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Association of alcohol abstinence with risk of hyperuricemia in rural Chinese adults: the Henan Rural Cohort Study

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Abstract

Background Alcohol drinking can cause hyperuricemia (HUA), but few studies have explored alcohol abstinence's health effects, particularly the abstinence duration on HUA. This study aimed to evaluate the associations of abstinence with HUA in rural Chinese adults.

Methods This was a cross-sectional study of 38,855 participants (15,371 males and 23,484 females) using the baseline data (2015–2017) from the Henan Rural Cohort Study. A questionnaire survey collected information on alcohol consumption patterns. Multivariate logistic regression analyses were used to evaluate the associations of type of alcoholic beverages, abstinence status and abstinence duration with HUA, respectively. Restricted cubic spline models were applied to visualize the dose-response trend of HUA risk with increasing abstinence duration.

Results 3,978 cases of 38,855 participants were identified with HUA. Total alcohol intake, including beer, liquor and rice wine intake was significantly associated with the increased risk of HUA, especially for male participants. Compared with current drinkers, former drinkers and non-drinkers presented lower *ORs* (95%*CIs*) of 0.686 (0.676, 0.844) and 0.718 (0.649, 0.793) for HUA. Furthermore, the a*ORs* (95%*CIs*) for those former drinkers with < 5, 6–10 and ≥ 11 years abstinence duration were 0.868 (0.693, 1.086), 0.753 (0.519, 1.092) and 0.717 (0.517, 0.990), respectively. In addition, the risk of HUA decreased with the increasing years of abstinence duration (*P* for trend < 0.050) and negative linear dose-response associations were observed.

Conclusion Former drinkers were associated with a reduced risk of HUA compared with current drinkers. Moreover, sustained alcohol abstinence could be beneficial for preventing HUA.

Clinical Trial Registration The Henan Rural Cohort Study was registered on the Chinese Clinical Trial Register (Registration number: ChiCTR-OOC-15006699). Date of registration: 2015-07-06 http://www.chictr.org.cn/showproj.aspx?proj=11375.

Keywords Drinking status, Alcohol abstinence, Hyperuricemia, Alcoholic beverages, Rural adults

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Background

Hyperuricemia (HUA) is the leading risk factor for gout, and it has emerged as a significant public health concern due to its high prevalence worldwide [1, 2]. Many epidemiological studies have found hyperuricemia to be closely related to multiple chronic disorders such as hypertension, type 2 diabetes mellitus (T2DM), and cardiovascular disease [3–6]. Hyperuricemia prevalence has increased markedly in recent years. In China, the latest nationwide survey shows that the prevalence of HUA was 13.7–18.8% in 31 provinces [7], significantly higher than the 8.4% among Chinese adults in 2009–2010 [8]. Significant escalating trends of HUA prevalence were also observed between 2015 and 2016 and 2018–2019 [9]. Therefore, the current management of the prevalence of HUA is still essential.

The consumption of purine-rich foods and beverages, including meat, seafood, and alcohol has traditionally been considered a significant risk factor for HUA [10, 11]. A strong relationship between alcohol consumption and elevated serum uric acid has been consistently confirmed by many epidemiology studies [12–14]. While these studies mainly focused on the association of total alcohol intake or daily or weekly alcohol intake with HUA, less attention has been paid to the effect of different drinking types and abstinence status with HUA. In particular, the benefits of abstinence are being promoted due to the various health hazards of drinking alcohol [15]. However, no population-based studies have demonstrated the effect of alcohol abstinence on HUA.

Moreover, several large sample studies suggested that the risk of HUA could vary depending on the individual type of alcoholic beverages (i.e., beer, liquor, and wine) in America, Brazil, Japan and Australia [14, 16–19]. However, considering the differences in the regional economy, ethnicity, etc., most of these studies on the associations of alcohol with HUA were conducted in developed countries or high-income regions. Whether these conclusions can be extrapolated to low-income countries or regions with limited resources is uncertain.

Alcohol consumption is one of the leading risk factors for death and disease worldwide. International studies have recently found that alcohol-related harms appear more prevalent in rural and remote regions than in urban areas [20]. Meanwhile, drinking alcohol is becoming a normal part of the daily diet among the Chinese rural population [21]. For those at high risk of drinking in rural areas, abstinence seems to become imperative for healthy living. Moreover, the prevalence of HUA has also been high in rural China [22]. Therefore, an in-depth exploration of the relationship between drinking status including abstinence and HUA in rural China, will provide valuable public health advice on the prevention of HUA. Given this, based on the Henan rural Cohort Study, the main objective of this study was to investigate the associations between abstinence status, including abstinence duration and the risk of HUA in rural Chinese adults [23]. In addition, associations of total alcohol intake and type of alcoholic beverages with HUA were to be examined.

Methods

Study population

Detailed descriptions of the Henan Rural Cohort Study design and eligibility criteria have been previously described [24, 25]. This aforementioned study was conducted in 5 rural regions of Henan province in China from July 2015 to September 2017. In brief, 41,893 participants were invited and 39,259 participants (93.7%) aged 18–79 years old were enrolled to complete a questionnaire and physical measurements at baseline.

In the present cross-sectional study, those participants with previously diagnosed cancer ($n=322$) or missing data for serum urate levels ($n=54$) or who had serious renal disease ($n=18$) were excluded. The final analyses included 38,855 participant. (see Supplementary Figure S1). Each participant included completed a written informed consent. The Zhengzhou University Life Science Ethics Committee approved the study.

Ascertainment of hyperuricemia

Venous blood samples were drawn from the subjects who had been fasting overnight. The serum was separated at a rate of 2000 revolutions per minute for 10 min, four times, and stored at -20˚C. Serum urate level was measured by ROCHE Cobas C501 automatic biochemical analyzer using the enzymatic colourimetric method. In the present study, HUA was universally defined as serum urate level > 7.0 mg/dL (417μmol/L) in male and serum urate level > 6.0 mg/dL (357μmol/L) in female [22].

Information on drinking status and abstinence

Alcohol consumption was collected through a face-to-face interview questionnaire, which included screening questions to distinguish drinking status (non-drinkers, current drinkers, and former drinkers) [24]. Participants were asked whether they had ever consumed alcoholic drinks, and if they had, they were asked whether they were former or current drinkers. Current drinkers were further asked to report their frequency of alcohol intake (daily, weekly, monthly, yearly, or never), average amount and type of alcoholic beverage (beer, liquor, red wine, and rice wine) in the past 12 months. Participants reported their usual average consumption for each beverage in the preceding year. We used standard units to estimate these alcoholic beverages' consumption: a bottle (500 g) for beer, a Liang (50 g) for liquor, red wine, and rice wine; then, the daily consumption (g/day) of each beverage was computed by its alcohol content. In the final, total daily alcohol intake was calculated by summing the values. According to the WHO drinking risk levels standard [26], total alcohol intake was also grouped into the following four categories: Non-drinker, total alcohol intake = 0 g/d; Moderate, 0 < total alcohol intake ≤ 25 g/d for male, 0 < total alcohol intake ≤ 15 g/d for female; Heavy, 25 < total alcohol intake ≤ 60 g/d for male, 15 < total alcohol intake ≤ 40 g/d for female; Severe, total alcohol intake > 60 g/d for male and total alcohol intake > 40 g/d for female [21].

Moreover, for former drinkers (people who used to drink alcohol and now do not drink alcohol are considered abstainers), the duration of abstinence (years) was calculated by subtracting the age at which alcohol consumption stopped from the age at which data were collected [21]. Then, the abstinence duration was categorized into ≤ 5 years, 6–10 years, and ≥ 11 years.

Data collection and assessment of covariates

Detailed information regarding sociodemographic characteristics (gender, age, marital status, educational level, average monthly income) and lifestyle factors (physical activity, smoking and drinking status) were collected by the trained public health investigators using a standardized questionnaire through face-to-face interviews [27]. Marital status included married/living together and divorced/widowed/separated and unmarried. Education levels were divided into two groups: primary school or below and middle school or above. Average monthly income was grouped by < 500 Chinese Yuan (CNY), 500–1000 CNY and > 1000 CNY. Both smoking and drinking status were classified into current, former and never groups. Physical activity included light, moderate and vigorous [28]. Height and weight were measured by trained physicians, and body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). The average daily intake of staple food, red meat, white meat, fish, milk, eggs, vegetables, fruits, grains, nuts, beans and animal oil were derived from a validated food frequency questionnaire (FFQ). The FFQ assessment of dietary intake is a valid and reliable method for assessing average dietary consumption [29].

Statistical analysis

All statistical analyses were performed using SPSS version 21.0 and R software version 3.5.3. According to HUA status, the basic characteristics of study participants were presented as the mean (standard deviation, SD) or median (interquartile range, IQR) for continuous variables and number (percentage) for categorical variables. To compare the differences between groups, categorical and continuous variables were analyzed by the Chi-square test and Student's t-test, respectively.

First, multivariate logistic regression analysis was performed to investigate the association between total alcohol intake and HUA according to the WHO risk drinking levels, and the non-drinkers was considered the reference group. Effect estimates are presented as odd ratios (*ORs*) and corresponding 95% confidence intervals (*CIs*). *P* for linear trend was tested in all consumers by entering the different categories of drinking levels as ordinal categorical variables in regression models. Then, we also used logistic regression to explore the association of alcoholic beverage type with the risk of HUA. In this analysis, we treat the intake of each alcoholic beverage, including total alcohol intake as continuous variables. The estimates were presented as effects of per 10 g/day increase in each alcoholic beverage intake on the risk of HUA.

To explore the effect of abstinence on HUA prevalence, the crude and age-adjusted prevalence of HUA was compared among different groups of drinking status and abstinence duration. Furthermore, logistic regression analysis was separately employed to evaluate the association of drinking status or abstinence duration with HUA, with current drinkers as the reference group. Additionally, for the relationship between abstinence duration with HUA, restricted cubic spline models were applied to visualize the dose-response trend of HUA risk with increasing years of abstinence duration.

Two main models were fitted for these logistic analyses: Model 1, adjusted for age and gender (only for total population); Model 2, adjusted for age, gender, body mass index, education level, marital status, averaged monthly income, smoking, physical activity and statistically significant food group variables related with HUA (red-meat, white-meat, fish, egg, milk, vegetable, fruit and bean). In exploring the association between alcoholic beverage type and HUA risk, model 2 was additionally adjusted for other groups of alcoholic beverages. Moreover, given the strong correlation between age and length of abstinence, an unadjusted model was also presented to explore the association between abstinence duration and HUA risk.

All *P* values are two-sided, and $P < 0.050$ was considered statistically significant.

Result

General characteristics

Table 1 presents the general characteristics of the 38,855 individuals according to their HUA status. Among these participants, 3,978 (10.23%) cases of HUA were identified. The mean age was 55.56 ± 12.21 years, and 60.44% were female. Participants with HUA were younger, male, unmarried and were more frequently current smokers and drinkers (all $P < 0.001$), compared with Non-HUA participants. Moreover, they had a higher education level, average monthly income and BMI. They consumed more food groups, including staple food, red meat, white

Table 1 Basic characteristics of study participants with and without HUA ($n = 38855$)

Characteristics	Total ($n = 38855$)	Non-HUA ($n = 34877$)	HUA ($n = 3978$)	*P*-value
Age (year, mean ± SD)	55.56 ± 12.21	55.74 ± 12.05	54.04 ± 13.43	< 0.001
Gender (n, %)				< 0.001
Male	15,371 (39.56)	13,403 (87.19)	1968 (12.81)	
Female	23,484 (60.44)	21,474 (91.44)	2010 (8.56)	
Education level (n, %)				< 0.001
≤Primary school	17,385 (44.74)	15,748 (90.58)	1637 (9.42)	
≥Middle school	21,470 (55.26)	19,129 (89.10)	2341 (10.90)	
Marital status (n, %)				< 0.001
Married/living together	34,872 (89.75)	31,309 (89.78)	3563 (10.22)	
Divorced/widowed/separated	3376 (8.69)	3056 (90.52)	320 (9.48)	
Unmarried	607 (1.56)	512 (84.35)	95 (15.65)	
Average monthly income (n, %)				< 0.001
< 500 CNY	13,837 (35.61)	12,432 (89.85)	1405 (10.15)	
500–1000 CNY	12,795 (32.93)	11,608 (90.72)	1187 (9.28)	
> 1000 CNY	12,223 (31.46)	10,837 (88.66)	1386 (11.34)	
Smoking status (n, %)				< 0.001
Nonsmokers	28,260 (72.73)	25,628 (90.69)	2632 (9.31)	
Former smokers	3134 (8.07)	2739 (87.40)	395 (12.60)	
Current smokers	7461 (19.20)	6510 (87.25)	951 (12.75)	
Drinking status (n, %)				< 0.001
Non-drinkers	30,018 (77.26)	27,323 (91.02)	2695 (8.98)	
Former drinkers	1796 (4.62)	1610 (89.64)	186 (10.36)	
Current drinkers	7041 (18.12)	5944 (84.42)	1097 (15.58)	
Physical activity, n (%)				< 0.001
Light	12,563 (32.33)	11,077 (88.17)	1486 (11.83)	
Moderate	14,644 (37.69)	13,222 (90.29)	1422 (9.71)	
Vigorous	11,648 (29.98)	10,578 (90.81)	1070 (9.19)	
BMI (kg/m^2), mean ± SD	24.83 ± 3.57	24.62 ± 3.49	26.66 ± 3.73	< 0.001
Staple-food (g/day), mean ± SD	422.72 ± 155.33	422.65 ± 155.07	423.30 ± 157.64	0.805
Red-meat (g/day), median (IQR)	16.67 (36.19)	14.29 (36.19)	21.42 (42.86)	< 0.001
White-meat (g/day), median (IQR)	6.67 (15.30)	6.67 (15.30)	8.33 (19.24)	< 0.001
Fish (g/day), median (IQR)	1.37 (4.66)	1.37 (4.11)	2.05 (6.85)	< 0.001
Egg (g/day), mean ± SD	55.45 ± 44.98	55.51 ± 44.92	54.90 ± 45.54	0.420
Milk (g/day), median (IQR)	0 (16.67)	0 (16.67)	0 (25.42)	0.002
Vegetable intake (g/d), mean ± SD	317.40 ± 180.73	315.89 ± 179.91	330.70 ± 187.32	0.003
Fruit intake (g/d), mean ± SD	140.16 ± 137.03	139.43 ± 136.32	146.56 ± 143.00	< 0.001
Beans (g/day), median (IQR)	16.67 (37.86)	16.67 (37.86)	16.67 (36.19)	0.583
Nut (g/day), median (IQR)	6.85 (21.16)	6.85 (21.16)	7.14 (20.75)	0.097
Grains (g/day), median (IQR)	35.71 (86.67)	35.71 (86.67)	35.71 (86.67)	0.708
Animal oil (g/day), median (IQR)	0 (0)	0 (0)	0 (0)	0.320

HUA, hyperuricemia; SD, standard deviation; CNY, Chinese Yuan; BMI, body mass index; IQR, interquartile range

meat, fish, milk, vegetable and fruit (all $P < 0.050$). However, compared with non-HUA participants, participants with HUA had lower physical activity levels ($P < 0.001$). In addition, significant group differences in drinking status and alcohol intake between male and female are shown in Supplemental Table S1.

Association between total alcohol intake and hyperuricemia

Total alcohol intake at all levels was significantly related to increased risk of HUA in the total population and male participants according to the WHO risk drinking levels (both *P* for trend < 0.001) (Table S2). Among the total population, compared with non-drinkers, the adjusted *ORs* (a*ORs*) and 95% *CIs* in moderate, heavy and severe drinkers were 1.157 (1.037,1.291), 1.543 (1.332, 1.788) and 1.556 (1.326, 1.827) in model 2, respectively. But for female, no significant association was found.

Risk of HUA according to the type of alcoholic beverage intake

Figure 1 and Table S3 show that the HUA risk elevated with increasing total alcohol, beer or liquor intake among the total population and male participants (all *P* for trend < 0.001). After adjusting for age and gender, per 10 g/day increment of alcohol content in total alcohol, beer and liquor intake was associated with 1.025 (95% *CI*: 1.016, 1.035), 1.121 (1.066, 1.180) and 1.027 (1.017, 1.037) times risk of HUA, respectively. After adjusting for all covariates, including other groups of alcoholic beverages, the a*ORs* (95%*CIs*) of HUA for total alcohol, beer and liquor intake (per 10 g/day increment) was 1.025 (95%*CI*: 1.016, 1.035), 1.121 (1.062, 1.183) and 1.019 (1.009, 1.030), respectively. In addition, the magnitudes of these associations with different alcoholic beverages were larger among those who drank rice wine and beer than liquor for male participants. However, no significant association was found with any alcoholic beverage intake for female (Fig. 1 and Table S3).

Prevalence of HUA according to the drinking status and abstinence duration

In Fig. 2, the crude prevalence of HUA was lower among non-drinkers (15.6% and 16.4%) and former drinkers (9.0% and 10.2%) than current drinkers (10.4% and 10.5%) in the overall population and male participants. Similar results were also observed for HUA's age and gender-adjusted prevalence among different groups. Moreover, the crude and age and gender-adjusted prevalence of HUA decreased with increasing abstinence duration in the overall population and male participants compared with the current drinkers.

Association between drinking status, abstinence duration and hyperuricemia

Associations between drinking status and HUA are shown in Table 2. After adjusting for the potential confounding factors (Model 2), compared with the current drinkers, the odds of HUA was significantly lower among both non-drinkers (a*OR* = 0.718 (95%*CI*: 0.649, 0.793)) and former drinkers (a*OR* = 0.686 (0.577, 0.816)). Similarly, among male participants, the a*OR* (95%*CI*) was 0.755 (0.676, 0.844) for non-drinkers, 0.788 (0.659, 0.942) for former drinkers, compared with the current drinkers. Among female participants, no significant association was found.

Furthermore, the associations of abstinence duration with HUA are presented in Table 3. In the total population, compared with the current drinkers, the odds of HUA decreased with the increasing years of abstinence duration (all *P* for trend < 0.05). After adjustment for all

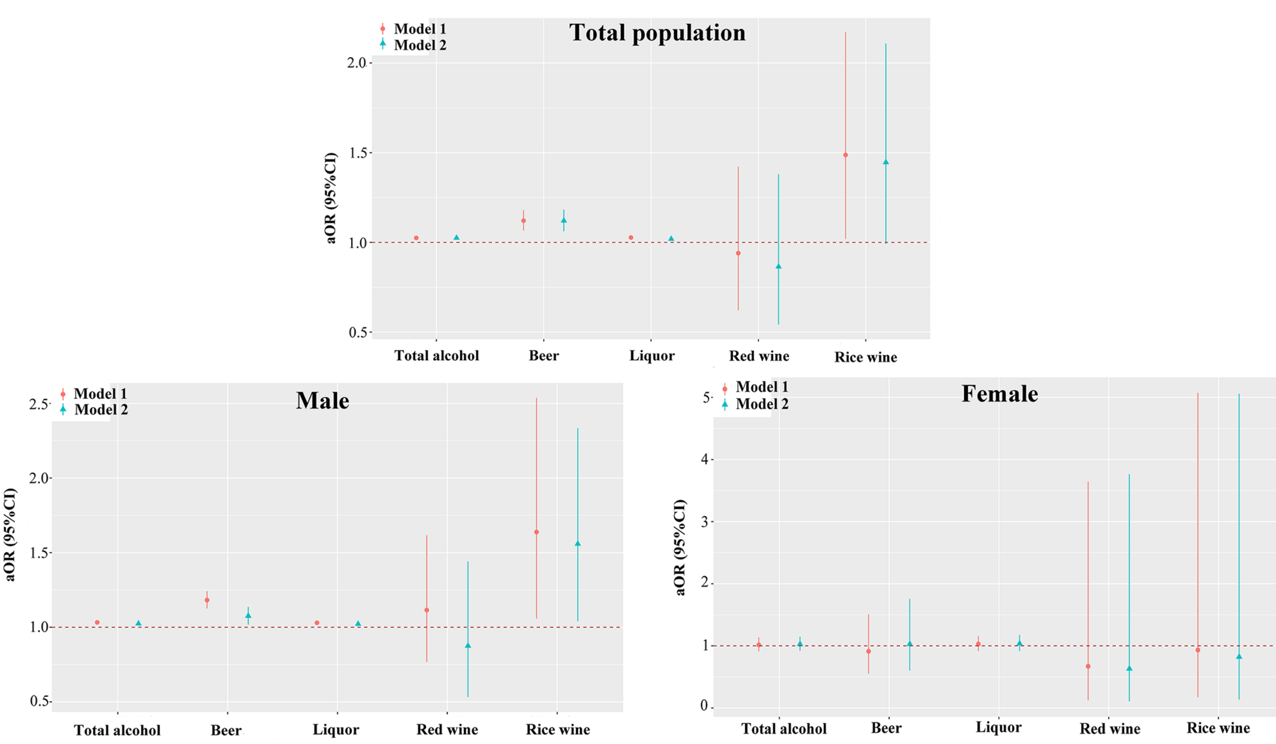

Fig. 1 Categories of alcoholic beverages intake (per 10 g/day increment) and hyperuricemia by gender. Model 1: Adjusted age and gender. Model 2: Adjusted for age, gender, body mass index, education level, marital status, averaged monthly income, smoking, physical activity, red-meat (g/day), white-meat (g/day), fish (g/day), egg (g/day), milk (g/day), vegetable intake (g/d), fruit intake (g/d), bean (g/d)

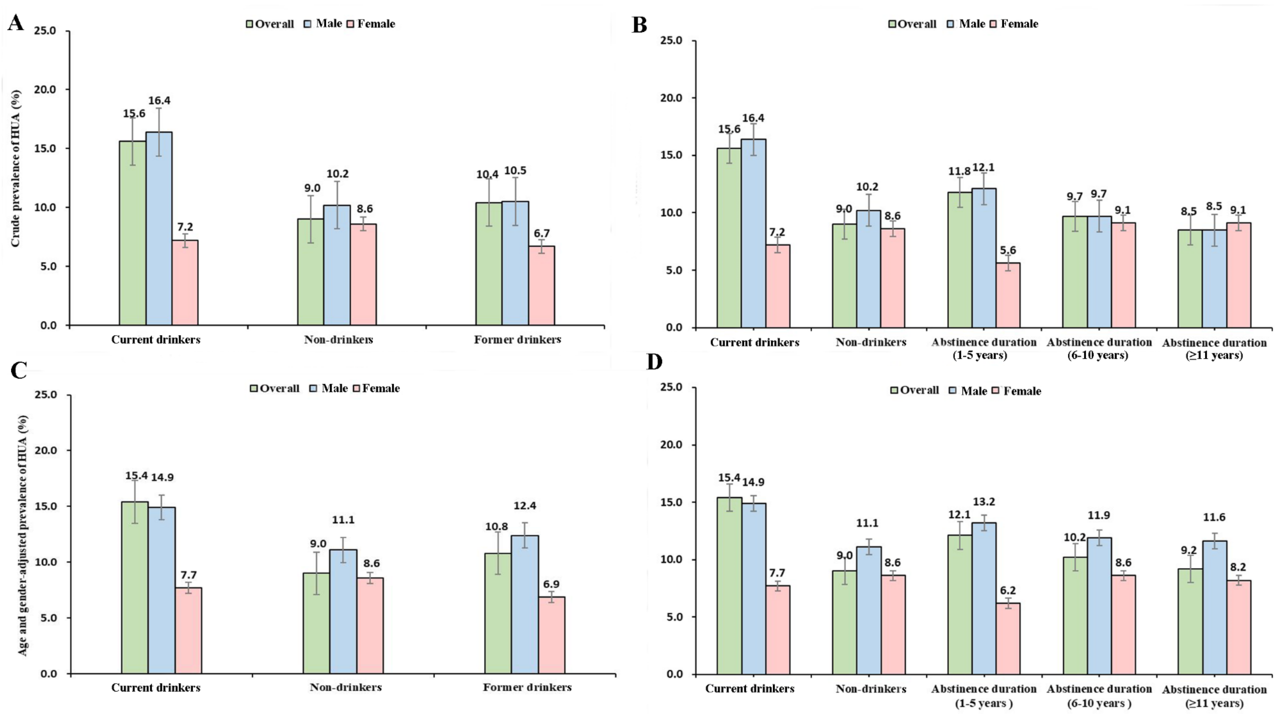

Fig. 2 Prevalence of HUA according to the drinking status and abstinence duration. Bars represent proportion and error bar 95% CI. (**A**) and (**B**) Crude prevalence of HUA by drinking status and abstinence duration; (**C**) and (**D**) Age and gender-adjusted prevalence of HUA by drinking status and abstinence duration

Table 2 Association between drinking status and hyperuricemia ($N = 38855$)

Variable	**Drinking status, aOR (95%CI)**		
	Current drinkers	**Non-drinkers**	**Former drinkers**
Total population			
Model 1	**1.00 (Reference)**	0.668 (0.608, 0.733)	0.669 (0.566, 0.790)
Model 2	**1.00 (Reference)**	0.718 (0.649, 0.793)	0.686 (0.577, 0.816)
Male			
Model 1	**1.00 (Reference)**	0.695 (0.627, 0.771)	0.806 (0.679, 0.957)
Model 2	**1.00 (Reference)**	0.755 (0.676, 0.844)	0.788 (0.659, 0.942)
Female			
Model 1	**1.00 (Reference)**	1.139 (0.835, 1.555)	0.884 (0.306, 2.555)
Model 2	**1.00 (Reference)**	1.152 (0.839, 1.582)	1.106 (0.346, 2.980)

Model 1: Adjusted for age and gender (only for total population)

Model 2: Adjusted for age, gender, body mass index, education level, marital status, averaged monthly income, smoking, physical activity, red-meat (g/day), white-meat (g/day), fish (g/day), egg (g/day), milk (g/day), vegetable (g/d), fruit (g/d), bean (g/d)

potential confounders, the a*ORs* (95%*CIs*) for those former drinkers with < 5, 6–10 and ≥ 11 years duration was 0.868 (0.693, 1.086), 0.753 (0.519, 1.092) and 0.717 (0.517, 0.990), respectively. Similar associations between abstinence duration and risk of HUA were observed in male participants. Among female participants, however, we did not find any significant associations. In addition, negative linear dose-response associations were noted between years of abstinence duration and prevalence of HUA in the total population and male participants in Fig. 3 (all P for non-linearity > 0.05).

Discussion

To our knowledge, this study is the first to assess the associations of drinking status, including abstinence duration with HUA in rural China. The results of this large sample cross-sectional study indicate that increases in total alcohol intake at all levels were significantly associated with a greater risk of HUA in the total population and male participants according to the WHO risk drinking levels. Moreover, when grouped by types of alcoholic beverages, beer, liquor and rice wine, but not wine, were positively associated with the HUA risk in male participants. For the total population and male participants,

Table 3 The association of abstinence duration with hyperuricemia ($N = 8837$)

Abstinence duration	Un-adjusted model	Model 1	Model 2
	OR (95%CI)	**aOR (95%CI)**	**aOR (95%CI)**
Total population			
Current drinkers	**1.00 (Reference)**	**1.00 (Reference)**	**1.00 (Reference)**
Non-drinkers	0.534 (0.496, 0.576)	0.668 (0.608, 0.733)	0.718 (0.649, 0.793)
Abstinence duration			
≤ 5 years	0.728 (0.589, 0.900)	0.860 (0.693, 1.067)	0.868 (0.693, 1.086)
6–10 years	0.583 (0.407, 0.835)	0.762 (0.529, 1.098)	0.753 (0.519, 1.092)
≥ 11 years	0.502 (0.367, 0.685)	0.702 (0.510, 0.966)	0.717 (0.517, 0.990)
***P* for trend**	< 0.001	0.006	0.002
Male			
Current drinkers	**1.00 (Reference)**	**1.00 (Reference)**	**1.00 (Reference)**
Non-drinkers	0.579 (0.523, 0.640)	0.695 (0.627, 0.771)	0.755 (0.676, 0.844)
Abstinence duration			
≤ 5 years	0.704 (0.568, 0.872)	0.881 (0.708, 1.097)	0.857 (0.684, 1.073)
6–10 years	0.551 (0.382, 0.794)	0.770 (0.532, 1.115)	0.742 (0.511, 1.078)
≥ 11 years	0.472 (0.344, 0.648)	0.716 (0.518, 0.989)	0.682 (0.492, 0.947)
***P* for trend**	< 0.001	0.012	0.005
Female			
Current drinkers	**1.00 (Reference)**	**1.00 (Reference)**	**1.00 (Reference)**
Non-drinkers	1.208 (0.886 1.648)	1.139 (0.835, 1.555)	1.152 (0.839, 1.582)
Abstinence duration			
≤ 5 years	0.755 (0.176, 3.248)	0.767 (0.177, 3.332)	0.871 (0.192, 3.945)
6–10 years	1.284 (0.161, 10.262)	1.029 (0.128, 8.288)	0.838 (0.096, 7.280)
≥ 11 years	1.284 (0.161, 10.262)	0.909 (0.111, 7.419)	0.419 (0.033, 5.391)
***P* for trend**	0.892	0.854	0.511

Model 1: Adjusted for age and gender (only for total population)

Model 2: Adjusted for age, gender, body mass index, education level, marital status, averaged monthly income, smoking, physical activity, red-meat (g/day), white-meat (g/day), fish (g/day), egg (g/day), milk (g/day), vegetable (g/d), fruit (g/d), bean (g/d)

compared with the current drinkers, both non-drinkers and former drinkers were significantly associated with a lower risk of HUA. More importantly, the odds of HUA decreased gradually with increasing years of abstinence duration, presented in a linear dose-response trend.

Most previous studies on the associations between alcohol intake and HUA or gout were conducted in developed countries or high-income regions like the USA [14, 16], Australia [18], Japan [12, 19] and Singapore [30]. Few studies have examined this issue in developing countries or resource-poor regions, such as in rural areas of China, which face dual problems of alcohol consumption prevalence and high prevalence of HUA [21, 22]. Therefore, the current study comprehensively assessed the associations of alcohol consumption with HUA in rural China. Firstly, our results support previous evidence indicating that total alcohol intake was significantly associated with a greater risk of HUA [17]. Some experimental research has proven that ethanol intake can increase urate production in the liver by degrading adenosine triphosphate and decreasing urate excretion due to dehydration and metabolic acidosis [31, 32], which will eventually develop into HUA. Moreover, the current study only showed a significant positive association of alcohol consumption with HUA in male, not in female, which could be explained by the very low current drinking rate and total alcohol intake among female compared to male participants in Henan rural areas (Table S1). Besides, this may also be influenced by differences in the ratio of uric acid to creatinine clearance between the sexes [33, 34].

Although some studies have explored the relationship between different types of alcohol consumption and HUA [13, 14, 16, 17, 30, 35], the results are not entirely consistent. Moreover, most of these studies did not perform analysis adjusted for the simultaneous intake of other groups of alcoholic beverages when only assessed the association of one alcoholic beverage with HUA, which is key to controlling for confounding bias from different types of drinking. In this study, we observed that beer, liquor and rice wine, but not wine, were positively associated with the HUA risk, especially in male participants. Specifically, we found per 10 g/day increment (alcoholic content) in beer intake appears to be at higher risk for HUA than liquor intake (the *OR* and 95%*CI* were 1.121 (1.062, 1.183) and 1.019 (1.009, 1.030) for beer and liquor, respectively), which is comparable to previous studies in other countries and regions [14, 17, 18, 36]. A study based on the US Third National Health and Nutritional

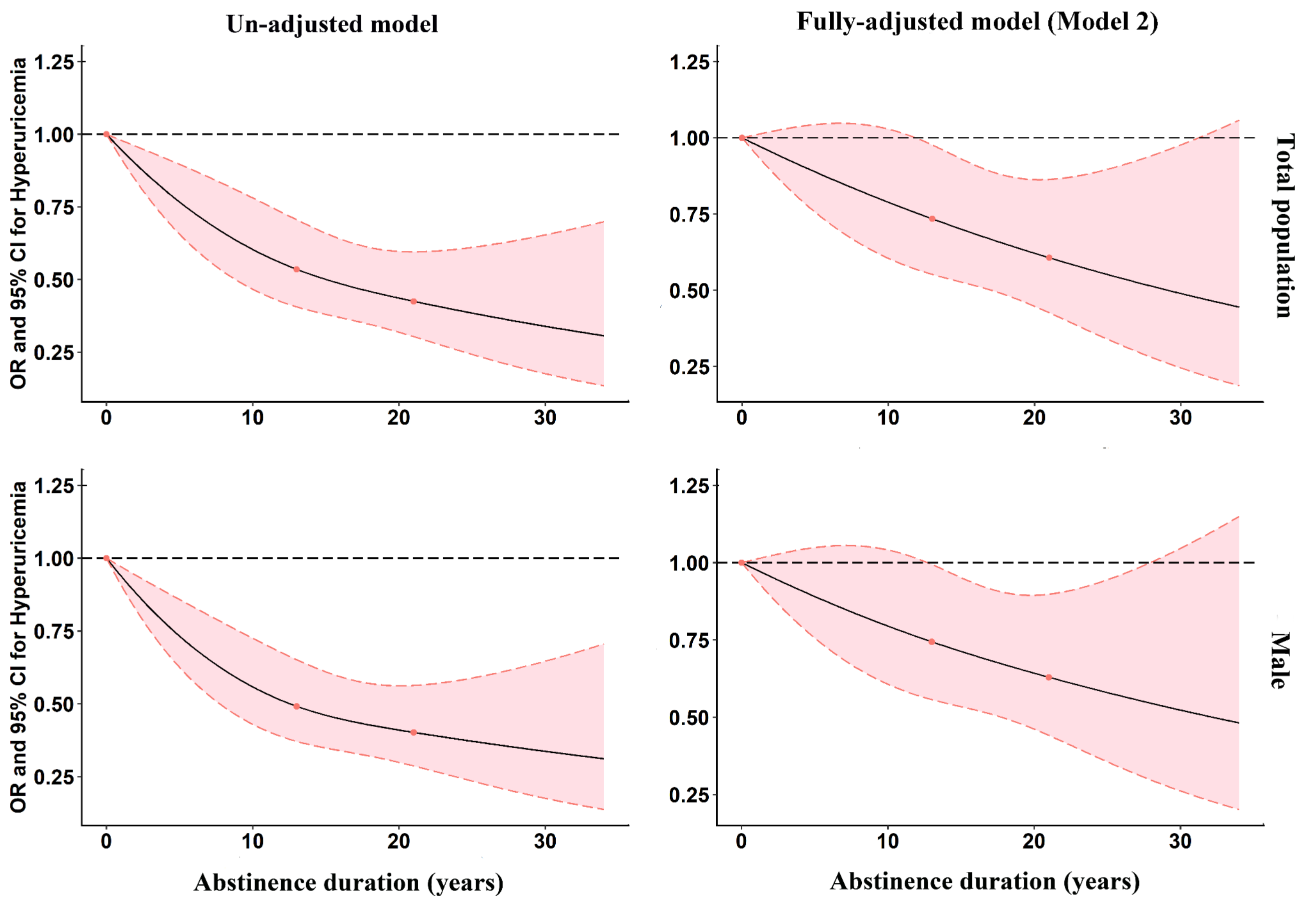

Fig. 3 *OR* and 95% *CI* of hyperuricemia along with the increasing abstinence duration from restricted cubic splines. Model 2: Adjusted for age, gender, body mass index, education level, marital status, averaged monthly income, smoking, physical activity, red-meat (g/day), white-meat (g/day), fish (g/day), egg (g/day), milk (g/day), vegetable (g/d), fruit (g/d), bean (g/d)

Examination Survey concluded that beer confers a larger increase than liquor. In contrast, moderate wine drinking does not increase serum uric levels [14]. Two cross-sectional surveys of Caucasian adults from Australia and Norway observed that beer has the most prominent effect on serum uric acid among alcoholic beverages [18]. A recent study using the Brazilian Longitudinal Study of Adult Health data also found that moderate and high intake of alcoholic beverages, specifically beer and spirits, but not wine, increased uric acid levels [17]. In addition, only one study among Chinese male adults did observe that the intake of beer and spirits was associated with elevated serum uric acid and HUA risk. The study however focused on the interaction effect of alcohol intake and obesity and did not investigate the effect of other drinking types on HUA [37]. Furthermore, experimental data had already confirmed that the stronger effect of beer on increasing serum uric acid concentrations might be attributed to the high amount of purine content in beer [38]. On the other hand, wine intake did not increase the HUA risk in our study, which is generally consistent with earlier studies. This may be related to some non-alcoholic antioxidants in wine, such as polyphenols, which play a role in mitigating the impact of ethanol intake on serum uric acid levels [39]. However, a study of older adults in Spain found that intake of no less than seven glasses/week of wine was associated with a higher prevalence of HUA [40]. It is worthy of note that the average intake levels in this Spanish study are much higher than in the current study and others, which may be the reason for the difference. Surprisingly, this study found that rice wine intake had a greater effect on inducing HUA risk among male participants, even more than beer or liquor intake. Rice wine is a traditional alcoholic beverage in China fermented with cereals [41]. To our knowledge, no previous study has explored the independent effect of rice wine on uric acid levels or HUA. Therefore, our study has filled this gap. Although the underlying mechanism is unclear, the sweetness in rice wine, especially the large amount of sugar produced during fermentation, may therefore be regarded as a high-sugar drink, promoting uric acid synthesis [41–43]. However, further prospective and experimental studies are needed to validate our findings.

An essential finding of the current study is that former drinkers were significantly associated with a lower HUA risk than the current drinkers. Moreover, the risk of HUA decreased gradually with increasing years of abstinence duration, former drinkers who had ≥ 11 years of abstinence duration showed the lowest risk of HUA. Alcohol abstinence is often recommended due to adverse health outcomes and the large disease burden caused by alcohol consumption worldwide [15, 44], but few studies have quantified its effects on health. Primarily because of the regulated state of uric acid levels [45], it is worth exploring whether the length of abstinence can bring different benefits to HUA. Only one Chinese study has observed that former drinkers were not significantly with increased uric acid levels compared to never drinkers [22, 46]. In addition, a similar finding from our previous study indicated that the risk of T2DM decreased with increasing abstinence duration compared to never drinkers and no association between alcohol abstinence and T2DM was found when the abstinence period was ≥11 years [21]. However, no study has reported the potential health effects of abstinence behavior in those former drinkers compared with the current drinkers. Considering the clear harm of high uric acid caused by alcohol drinking, the present study further demonstrated that those who abstained from alcohol for longer had a lower risk of developing HUA compared with the current drinkers, which may have significant public health significance for preventing HUA and gout. It suggests that for those who are current drinkers or have high HUA, timely abstinence and long-term adherence will help reduce and maintain normal uric acid levels. In addition, more longitudinal studies are needed to verify our findings.

Several strengths and some limitations in this study deserve attention. To our knowledge, this study is the first to explore the effects of abstinence, especially the abstinence duration on the risk of HUA in rural Chinese adults. Other strengths include the large sample size and adjustments for important covariates closely related to uric acid levels, such as the intake of different food groups and other alcoholic beverages. Some limitations are as follows. First, conclusions on causal relationships cannot be drawn due to the nature of cross-sectional analyses. Thus, prospective studies will be expected to investigate these associations. Second, information on alcohol consumption was collected by an interview using a questionnaire without verification using biological markers; other dietary information of participants was also obtained through the FFQ, and some recall bias is inevitable. Therefore, further studies will try to reduce recall bias and obtain accurate diet data based on a 3-day-24-h dietary survey method. Third, we did not account for the effect of urate-lowering drug use, which may lead to a non-differential measurement error. Considering this effect, in future follow-up questionnaires, we will collect information on the use of urate-lowering drugs and control for this confounding factor. Finally, all participants in this study are from rural China with limited resources, which may affect our findings to be extrapolated to other countries and regions. Therefore, future research must be conducted in different countries and regions to validate our findings.

Conclusions

The current study indicated that former drinkers were associated with a reduced risk of HUA compared with current drinkers among rural Chinese adults, especially for male participants. Furthermore, the risk of HUA decreased gradually with increasing years of abstinence duration. These findings have important public health and clinical implications for the prevention of HUA and gout in rural adults. It suggests that reducing total alcohol consumption, including limiting the intake of different types of alcoholic beverages, should be encouraged to prevent HUA. For people who are currently drinking alcohol and have high uric acid levels, timely abstinence and long-term adherence may help reduce and return to normal uric acid levels.

Abbreviations

BMI	Body mass index
CI	Confidence interval
FFQ	Food frequency questionnaire
HUA	Hyperuricemia
IQR	Interquartile range
OR	Odds ratio
SD	Standard deviation
T2DM	Type 2 diabetes mellitus

Supplementary Information

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Additional File 1: **Table S1**. Summary of participants' drinking status and alcohol intake by gender (***N*** = 38855). **Table S2**. Association between total alcohol intake and HUA according to the WHO risk drinking levels (***N*** = 38855). **Table S3**. Categories of alcoholic beverage intake (per 10 g/day increment) and hyperuricemia (***N*** = 38855).

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Author contributions

CJW and LY: conceived and designed the study. XKD, LLZ, NK, HXZ, WL, XTL and PLL coordinated data collection. XKD and LLZ performed statistical analysis. XKD wrote the manuscript. CJW: had primary responsibility for final content. All authors have read and approved the final manuscript. All authors read and approved the final manuscript.

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Data availability
Data described in the manuscript, code book, and analytic code will be made available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All procedures involving human participants were following the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its ethical standards. Written informed consent was obtained for all participants recruited in the study. Ethics approval was obtained from the "Zhengzhou University Life Science Ethics Committee". Ethic approval code: [2015] MEC (S128).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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