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Association between alcohol consumption and renal function in patients with diabetes mellitus and hypertension: insights from the Taiwan Biobank

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Abstract

Background Alcohol consumption is linked to varied health outcomes. While alcohol appears to have a protective effect on renal function, the impact on patients with diabetes mellitus (DM) and hypertension (HTN) remains unclear. This cross-sectional observational study aims to explore the association between alcohol use and renal function, particularly for individuals with these comorbidities.

Methods Data from participants in the Taiwan Biobank were analyzed. Participants were divided into drinkers and non-drinkers. Drinkers were defined as an alcohol intake of 150 mL or more per week for at least six months. Renal function was assessed using creatinine levels and 2021 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine for estimated glomerular filtration rate (eGFR). Multivariate multiple regression models were used to examine the relationships between alcohol consumption, DM, HTN, and renal function.

Results Drinkers had better renal function than non-drinkers, with higher eGFR values and lower creatinine levels. Alcohol consumption was linked to better renal function in DM patients but not HTN patients. A three-way interaction (drinking/DM/HTN) also revealed improved renal function.

Conclusions This study suggests that alcohol consumption may be associated with better renal function outcomes, particularly in patients with DM and HTN. However, these findings should be interpreted cautiously given the cross-sectional nature of the study. Further longitudinal and mechanistic research is warranted to validate the findings.

Clinical trial number Not applicable.

Keywords Renal function, Alcohol, CKD-EPI, Diabetes mellitus, Hypertension, Taiwan Biobank

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Background

Alcohol consumption and its health impact

Alcohol consumption is a prevalent behavior worldwide, largely due to its historical context, personal pleasure, and social value. According to a report by the World Health Organization (WHO), 43% of people worldwide aged 15 and older consumed alcohol in 2015 [1]. In some regions, the consumption rate is significantly higher than in others. For example, in the European region, 59.9% of the population consumes alcohol, whereas in the Southeast Asia region, only 33.1% are current drinkers [1]. This indicates that alcohol consumption in Southeast Asia, including Taiwan, is relatively moderate. However, the detrimental effects of alcohol cannot be overlooked. A 2018 study indicated that the prevalence of harmful alcohol use in Taiwan is 5.79% or approximately 1 million citizens profoundly affected by alcohol [2].

Alcohol poses numerous negative effects on health, including the development of various cancers [3, 4], liver diseases [5–7], and hypertension (HTN) [8]. Nevertheless, alcohol appears to be beneficial if consumed responsibly under certain circumstances. Moderate alcohol consumption has been correlated with a decreased risk of developing diabetes mellitus (DM) [9–12]. Among diabetic patients, alcohol may reduce the risk of coronary heart disease and mortality from coronary disease [11, 13]. The risk of ischemic stroke may also be reduced by moderate alcohol intake, although this benefit does not extend to binge drinkers [14, 15]. The relationship between alcohol consumption and renal dysfunction, particularly chronic kidney disease (CKD), remains debated [16–19]. CKD is characterized by a gradual loss of kidney function, defined as a glomerular filtration rate (GFR) of less than 60 mL/min/1.73 m^2 for at least three months, or the presence of kidney damage, such as albuminuria [20]. From a pathophysiological perspective, alcohol can lead to electrolyte imbalance, disturbances in kidney-regulating hormones, and expansion of body fluids causing HTN, thus damaging the kidney [21]. Observational studies have supported this hypothesis, demonstrating that heavy alcohol consumption accelerates the progression of CKD [19]. However, other studies have reported inverse associations, suggesting that alcohol consumption may have a protective effect on renal function [17, 18, 22, 23].

Risk factors for renal impairment

Several risk factors have been reported to influence renal function. HTN, a well-known contributor, has accounted for 27% of end-stage renal disease (ESRD) patients in the United States [24]. The underlying mechanism involves increased intraglomerular capillary pressure, causing glomerulosclerosis and impaired renal function [25]. Renal impairment typically develops after 10 years of uncontrolled essential HTN [24]. DM is another major cause of CKD and ESRD in most regions worldwide primarily due to diabetic nephropathy. The mechanisms involved include hyperfiltration injury, the formation of advanced glycosylation end products, and the presence of reactive oxygen species (ROS) [24, 25]. Approximately 80% of newly diagnosed type 2 DM patients already exhibit proteinuria. If initially free of proteinuria, 41% of the patients develop diabetic nephropathy over the next 20 years [26]. Nephrotoxins, including analgesic drugs, certain Chinese herbs, and heavy metals have also been associated with renal damage [27, 28].

Renal impact of alcohol consumption in hypertensive and diabetic patients

The relationship between alcohol consumption and renal function in patients with underlying conditions is complex. HTN and DM are the two primary causes of renal impairment. Alcohol may elevate blood pressure, thereby worsening hypertensive renal disease, but it has also been associated with reductions in albuminuria [29]. For diabetic patients, alcohol may improve insulin sensitivity, potentially benefiting renal function indirectly through better glycemic control [9, 12]. The overall effect of alcohol consumption on renal function for hypertensive and diabetic patients is not straightforward and warrants further investigation.

Study objective

Previous studies have shown an inverse association between alcohol consumption and the risk of renal dysfunction in various ethnic groups [17, 18, 22, 23, 30, 31]. However, limited studies considered the effect of comorbidities. By utilizing data from the Taiwan Biobank, we aim to validate findings observed in Han Chinese populations in previous studies [30, 31], analyze information on participants' underlying conditions, and benefit from the large, representative sample size. This study aims to explore the association between alcohol consumption and renal function biomarkers in the general population as well as in hypertensive and diabetic patients, clarifying how this lifestyle factor affects one of our most vital organs.

Materials and methods

Taiwan Biobank and study design

This cross-sectional observational study utilized data from the Taiwan Biobank. The Taiwan Biobank is a major biomedical project held by Academia Sinica. Starting in 2012, the project aimed to collect biological specimens and health-related information from a target sample size of 200,000 healthy individuals. The inclusion criteria of the project included men and women aged between 20 and 70 years old, with no prior diagnosis of cancer. Data

were collected through questionnaires, physical examinations, and blood and urine tests [32]. Detailed information on the questionnaire content is available in a previous publication [32]. We harnessed this database and collected demographic data, social habits, comorbidities, gamma-glutamyl transpeptidase (GGT) levels, and renal biomarkers from a cohort of 118,780 participants registered between 2012 and 2018 for further analyses. Alcohol consumption was defined as an alcohol intake of 150 mL or more per week, sustained for at least six months. Participants who did not provide information on alcohol consumption in the questionnaire were excluded from the study. These cases were not included in any group and were not subjected to subsequent analyses. The study protocol was approved by the Ethics Committee of Kaohsiung Medical University Hospital (IRB number: KMUHIRB-G(II)-20200007).

Renal function assessment

Renal function was evaluated using the 2021 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) creatinine equation to calculate the estimated glomerular filtration rate (eGFR) [33]. The 2021 CKD-EPI creatinine equation is a pivotal tool for estimating GFR, particularly in individuals with normal to mildly reduced renal function. The equation incorporates serum creatinine levels, age, and sex to provide a more precise eGFR across diverse populations. Compared to the earlier Modification of Diet in Renal Disease (MDRD) study equation, CKD-EPI provides a more precise estimate at higher eGFR values, especially above 60 mL/min/1.73 m^2 [34], which is more relevant to our studied population. The 2021 CKD-EPI creatinine formula is provided in Table 1 for reference.

Statistics analysis

Matching was performed based on gender and age, with a 4:1 ratio of non-drinkers to drinkers. This ratio allowed for enough matches without introducing a significant imbalance between the two groups. The purpose was to control potential confounding variables, ensuring that comparisons were made between groups with similar key characteristics. Demographic characteristics were analyzed by independent t-tests for continuous variables and chi-square tests for categorical variables. A multivariate multiple linear regression model was utilized for the association between alcohol consumption and renal function. Creatinine and eGFR were dependent variables, while the covariates included body mass index (BMI), DM, HTN, and drinking. Two-way interactions term between drinking and DM or HTN, as well as a three-way interaction terms for drinking, DM, and HTN, were also included as covariates. This approach may help evaluate the potential interactions or confounding effects between different variables. All statistical analyses were performed using SPSS version 21 (IBM). Statistical significance was determined at $p < 0.05$ for all tests.

Results

This study included 118,780 participants, non-drinkers and drinkers were matched in a 4:1 ratio for statistical purposes. As a result, these participants were divided into non-drinkers ($n = 28880$) and drinkers ($n = 7220$). The demographic characteristics of the two groups are summarized in Table 2. As matching was conducted based on age and gender, no significant differences were observed between the two groups for these variables. Other substance use, including smoking and betel nut consumption, were more commonly reported in the drinkers group. Drinkers had a higher GGT level than non-drinkers (43.61 versus 26.71 U/L). Drinkers had better eGFR when compared with non-drinkers (100.83 versus 98.56 mL/min/1.73 m^2). Creatinine levels were also lower among drinkers (1.26 versus 1.41 mg/dL). Regarding comorbidities, the prevalence of HTN was higher in the drinkers group (17.4% versus 14.3%), but the prevalence of DM showed no difference between the two groups.

The impact of alcohol consumption and various comorbidities on renal function was further examined using multivariate multiple linear regression analyses in Table 3. When considered independently, drinking was significantly associated with improved renal function: eGFR increased by 2.54 mL/min/1.73 m^2 (95% CI: 1.91 to 3.18) and creatinine levels decreased by 0.15 mg/dL (95% CI: -0.22 to -0.08). In contrast, BMI, DM, and HTN were each significantly negatively associated with renal function. The presence of DM showed a 4.76 mL/min/1.73 m^2 reduction in eGFR, while HTN showed a 7.38 mL/min/1.73 m^2 reduction. We examined two-way and three-way interactions in our model to understand potential interaction effects. Among the two-way interactions (Drinking*HTN and Drinking*DM), HTN

Table 1 2021 CKD-EPI creatinine equation

Sex	Serum Creatinine (mg/dL)	Equation
Female	≤ 0.7	$eGFR = 142 \times (Scr/0.7)^{-0.241} \times 0.9938^{Age} \times 1.012$
Female	> 0.7	$eGFR = 142 \times (Scr/0.7)^{-1.200} \times 0.9938^{Age} \times 1.012$
Male	≤ 0.9	$eGFR = 142 \times (Scr/0.9)^{-0.302} \times 0.9938^{Age}$
Male	> 0.9	$eGFR = 142 \times (Scr/0.9)^{-1.200} \times 0.9938^{Age}$

CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration; eGFR, estimated glomerular filtration rate = mL/min/1.73 m^2; Scr, Serum Creatinine

Table 2 Demographic characteristics of non-drinkers and drinkers

Variable		Non-drinkers (*N* = 28880)		Drinkers (*N* = 7220)	
		Mean	**%/SD**	**Mean**	**%/SD**
Age (years)		49.73	10.3	49.73	10.3
Sex	Male	22,908	79.3%	5727	79.3%
	Female	5972	20.7%	1493	20.7%
BMI (kg/m^2)		24.9	3.7	25.00	3.6
Smoker	No	15,963	55.3%	1916	26.5%
	Yes	12,912	44.7%	5303	73.5%
Betel nut usage	No	25,982	90.1%	5029	69.8%
	Yes	2845	9.9%	2173	30.2%
GGT (U/L)		26.71	28.37	43.61	71.45
Creatinine (mg/dL)		1.41	2.8	1.26	2.4
eGFR[#](mL/min/1.73m^2)		98.56	25.2	100.83	23.9
DM	No	27,230	94.3%	6797	94.1%
	Yes	1650	5.7%	423	5.9%
HTN	No	24,741	85.7%	5966	82.6%
	Yes	4139	14.3%	1254	17.4%

[#] The eGFR was calculated using the 2021 CKD-EPI Creatinine Equation (See Table 1)

SD, standard deviation; BMI, body mass index; GGT, gamma-glutamyl transpeptidase; eGFR, estimated glomerular filtration rate; DM, diabetes mellitus; HTN, hypertension; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration

patients with drinking habits did not significantly affect renal function. However, diabetic patients with drinking habits exhibited better renal outcomes, with a 3.12 mL/min/1.73 m^2 increase in eGFR (95% CI: 0.4 to 5.84). In the three-way interaction analysis (Drinking*HTN*DM), combined exposure was associated with a 5.19 mL/min/1.73 m^2 increase in eGFR (95% CI: 1.57 to 8.8).

Discussion

The study demonstrated the complex relationship between alcohol consumption and renal outcomes. We analyzed participants from the Taiwan Biobank, including their demographic data, social habits, preexisting comorbidities, and the corresponding renal function indices, including serum creatinine levels and eGFR. In contrast to the well-established detrimental effects of alcohol on other organs, drinkers in our population appeared to have preserved renal function and lowered creatinine levels. This finding is consistent with several previous studies. A meta-analysis of 15 cohort studies concluded that moderate drinkers who consume less than 60 g of alcohol daily had a lower risk of eGFR decline [22]. Regionally, a Taiwan-based cross-sectional cohort study also reported an inverse association between alcohol consumption and the incidence of stage 3 CKD [30]. Possible explanations include polyphenols contained in various alcoholic beverages, which exhibit anti-oxidative properties and may benefit the kidney by reducing ROS, modulating intestinal microbiota, and exerting anti-inflammatory effects [35, 36]. Experimental studies have suggested that alcohol may protect the kidney by reducing the hyalinization of renal arterioles and preventing ischemia-reperfusion injury, as seen in animal models [30, 37, 38].

In line with established knowledge, our study confirmed that comorbidities including DM and HTN were found to harm renal function. However, few studies have

Table 3 Regression models of the association between drinking and renal function indices

	Creatinine[†] (mg/dL)			**eGFR[#†] (mL/min/1.73m^2)**					
	Estimate	**95%LCI**	**95%UCI**	**Estimate**	**95%LCI**	**95%UCI**			
Intercept	0.91	0.72	1.11	108.48	106.70	110.27			
Drinking	**-0.15**	**-0.22**	**-0.08**	**2.54**	**1.91**	**3.18**			
BMI	**0.02**	**0.01**	**0.03**	**-0.35**	**-0.42**	**-0.27**			
DM	0.09	-0.03	0.21	**-4.76**	**-5.88**	**-3.64**			
HTN	0.02	-0.06	0.10	**-7.38**	**-8.13**	**-6.64**			
	eGFR[#†](mL/min/1.73m^2)			**eGFR[#†](mL/min/1.73m^2)**			**eGFR[#†](mL/min/1.73m^2)**		
	Estimate	**95%LCI**	**95%UCI**	**Estimate**	**95%LCI**	**95%UCI**	**Estimate**	**95%LCI**	**95%UCI**
Intercept	108.51	106.73	110.30	108.55	106.77	110.34	108.55	106.77	110.33
Drinking	**2.29**	**1.59**	**2.99**	**2.36**	**1.71**	**3.02**	**2.40**	**1.76**	**3.05**
BMI	**-0.35**	**-0.42**	**-0.27**	**-0.35**	**-0.42**	**-0.28**	**-0.35**	**-0.42**	**-0.28**
DM	**-4.76**	**-5.88**	**-3.64**	**-5.39**	**-6.64**	**-4.14**	**-5.24**	**-6.41**	**-4.07**
HTN	**-7.73**	**-8.57**	**-6.89**	**-7.39**	**-8.13**	**-6.65**	**-7.51**	**-8.26**	**-6.76**
Drinking*HTN	1.54	-0.17	3.25						
Drinking*DM				**3.12**	**0.40**	**5.84**			
Drinking*HTN*DM							**5.19**	**1.57**	**8.80**

[#] The eGFR was calculated using the 2021 CKD-EPI Creatinine Equation (See Table 1).; [†] for each 1-unit increase

Values presented in **bold** indicate a significance of $p < 0.01$

eGFR, estimated glomerular filtration rate; BMI, body mass index; DM, diabetes mellitus; HTN, hypertension; LCI, lower confidence interval; UCI, upper confidence interval; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration

considered the modifying effect of alcohol consumption. A Korean cohort study on alcohol intake stated that pre-existing conditions including DM and HTN had no association with final renal outcomes [18]. In our study population, alcohol consumption was positively associated with renal function in diabetic participants, as well as in participants with both DM and HTN. One possible explanation is that alcohol may facilitate vascular health by increasing serum concentrations of high-density lipoprotein (HDL) or by slowing the decline of HDL levels [39]. Diabetic and hypertensive patients develop nephropathy partially due to advanced atherosclerosis [24]. HDL may reduce the risk of atherosclerosis development by promoting endothelial cell survival and exerting antioxidative effects [40]. In addition, alcohol increases insulin sensitivity and lowers blood glucose levels in several established studies, particularly in post-menopausal women, insulin-resistant individuals, and diabetic people [9, 41–43]. Since insulin resistance is commonly associated with CKD [44], improved sensitivity may help preserve renal function in diabetic people. Furthermore, resveratrol, a polyphenolic compound commonly found in alcoholic beverages, particularly benefits type 2 diabetes patients. This compound can potentially improve lipid profile, and lower hemoglobin A_{1c}, blood urea nitrogen, and serum creatinine levels among diabetic patients, indicating a protective effect on the kidneys [45]. Lastly, the participants in our study are relatively healthy with few binge or heavy drinkers [32]. Since light to moderate drinking is beneficial to renal function [17, 22, 23], individuals with DM or HTN who drink moderately might experience better renal outcomes compared to non-drinkers. Lifestyle differences may further support this observation. Naimi et al. reported that regular drinkers tend to have fewer health risk factors and rarely exceed drinking limits compared to infrequent drinkers [46]. Per our study population, infrequent drinkers may report as "non-drinkers" but could have more negative issues affecting the kidneys. These factors may explain the seemingly paradoxical findings observed in our study.

We considered the state of hepatic function in our study's population. Liver enzymes, GGT in particular, reflect the status of alcohol consumption [47]. As shown in Table 2, GGT levels were significantly higher in the drinkers group compared to the non-drinkers group. This indicates that liver enzyme elevation is correlated with drinking habits. The "sick quitter" phenomenon has been proposed to explain potential bias in observational studies, wherein individuals cease alcohol drinking following the diagnosis of certain health issues, including cancers, cardiovascular diseases, and mental health disorders [48]. In our population, it is reasonable that people with comorbidities such as DM and HTN receive medical advice to reduce or quit alcohol consumption. Individuals with a previous drinking history may therefore report as "non-drinkers", exaggerating the benefit of alcohol consumption. However, after considering the effect of GGT on renal function, as presented in Supplementary Table 1, the overall trend remained unchanged. This suggested that although the GGT was elevated in the drinking group, it was not a determining factor affecting renal function in our study. A possible explanation is that the Taiwan Biobank recruits relatively healthy volunteers without a prior cancer diagnosis and with greater health awareness [32]. The proportion of individuals who abstain from alcohol due to liver dysfunction is likely low, minimizing its impact on the overall interpretation of the results.

The strength of our study includes the novel approach of providing an in-depth analysis of the effects of alcohol consumption on renal function specifically among patients with DM and HTN, which has rarely been discussed previously. The large sample size which consisted of 118,780 biobank participants may provide reliability and generalizability for our result. However, several limitations of the study should be identified. First, as a cross-sectional observational study, we were unable to establish causal relationships, as other confounding factors such as average hydration status, liver dysfunction, dietary habits, or drug usage may have been unmeasured. Previous study has demonstrated the association between hydration level and renal function [49]. To address possible confounding factors, we considered the effect of hydration status, defined as average daily fluid intake (mL/day). The data was collected from the biobank questionnaire, specifically from the question: "How much water do you consume on an average day?". A high proportion of missing values was observed, with response rates of 13.5% in the non-drinker group and 30.4% in the drinker group. Further statistical analysis showed no significant difference in hydration status between groups, as shown in Supplementary Table 2. In our population, hydration status may be less considered a confounding factor. Additionally, people with impaired liver function may result in alcohol abstinence, and liver dysfunction itself could contribute to decreased renal function [50], rather than being a direct effect of alcohol. This raises the possibility of reverse causality, and longitudinal study may be required to clarify the relationship. Second, since our analysis relied on self-reported data regarding alcohol consumption and comorbidities, reporting bias or inaccuracies might have occurred. However, the results in Table 2 indicate that alcohol consumption appears to have a protective effect on renal function, which is consistent with current mainstream research findings, suggesting limited influence from this bias. Lastly, the biobank's participants are mainly composed of healthy individuals, the effect of alcohol on CKD patients might be underrepresented. We

also assumed these individuals drank responsibly, rather than heavy or binge drinkers. These limitations provide valuable directions for further research.

Conclusion

Our study on participants from the Taiwan Biobank suggested a possible association between alcohol intake and better renal outcomes. This association appeared stronger in individuals with DM and HTN, potentially due to factors including vascular protection, the effect of polyphenols, improved glucose metabolism, and lifestyle differences. Although pre-existing liver conditions and hydration status were considered, given the cross-sectional design, the observed associations should be interpreted with caution. Our results do not suggest the encouragement of alcohol consumption, as damage to other organs remains a significant concern. The findings may be applied to the Taiwanese population given that the national-level database primarily comprises Taiwanese individuals. Further longitudinal and mechanistic research is warranted to validate these findings.

Abbreviations

BMI	Body mass index
CKD	Chronic kidney disease
CKD-EPI	Chronic Kidney Disease Epidemiology Collaboration
DM	Diabetes mellitus
ESRD	End-stage renal disease
eGFR	Estimated glomerular filtration rate
GFR	Glomerular filtration rate
GGT	Gamma-glutamyl transpeptidase
HDL	High-density lipoprotein
HTN	Hypertension
MDRD	Modification of Diet in Renal Disease
ROS	Reactive oxygen species
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

C–C. Yang, H–Y. Chuang contributed to the conception and design of the study; C–C. Yang, S–K. Luo, and H–P. Tu contributed to acquisition; C–C. Yang, and S–K. Luo contributed to analysis; C–C. Yang and H–P. Tu contributed to interpretation of data; F–C. Lin, C–C. Yang and H–Y. Chuang drafted the article/revised the article; C–H. Hung contribute to supervision. All authors read and approved the final manuscript.

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Data availability

The data supporting the findings of this study are available from the corresponding author, Dr. Chen–Cheng Yang, at abcmacoto@gmail.com, upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Kaohsiung Medical University Hospital, which also waived the need for consent to participate (IRB number: KMUHIRB-G(II)-20200007). The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. This article does not contain any studies with animals performed by any of the authors.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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