Original Article

Kidney stones are associated with metabolic syndrome in a health screening population: a cross-sectional study

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Background: In parallel with the rise in obesity and metabolic syndrome (MetS), kidney stones are becoming more common. In this study, the relationship between MetS components and kidney stones in a health screening population was examined.

Methods: Subjects who underwent health checkups in the Health Promotion Centre of Sir Run Run Shaw Hospital of Zhejiang University between January 2017 and December 2019 were recruited for this study. In this cross-sectional study, 74,326 participants were aged 18 or older. MetS diagnostic criteria were based on the joint statement of the International Diabetes Federation (IDF) and other associations on MetS in 2009. The association between MetS and its components with kidney stones was examined using multivariable logistic regression.

Results: A total of 74,326 participants took part in this cross-sectional study, including 41,703 men (56.1%) and 32,623 women (43.9%). There were 24,815 (33.4%) patients with MetS and 2,032 (2.7%) patients with kidney stones. The prevalence of kidney stones was 3.3% in subjects with MetS and 2.4% in subjects without MetS (P<0.001). The odds ratio and 95% confidence interval (CI) for kidney stones in MetS patients were 1.157 (95% CI: 1.051–1.273). Accordingly, the prevalence of kidney stones showed a statistically significant trend of gradual increase as the number of MetS components increased (P<0.001). Among the components of MetS, elevated waist circumference, reduced high-density lipoprotein cholesterol (HDL-C), and elevated fasting blood glucose (FBG) were independent influencing factors of kidney stones (P<0.001), with odds ratios of 1.205 (95% CI: 1.085–1.337), 1.222 (95% CI: 1.105–1.351) and 1.335 (95% CI: 1.202–1.482), respectively.

Conclusions: MetS is an independent risk factor for kidney stones. Therefore, the control of MetS may help reduce the incidence of kidney stones.

Keywords: Kidney stones; metabolic syndrome (MetS); obesity; diabetes; cross-sectional study

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Introduction

Kidney stone is a common urological disease worldwide. With the great changes in people's lifestyle and diet structure, the incidence of kidney stones has been gradually increasing in recent years, with the global prevalence of about 7.2–7.7% (1) and the incidence of kidney stones in China being about 5.8% (2). It is possible that kidney stones are a systemic disease caused by the interaction of several metabolic risk factors rather than an independent urinary problem (3). Numerous studies showed that males, age, race, obesity, and metabolic syndrome (MetS) were all associated with an increased prevalence of kidney stones (4,5).

At the same time, the prevalence of MetS is increasing year by year (6-9). According to the China Noncommunicable Disease Surveillance 2010 survey, the prevalence of MetS was 33.9% among participants aged 18 years and older (10). MetS is a collection of clinical syndromes which are closely connected to obesity, hyperglycemia, dyslipidemia, and hypertension. It is a group of risk factors that are associated with metabolism (11,12).

Some studies demonstrated a strong link between MetS and kidney stones, and each component of MetS increased the risk of kidney stones separately (13,14). Although the MetS are unclear, it has been shown that MetS is associated with changes in urine composition, including decreased urinary pH, decreased citrate excretion, and increased uric acid and calcium excretion, leading to an increased risk of kidney stone formation (13).

Despite this, few large-scale cross-sectional studies have linked MetS and kidney stones. Therefore, this study was conducted to investigate the relationship of MetS and its components with kidney stones in a health screening population and to further investigate which metabolic factors have the greatest influence on kidney stone incidence, which may be useful for the prevention and treatment of kidney stones. This article was presented in accordance with the STROBE reporting checklist (available at https://tau.amegroups.com/article/view/10.21037/tau-23-51/rc).

Highlight box

Key findings
- In this large-scale cross-sectional study, MetS was found to be an independent risk factor for kidney stones, and the risk of kidney stones increased with the increase in the number of components of MetS.

What is known and what is new?
- MetS is an independent risk factor for kidney stones.
- Among the five components of MetS, elevated waist circumference, low HDL-C and elevated blood glucose were independent influencing factors of kidney stones.

What is the implication, and what should change now?
- More attention should be paid to the prevention and treatment of MetS, which may be helpful to correct urinary tract metabolic abnormalities, thus contributing to the prevention of kidney stones. Future large-scale cohort studies will be done to test this hypothesis.

Methods

Participants

This study was a cross-sectional analysis. Research subjects were selected from people who took part in a health checkup in the Health Promotion Center at Sir Run Run Shaw Hospital affiliated with Zhejiang University in Hangzhou between January 2017 and December 2019.

Inclusive criteria were as follows:

(I) Age ≥18 years old;
(II) Provision of detailed medical histories;
(III) Completion of physical examination items.

Exclusion criteria were as follows:

(I) Vulnerable groups, including mental illness, cognitive impairment, critically ill patients, and pregnant or lactating women;
(II) Patients with malignant tumors, cerebral hemorrhages, cerebral infarction, heart disease, liver failure, end-stage renal disease, or autoimmune diseases.

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Sir Run Run Shaw Hospital, affiliated with Medical College of Zhejiang University (No. 2022-0311). Patient consent was waived due to the research using the data obtained in the previous clinical diagnosis and treatment, without using the medical records that the patient has clearly refused to use. The study will not have an adverse impact on the rights and health of the subjects, and the privacy and personal identity information of the subjects will be protected.

Data collection

Medical histories were collected by trained general practitioners from Sir Run Run Shaw Hospital affiliated with Zhejiang University. The main contents included the chief complaint, current disease, previous illness, personal history, family history, and physical examination. Alcohol consumption was classified as current (>6 months on a daily basis) or non-current drinker. Smoking status was classified as current (>6 months on a daily basis) or non-current smoker. Weight, height, blood pressure (BP), and waist circumference (WC) were measured by trained nurses. An individual's body mass index (BMI) was determined by the division of their weight (kg) by their height squared (m^2). Total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), fasting blood glucose (FBG), blood urea nitrogen (BUN), blood creatinine (CR), and blood uric acid (UA) were all examined. All patients had undergone a comprehensive urinary system examination to determine if kidney stones present, and if so, its number and size. The routine urinalysis was conducted in the hospital laboratory, including urine pH, urine specific gravity, red blood cell, white blood cell, protein, and bacteria.

Diagnostic criteria for MetS

The diagnosis criteria of MetS were based on the International Diabetes Foundation (IDF) and included three or more of the following (15):

(I) Elevated waist circumference: Abdominal obesity was defined according to the global definition for Chinese populations as waist circumference ≥85 cm in men or ≥80 cm in women.

(II) Elevated triglycerides: TG ≥1.7 mmol/L (150 mg/dL) and/or specific medication to treat.

(III) Reduced HDL-C: HDL-C <1.0 mmol/L (40 mg/dL) in men or HDL-C <1.3 mmol/L (50 mg/dL) in women, and/or specific medication to treat.

(IV) Elevated blood pressure: systolic pressure ≥130 mmHg and/or diastolic pressure ≥85 mmHg (1 mmHg =0.133 kPa), and/or patients diagnosed and treated for hypertension;

(V) Elevated fasting glucose: fasting plasma glucose ≥5.6 mmol/L (100 mg/dL) and/or patients diagnosed with and treated for diabetes.

Statistical analysis

All statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). In the process of statistical analysis, clinical characteristics were summarized by median (interquartile range) for continuous variables and frequency or percentage for categorical variables. Continuous variables were analyzed using the *t*-test or Mann-Whitney U-test. Pearson χ^2 (Chi-square) test was used to assess relationships between binary categorical variables, and the χ^2 trend (Linear-by-Linear Association) was used to assess trends for ordinal categorical variables. After univariate analysis, factors with P<0.05 were included in multivariate logistic regression. Three models were established: Model 1 was unadjusted; Model 2 adjusted for age and gender; Model 3 adjusted for age, gender, smoking history, urine red blood cell, urine protein, CR, and UA. Univariate and multivariate logistic regression models were used to evaluate the odds ratios (OR) and 95% confidence intervals (CI) of factors associated with kidney stones, and to compare the OR and 95% CI of kidney stones in different MetS components. In all statistical tests, a two-sided P<0.05 was considered significant.

Results

This cross-sectional study involved 74,326 subjects, 41,703 males (56.1%) and 32,623 females (43.9%). Among these, 24,815 patients (33.4%) had MetS, while 2,032 patients (2.7%) had kidney stones. *Table 1* shows the clinical characteristics of all participants.

Table 1 shows that there are significant differences between the kidney stones group and the non-kidney stones group in gender, age, smoking history, BMI, five components of MetS, urinary red blood cell, urinary protein, CR, and UA (P<0.05). Among them, male proportion, age, smoking history proportion, BMI, waist circumference, SBP, DBP, FBG, TG, the positive rate of urine red blood cells, urine protein, CR, and UA in the kidney stones group are higher than those in the non-kidney stones group. HDL-C in the kidney stones group is lower than those in the non-kidney stones group.

Figure 1 shows that there are significant differences between the MetS group and the non-MetS group in urine pH and urine specific gravity. The MetS group has a lower urinary pH and a higher urine specific gravity than the non-MetS group.

As shown in *Table 2* and *Figure 2A*, the prevalence of kidney stones is 3.3% in the MetS group and 2.4% in the non-MetS group (P<0.001). The five components of MetS, elevated waist circumference, increased TG, decreased HDL-C, increased BP, and increased FBG are all significantly correlated with kidney stones (P<0.05). Among them, the prevalence of kidney stones in patients with elevated FBG is the highest (3.8%). At the same time, *Figure 2B* further analyzes that with the increase in the number of components of MetS, the prevalence of kidney stones shows a statistically significant trend of gradual increase (P<0.001 for trend). As shown in *Figure 3A*, the proportion of multiple kidney stones in total kidney stones is higher in the MetS group than in the non-MetS group (P<0.05). Moreover, *Figure 3B* presents the maximum size of kidney stones is larger in the MetS group than in the non-MetS group (P<0.05).

Table 3 shows the relationship between MetS and

Table 1 Basic characteristics of the study participants

Characteristics	Total	Non-kidney stones	Kidney stones	P value
Total patients	74,326	72,294 (97.3)	2,032 (2.7)	
Sex				<0.001†
Male	41,703 (56.1)	40,227 (96.5)	1,476 (3.5)	
Female	32,623 (43.9)	32,067 (98.3)	556 (1.7)	
Age (years)	45 (35–53)	45 (35–53)	45 (36–54)	0.04‡
Smoking				0.008†
Non-smoker	72,750 (97.9)	70,778 (97.3)	1,972 (2.7)	
Current smoker	1,576 (2.1)	1,516 (96.2)	60 (3.8)	
Alcohol consumption				0.264†
Non-drinker	72,893 (98.1)	70,907 (97.3)	1,986 (2.7)	
Current drinker	1,433 (1.9)	1,387 (96.8)	46 (3.2)	
BMI (kg/m^2)	23.63 (21.45–25.9)	23.6 (21.42–25.9)	24.3 (22.1–26.6)	<0.001‡
Waist circumference (cm)	83 (75–90)	83 (75–90)	86 (79–92)	<0.001‡
SBP (mmHg)	121 (110–132)	121 (110–132)	124 (112–136)	<0.001‡
DBP (mmHg)	72 (65–80)	72 (65–80)	76 (68–84)	<0.001‡
FBG (mmol/L)	5.08 (4.76–5.46)	5.07 (4.76–5.45)	5.23 (4.89–5.67)	<0.001‡
TG (mmol/L)	1.27 (0.87–1.9)	1.26 (0.86–1.89)	1.41 (0.95–2.1)	<0.001‡
HDL-C (mmol/L)	1.21 (1.02–1.44)	1.21 (1.02–1.45)	1.18 (1–1.42)	<0.001‡
Urine pH	6 (6–6.5)	6 (6–6.5)	6 (6–6.5)	0.61‡
Urine specific gravity	1.02 (1.015–1.025)	1.02 (1.015–1.025)	1.02 (1.015–1.025)	0.275‡
Urine erythrocyte				<0.001†
Positive	2,672 (3.6)	2,561 (95.8)	111 (4.2)	
Weakly positive	2,311 (3.1)	2,232 (96.6)	79 (3.4)	
Negative	69,343 (93.3)	67,501 (97.3)	1,842 (2.7)	
Urine leukocyte				0.191†
Positive	8,137 (10.9)	7,911 (97.2)	226 (2.8)	
Weakly positive	3,452 (4.6)	3,341 (96.8)	111 (3.2)	
Negative	62,737 (84.4)	61,042 (97.3)	1,695 (2.7)	
Urine protein				<0.001†
Positive	3,637 (4.9)	3,477 (95.6)	160 (4.4)	
Weakly positive	13,732 (18.5)	13,369 (97.4)	363 (2.6)	
Negative	56,957 (76.6)	55,448 (97.4)	1,509 (2.6)	
Urine bacteria				0.162†
Positive	919 (1.2)	887 (96.5)	32 (3.5)	
Negative	73,407 (98.8)	71,407 (97.3)	2,000 (2.7)	
BUN (mmol/L)	4.76 (3.99–5.79)	4.76 (3.99–5.79)	4.87 (4.05–5.82)	0.082‡
CR (μmol/L)	70 (58–82)	70 (58–81)	75 (64–86)	<0.001‡
UA (μmol/L)	342 (281–409)	341 (280–408)	371 (308–432.75)	<0.001‡

Values are presented as median (interquartile range, IQR) for non-normal variables or n (%) for categorical variables. †, Chi-square test; ‡, Mann-Whitney U-test; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; BUN, blood urea nitrogen; CR, creatinine; UA, urine acid.

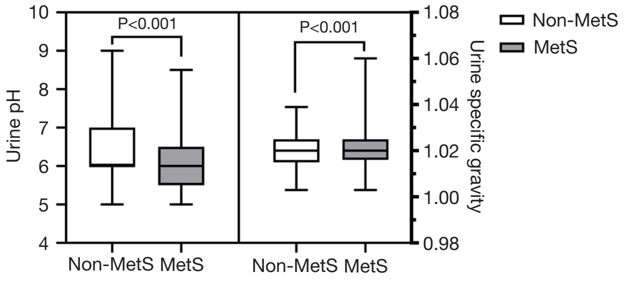

Figure 1 Differences in urine pH and urine specific gravity between the MetS group and non-MetS group. MetS, metabolic syndrome.

kidney stones, and three models are established. Model 1 is unadjusted; Model 2 adjusts for age and gender; Model 3 adjusts for age, gender, smoking history, urine red blood cell, urine protein, CR, and UA. After adjusting for all possible confounding factors, Model3 shows that MetS is an independent influencing factor for kidney stones (P<0.05). The risk of kidney stones in MetS patients is 1.157 times (95% CI: 1.051–1.273) higher than that in non-MetS patients. Compared with participants without MetS components, the odds ratio (OR) of kidney stones in participants with 2, 3, 4, and 5 MetS composition are 1.19

Table 2 MetS and its components in participants with and without kidney stones

Items	Total (N=74,326)	No kidney stones (n=72,294)	Kidney stones (n=2,032)	P value
MetS, n (%)				<0.001†
No	49,511 (66.6)	48,310 (97.6)	1,201 (2.4)	
Yes	24,815 (33.4)	23,984 (96.7)	831 (3.3)	
Components of MetS, n (%)				
Elevated waist circumference	37,946	36,701 (96.7)	1,245 (3.3)	<0.001†
Elevated TG	26,083	25,251 (96.8)	832 (3.2)	<0.001†
Reduced HDL-C	30,222	29,456 (97.5)	766 (2.5)	0.006†
Elevated BP	27,217	26,336 (96.8)	881 (3.2)	<0.001†
Elevated FBG	15,003	14,430 (96.2)	573 (3.8)	<0.001†

†, Chi-square test; MetS, metabolic syndrome; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; BP, blood pressure; FBG, fasting blood glucose.

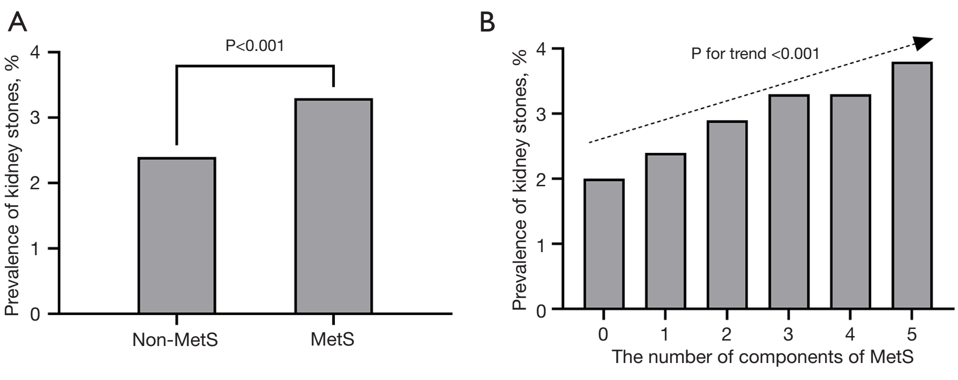

Figure 2 The relationship between the prevalence of kidney stones and MetS. (A) Prevalence of kidney stones in participants with or without MetS; (B) relationship between the prevalence of kidney stones and the number of MetS components. MetS, metabolic syndrome.

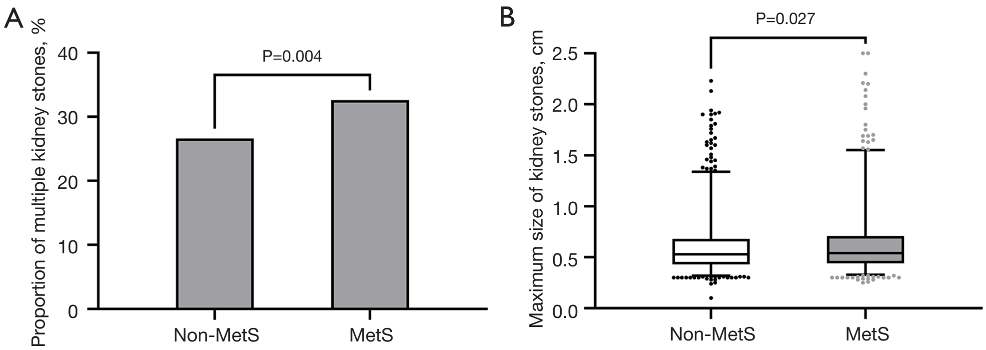

Figure 3 The relationship between MetS and the number and size of kidney stones. (A) The proportion of multiple kidney stones to total kidney stones in participants with or without MetS; (B) maximum size of kidney stones in participants with or without MetS. MetS, metabolic syndrome.

Table 3 Logistic regression analysis of MetS and its components in participants with and without kidney stones

Item	Model 1, OR (95% CI)	Model 2, OR (95% CI)	Model 3, OR (95% CI)
MetS condition	1.394 (1.274–1.525)	1.183 (1.077–1.3)	1.157 (1.051–1.273)
Single components of MetS			
Elevated waist circumference	1.381 (1.248–1.527)	1.204 (1.086–1.336)	1.205 (1.085–1.337)
Elevated TG	1.194 (1.078–1.323)	1.05 (0.946–1.166)	1.045 (0.94–1.162)
Reduced HDL-C	1.335 (1.21–1.474)	1.195 (1.081–1.321)	1.222 (1.105–1.351)
Elevated BP	1.106 (1.005–1.218)	1.065 (0.967–1.172)	1.054 (0.957–1.16)
Elevated FBG	1.38 (1.243–1.531)	1.35 (1.216–1.499)	1.335 (1.202–1.482)
Number of components of MetS			
0	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	1.186 (1.026–1.37)	1.087 (0.939–1.258)	1.073 (0.927–1.242)
2	1.44 (1.25–1.659)	1.213 (1.048–1.404)	1.19 (1.027–1.378)
3	1.622 (1.406–1.87)	1.286 (1.108–1.493)	1.252 (1.076–1.456)
4	1.671 (1.425–1.961)	1.306 (1.105–1.544)	1.26 (1.063–1.493)
5	1.892 (1.527–2.344)	1.47 (1.179–1.833)	1.405 (1.124–1.756)
P for trend	<0.001	0.001	0.009

Model 1, crude OR; Model 2, adjusted for age and sex; Model 3, adjusted for age and sex, smoking, urine erythrocyte, urine protein, CR, and UA. MetS, metabolic syndrome; OR, odds ratio; CI, confidence interval; TG, triglyceride; HDL-C, high-density lipoprotein cholesterol; BP, blood pressure; FBG, fasting blood glucose.

(1.027–1.378), 1.252 (1.076–1.456), 1.26 (1.063–1.493), 1.405 (1.124–1.756) (P for trend <0.05). Among the components of MetS, elevated waist circumference, reduced HDL-C, and elevated FBG are independent influencing factors of kidney stones (P<0.001), with the ORs of 1.205 (1.085–1.337), 1.222 (1.105–1.351), 1.335 (1.202–1.482), respectively.

Discussion

In this large-scale cross-sectional study, 74,326 participants were included and the prevalence of MetS was 33.4%, and the prevalence of kidney stones in the MetS group was 3.3%. This is similar to a study involving urban adults in northeast China, where the prevalence of MetS was about 27.0% (16).

The prevalence of kidney stones in China is about 5.8% (2). Another study showed that the prevalence rate of kidney stones was 4.0%, and the prevalence rate in the north (4.1%) was slightly higher than that in the south (4.0%) (17). The prevalence of kidney stones in this study was slightly low, which was inconsistent with the results of other studies (2,17). This may be because the population in this study was mainly the health screening population in southern China. Nevertheless, we found that the prevalence of kidney stones was significantly higher in the MetS group than in the non-MetS group among those with a slightly lower overall kidney stone prevalence, suggesting that MetS may increase the risk of kidney stones.

Notably, this study found that urinary pH was lower in the MetS group than in the non-MetS group. A large database study showed that urine pH was negatively correlated with BMI, that is, the fatter people were, the lower their urine pH was (18,19). Further study by Otsuki *et al.* found that decreased urine pH was significantly associated with all the features of MetS except blood pressure (20). The main mechanism of MetS is insulin resistance, which produces too much acidic urine and leads to uric acid kidney stones (21). In general, insulin stimulates ammonia production (22) and increases Na^+/H^+ exchange activity in proximal renal tubules (23).

In addition, in this study, the urinary specific gravity in the MetS group was higher than that in the non-MetS group. Urinary specific gravity is an important indicator of body water content and sodium intake (24). Studies have shown that high sodium intake is associated with increased blood pressure (25,26). A Korean study showed that an estimated 24-hour urine excretion of sodium (as a proxy for sodium intake) was associated with MetS and its components (27).

The key to our study was the relationship between MetS and kidney stones. The incidence of kidney stones was higher in the MetS group than in the non-MetS group, and there was a statistically significant increase in kidney stone prevalence as the number of components of the MetS increased. In addition, elevated waist circumference, high TG, low HDL-C, hypertension, and hyperglycemia all increased the risk of kidney stones. Furthermore, increases in the number and size of kidney stones have been associated with MetS, providing further evidence for a link between kidney stones and MetS.

This study showed that men, with older age, smoking history, higher BMI, a high percentage of urine red blood cells or protein-positive, and high serum creatinine and uric acid levels were associated with an increased risk of kidney stones. It has been shown that the incidence of kidney stones varies by gender, age, and race (28). Kidney stones are more common in middle-aged and elderly men, with a male to female ratio of about 2:1 (29). Interestingly, estrogen has a protective effect against kidney stone formation, explaining the higher kidney stone prevalence in men (30). Risk factors for kidney stones also include high BMI, hypertension, diabetes, and smoking (3,31). An increasing body mass index promotes calcium, oxalate, and uric acid excretion, which assists in kidney stone formation (5,32). In addition, the increased incidence of the disease is also related to poor dietary habits, such as increased protein intake, decreased fruit and vegetable intake, and insufficient water intake, resulting in increased serum creatinine and uric acid, which ultimately lead to kidney stones (33).

After including confounding factors, the MetS condition was found to be an independent risk factor for kidney stones, with a 1.157-fold higher incidence than the non-MetS group (95% CI: 1.051–1.273). Furthermore, the risk of kidney stones increased with the number of MetS components. Among the five components of MetS, elevated waist circumference, low HDL-C, and elevated blood glucose were independent influencing factors of kidney stones, and their OR values were 1.205 (95% CI: 1.085–1.337), 1.222 (95% CI: 1.105–1.351) and 1.335 (95% CI: 1.202–1.482), respectively. Similar to this study, several studies found an association between MetS and kidney stones (34,35) and confirmed that each of the five components of MetS increased the risk of kidney stones individually (13,14,36-38). For example, similar findings were obtained in a cross-sectional analysis in South Korea, where kidney stones were diagnosed by ultrasound or CT. Among 34,895 screened individuals, the prevalence of kidney stones increased as the number of MetS components increased (3).

Although the exact mechanism of the association between kidney stones and MetS is unclear, several hypotheses have been proposed. Factors associated with MetS include elevated waist circumference, increased inflammation, dyslipidemia, hyperglycemia, altered hormone, and adipokine levels, as well as increased excretion of uric acid, calcium, and oxalate, and reduced excretion of citrate (13). A leading hypothesis is that MetS is associated with excessive lipotoxicity, a buildup of lipids in the kidneys that leads to changes in kidney structure and function (13). Lipotoxicity can lead to increased net acid excretion, decreased ammonia synthesis, and ammonium excretion, resulting in decreased urine pH, and these metabolic disorders can lead to the formation of kidney stones. Studies have reviewed the relationship between kidney stones and a variety of diseases, including hypertension, diabetes, chronic kidney disease, and MetS. It is also hypothesized that the generation of reactive oxygen species and the development of oxidative stress may be a common pathway leading to the development of kidney stone formation and comorbidities (39). Additionally, obesity is known to cause insulin resistance (40), which, if left untreated, can lead to diabetes, another recognized risk factor for stone formation (36). A study found that weight loss intervention can improve the low urine pH value to reduce the risk of uric acid calculi formation, and increase urinary citrate excretion to reduce the risk of calcium oxalate stone formation (41). However, kidney stones are a complex disease consisting of multiple interrelated factors, and the potential association between MetS and kidney stones should be confirmed through continued further research.

This study had certain advantages that a large enough sample size and the determination of standardized clinical indicators can better support this research result. However, there are some limitations in this study. First, our cross-sectional study avoided drawing causal conclusions. Secondly, this study was based on health screening patients from the physical examination database, and there was no information on the specific types of kidney stones and the specific composition of urine, so the relationship between MetS and specific stone types and the mechanism of stone formation could not be analyzed. Last, due to the retrospective nature and the data limitation, major parameters of kidney stones such as genetic or family history of kidney stones, dietary and lifestyles, medication, and other major factors were not obtained, which may have affected our results. In the future, large cohort prospective validation studies are worth conducted.

Conclusions

In summary, MetS was found to be an independent risk factor for kidney stones, and the risk of kidney stones increased with the increase in the number of components of MetS. Among the five components of MetS, elevated waist circumference, low HDL-C and elevated blood glucose were independent influencing factors of kidney stones. Therefore, more attention should be paid to the prevention and treatment of MetS, which may be helpful to correct urinary tract metabolic abnormalities, thus contributing to the prevention of kidney stones. Future large-scale cohort studies will be done to test this hypothesis.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tau.amegroups.com/article/view/10.21037/tau-23-51/rc

Data Sharing Statement: Available at https://tau.amegroups.com/article/view/10.21037/tau-23-51/dss

Peer Review File: Available at https://tau.amegroups.com/article/view/10.21037/tau-23-51/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tau.amegroups.com/article/view/10.21037/tau-23-51/coif). JP reports funding from Medical Health Science and Technology Project of Zhejiang Provincial Health Commission (No. 2020KY598). LC reports funding from Health Management Foundation of China (No. 2021-KYY-518053-0035). The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013), and approved by the Ethics Committee of Sir Run Run Shaw Hospital, affiliated with Medical College of Zhejiang University (No. 2022-0311). Patient consent was waived due to the research using the data obtained in the previous clinical diagnosis and treatment, without using the medical records that the patient has clearly refused to use. The study will not have an adverse impact on the rights and health of the subjects, and the privacy and personal identity information of the subjects will be protected.

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