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A Study of Diet and Lifestyle and the Risk of Urolithiasis in 1,519 Patients in Southern China

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Background: This study aimed to evaluate the risk factors associated with the development of urolithiasis in a population in Southern China.

Material/Methods: A questionnaire-based study was conducted between March 2017 to April 2018 that included 1,519 patients in Southern China and included questions on patient demographics, diet, and lifestyle. Patients were divided into the urolithiasis group who had urinary calculi and the control group.

Results: There were 829 patients (54.6%) in the urolithiasis group and 690 patients (45.4%) in the control group. Using a chi-squared (χ^2) test, 13 variables were found to be significantly associated with urolithiasis, including age, physical activity, and dietary factors that included high sodium, protein, fat, lean meat, vegetables, pickled food, fluid intake, drinking habits and tea consumption, and frequency and duration of physical exercise. Multivariate logistic regression analysis showed that dietary factors, including vegetables (OR, 0.856; 95% CI, 0.769–0.948), pickled foods (OR, 1.271; 95% CI, 1.030–1.357), and animal protein intake (OR, 1.138; 95% CI, 1.031–1.258), drinking strong tea (OR, 0.793; 95% CI, 0.702–0.897), fluid intake (OR, 0.758; 95% CI, 0.644–0.816), and duration of physical exercise (OR, 0.840; 95% CI, 0.808–0.973) were significantly associated with the occurrence of urolithiasis and were independent risk factors.

Conclusions: High consumptions of pickled foods and animal protein were the main risk factors for the development of urolithiasis in a population of southern China, but high fluid intake with a preference for strong tea, a diet of vegetables, and physical exercise were protective factors.

MeSH Keywords: Epidemiology • Food Habits • Life Style • Risk Factors • Urinary Calculi

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Background

Recently, the epidemiology of urolithiasis has changed due to changes in dietary habits and advances in diagnosis and the treatment. From 1991 to 2000, 2001 to 2010, and 2011 to 2016, the prevalence of urolithiasis in China were 5.95%, 8.86%, and 10.63%, respectively, which shows an increasing trend [1]. Data have shown that rural areas have a higher incidence of urolithiasis than urban areas, and the prevalence in the southern regions in China has been reported to be higher than that in northern regions [2]. Also, the five-year recurrence rate of stone formation has been reported to be between 31.5–50%, and the 20-year recurrence rate is 72% [3,4]. This epidemiological data supports that urologists in southern China should not only to focus on surgical treatment of urinary calculi but should reduce the recurrence rate of stone formation.

This study aimed to evaluate the risk factors associated with the development of urolithiasis in a population in southern China.

Material and Methods

Ethical approval and patient consent

This study was approved by the Ethics Committee of The First Affiliated Hospital, Yijishan Hospital of Wannan Medical College (Approval No. HECYJS-2016002). Informed consent was obtained from all the individuals who participated in the study.

Clinical data

From March 2017 to April 2018, a questionnaire survey was conducted on patients admitted to the Department of Urology, the First Affiliated Hospital, Yijishan Hospital of Wannan Medical College. Inclusion criteria were a diagnosis of urolithiasis, age >18 years, residents in South China, and the availability of complete clinical data. Patients were excluded if they had incomplete clinical data, serious disease of the major organs, including the heart, lung, brain, gastrointestinal tract, and liver, chronic non-obstructive kidney disease, hematological or autoimmune diseases, or had lived away from southern China for more than five years. The individuals in the control group were also enrolled from the urology clinic and had the same inclusion and exclusion criteria as the urolithiasis study group, but with B-scan (B-mode) ultrasonography that confirmed the absence of urolithiasis.

There were 1,519 patients that included 829 patients (54.6%) with urinary calculi who were assigned to the urolithiasis group, and 690 patients (45.4%) without urinary calculi who were assigned to the control group. The control group without urolithiasis attended the urology clinic with a diagnosis of urologic neoplasm (62.2%), cyst disease (18.4%), urinary infection (4.6%), urinary injury (8.0%) and infertility (6.8%).

Patient questionnaire

The questionnaire was designed by urologists and epidemiologists and was completed by the designated study investigators who were trained nurses and resident doctors in the urology wards, who interviewed the study participants in the urolithiasis group and the control group. Questions on established risk factors for urinary calculi included demographic characteristics, of gender, age, occupation, residence, education level, dietary habits, fluid intake, and physical activity.

Daily fluid intake was directly measured in milliliters in the hospital wards, and the frequency and type of liquid intake (milk, coffee, tea, carbonated beverages, and juices) were recorded. The strength of tea that was drunk was divided into strong, medium, and light, according to the volume of tea leaves used. Individual dietary preference for spicy food, acidic food, dietary preference for fatty or lean meat, sodium intake, and carbohydrate intake were recorded by direct questioning of the patient. Particular common food preferences in southern China, such as pickles (Chinese homemade salty vegetables) and salted bacon, were also included in the survey. Occupation was classified into office worker, non-manual worker or home-based, and manual laborer.

Statistical analysis

Data were analyzed with EpiDate3.1 and SPSS version 17.0 software (IBM, Chicago, IL, USA). A chi-squared (χ^2) test was used to determine the significance of the variables, and multivariate logistic analysis was used to test the independent risk factors for urolithiasis. A P-value <0.05 was considered to be statistically significant.

Results

Data analysis using the chi-squared (χ^2) test identified 13 variables that were statistically significant (P<0.05), including age, physical activity, high sodium intake, animal protein consumption, fatty or lean meat preference, vegetables intake, pickled food consumption, fluid intake, drinking habits, tea consumption, strong tea preference, and frequency and duration of physical exercise (Table 1).

The 13 variables were included in the multivariate logistic regression analysis model. Work stress was also included (P=0.074). Multivariate logistic regression analysis showed that dietary factors, including vegetables (OR, 0.856; 95% CI, 0.769–0.948), pickled foods (OR, 1.271; 95% CI, 1.030–1.357),

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Table 1. Stratification analysis of the relationship between urolithiasis and diet and lifestyle.

	Urolithiasis group n (%)		Control group n (%)		c^2	*P*
Age					13.362	0.010*
18–29	100	(12.1)	117	(17.0)		
30–39	149	(18.0)	103	(14.9)		
40–49	207	(25.0)	138	(20.0)		
50–59	174	(21.0)	158	(22.9)		
≥60	199	(24.0)	174	(25.2)		
Gender					1.426	0.241
Male	510	(61.5)	445	(64.5)		
Female	319	(38.5)	245	(35.5)		
BMI					2.376	0.305
<18.5	59	(7.1)	53	(7.7)		
18.5–23.9	439	(53.0)	338	(49.0)		
≥24	331	(39.9)	299	(43.3)		
Residence	176	(21.2)	131	(19.0)	1.490	0.475
Urban	187	(22.6)	152	(22.0)		
Town	466	(56.2)	407	(59.0)		
Rural						
Occupation					1.921	0.383
Office worker	518	(62.5)	438	(63.5)		
Housekeeper	142	(17.1)	101	(14.6)		
Manual laborer	169	(20.4)	151	(21.9)		
Labor intensity					7.986	0.046*
Rare	179	(21.6)	190	(27.5)		
Light	276	(33.3)	224	(32.5)		
Medium	160	(19.3)	122	(17.7)		
Heavy	214	(58.2)	154	(22.3)		
Work stress					5.217	0.074
Light	463	(55.9)	424	(61.4)		
Medium	304	(31.3)	216	(31.3)		
High	62	(7.5)	50	(7.2)		
Educational level					3.050	0.384
Illiteracy	382	(46.1)	289	(41.9)		
Elementary	278	(33.5)	253	(36.7)		
Middle	92	(11.1)	85	(12.3)		
College and above	77	(9.3)	63	(9.1)		
Smoking					5.678	0.128
Never	472	(56.9)	378	(54.8)		
Occasionally	129	(15.6)	96	(13.6)		
Usually	44	(5.3)	56	(8.1)		
Cessation	184	(22.2)	160	(23.2)		
Alcohol					5.466	0.141
Never	277	(33.4)	260	(37.7)		
Occasionally	321	(38.7)	256	(37.1)		
Usually	105	(12.7)	66	(9.6)		
Cessation	126	(15.2)	108	(15.7)		
Spicy food preference					0.834	0.361
No	561	(67.7)	482	(69.9)		
Yes	268	(32.3)	208	(30.1)		
High sodium intake					4.975	0.026*
No	403	(48.6)	375	(54.3)		
Yes	426	(51.4)	315	(45.7)		

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Table 1 continued. Stratification analysis of the relationship between urolithiasis and diet and lifestyle.

	Urolithiasis group n (%)		Control group n (%)		c^2	*P*
High Carbohydrate Diet					0.627	0.429
No	522	(63.0)	448	(64.9)		
Yes	307	(37.0)	242	(35.1)		
Acidic food preference					2.525	0.112
No	680	(82.0)	587	(85.1)		
Yes	149	(18.0)	103	(14.9)		
Types of edible oil					1.257	0.533
Salad oil	427	(51.5)	346	(50.1)		
Homemade vegetable oil	302	(36.4)	269	(39.0)		
Animal oil	100	(12.1)	75	(10.9)		
Animal protein consumption					6.596	0.037*
6–7 days/week	338	(40.8)	238	(34.5)		
4–5 days/week	266	(32.1)	237	(34.3)		
<3 days/week	225	(27.1)	215	(31.2)		
Fatty or lean meat preference					6.215	0.045*
Lean meat	282	(33.9)	330	(47.8)		
Half and half	315	(38.1)	110	(15.9)		
Fat meat	232	(28.0)	250	(36.3)		
Vegetables					11.368	0.003*
6–7 days/week	344	(41.5)	297	(43.0)		
4–5 days/week	257	(31.0)	164	(23.8)		
<3 days/week	228	(27.5)	229	(33.2)		
Pickled foods					20.892	0.000*
Little	74	(8.9)	85	(12.3)		
≤3 times/month	312	(37.6)	294	(42.6)		
≥1 time/week	234	(28.2)	199	(28.8)		
>3 times/week	209	(25.2)	112	(16.2)		
Animal giblets					3.089	0.378
Little	260	(31.4)	237	(34.3)		
≤3 times/month	438	(52.8)	360	(52.2)		
≥1 time/week	79	(9.5)	51	(7.4)		
>3 times/week	52	(6.3)	42	(6.1)		
Dried fruits					1.832	0.608
Little	155	(18.7)	126	(18.3)		
≤3 times/month	438	(52.8)	370	(53.6)		
≥1 time/week	168	(20.3)	149	(21.6)		
>3 times/week	68	(8.2)	45	(6.5)		
Soy bean products					2.833	0.418
Little	57	(6.9)	46	(6.7)		
≤3 times/month	343	(41.4)	283	(41.0)		
≥1 time/week	330	(39.8)	259	(37.5)		
>3 times/week	99	(11.9)	102	(14.8)		
Water drinking habits					6.138	0.046*
Drink whenever thirsty	194	(23.4)	126	(16.3)		
After meal	470	(56.7)	423	(52.8)		
Drink at any time	165	(19.9)	141	(20.9)		
Fluid intake					26.825	0.000*
<1000 ml/day	281	(33.9)	165	(23.9)		
1000–3000 ml/day	306	(36.9)	246	(35.7)		
>3000 ml/day	242	(29.2)	279	(40.4)		

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Table 1 continued. Stratification analysis of the relationship between urolithiasis and diet and lifestyle.

	Urolithiasis group n (%)		Control group n (%)		c^2	*P*
Milk					4.551	0.208
Little	306	(36.9)	267	(38.7)		
≤3 times/month	313	(37.8)	280	(40.6)		
≥1 time/week	131	(15.8)	88	(12.8)		
>3 times/week	79	(9.5)	55	(8.0)		
Coffee					1.589	0.452
Little	713	(86.0)	601	(87.1)		
≤3 times/month	82	(9.9)	69	(10.0)		
≥1 time/week	34	(2.9)	20	(2.9)		
Tea					6.398	0.041*
>3 times/week	399	(47.5)	294	(42.6)		
≥1 time/week	224	(22.4)	188	(27.2)		
≤3 times/month	206	(24.8)	208	(30.1)		
Tea concentration					9.402	0.024*
Strong	282	(34.0)	189	(27.4)		
Medium	165	(19.9)	144	(20.9)		
Light	176	(21.2)	149	(21.6)		
Overnight tea					6.073	0.108
>3 times/week	109	(13.1)	83	(12.0)		
≥1 time/week	205	(24.7)	148	(21.4)		
≤3 times/month	309	(37.4)	251	(36.4)		
Carbonated beverages					1.436	0.488
Little	390	(47.0)	342	(49.6)		
≤3 times/month	283	(34.1)	216	(31.3)		
≥1 time/week	156	(18.8)	132	(19.1)		
Juice beverages					0.484	0.785
Little	396	(47.8)	322	(46.7)		
≤3 times/month	297	(35.8)	259	(37.5)		
≥1 time/week	136	(16.4)	109	(15.8)		
Physical exercise frequency					9.404	0.024*
6–7 days/week	149	(18.0)	116	(16.8)		
4–5 days/week	183	(22.1)	173	(25.1)		
<3 days/week	242	(29.2)	232	(33.6)		
Never	255	(30.8)	169	(24.5)		
Types of physical exercise					9.236	0.100
Running	55	(6.6)	42	(6.1)		
Walking	303	(36.6)	290	(42.0)		
Dancing or boxing	105	(12.7)	95	(13.8)		
Ball games	68	(8.2)	53	(7.7)		
Others	43	(5.2)	41	(5.9)		
Duration of exercise per day					8.235	0.040*
<30 min	125	(15.1)	129	(18.7)		
30–60 min	296	(35.7)	284	(41.2)		
>60 min	153	(18.5)	108	(15.7)		

* P<0.05. Numbers may not add up to the total number of participants due to missing values.

and animal protein intake (OR, 1.138; 95% CI, 1.031–1.258), drinking strong tea (OR, 0.793; 95% CI, 0.702–0.897), fluid intake (OR, 0.758; 95% CI, 0.644–0.816), and duration of physical exercise (OR, 0.840; 95% CI, 0.808–0.973) were significantly associated with the occurrence of urolithiasis and were independent risk factors. High consumption of pickled food and animal protein were the main risk factors of urolithiasis in the population of southern China, and high fluid and vegetable

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Table 2. Multivariate logistic regression analysis.

Risk factors	Regression coefficient	SE	Wald value	P value	OR value	95% CI	
						Lower limit	Upper limit
Animal protein	0.213	0.067	6.582	0.012	1.138	1.031	1.258
Vegetables	–0.463	0.056	3.920	0.048	0.856	0.769	0.948
Duration of physical exercise	–0.317	0.049	4.162	0.027	0.840	0.808	0.973
Pickled foods	0.246	0.058	13.267	0.000	1.271	1.030	1.357
Preference for strong tea	–0.323	0.064	5.285	0.018	0.793	0.702	0.897
Fluid intake	–0.276	0.068	6.484	0.014	0.758	0.664	0.816
Constant	0.531	0.327	2.632	0.105	1.091		

SE – standard error; OR – odds ratio; 95% CI – 95% confidence interval.

intake, physical exercise and preference for strong tea appeared to be the protective factors (Table 2).

Discussion

The mechanisms involved in urolithiasis are complex, but several studies have shown that diet and lifestyle are contributing factors [5]. In the present study, we demonstrated that high consumptions of pickled foods and animal protein were the main risk factors for urolithiasis in the population of southern China. However, high intake of fluid and vegetables, physical exercise, and preference for strong tea were protective factors. Previous studies support these findings, but with some differences in the identified risk factors for urolithiasis. For example, high fluid intake has previously been shown to reduce the risk of stone formation, but no significant effects of the intake of different fluids was observed to affect stone formation in the present study [6,7]. This study also investigated the impact of pickled foods and a preference for strong tea on stone formation.

High sodium intake is thought to promote urinary sodium excretion and inhibit calcium absorption in the renal tubules, which induces hyperuricemia and the formation of calcium oxalate crystals [8]. A previously reported study included 210 patients with urolithiasis who were randomly divided into a control group and a low-sodium diet group, and their urinary calcium excretion was evaluated [9]. A low-salt diet reduced calcium excretion in patients who formed hypercalciuric stones (271 mg/day *vs.* 361 mg/day) (P<0.001), showing that dietary salt intake affected calcium excretion and stone formation [9]. In 2012, Sorensen et al. evaluated the relationship between diet and kidney stone formation and showed that by increasing dietary sodium intake by a fifth increased the risk of nephrolithiasis by 11–61% (P<0.001), with the greatest impact on women who had the highest sodium intake [10]. Another study also showed that increased sodium intake was associated with increased urinary sodium and calcium excretion, and the correlation was linear [8].

Pickles and salted bacon refer to certain types of sodium-rich foods, which are particularly popular in southern China. The sodium intake from these foods is high, but its relationship to stone formation is unclear. To the best of our knowledge, this was the first study to investigate the impact of the preference of pickled foods on the prevalence of urolithiasis, and showed that the consumption of pickled foods increased the risk of urinary stone formation (OR, 1.271). We believe that high consumption of pickled foods indirectly increased the daily intake of sodium, which might promote stone formation. Based on the findings from previous studies and this present study, it may be advisable to recommend limiting the intake of sodium and the consumption of pickles and salted bacon in the population of southern China.

Our findings indicated that high fluid intake decreased the risk of stone formation (OR, 0.758), which was consistent with previous studies. High fluid intake has been shown to increase urine volume to reduce the concentration of calcium oxalate in the urine reducing the risk and recurrence rate of stone formation by 50% and by 60–80%, respectively [11,12]. However, it remains unknown whether all liquids more or less similarly affect the risk of stone formation. It has also been shown that coffee, tea, beer, wine, and orange juice could reduce the risk of stone formation, while sugary drinks and carbonated drinks increased the risk [6]. Also, the impact of citrus fruits and fruit juices on the risk of stone formation remains controversial, and a previous study showed that individuals who drank more than 160 mL of carbonated fluid a day had a reduced risk of recurrence of symptomatic stones after they stopped drinking carbonated fluids (33.7% *vs.* 40.6%) [13]. In this study, we also found that high fluid intake reduced the risk of stone formation, and we further investigated the influence of different liquids on stone formation, including tea, milk, coffee,

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carbonated drinks, and juices. Unlike previous studies, in the present study, no significant effect of these drinks was found on urolithiasis, except for tea. This different result might have been due to distribution bias, but the association between tea drinking and stone formation requires further investigation.

In the present study, tea drinking was shown to affect urinary stone formation, which was contrary to our previous finding that long-term consumption of tea increased the risk of stone formation due to an increased intake of oxalate [14]. Also, recent studies have shown the beneficial effects of tea consumption on the prevention of stone formation [15–17]. Southern China is a tea-growing area, and tea consumption is high. In this study, tea consumption was shown to be associated with a lower risk of stone formation. Subgroup analysis by tea-drinking habits showed that strong tea preference might be a protective factor of urolithiasis (OR, 0.793). As shown in Table 1, a preference for strong tea was more prevalent in the urolithiasis group, which was different from the result of the multivariate logistic regression analysis. However, the mechanism of stone formation is complex and is likely to involve diverse risk factors. Multivariate analysis was considered to be more objective and accurate due to the exclusion of other confounding factors. The mechanism by which tea exerts its protective role for urolithiasis remains unclear. Numbers of polyphenols, including catechin, epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin gallate (EGCG), account for about 30% of the dry weight in different types of tea. These polyphenols, along with other phytochemicals, are associated with antioxidation and superoxide dismutase activation, which might contribute to the prevention of stone formation [16,18–20].

High protein intake, especially animal protein, is a known risk factor for urinary stone formation. By creating an animal model of increased protein intake, a previous study showed that with a high casein diet, urinary calcium excretion was significantly increased, and urinary citrate excretion and urinary pH were marginally lower [21]. Heilberg et al. [22] reported that short-term restriction of animal protein significantly reduced the excretion of calcium, phosphate, hydroxyproline, uric acid, and oxalate, but increased the excretion of citrate in the urine, which increased the risk of stone formation. Consistent with previous studies, the association between high animal protein consumption and an increased risk of urinary calculi was also found in this study (OR, 1.138). Also, Tracy et al. [23] compared the effects of three animal protein sources including fish, chicken, and beef on the risk of urolithiasis and showed that fish had the highest purine content and resulted in a higher 24-hour urinary uric acid excretion, compared with chicken and beef. Therefore, patients with recurrent calcium oxalate and urate calculi should minimize their consumption of animal protein and avoid foods rich in purines.

It has previously been reported that a Dietary Approaches to Stop Hypertension (DASH) diet, rich in fruits, vegetables, whole grains, and low-fat dairy foods, is associated with a significantly reduced risk of kidney stone formation [24]. Meschi et al. [25] reported that urinary excretion of citrate was significantly reduced and calcium excretion was significantly increased after a two-week diet of vegetables in a normal population. However, adding vegetables to the diet of people who rarely consume vegetables not only increased citrate excretion and urine volume, but reduced the urinary saturation of calcium oxalate and uric acid [25]. In another study, multivariate-adjusted urinary citrate excretion was 11–16% greater ($P < 0.01$) in the participants with the highest quintiles of the DASH score than that of the participants with the lowest quintiles of the DASH score [26]. Urinary citrate can bind with calcium, reducing calcium ion concentration to inhibit the polymerization of calcium oxalate and calcium phosphate crystals [27]. Fresh vegetables are rich in fiber in which inositol hexaphosphate and uronic acid are combined with calcium chelate, leading to reduced absorption of calcium and inhibition of the aggregation of calcium oxalate crystals and attachment to cells, inhibiting the formation of stones [28,29]. The findings of the present study support these previous findings as a high dietary intake of vegetables were a protective factor for urolithiasis (OR, 0.856).

This study had several limitations. The design was a case-control study that investigated the causal relationship between the potential risk factors and the occurrence of urolithiasis. Some study variables, such as dietary intake, could not be measured accurately, and there may have been high individual variables that could not have been avoided. Future studies require more accurate methods of measurement. Also, this was a small study conducted at a single center that may be associated with bias, and future large-scale multicenter controlled prospective studies are needed to validate the findings from this study.

Conclusions

This study aimed to evaluate the risk factors associated with the development of urolithiasis in a population in southern China. High consumptions of pickled foods and animal protein were the main risk factors for the development of urolithiasis, but high fluid intake with a preference for strong tea, a diet of vegetables, and physical exercise were protective factors. The findings from this study may provide an approach for the prevention of urolithiasis in southern China.

Conflict of interest

None.

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