysted A, Hłlmer G. The coenzyme Q10 content of the average Danish diet. Int J Vitam Nutr Res. 1997;67(2):123–9.
27. Dai S, Tian Z, Zhao D, Liang Y, Zhong Z, Xu Y, Hou S, Yang Y. The Association between the Diversity of Coenzyme Q10 Intake from Dietary Sources and the Risk of New-Onset Hypertension: A Nationwide Cohort Study. *Nutrients* 2024, 16(7).
28. Zhao D, Tian Z, Kuang H, Xu Y, Zheng Y, Zhong Z, Liang L, Yang Y. Associations between Long-Term Dietary Coenzyme Q10 Intake and New-Onset Hypertension in Adults: Insights from a Nationwide Prospective Cohort Study. Nutrients 2024, 16(15).
29. Ng SW, Howard AG, Wang HJ, Su C, Zhang B. The physical activity transition among adults in China: 1991–2011. Obes Rev. 2014;15(Suppl 1):27–36.
30. Zou Q, Su C, Du W, Ouyang Y, Wang H, Zhang B, Luo S, Tan T, Chen Y, Zhong X et al. The Mediation and Moderation Effect Association among Physical Activity, Body-Fat Percentage, Blood Pressure, and Serum Lipids among Chinese Adults: Findings from the China Health and Nutrition Surveys in 2015. Nutrients 2023, 15(14).
31. Fan M, Lyu J, He P. [Chinese guidelines for data processing and analysis concerning the International Physical Activity Questionnaire]. Zhonghua liu xing bing xue za zhi = Zhonghua liuxingbingxue zazhi. 2014;35(8):961.
32. Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, DePalma SM, Gidding S, Jamerson KA, Jones DW et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension* 2018, 71(6).
33. Wang L, Peng W, Zhao Z, Zhang M, Shi Z, Song Z, Zhang X, Li C, Huang Z, Sun X, et al. Prevalence and Treatment of Diabetes in China, 2013–2018. JAMA. 2021;326(24):2498–506.
34. Strömberg U. Prevalence odds ratio v prevalence ratio. Occup Environ Med. 1994;51(2):143–4.
35. Deddens JA, Petersen MR. Approaches for estimating prevalence ratios. Occup Environ Med. 2008;65(7):481. 501 – 481, 506.
36. Villegas R, Xiang YB, Elasy T, Xu WH, Cai H, Cai Q, Linton MF, Fazio S, Zheng W, Shu XO. Purine-rich foods, protein intake, and the prevalence of hyperuricemia: the Shanghai Men's Health Study. Nutr Metab Cardiovasc Dis. 2012;22(5):409–16.
37. Zhao M, Tian Z, Zhao D, Liang Y, Dai S, Xu Y, Hou S, Yang Y. L-shaped association between dietary coenzyme Q10 intake and high-sensitivity C-reactive protein in Chinese adults: a national cross-sectional study. Food Funct 2023.
38. Aihemaitijiang S, Zhang Y, Zhang L, Yang J, Ye C, Halimulati M, Zhang W, Zhang Z. The Association between Purine-Rich Food Intake and Hyperuricemia: A Cross-Sectional Study in Chinese Adult Residents. Nutrients 2020, 12(12).
39. Chrysohoou C, Skoumas J, Pitsavos C, Masoura C, Siasos G, Galiatsatos N, Psaltopoulou T, Mylonakis C, Margazas A, Kyvelou S, et al. Long-term adherence to the Mediterranean diet reduces the prevalence of hyperuricaemia in elderly individuals, without known cardiovascular disease: the Ikaria study. Maturitas. 2011;70(1):58–64.
40. Sun L, Ni C, Zhao J, Wang G, Chen W. Probiotics, bioactive compounds and dietary patterns for the effective management of hyperuricemia: a review. Crit Rev Food Sci Nutr 2022.
41. Lee B-J, Tseng Y-F, Yen C-H, Lin P-T. Effects of coenzyme Q10 supplementation (300 mg/day) on antioxidation and anti-inflammation in coronary artery disease patients during statins therapy: a randomized, placebo-controlled trial. Nutr J. 2013;12(1):142.
42. Mohamed HA, Said RS. Coenzyme Q10 attenuates inflammation and fibrosis implicated in radiation enteropathy through suppression of NF-kB/TGF-β/MMP-9 pathways. Int Immunopharmacol. 2021;92:107347.
43. Mazidi M, Kengne AP, Banach M. Effects of coenzyme Q10 supplementation on plasma C-reactive protein concentrations: A systematic review and meta-analysis of randomized controlled trials. Pharmacol Res. 2018;128:130–6.
44. Su H-Y, Yang C, Liang D, Liu H-F. Research Advances in the Mechanisms of Hyperuricemia-Induced Renal Injury. *Biomed Res Int* 2020, 2020:5817348.
45. Akbari A, Mobini GR, Agah S, Morvaridzadeh M, Omidi A, Potter E, Fazelian S, Ardehali SH, Daneshzad E, Dehghani S. Coenzyme Q10 supplementation and oxidative stress parameters: a systematic review and meta-analysis of clinical trials. Eur J Clin Pharmacol. 2020;76(11):1483–99.
46. Singh D, Kumar V, Singh C. IFN-γ regulates xanthine oxidase-mediated iNOS-independent oxidative stress in maneb- and paraquat-treated rat polymorphonuclear leukocytes. Mol Cell Biochem. 2017;427(1–2):133–43.
47. Chen Y, Yang H, Hu X, Yang T, Zhao Y, Liu H, Fan H. Coenzyme Q10 ameliorates lipopolysaccharide-induced acute lung injury by attenuating oxidative stress and NLRP3 inflammation through regulating mitochondrial dynamics. Int Immunopharmacol. 2024;141:112941.
48. Yamada N, Iwamoto C, Kano H, Yamaoka N, Fukuuchi T, Kaneko K, Asami Y. Evaluation of purine utilization by Lactobacillus gasseri strains with potential to decrease the absorption of food-derived purines in the human intestine. Nucleosides Nucleotides Nucleic Acids. 2016;35(10–12):670–6.
49. Hsieh C-Y, Lin H-J, Chen C-H, Lai EC-C, Yang Y-HK. Chronic kidney disease and stroke. Lancet Neurol. 2014;13(11):1071.
50. Wu J, Wang K, Wang X, Pang Y, Jiang C. The role of the gut microbiome and its metabolites in metabolic diseases. Protein Cell. 2021;12(5):360–73.

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