Long-Term Drinking Behavior Change Patterns and Its Association With Hyperuricemia in Chinese Adults: Evidence From China Health and Nutrition Survey

Bowen Zhu
Zhongshan Hospital
Yang Li
Zhongshan Hospital
Yiqin Shi
Zhongshan Hospital
Nana Song
Zhongshan Hospital
Yi Fang
Zhongshan Hospital
Xiaoqiang Ding (ding.xiaoqiang@zs-hospital.sh.cn)
Zhongshan Hospital

Research Article

Keywords: hyperuricemia, drinking behavior change patterns, alcohol consumption, China Health and Nutrition Survey, nutritional epidemiology

Posted Date: December 28th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1114115/v1

Abstract

Background: We aimed to explore the association between long-term drinking behavior change patterns with hyperuricemia (HUA) in Chinese community adults.

Methods: This study was designed as a community-based cohort study involving 4127 adults aged between 18~75 years, derived from the China Health and Nutrition Survey (CHNS) in 1997 and 2009. We applied logistic regression models to explore the associations between drinking behavior change patterns and HUA.

Results: The average age of the participants was 54.6 (±11.3) years and 47.8% were male. The overall prevalence of HUA was 15.5%. Drinking behavior change patterns of quitting (aOR 1.8; 95%CI 1.1~2.8) and continued drinking (aOR 2.0; 95%CI 1.3~3.0) were positively associated with high risks of HUA in the male participants. Early drinking behaviors such as liquor intake (aOR 1.8; 95%CI 1.4~2.5) and high consumption or frequency showed a positive correlation with HUA. Of note, heavy alcoholism (aOR 2.0; 95%CI 1.4~2.8) and daily drinking (aOR 2.5; 95% CI 1.7~3.6) had the highest risks of HUA. Furthermore, there was a significant association between early alcohol intake and HUA was more pronounced at 18 standard drinks, with a stable increasing trend. In contrast, no statistical correlation was observed between the drinking behaviors and HUA in the female participants.

Conclusions: Drinking behavior change patterns of quitting and continued drinking are strongly associated with increased risks of HUA in males. The risks emanated from early drinking behaviors such as liquor drinking, high drinking frequency, and alcohol consumption. Although quitting drinking was associated with lower HUA risks compared to continued drinking, it still presented an undeniable risk for HUA.

Introduction

Hyperuricemia (HUA) is a potentially modifiable risk factor for kidney dysfunction, cardiovascular disease (CVD) or death, and affects 21% of the world population [1–3]. The burden of HUA has dramatically increased over recent decades: from approximately 8.5% in 2001 to approximately 18.4% in 2017 in China [4]. Asymptomatic HUA is associated with daily routine lifestyle activities, such as regular exercise, smoking status, daily diet structure, or alcohol drinking behaviors [5]. Notably, there are specific drinking patterns, demographic, physical indicators, or distribution in the Chinese population. The risks of drinking and associated behaviors in China have constantly changed over generations from 1993 to 2011, and are likely to continue through 2027 in China [6]. The China Kadoorie Biobank reported that 8% of males are drinkers and individuals engaging in heavy drinking episodes were likely to have multiple risk factors such as regular smoking, low physical activity, and hypertension [7]. Various diseases including diabetes, chronic kidney disease (CKD), and ischemic stroke are associated with heavy alcohol intake in the Chinese population [8.9]. Although drinking behaviors vary over time in China, there is emerging evidence that defines the potential correlation of the changing drinking behaviors with the development of HUA

Several cohort studies have reported that alcohol drinking is associated with approximately 1.5~2.0 fold higher risk with HUA, compared with non-drinking individuals [10]. The risk of HUA could conceivably vary depending on the type of alcoholic beverage (ie, beer, wine, and liqueur) or alcohol consumption [11]. A prospective study reported that alcohol consumption is strongly associated with increased risk of gout with a linear trend, and beer confers a higher risk than spirits, whereas moderate wine drinking does not fuel the risk [12]. Currently, data on the effect of the change in drinking behaviors on HUA as well as the underlying reasons remain scanty. Besides, most of these studies did not quantify standard alcohol intake.

To provide scientific evidence for the long-term alcohol consumption change patterns and their association with the risk of HUA among Chinese, data from the China Health and Nutrition Survey (CHNS) was used to explore the effect of long-term alcohol change patterns between 1997 and 2009 on the risk of HUA. The data on the risks of HUA and its association with different drinking patterns over time would have novel implications on the prevention and management of HUA in the Chinese population.

Material And Methods

Study design

CHNS was an ongoing cohort from 1989 to 2015 up to now, as well as an international collaborative project at the Chinese Center for Disease Control and Prevention (CCDC). The CHNS data included nine provinces (Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, Guizhou, and Heilongjiang). It aims to characterize how the social and economic transformation of Chinese society against the health and nutritional status of its population [13].

Since data on biomarkers including serum uric acid (SUA) were firstly performed in 2009 and alcohol consumption information was systematically collected in 1997, we extracted the data between 1997 and 2009. A total of 5335 individuals with alcohol consumption data and biomarkers matched by ID (marked as idind) were obtained from the surveys. After applying the exclusion criteria (supplementary figure 1), a total of 4127 participants were included in the formal analysis.

Data collection

A standardized structured questionnaire was administered by trained health staff to collect socio-demographic variables such as age, sex, educational attainment, urban-rural residence, history of diseases (hypertension, diabetes, apoplexy, and myocardial infarction), smoking status, alcohol use, tea intake, coffee intake, total protein intake, and extent of physical activity level. Measurement of waist and hip circumference, height, weight, and blood pressures (BP) were performed by trained clinical staff [14]. All individuals maintained a regular life pattern for at least three days before blood sample collection and 12 ml of blood was collected (in three 4 ml tubes) on empty stomach (http://www.cpc.unc.edu/projects /china/data/datasets/ biomarker-data). The biomarker data collected from CHNS in 2009 involved 26 fasting blood parameters on individuals over 7 years old [14]. Plasma and serum samples were then

frozen and stored at -86°C for later laboratory analysis. All samples were assayed in a national central lab in Beijing (medical laboratory accreditation certificate ISO 15189:2007) with strict quality control.

Total cholesterol (TC) was assayed using the CHOD-PAP (Hitachi 7600, Kyowa, Japan). Low-density lipoprotein cholesterol (LDL) was assayed using the enzymatic method (Hitachi 7600, Kyowa, Japan). Triglyceride (TG) was assayed using the GPO-PAP (Hitachi 7600, Kyowa, Japan). Creatinine was assayed using the picric acid method (Hitachi 7600, Randox, UK). The data were available online: https://www.cpc. unc.edu/projects/ china.

Data on educational year was derived from the questionnaires and divided into five categories: 0, 6 years or less, 6–8 years, 9–11 years, and 12 years or higher. Living conditions were divided into urban and rural. Smoking status was assessed by the question including 'Ever smoked cigarettes?' or 'Still smokes cigarettes?', with three response options: 'no', 'yes' or 'unknown'. The smoking status was categorized as non-smokers, ex-smokers, and current smokers. The total Metabolic equivalent (MET) per week was calculated to quantify the extent of physical activities. It was a composite index calculated by multiplying the frequency, duration, and intensity of physical activity, and categorized into tertiles [15]. Individual dietary intake for 3 consecutive days was determined for every household member. This determination was achieved by asking individuals to report all food consumed at home or away from home on a 24-hour recall basis each day. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). The BMI was then categorized into four levels: lean (< 18.5 kg/m2), normal (18.5~23.9 kg/m^2) or overweight (24.0~27.9 kg/m^2) and obesity (≥ 28 kg/m^2). The waist-to-hip ratio (WHR) was calculated as waist circumference (cm)/height (cm). The cutoffs for the WHR were set at 0.9 for men and 0.85 for women, according to the World Health Organization (WHO) guidelines [16]. The average SUA was recorded and HUA was defined as ≥ 7 mg/dL for males or 6 mg/dL for females [17]. The systolic and diastolic BP were expressed as a mean of three measurements. Hypertension was defined by a systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg or self-reported by questionnaire [18]. Diabetes mellitus was self-reported or obtained from diabetes treatment records. Dyslipidaemia was defined as total cholesterol 5.2 mmol/L or higher, LDL cholesterol 3.4 mmol/L or higher, or triglycerides 1.7 mmol/L or higher [19]. Estimated glomerular filtration rate (eGFR) was calculated as chronic kidney disease epidemiology collaboration (CKD-EPI) 2009 creatinine equation [20].

Alcohol consumption change patterns

Drinking behaviors were assessed through the question: 'Have you ever had beer, liquor or other alcoholic beverages?', and three responses were sought: 'no', 'yes' or 'unknown'. Alcohol drinkers were further asked to report the drinking frequency, types, and average weekly beer consumption (bottles/week), wine (grams/week), and liquor (grams/week). The drinking frequency was defined as never (no drinking), less than weekly (<1 time/week), weekly (1-4 times/week), or daily (almost every day). The alcohol concentration in different alcoholic beverages was in accordance with the 2010 China monitoring report on chronic disease risk factors (beer = 4%, grape wine = 10% and liqueur = 38%) : 1 bottle = 600 ml, 1

Liang = 50 ml [21]. A calculation method was provided for the volume of alcohol contained in the beverages and a formula to estimate the total volume of alcohol consumed:

A: Alcohol intake (beer) = bottle * 600 ml * 0.04

B: Alcohol intake (grape wine) = Liang * 50 ml * 0.1

C: Alcohol intake (liqueur) = Liang * 50 ml * 0.38

Total alcohol intake (Standard Drinks [SD])= (A + B + C)/10g*0.789

The alcoholism was divided into none (no drinking), mild (total alcohol intake< 14 SDs per week for men or < 7 SDs per week for women), or heavy (total alcohol intake ≥ 14 SDs per week for men or ≥ 7 SDs per week for women) [22]. Alcohol change patterns were assessed based on the current alcohol drinking (in 2009) and baseline alcohol drinking (in 1997). Drinking behavior change patterns were categorized into: never drinking (not drinking in 1997 and not drinking in 2009), change to drinking (not drinking in 1997 and drinking in 2009), quitting drinking (drinking in 1997 and not drinking in 2009), and continued drinking (drinking in 1997 and drinking in 2009). The type of drinking was categorized into beer drinker, wine drinker (including fruit wine, yellow rice wine, rice wine, etc), or liquor drinker. In addition, the drinking frequency was categorized into no drinking, less than weekly, weekly, or daily.

Statistical analysis

Data were presented as mean ± standard deviation (SD) for continuous variables or N (%) for categorical variables. Group comparison of drinking behaviors was performed using the chi-square test, fisher's exact test for categorical variables, and variance analysis for continuous variables where appropriate. Univariable and multivariable logistic regression models were used to explore the association between demographic, anthropometry, biochemical index or behavior information, and HUA. To determine whether drinking behavior change patterns and early drinking behaviors were independently associated with the HUA by gender. Variables that were both associated with the HUA and deemed to be causally related to drinking-related behaviors were included as potential confounders (seen in supplementary table 2). Multivariable logistic models were sequentially adjusted for: age (as continuous), BMI, WHR, hypertension, and diabetes; and smoking status, total protein intake (as continuous). Characteristics in the analytic sample and excluded samples were compared to explore potential selection bias on study results (Supplementary Table 1). Multivariate logistic regression analysis was performed to assess the dose-response correlation between alcohol intake and HUA by raising the alcohol intake cutoff point from 2 to 30 SDs for both males and females. The results were presented as odds ratios (OR) with 95% confidence intervals (95% CI). A two-sided p-value < 0.05 was used as a threshold of statistical significance. Data were analyzed using SAS version 9.3 (SAS Institute Inc).

Result

Characteristics of participants

A total of 5335 participants aged between 18 to 75 in 1997 were recruited at the beginning of our study. Out of the total 335 participants were excluded because 6 were pregnant, 211 had average protein dietary intake for three consecutive days of >110 g/day, 25 had the end-stage renal disease (ESRD) while 93 had no data on SUA. Finally, 4217 participants were included in the formal analysis (Supplement figure1). Demographic and behavioral characteristics of the analytic sample and excluded samples with missing SUA data were compared (Supplementary Table 1). The findings indicated that most of the characteristics had no significant differences (P>0.05). The average age of participants was 54.6 (±11.3) years and 47.8% (1974/4127) were male. The overall prevalence for HUA was 15.5%. Of the 4127 participants, 53.0% never drunk, 10.3% changed to drinking, 12.9% quit drinking while 23.8% continued drinking. Individuals who continued drinking were more likely to be current smokers, have higher education and have higher CVD risk factors. On the contrary, individuals who quit drinking had more traditional risk factors such as old age, hypertension, history of apoplexy (Table 1).

Prevalence and association of drinking behavior change patterns with HUA

The prevalence of quitting and continued drinking in the male participants was 20.7% (76/368) and 23.1% (216/935), respectively. Further analysis showed that participants who kept heavy drinking had a higher prevalence of HUA (30.7% [54/176]) than those with the other three drinking patterns (Figure 1a). The finding showed that quitting drinking (OR 1.5; 95%CI 1.0~2.0) and continued drinking (OR 1.7; 95%CI 1.2~2.3) was positively associated with HUA, compared to the non-drinking in male participants (Figure 1b, model 1). After adjusting for BMI, obese WHR, diabetes, hypertension, eGFR, smoking status, and total protein intake, there was a stronger association between the drinking behaviors and HUA (adjusted odds ratio [aOR] 1.8; 95%CI 1.1~2.8; aOR 2.0; 95%CI 1.3~3.0) (Figure 1b, model 3). Besides, mild to abstainer (aOR 1.8; 95% CI 1.1~2.9), mild to heavy (aOR 2.6; 95% CI 1.5~4.5), heavy-to-mild (aOR 2.2; 95% CI 1.3~3.8), and continued heavy drinkers (aOR 3.0; 95% CI 1.8~5.0) had higher risks of suffering from HUA (Figure 1c, model 3).

Correlation between early drinking behaviors and HUA

Early drinking behaviors in 1997 such as mild (aOR 1.5; 95%CI 1.1~2.1) or heavy alcoholism (aOR 2.0; 95%CI 1.4~2.8), weekly alcohol drinking (aOR 1.4; 95%CI 1.0~2.0), and almost daily drinking (aOR 2.5; 95% CI 1.7~3.6) and were positively associated with HUA in the males, compared to non-drinking (Figure 2a and b). Importantly, liquor intake was significantly associated with a higher risk of HUA (aOR 1.8; 95%CI 1.4~2.5), with 1.1 fold higher risk per 200 mL per week of liquor consumption (Figure 2c and d). However, the association between drinking behavior and HUA were not observed in the female.

Risk for HUA by threshold alcohol intake

We further analyzed the patterns of the threshold alcohol intake per week for HUA after adjusting for potential confounders (Figure 3). The association of alcohol intake in 1997 with HUA was more pronounced at 18 SDs with a stable and linear increasing trend: from 1.5 times at 18 SDs to 1.9 times at 30 SDs higher risk in the male (Figure 3a). In contrast, whereas the point estimates of alcohol intake per

week for HUA showed a steep trend without any regularity in the females, there was no association with HUA (Figure 3b).

Discussion

The current study was the first large cohort study to explore the association between drinking behavior change patterns and HUA in the Chinese population. The findings showed that quitting drinking and continued drinking was associated with increased risks for HUA in the males, and the trends were more pronounced among those with mild to abstainer, mild to heavy, heavy to mild, and heavy to heavy drinking patterns. The magnitude of these independent associations increased further after adjusting for potential confounders. However, there was no association between the drinking patterns and HUA in the females. The rate of HUA was in sync with the estimations in our previously published meta-analysis that evaluated a whole population of 2,277,712 in China (15.5% vs 16.4%, respectively) [4].

Although the risk of HUA was lower in those who quit drinking compared to those with continued drinking, it still elevates the risk of HUA, compared to non-drinking. This result implies that early drinking could lead to an increased risk of HUA in males. The mechanism of decreased urate excretion has been implicated in the pathogenesis of alcohol-induced HUA. The study showed that HUA develops following conversion of alcohol to lactic acid, thus reducing uric acid excretion by competitively inhibiting uric acid secretion by the proximal tubule [23]. Faller et al. report that ethanol increases urate synthesis by enhancing the turnover of adenine nucleotides [24]. In addition, ethanol administration has been shown to increase the production of uric acid by enhancing the degradation of adenosine triphosphate to adenosine monophosphate, a uric acid precursor [25]. Our findings demonstrated that current heavy drinkers (drinking in 2009) had an increased risk of HUA in male participants (Supplementary figure 2), early mild or heavy drinkers (drinking in 1997) had increased risks of HUA (Figure 2). The consistent and significant association between mild to abstainer, mild to heavy drinking patterns, and HUA further validated the long-term effect of mild drinking patterns. We speculate that even mild alcohol intake could continuously decrease the glomerular filtration rate, which could promote the excretion of uric acid. Takashi et al. followed 8097 male workers for 8 years and showed that alcohol consumption at 2.5 gou/day (=ethanol 55 g/day) led to a distinct increase in the risk of HUA [26]. Baglietto et al. demonstrated that mortality curves were J-shaped (nadir at 9~12 g/day of alcohol consumption; the upper protective dose of 42~76 g/day) [27]. These findings showed that an average of 26 g/day (=18 SD*10/7 days, Figure 3) in 1997 or 16 g/day in 2009 (=11 SD*10/7 days, seen in Supplementary Figure 3) could cause a stable increase in the risk of HUA. The difference in threshold alcohol intake might be contributed to population heterogeneity (such as age, occupation, or health-related behaviors). As for the long-term effect of alcohol, our findings agreed with the Dietary Guidelines for Chinese Residents' report which showed that adult males should drink less than 25 g of alcohol per day [28].

Consistent with a single-center study in Liaoning of China [29], our findings demonstrated that alcohol consumption increased the risk of HUA only in males rather than females. It could be explained by the fact that the sample size of female drinkers was relatively small, thus leading to a low statistical power

outcome. Besides, due to differences in androgen production, the ratio of uric acid to creatinine clearance is higher in women than in men [30, 31]. There is, therefore, a need for further studies to explore the mechanism underlying our findings. Of note, distinct risks of HUA in the three types of drinking were observed in our study. Liquor drinking at baseline led to a 1.8-fold increase in the risk of HUA compared with non-liquor drinking with a 1.1-fold risk per 200 ml (Figure 2c and d). A similar trend was observed in liquor drinkers in 2009 (Supplementary figure 2c and d). A 7-year cohort study (1988–1994) with 14,809 participants reported that increased SUA levels with increasing beer or liquor intake but not with increasing wine intake. However, the effect of ingested purine in beer on uric acid in blood might be sufficient to augment the HUA effect of alcohol in exerting a greater risk of gout than liquor or wine [32]. Previous studies showed that beer is the only alcoholic beverage with large purine content, which is predominantly guanosine. Guanosine is more readily absorbed than other nucleosides, nucleotides, or bases [33, 34]. Our data showed that drinking beer was marginally associated with HUA but without a dose-response relationship. Since beer contains large amounts of purines, it is feasible to speculate that the disparity in beer drinking in the male cohort could be due to the relatively small amount of beer consumption (an average of 2057 ml per week, data not shown). Because uric acid is considered an indicator for increased oxidative stress, polyphenols in wine with antioxidant properties might potentially play a role in mitigating the impact of alcohol on serum uric acid levels [35–37]. Furthermore, assessing the effect of drinking frequency in HUA showed that there was an increase in the magnitude of associations with increasing frequency of drinking [38, 39]. Thus, our findings provide a novel perspective that although the risk of HUA as a result of early drinking is lower than that associated with continued drinking, it still elevates the risk of HUA, as compared with the non-drinking.

Potential limitations of our study deserve comment. Firstly, our data lacked more than half of the variables on physical activity. To bridge this gap, we tried to adjust partly for total protein intake. In addition, since information on drinking behaviors was self-reported, inaccurate recall or under-reporting might have affected the results. Besides, our data failed to eliminate possible effects of underlying diseases and medications used for diseases such as uric-acid-lowering medication which might have affected the outcome.

Taken together, our study demonstrated that drinking behavior change patterns such as quitting and continued drinking are strongly associated with increased risks of HUA in males. The risks emanated from early drinking behaviors such as liquor drinking, high drinking frequency, and alcohol consumption. Although the risk of HUA in quitting drinking was lower than that in continued drinking patterns, it was positively associated with HUA. The long-term effect of early drinking behaviors on HUA could not be ignored.

Abbreviations

BMI, body mass index; BP, blood pressure; CCDC, Chinese Center for Disease Control and Prevention; CHNS, China Health and Nutrition Survey; CKD, chronic kidney disease; CI, confidence interval; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; ESRD, end-stage renal disease; HUA,

hyperuricemia; IQR, interquartile range; MI, myocardial infarction; OR, odds ratio; SD, standard deviation; SDs, standard drinks; SUA, serum uric acid; WHR, waist to hip circumference ratio.

Declarations

Ethical approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all participants. CHNS was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill and local IRB (institutional review board or ethics committee).

Consent for publication

Not applicable

Availability of data and materials

The data were available online: https://www.cpc. unc.edu/projects/ china.

Competing interests

The authors declare no conflict of interest.

Funding

Apart from the original grants to the CHNS, this study was sponsored by the Natural Science Foundation of Shanghai (21ZR1412400), National Natural Science Foundation of China (82103911), Shanghai Key Laboratory of Kidney and Blood Purification (14DZ2260200), Shanghai Science and Technology Commission (18411960800), Innovation Program of Shanghai Municipal Education Commission (2017-01-07-00-07-E00009), and Shanghai Municipal Key Clinical Specialty (shslczdzk02501).

Authors' contributions

BZ and XD contributed to the conception or design of the work. BZ and YL contributed to the acquisition, analysis, or interpretation of data for the work. BZ and YL drafted the manuscript. YL and YF critically revised the manuscript. BZ, YL, NS, YS, YF and XD contribute to analysis, or interpretation of the work. All gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Acknowledgements

This research uses data from China Health and Nutrition Survey (CHNS). We are grateful to research grant funding from the National Institute for Health (NIH), the Eunice Kennedy Shriver National Institute of

Child Health and Human Development (NICHD) for R01 HD30880, National Institute on Aging (NIA) for R01 AG065357, National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) for R01DK104371 and R01HL108427, the NIH Fogarty grant D43 TW009077 since 1989, and the China-Japan Friendship Hospital, Ministry of Health for support for CHNS 2009, Chinese National Human Genome Center at Shanghai since 2009, and Beijing Municipal Center for Disease Prevention and Control since 2011.

References

1. Kuo CF, Grainge MJ, Mallen C, Zhang W, Doherty M. Rising burden of gout in the UK but continuing suboptimal management: a nationwide population study. *Ann Rheum Dis.* 2015; 74: 661–667. Medline:24431399 doi:10.1136/annrheumdis-2013-204463
2. Li J, Huang JY, Liu L, Lo K, Sun S, Chen CL, Zhang B, Feng YQ, Huang YQ. Relationship between serum uric acid level and all-cause and cardiovascular mortality in population with obesity. *Postgraduate Medical Journal.* 2020; 96 (1141): 660–665. Medline:31911448 doi:10.1136/postgradmedj-2019-137236
3. Lin WD, Deng H, Guo P, Liu FZ, Chen RY, Fang XH, Zhan XZ, Liao HT, Huang WX, Liu Y, Wang F, Zheng MR, Liu HZ, Huang J, Wei W, Xue YM, Wu SL. High prevalence of hyperuricaemia and its impact on non-valvular atrial fibrillation: the cross-sectional Guangzhou (China) Heart Study. *BMJ Open.* 2019; 9(5): e028007. Medline: 31147367 doi: 10.1136/bmjopen-2018-028007
4. Li Y, Shen Z, Zhu B, Zhang H, Zhang X, Ding X. Demographic, regional and temporal trends of hyperuricemia epidemics in Mainland China from 2000 to 2019: a systematic review and meta-analysis. *Global Health Action.* 2021; 14(1): 1874652. Medline: 33475474 doi: 10.1080/16549716.2021.1874652
5. Xiong X, He F, Sun G, Li Y, Shi Y, Ge X, Zheng S, Xu R. The relationship between self-reported habitual snoring and hyperuricemia among Chinese urban adults: a cross-sectional study. *Sleep Medicine.* 2020; 68: 207-212. Medline: 32143022 doi: 10.1016/j.sleep.2019.11.1257
6. Lee K, Salomon J, Goldhaber-Fiebert J. Patterns of heavy drinking behaviour over age and birth cohorts among Chinese men: a Markov model. *BMJ Open.* 2021; 11(3): e043261. Medline: 33653752 doi: 10.1136/bmjopen-2020-043261
7. Im PK, Millwood IY, Guo Y, Du H, Chen Y, Bian Z, Tan Y, Guo Z, Wu S, Hua Y, Li L, Yang L, Chen Z; China Kadoorie Biobank (CKB) collaborative group. Patterns and trends of alcohol consumption in rural and urban areas of China: findings from the China Kadoorie Biobank. *BMC Public Health.* 2019; 19(1): 217. Medline: 30786877 doi: 10.1186/s12889-019-6502-1
8. Han T, Zhang S, Duan W, Ren X, Wei C, Sun C, Li Y. Eighteen-year alcohol consumption trajectories and their association with risk of type 2 diabetes and its related factors: the China Health and Nutrition Survey. *Diabetologia.* 2019; 62(6): 970-980. Medline: 30923839 doi: 10.1007/s00125-019-4851-z

9. Okada Y, Uehara S, Shibata M, Koh H, Oue K, Kambe H, Morimoo M, Sato KK, Hayashi T. Habitual Alcohol Intake Modifies Relationship of Uric Acid to Incident Chronic Kidney Disease. *American Journal of Nephrology.* 2019; 50(1): 55-62. Medline: 31170706 doi: 10.1159/000500707
10. Li R, Kang Y, Li C. Dietary factors and risk of gout and hyperuricemia: a meta-analysis and systematic review. *Asia Pacific Journal of Clinical Nutrition.* 2018; 27(6): 1344-1356. Medline: 30485934 doi: 10.6133/apjcn.201811_27(6).0022
11. Tu HP, Tung YC, Tsai WC, Lin GT, Ko YC, Lee SS. Alcohol-related diseases and alcohol dependence syndrome is associated with increased gout risk: A nationwide population-based cohort study. *Joint Bone Spine.* 2016; 84(2): 189-196. Medline: 27238189 doi:10.1016/j.jbspin.2016.02.024
12. Choi HK, Atkinson K, Karlson EW, Willett W, Curhan G. Alcohol intake and risk of incident gout in men: a prospective study. *Lancet.* 2004; 363(9417): 1277-81. Medline: 15094272 doi:10.1016/S0140-6736(04)16000-5
13. Popkin BM, Du S, Zhai F, Zhang B. Cohort Profile: The China Health and Nutrition Survey–monitoring and understanding socioeconomic and health change in China, 1989-2011. *Int J Epidemiol.* 2010; 39: 1435–40. Medline:19887509 doi:10.1093/ije /dyp322
14. Yan S, Li J, Li S, Zhang B, Du S, Gordon-Larsen P, Adair L, Popkin B. The expanding burden of cardiometabolic risk in China: the China Health and Nutrition Survey. *Obes Rev.* 2012; 13(9): 810–21. Medline:22738663 doi:10.1111/j.1467-789X.2012.01016.x
15. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011; 43 (8): 1575–1581. Medline:21681120 doi:10.1249/MSS.0b013e31821ece12
16. Nishida C, Ko GT, Kumanyika S. Body fat distribution and non-communicable diseases in populations: overview of the 2008 WHO Expert Consultation on Waist Circumference and Waist-Hip Ratio. *Eur J Clin Nutr.* 2010; 64(1): 2-5. Medline: 19935820 doi:10.1038/ejcn.2009.139
17. Maloberti A, Giannattasio C, Bombelli M, Desideri G, Cicero AFG, Muiesan ML, Rosei EA, Salvetti M, Ungar A, Rivasi G, Pontremoli R, Viazzi F, Facchetti R, Ferri C, Bernardino B, Galletti F, D'Elia L, Palatini P, Casiglia E, Tikhonoff V, Barbagallo CM, Verdecchia P, Masi S, Mallamaci F, Cirillo M, Rattazzi M, Pauletto P, Cirillo P, Gesualdo L, Mazza A, Volpe M, Tocci G, Iaccarino G, Nazzaro P, Lippa L, Parati G, Dell'Oro R, Quarti-Trevano F, Grassi G, Virdis A, Borghi C; Working Group on Uric Acid and Cardiovascular Risk of the Italian Society of Hypertension (SIIA). Hyperuricemia and Risk of Cardiovascular Outcomes: The Experience of the URRAH (Uric Acid Right for Heart Health) Project. *High Blood Press Cardiovasc.* 2020; 27(2): 121–128. Medline:32157643 doi:10.1007/s40292-020-00368-z
18. Joint Committee for Guideline Revision. 2018 Chinese Guidelines for Prevention and Treatment of Hypertension-A report of the Revision Committee of Chinese Guidelines for Prevention and Treatment

of Hypertension. *J Geriatr Cardiol. 2019;* 16(3): 182-241. Medline: 31080465 doi: 10.11909/j.issn. 1671-5411.2019.03.014.

19. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). *JAMA.* 2001; 285(19): 2486–97. Medline:11368702 doi:10.1001/jama.285.19.2486
20. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF 3rd, Feldman HI, Kusek JW, Eggers P, Van Lente F, Greene T, Coresh J; CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration). A New Equation to Estimate Glomerular Filtration Rate. *Annals of internal medicine.* 2009; 150(9): 604-W: 108. Medline:19414839 doi:10.7326/0003-4819-150-9-200905050-00006
21. Chinese Center for Disease Control and Prevention. Surveillance report on chronic diseases and its risk factors in China. Beijing: Military Medical Science Press. 2010.
22. Rolland B, Chazeron I, Carpentier F, Moustafa F, Viallon A, Jacob X, Lesage P, Ragonnet D, Genty A, Geneste J, Poulet E, Dematteis M, Llorca PM, Naassila M, Brousse G. Comparison between the WHO and NIAAA criteria for binge drinking on drinking features and alcohol-related aftermaths: Results from a cross-sectional study among eight emergency wards in France. *Drug Alcohol Depend.* 2017; 175: 92–98. Medline:28411560 doi:10.1016/j.drugalcdep.2017.01.034
23. Eastmond CJ, Garton M, Robins S, Riddoch S. The effects of alcoholic beverages on urate metabolism in gout sufferers. *Br J Rheumatol.* 1995; 34: 756–59. Medline:7551661 doi:10.1093/ rheumatology/34.8.756
24. Faller J, Fox IH. Ethanol-induced hyperuricemia: evidence for increased urate production by activation of adenine nucleotide turnover. N Engl J Med. 1982; 307(26): 1598–602. Medline:7144847 doi: 10.1056/NEJM198212233072602
25. Iracheta-Vellve A, Petrasek J, Satishchandran A, Gyongyosi B, Saha B, Kodys K, Fitzgerald KA, Kurt-Jones EA, Szabo G. Inhibition of sterile danger signals, uric acid and ATP, prevents inflammasome activation and protects from alcoholic steatohepatitis in mice. *J Hepatol.* 2015; 63(5): 1147–55. Medline:26100496 doi:10.1016/j.jhep.2015.06. 013
26. Makinouchi T, Sakata K, Oishi M, Tanaka K, Nogawa K, Watanabe M, Suwazono Y. Benchmark dose of alcohol consumption for development of hyperuricemia in Japanese male workers: An 8-year cohort study. *Alcohol.* 2016; 56: 9–14. Medline:27814794 doi:10.1016/j.alcohol.2016.08.002
27. Baglietto L, English DR, Hopper JL, Powles J, Giles GG. Average volume of alcohol Consumed, type of beverage, drinking pattern and the risk of death from all causes. *Alcohol.* 2006; 41(6): 664–671. Medline:17050568 doi:10.1093/alcalc/agl087
28. Chinese Nutrition Society. Dietary guidelines for Chinese residents: revision in 2011. Tibet people's Publishing House. 2011.
29. Li Z, Guo X, Liu Y, Chang Y, Sun Y, Zhu G, Abraham MR. The Relation of Moderate Alcohol Consumption to Hyperuricemia in a Rural General Population. *Int J Environ Res Public Health.* 2016; 13(7): 732. Medline:27447659 doi:10.3390/ijerph13070732

30. Liu H, Peng L, Ma J, He L, Long K, Ouyang X, Wu C, Xie M, Dai L, Cai X. Low expression of estrogen receptor β in renal tubular epithelial cells may cause hyperuricemia in premenopausal patients with systemic lupus erythematosus. *Lupus.* 2021; 30(4): 560–567. Medline:33407049 doi:10.1177/0961203320984231
31. Nicholls A, Snaith ML, Scott JT. Effect of oestrogen therapy on plasma and urinary levels of uric acid. *BMJ.* 1973; (5851): 449–51. Medline:4689833 doi:10.1136/bmj.1.5851.449
32. Choi HK, Curhan G. Beer, liquor, and wine consumption and serum uric acid level: the Third National Health and Nutrition Examination Survey. *Arthritis Rheum.* 2004; 51(6): 1023–9. Medline:15593346 doi:10.1002/art.20821
33. Valls-Belles V, Torres Mdel C, Boix L, Muñiz P, Gonzalez-Sanjose ML, Codoñer-Franch P. alpha-Tocopherol, MDA-HNE and 8-OHdG levels in liver and heart mitochondria of adriamycin-treated rats fed with alcohol-free beer. *Toxicology.* 2008; 249(2-3): 97–101. Medline:18513847 doi:10.1016/j.tox.2008.04.010
34. B Bartolomé, PeA-Neira A, C Gómez-Cordovés. Phenolics and related substances in alcohol-free beers. *European Food Research & Technology.* 2000; 210(6): 419–423. doi:10.1007/s002170050574
35. Booyse FM, Parks DA. Moderate wine and alcohol consumption: beneficial effects on cardiovascular disease. *Thromb Haemost.* 2001; 86: 517–28. Medline:11521997 doi:10.1055/s-0037-1616080
36. Maxwell S, Cruickshank A, Thorpe G. Red wine and antiox-idant activity in serum. *Lancet.* 1994; 344: 193–4. Medline:7912786 doi:10.1016/s0140-6736(94)92795-2
37. Sluik D, Brouwer-Brolsma EM, de Vries JH, Geelen A, Feskens EJ. Associations of alcoholic beverage preference with cardiometabolic and lifestyle factors: the NQplus study. *BMJ Open.* 2016; 6(6): e010437. Medline:27311903 doi:10.1136/bmjopen-2015 -<background-color:#D279AA;>010437</background-color:#D279AA;>.
38. Cui L, Meng L, Wang G, Yuan X, Li Z, Mu R, Wu S. Prevalence and risk factors of hyperuricemia: results of the Kailuan cohort study. *Mod Rheumatol.* 2017; 27(6): 1066–1071. Medline:28395604 doi:10.1080/14397595.2017.1300117
39. Choi HK, McCormick N, Lu N, Rai SK, Yokose C, Zhang Y. Population Impact Attributable to Modifiable Risk Factors for Hyperuricemia. *Arthritis Rheumatol.* 2020; 72(1): 157–165. Medline:31486212 doi:10.1002/art.41067

Tables

Table1. Characteristics of participants among four groups of drinking behavior change patterns (n=4127)

	Drinking behavior change pattern				Total	*P-value**
	Never drinking	Change to be drinkers	Quit drinking	Keep drinking		
Participants (n)	2187	424	532	984	4127	
Age (years)	54.5 (±11.1)	49.4 (±12.2)	56.8 (±11.1)	53.8 (±10.4)	54.6 (±11.3)	<0.001
Male (%)	369 (16.9)	302 (71.2)	368 (69.2)	935 (95.0)	1974 (47.8)	<0.001
Education (years)						<0.001
0	475 (21.7)	42 (9.9)	64 (12.1)	54 (5.5)	635 (15.4)	
1–6	804 (36.8)	122 (28.8)	186 (35.0)	310 (31.6)	1422 (34.5)	
7–9	606 (27.7)	170 (40.2)	176 (33.2)	375 (38.3)	1327 (32.1)	
10–12	180 (8.2)	47 (11.1)	60 (11.3)	143 (14.6)	430 (10.4)	
>12	120 (5.5)	42 (9.9)	45 (8.5)	98 (10.0)	305 (7.4)	
Rural (%)	1634 (74.7)	288 (67.9)	367 (69.0)	702 (71.3)	2991 (72.5)	0.003
Anthropometry parameters						
Waist (cm)	82 (±10)	82 (±10)	84 (±10)	85 (±10)	83 (±10)	<0.001
Hip (cm)	94 (±8)	94 (±7)	94 (±8)	94 (±8)	94 (±8)	0.531
Obese WHR	1155 (54.4)	177 (42.9)	233 (45.5)	457 (48.3)	2022 (49.0)	<0.001
BMI (kg/m2)						0.002
Lean (<18.5)	129 (5.9)	26 (6.1)	22 (4.1)	41 (4.2)	218 (5.3)	
Normal (18.5–23.9)	1185 (54.2)	236 (55.7)	303 (57.0)	543 (55.2)	2267 (54.9)	
Overweight (24–27.9)	648 (29.6)	120 (28.3)	159 (29.9)	340 (34.6)	1267 (30.7)	
Obesity (≥28.0)	225 (10.3)	42 (9.9)	48 (9.0)	60 (6.1)	375 (9.1)	
Systolic BP (mm	125 (±19)	122 (±17)	126	126 (±17)	125	0.010

Hg)			(±18)		(±19)	
Diastolic BP (mm Hg)	80 (±11)	80 (±11)	81 (±10)	83 (±12)	81 (±11)	<0.001
Hypertension	557 (29.4)	86 (22.7)	149 (34.1)	244 (29.6)	1036 (25.1)	0.005

Continue.

Diabetes	56 (2.6)	5 (1.2)	19 (3.6)	25 (2.5)	105 (2.5)	0.142
Serum uric acid (mg/dL)	5 (±2)	5 (±2)	5 (±2)	6 (±2)	5 (±2)	<0.001
Hyperuricemia	258 (11.8)	68 (16.0)	92 (17.3)	222 (22.6)	640 (15.5)	<0.001
Dyslipidemia	1314 (60.1)	236 (55.7)	327 (61.5)	619 (62.9)	2496 (60.5)	0.075
eGFR (ml/ min/l.73m2)	68 (±18)	83 (±33)	79 (±15)	83 (±14)	81 (±18)	<0.001
History of MI	22 (1.0)	3 (0.7)	9 (1.7)	6 (0.6)	40 (1.0)	0.208
History of apoplexy	16 (0.7)	3 (0.7)	14 (2.6)	8 (0.8)	41 (1.0)	<0.001
Health-related behavior						
Smoking status						<0.001
Never	1929 (88.2)	206 (48.6)	335 (63.0)	311 (31.6)	2781 (67.4)	
Ever	33 (1.5)	27 (6.4)	31 (5.8)	40 (4.1)	131 (3.2)	
Current	224 (10.3)	191 (45.1)	166 (31.2)	633 (64.3)	1214 (29.4)	
Tea intake	600 (27.4)	212 (50.0)	187 (35.2)	493 (50.1)	1492 (36.2)	<0.001
Coffee intake	25 (1.2)	16 (3.8)	7 (1.3)	18 (1.8)	66 (1.6)	0.001
Total protein intake (g/day)	59 (±18)	68 (±18)	63 (±19)	68 (±18)	63 (±19)	<0.001
Physical activity level (METs/week)						0.870
Low (<49.6)	728 (33.3)	130 (30.7)	185 (34.8)	333 (33.8)	1376 (33.3)	
Medium (49.6~143.7)	729 (33.3)	150 (35.4)	168 (31.6)	328 (33.3)	1375 (33.3)	
High (>143.7)	730 (33.4)	144 (34.0)	179 (33.7)	323 (32.8)	1376 (33.3)	

Abbreviation: BMI, body mass index; BP, blood pressure; eGFR, estimated glomerular filtration rate; MI, myocardial infarction; SUA, serum uric acid; WHR, waist to hip circumference ratio. Data are presented as No. (%), mean± SD or median (IQR);

*P values were calculated by using T-test or Wilcoxon test for continuous variables and $\chi 2$ test or Fisher exact test for categorical variables.

8 participants were not available for education level; 133 participants were not available for WHR; 591 participants were not available for hypertension;

31 participants were not available for drinking frequency; 9 participants were not available for coffee intake; 7 participants were not available for tea intake; 3 participants were not available for the history of myocardial infarction; 1 participant was not available for the history of apoplexy; 1 participant was not available for smoking status; 26 participants were not available for drinking frequency; 9 participants were not available for beer drinking; 10 participants were not available for wine drinking; 11 participants were not available for liquor drinking.

Figures

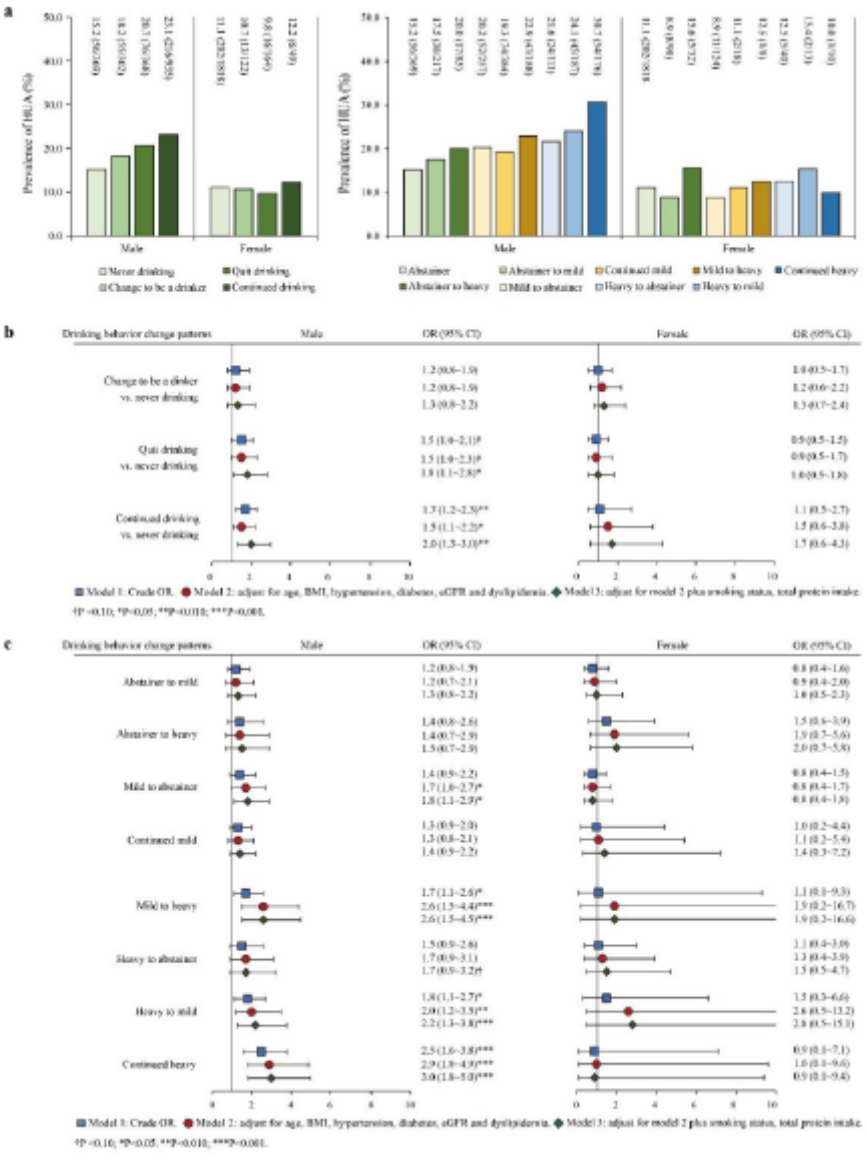

Figure 1

Prevalence and logistic regression analysis of the association between drinking behavior change patterns and HUA by gender (a. Prevalence of drinking behavior change patterns; b/c. Univariate and multivariate logistic regression analysis of the association between drinking behavior change patterns and HUA)

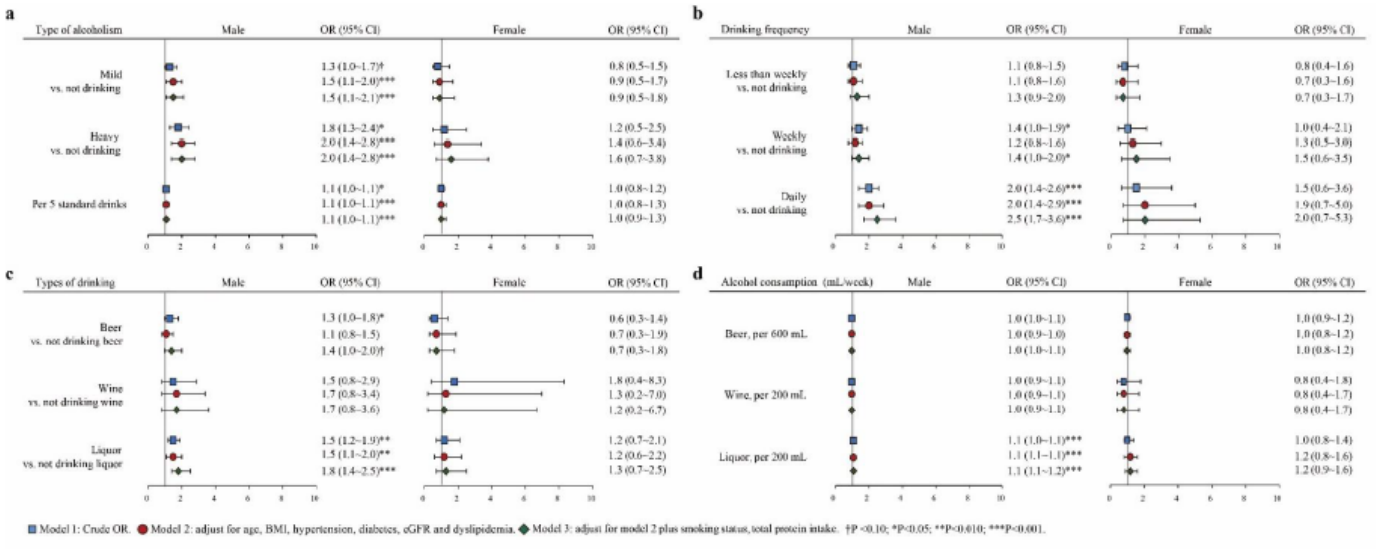

Figure 2

Univariate and multivariate logistic regression analysis of the association between drinking-related behaviors in 1997 and HUA by gender (OR, odds ratio; CI, confidence interval; SD, standard drink; Other abbreviations are indicated in Table 1)

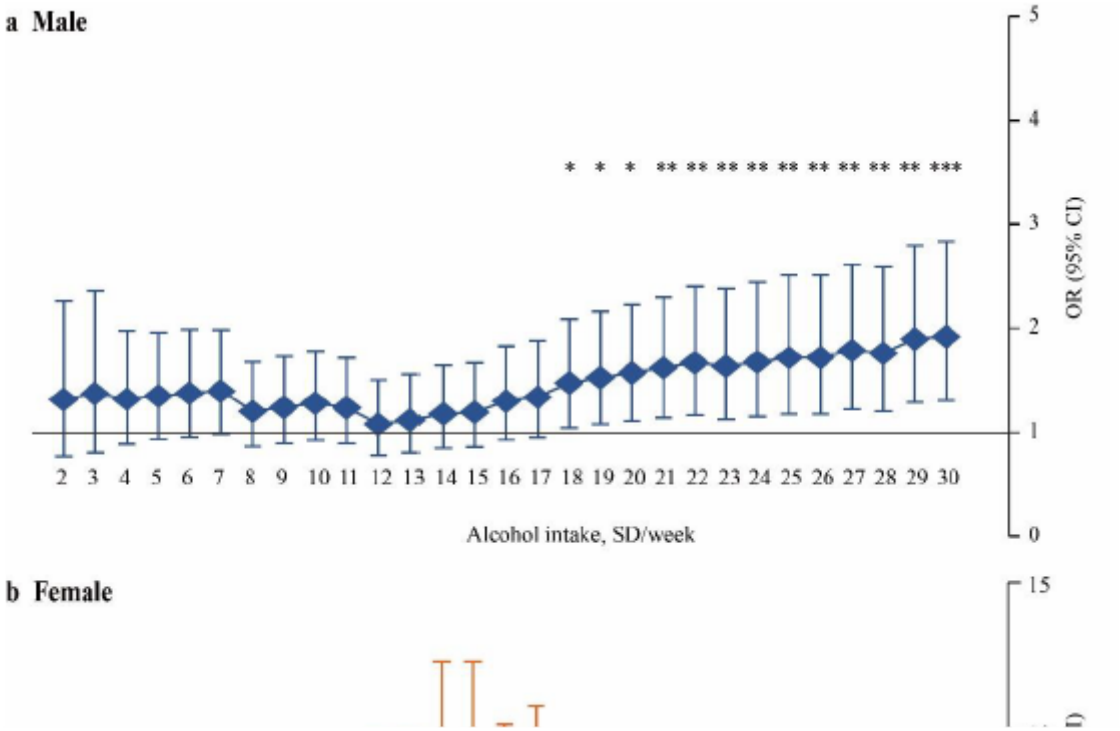

Figure 3

Risk of HUA by threshold alcohol intake. (OR was adjusted for age (as continuous), BMI, hypertension, diabetes, eGFR and dyslipidemia, smoking status and total protein intake; †P <0.10; * P<0.05; ** P<0.010; *** P<0.001; Abbreviations are indicated in Figure 2)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1123.docx