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ORIGINAL ARTICLE

Increased amount and duration of tea consumption may be associated with decreased risk of renal stone disease

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Abstract

Purpose Previous studies have looked into the association between tea consumption and renal stone disease, but the impact of tea consumption over time has not yet been fully clarified. Our study aimed to examine the amount and duration of tea consumption concomitantly in relation to the risk of renal stone disease.

Methods A total of 13,842 subjects who underwent health check-ups were recruited. Average tea consumption per day was defined as the amount of tea consumption per day multiplied by the frequency per week divided by seven. A "cup" was defined as 120 mL for each Chinese traditional teapot," and "cup-year" was calculated by multiplying the number of daily cups and the years of tea consumption to express the cumulative dose of tea consumption over time. The diagnosis of renal stone disease was established based on the results of abdominal sonography.

Results The amount of daily tea consumption was 119.2 ± 306.8 and 131.7 ± 347.3 mL in groups with and without renal stone disease. After adjusting for other clinical variables, daily tea consumption ≥ 240 mL vs. none was related to lower risk of renal stone disease (OR = 0.84, CI 0.71–0.99, $p = 0.037$). In another model, the associated risk of renal stone disease decreased significantly with tea consumption ≥ 20 cup-year (OR = 0.79, CI 0.66–0.94, $p = 0.008$), but not < 20 cup-year (OR = 0.92, CI 0.78–1.09, $p = 0.34$).

Conclusions Daily tea consumption ≥ 240 mL (two cups) was associated with a lower risk of renal stone disease. Tea consumption ≥ 20 cup-year also had a decreased associated risk of renal stone disease.

Keywords Tea · Amount · Cup-year · Renal stone disease

Introduction

Renal stone disease refers to the presence or formation of concretions in the kidney. The prevalence of this condition has increased in recent decades [1]. Both genetic features and environmental factors play a role in the urinary supersaturation process. Among the environmental risk factors, diet is an important one [2]. Increased water intake is associated with a lower risk of renal stone disease, but this is not true for all types of fluids [3]. Increased consumption of coffee, beer, wine, and orange juice is associated with a reduced associated risk, while consumption of sugar-sweetened soda and punch is not [4, 5]. In many countries, including Taiwan, tea is one of the most commonly consumed beverages, second only to water. Previous studies have investigated the association between tea consumption and renal stone disease, but the results are still unclear [4, 6–8]. Two of these studies used only questionnaires to evaluate the diagnosis of renal stone disease [4, 6]. In addition, the impact of the duration of tea consumption was not investigated in the aforementioned studies. Therefore, the objective of this study was to examine the amount and duration of tea consumption in relation to the risk of renal stone disease.

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Methods

Study population and data collection

The present study was conducted as a retrospective study to investigate the relationship between tea consumption and renal stone disease. The study participants were recruited from examinees who were ≥ 18 years old undergoing health check-ups including abdominal sonography at the health examination center of National Cheng Kung University Hospital from June 2001 to August 2009. Because this study was aimed toward an investigation of calcium renal stones, individuals with a history of hyperuricemia or gout at baseline ($n = 153$) or abdominal sonography showing gouty nephropathy ($n = 106$) were excluded. Subjects with findings of sonography showing transplanted kidney ($n = 3$), only one kidney ($n = 37$), or missing data ($n = 2013$) were also excluded. Finally, a total of 13,842 participants were enrolled in this study. The Ethical Committee for Human Research at the National Cheng Kung University Hospital approved the study protocol used in this work (IRB number: B-ER-106-066). The participants' informed consent was not needed because the data did not contain personal identification and were analyzed anonymously.

Demographic information, personal medical history, tea consumption, alcohol consumption, smoking, and regular exercise were collected with a self-administered questionnaire survey prior to routine health check-ups. Body mass index (BMI) was calculated as weight (kilograms) divided by height (meters) squared. Systolic and diastolic blood pressures (SBP, DBP) were measured with an automatic blood pressure monitor, with the subjects in a supine position after at least 5 min of rest. All participants were asked to fast overnight and had blood samples collected for analysis of fasting plasma glucose (FPG), HbA1c, uric acid, and renal function. With the exception of pregnant women and those taking oral hypoglycemic agents or insulin injections, all participants received a 75-g oral glucose tolerance test and were checked for 2-h post-load glucose (2 h PG).

Assessment of tea consumption

Information on tea consumption [9] was obtained with four closed-ended questions, including: (1) Have you drunk tea habitually once a week for at least 6 months? (2) How much (in milliliters) tea do you drink each day? (3) How many times do you drink tea in 1 week? (4) How many years have you been drinking tea in this way? We provided examples of tea containers to help participants answer the amount of tea consumption more accurately, such as 120 mL for a traditional Chinese teapot, 250 mL for tea drink in a mug, 300 mL per pack for aluminum foil packed tea, and 350 mL per can for canned tea.

Based on this questionnaire, average tea consumption per day was calculated as the amount of tea consumed per day multiplied by the frequency per week then divided by seven. Using the average tea consumption per day, we categorized the participants into three subgroups: (1) no tea consumption, (2) tea consumption < 240 mL per day, and (3) tea consumption ≥ 240 mL per day. In addition, we defined a "cup" of tea as120 mL for each Chinese traditional teapot, and thus the number of cups of daily tea consumption was calculated as daily tea consumption divided by 120 mL. By multiplying the daily cups and the years of tea consumption, we obtained the variable "cup-year" to express the cumulative dose of tea consumption over time.

Assessment of renal stones

All participants were asked to fast more than 8 h and underwent abdominal sonography performed by experienced radiologists who were unaware of the objectives of the study, using a convex-type real-time electronic scanner (XarioSSA-660A, Toshiba, Tokyo, Japan). The diagnosis of renal stones was established on the results of the abdominal sonography, which showed (1) light points or light regiments in the kidney, accompanied by vertical acoustic shadows or (2) several echo light bands, strong echoes, or acoustic shadows [7].

Definition of other covariates

Cigarette users were classified as non-smoker, ex-smoker, or current-smoker, and alcohol consumption was classified to no alcohol consumption, previous alcohol consumption, and current alcohol consumption. Regular exercise was defined as a minimum of 20 min at least three times per week. We defined obesity as BMI ≥ 27 kg/m^2 and overweight as 24 kg/m^2 ≤ BMI < 27 kg/m^2. Hypertension was diagnosed as participants having SBP/DBP ≥ 140/90 mmHg or a positive history of hypertension. Diabetes mellitus was defined as FPG ≥ 126 mg/dl, 2 h PG ≥ 200 mg/dl, HbA1c ≥ 6.5% or a positive history of diabetes.

Statistical analyses

The 17th version of the SPSS (Chicago, Illinois, USA) software was used to carry out the analysis. Continuous variables were expressed as the mean ± standard deviation, and categorical variables were expressed as numbers (percentages). Student's t test and the Mann–Whitney U test, where appropriate, were performed to compare continuous variables, and a Chi-square test was used for between-group

comparison of participants with and without renal stone disease. Variables including age, gender, BMI, hypertension, diabetes, plasma creatinine and uric acid level, smoking, alcohol consumption, and regular exercise were considered risk factors for renal stones, so these variables were included for adjustment. Using a multiple logistic regression model with adjustments for these variables, we calculated the adjusted odds ratio (OR) and the 95% confidence interval (CI) of tea drinking for the risk of renal stone disease. Throughout the analyses, we considered a two-sided p value < 0.05 as statistically significant.

Results

The demographic and clinical parameters are summarized in Table 1. A total of 1445 subjects (10.4%) had renal stone disease. Compared to those without renal stone disease, subjects with it were more likely to be male, older, and smokers, and had a higher BMI, higher plasma creatinine and uric acid levels, and a prevalence of hypertension and diabetes was also found. The amount of daily tea consumption was 119.2 ± 306.8 and 131.7 ± 347.3 mL in the groups with and without renal stone disease, but the difference was not statistically significant ($p = 0.15$) in the Mann–Whitney U analysis. No significant between-group differences were noted in the alcohol consumption and regular exercise groups.

Table 2 shows the relationship between the clinical variables and renal stone disease based on a multiple logistic regression. In model 1, after adjusting for age, gender, BMI, hypertension, diabetes, plasma creatinine and uric acid level, smoking, alcohol consumption, and regular exercise, daily tea consumption ≥ 240 mL were related to a lower risk of renal stone disease (OR = 0.84, CI 0.71–0.99, $p = 0.037$). When we changed the variable ''amount' of daily tea consumption" into ''cup-year'' in the multiple logistic regression (model 2), tea consumption ≥ 20 cup-year was related to a 20% reduced risk of renal stone disease. The risk for renal stone disease decreased significantly with tea consumption ≥ 20 cup-year (OR = 0.79, CI 0.66–0.94, $p = 0.008$), but not < 20 cup-year (OR = 0.92, CI 0.78–1.09, $p = 0.34$). In the analysis considering the types of tea (data not shown), oolong tea (OR = 0.84, CI 0.72–0.98, $p = 0.03$) showed a significant inverse association with renal stone disease. Green tea exhibited a borderline association (OR = 0.83, CI 0.66–1.06, $p = 0.13$), while black tea and "others" did not.

Discussion

This was the first study to show tea consumption to be associated with a lower risk of renal stone disease when considering both the amount of tea consumption and time.

Table 1 Comparisons of clinical parameters between subjects with and without renal stone disease

	Renal stone diseases		p value
	No ($n = 12,397$)	Yes ($n = 1445$)	
Age, year	49.0 ± 12.9	51.8 ± 11.7	< 0.001
Male gender	7148 (57.7)	1046 (72.4)	< 0.001
Body mass index, kg/m^2	24.3 ± 3.6	24.9 ± 3.4	< 0.001
BMI statuses, < 24 kg/m^2	6074 (49.0)	595 (41.2)	< 0.001
24–26.9 kg/m^2	3848 (31.0)	493 (34.1)	
≥ 27 kg/m^2	2475 (20.0)	357 (24.7)	
SBP, mmHg	118.4 ± 17.9	122.8 ± 18.4	< 0.001
DBP, mmHg	69.6 ± 10.9	73.1 ± 11.5	< 0.001
Hypertension	2279 (18.4)	377 (26.1)	< 0.001
FPG, mg/dL	94.8 ± 26.5	97.9 ± 27.4	0.001*
2 h PG mg/dL	123.9 ± 53.6	130.8 ± 58.5	0.009*
HbA1c, %	5.8 ± 1.0	5.9 ± 1.0	0.003*
Diabetes mellitus	1720 (13.9)	270 (18.7)	< 0.001
Creatinine, mg/dL	0.88 ± 0.45	0.92 ± 0.21	< 0.001*
eGFR, ml/min/1.73 m^2	92.5 ± 18.5	90.0 ± 18.7	< 0.001
Uric acid, mg/dL	6.0 ± 1.5	6.4 ± 1.6	< 0.001
Smoking, none	10,385 (83.8)	1167 (80.8)	0.001
Ex	778 (6.3)	125 (8.7)	
Current	1234 (10.0)	153 (10.6)	
Alcohol consumption, none	10,736 (86.6)	1236 (85.5)	0.40
Ex	383 (3.1)	53 (3.7)	
Current	1278 (10.3)	156 (10.8)	
Tea consumption, none	8886 (71.7)	1062 (73.5)	0.34
< 240 mL/day	1446 (11.7)	160 (11.1)	
≥ 240 mL/day	2065 (16.7)	223 (15.4)	
Tea consumption, none	8886 (71.7)	1062 (73.5)	0.21
< 10 years	1507 (12.2)	154 (10.7)	
≥ 10 years	2004 (16.2)	229 (15.8)	
Regular exercise	958 (7.7)	117 (8.1)	0.62

Data expressed as mean ± standard deviations or number (%)

BMI Body mass index, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *FPG* fasting plasma glucose, *2h PG* 2-hour post-load glucose

*Mann–Whitney U test

Previous studies [4, 6–8] have not addressed the association between tea consumption over time and renal stone disease although the association between the amount of tea consumed and renal stone disease has been examined. Studies have found that higher amounts of tea consumption are related to a lower incidence of renal stone disease [4, 6], but others have found no significant association [7, 8]. A recently published meta-analysis of three studies found protective associations for an increased intake of tea, and the protective effect of tea consumption appeared to begin at a daily intake level of approximately 250 mL [3]. This study

Table 2 Multiple logistic regression models for the relationship between clinical variables and renal stone disease

	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Age, ≥ 65 vs < 65 years	1.00 (0.84–1.19)	1.00 (0.84–1.19)
Gender, male vs female	1.76 (1.52–2.04)***	1.76 (1.52–2.05)***
BMI, 24–26.9 vs < 24 kg/m^2	1.01 (0.92–1.19)	1.05 (0.92–1.19)
≥ 27 vs < 24 kg/m^2	1.10 (0.95–1.28)	1.11 (0.95–1.29)
Hypertension, yes vs no	1.40 (1.22–1.60)***	1.40 (1.22–1.61)***
Diabetes mellitus, yes vs no	1.24 (1.07–1.45)**	1.24 (1.07–1.45)**
Creatinine, mg/dl	0.83 (0.67–1.03)	0.83 (0.67–1.03)
Uric acid, mg/dl	1.09 (1.05–1.14)***	1.09 (1.05–1.14)***
Smoking, ex vs none	1.17 (0.94–1.45)	1.17 (0.94–1.46)
Current vs none	0.98 (0.80–1.19)	0.98 (0.81–1.20)
Alcohol consumption		
Ex vs none	0.94 (0.69–1.28)	0.93 (0.68–1.27)
Current vs none	0.87 (0.71–1.06)	0.87 (0.72–1.07)
Tea consumption		
< 240 mL/day vs none	0.87 (0.73–1.05)	
≥ 240 mL/day vs none	0.84 (0.71–0.99)*	
Tea consumption		
< 20 cup-year vs none		0.92 (0.78–1.09)
≥ 20 cup-year vs none		0.79 (0.66–0.94)**
Regular exercise, yes vs no	1.03 (0.84–1.27)	1.03 (0.84–1.26)

*$p < 0.05$

**$p < 0.01$;

***$p < 0.001$

found daily tea consumption ≥ 240 mL was related to a 16% reduced risk of renal stone disease, but the same finding for daily tea consumption < 240 mL was not found in the multivariate analysis. The insignificant difference in the proportion of tea consumption ≥ 240 mL/day between subjects with and without renal stone disease shown in Table 1 may be related to a higher prevalence of renal stone disease in males because we found that after adjusting for gender, tea consumption ≥ 240 mL/day became significantly related to renal stone disease based on adding other covariates in the multiple logistic regression step by step. Furthermore, we used a new term, namely "cup-year," to express the cumulative dose of tea consumption over time reflecting the impact of tea consumption amount and time simultaneously. Tea consumption ≥ 20 cup-year was related to a 20% reduced risk of renal stone disease, while tea consumption < 20 cup-year was not. It seems that the protective effect of tea consumption on renal stone disease is not only dose-dependent, but also time-dependent. Considering the impact of types of tea, it was also found that a lower associated risk of renal stone disease was significant in subjects who consumed oolong tea and borderline in those with green tea consumption. To our knowledge, oolong tea and green tea are known to have lower oxalate content as compared to black tea [10], and oxalates are injurious to renal tubular cells and a risk factor for crystal formation in the kidney [11]. Although lower oxalate content could partially explain the inverse association of oolong tea and renal stone disease; the exact mechanisms require further study.

Increased fluid intake is known to be associated with a reduced risk of renal stone disease, and daily fluid intake of 2.5–3 L or urine output of 2.5 L is recommended [12]. Since the recommended amount of fluid intake is far more than the 240 mL tea consumption observed in our study, the effects of tea on renal stone disease may be related to factors other than the amount of fluid intake. The mechanism underlying the inverse association between tea and renal stone disease may be related to the effects of caffeine and epigallocatechin-3-gallate (EGCG) on the dilution of urine, the calcium oxalate monohydrate (COM)-binding protein, and the antioxidative properties of tea. Previous studies have shown that administration of caffeine causes an increase in urine output, and the dilution of urine associated with tea consumption may contribute to the lower risk of renal stone disease [5, 13]. The COM stone is the most common type of renal stone in clinical calculi [14, 15]. COM crystal-binding proteins (e.g., annexin A1, α-enolase, heat shock protein 90) located on the apical membranes of renal tubular epithelial cells are found to play an important role in COM crystal adhesion, intratubular COM crystal retention, and subsequently stone formation [16–18]. Caffeine and EGCG are two main components in tea leaves that may be potential modulators, which can alter the expression of COM crystal receptors and subsequently decrease the risk of renal stone disease [16, 19]. In addition, tea consumption has been shown to decrease the excretion of urinary oxalate and to inhibit the free radical production induced by oxalate, possibly due to the antioxidative properties of EGCG [11, 20]. However, the impacts of tea on renal stone disease need further studies.

Among the factors independently related to renal stone disease examined in this study, tea consumption was found to be one of the weak ones. Consistent with previous research [1, 21], the findings of this study also confirmed the associated risk factors of renal stone disease, including male gender, hypertension, and diabetes. Serum uric acid level has been considered an important risk factor of renal stone disease [12], and this study showed a similar result even after excluding individuals with a history of hyperuricemia or gout and abdominal sonography of gouty nephropathy. The results of the association of renal stone disease with age [22] and obesity [1] in this and previous studies were inconsistent. These inconsistencies were possibly related to the confounding effect of other cardiac metabolic variables. Life style habits, such as smoking [23,

24], alcohol consumption [3, 25] and exercise [23, 26], have also been found in the literature to be inconsistently associated with renal stone disease. An explanation for this discrepancy may be related to the definition of the amount and time of the given habit under examination. In addition, in this cross-sectional study, another explanation for such discrepancies might be related to the fact that people with habits including smoking, alcohol consumption, and physical inactivity may change their lifestyle when their health deteriorates.

Our study has some limitations. As with any retrospective work, the limitations of retrospective design are inherent, and the causality for the effects of tea consumption on renal stone disease should be generalized with caution. Since the participants enrolled were mostly ethnic Taiwanese individuals, further studies are needed for other groups. The information regarding tea consumption was collected using questionnaires, and thus, the unique details of individual tea intake could not be obtained. Although non-contrast computerized tomography is a more precise method to assess renal stone disease, the participants in this study were health check-up examinees, and sonography was more suitable because it was non-aggressive and convenient. In addition, information on stone composition was lacking, and there were no data on the amount of other fluids consumed, such as water. Consumers who drink more tea may drink higher amounts of fluid in general because some people may brew the same tea leaves multiple times. Nevertheless, this study provides some evidence of the potentially beneficial effect of tea consumption on renal stone disease, and it would be interesting to compare groups with the same fluid intake, but different degrees of tea consumption regarding stone formation in future research.

In summary, our study suggests that a daily tea consumption ≥ 240 mL is related to decreased risk of renal stone disease, and when further considering the amount and duration of tea consumption concomitantly, tea consumption ≥ 20 cup-year is associated with lower risks of renal stone disease. Our results provided a further indication that greater tea consumption over time might be associated with a lower risk of renal stone disease.

Author contributions HYC Project development, data analysis, manuscript writing. JSW Project development, data collection and management. YFC Project development, data collection and management. ZJS Data collection and management. CJC: Data collection and management. FHL: Project development, data collection and management, critical review of the manuscript, primary responsibility for the final content. YCY: Project development, data collection and management, critical review of the manuscript. All authors read and approved the final manuscript.

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Compliance with ethical standards

Research involving human/animal participants The Ethical Committee for Human Research at the National Cheng Kung University Hospital approved the study protocol used in this work (IRB number: B-ER-106-066).

Informed consent The participants' informed consent was not needed because the data did not contain personal identification and were analyzed anonymously.

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