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Study Need and Importance: The proportion of adults who pass a kidney stone every year is largely unknown. Our study analyzed a representative subset of the population of the United States to estimate the incidence of kidney stones.

What We Found: The 12-month incidence of kidney stones was estimated to be 2.1% or 2,054 per 100,000 individuals, higher than previous reports. This could be a factor of our nationally inclusive methodology or of a rapid increase in the number of stones over the past several years. Our data showed Hispanic, Black and Asian races to be associated with a lower 12-month incidence as compared to White, while hypertension and hypercholesterolemia were associated with an increased incidence of stones.

Limitations: The main limitation of our study, given the survey design, is our dependence on self-reported stone history. The retrospective nature of the survey may introduce biases. While the number surveyed was large, the numbers of patients reporting stones every year were also relatively small. It is unclear whether the combination of these limitations would represent an under- or overestimation of the 12-month incidence.

Interpretation for Patient Care: Our data suggest kidney stones likely will continue to require substantial resources, and we can anticipate increased emergency department visits, urology consults and interventions such as lithotripsy or placement of stents. In addition, efforts aimed at stone prevention are important given the prevalence of disease.

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Incidence of Kidney Stones in the United States: The Continuous National Health and Nutrition Examination Survey

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Abbreviations and Acronyms

BMI = body mass index

NHANES = National Health and Nutrition Examination Survey

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Ethics Statement: This work was declared non-human subjects research, IRB protocol number STUDY20211027.

Data Availability: JES had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Purpose: The incidence of kidney stones in the United States is currently unknown. Here, we assessed the incidence of kidney stones using recent, nationally representative data.

Materials and Methods: We used the National Health and Nutrition Examination Survey (NHANES) from 2015 to 2018. During this time participants were asked, “Have you ever had a kidney stone?” and “In the past 12 months, have you passed a kidney stone?” Demographics analyzed include age, race, gender, body mass index, history of smoking, diabetes, hypertension, hypercholesterolemia and gout. Multivariable models were used to assess the independent impact of subject characteristics on kidney stone prevalence and incidence.

Results: Data were available on 10,521 participants older than age 20. The prevalence of kidney stones was 11.0% (95% CI 10.1–12.0). The 12-month incidence of kidney stones was 2.1% (95% CI 1.5–2.7), or 2,054 stones per 100,000 adults. We identified significant relationships between stone incidence and subject age, body mass index, race and history of hypertension.

Conclusions: Here we find a substantially higher 12-month incidence of kidney stones than previous reports. We also validate known risk factors for stone prevalence as associated with incidence. The remarkable incidence and prevalence of stones is concerning and has implications for disease prevention and allocation of medical resources.

Key Words: nephrolithiasis, urolithiasis, kidney calculi

The worldwide prevalence of nephrolithiasis, the formation of a stone in the kidney, is estimated to be between 5% and 10%.[1,2] In 1994, data from the National Health and Nutrition Examination Survey (NHANES) estimated the prevalence of stone disease at 6.3% among men and 4.1% among women.[3] A previous study using 2007–2010 NHANES estimated that 19% of men and 9% of women will be diagnosed with a kidney stone by the age of 70.[4] The cost of caring for patients with kidney stones in 2000 was estimated to be $2 billion in the United States.[5]

While the prevalence of kidney stones has been studied previously, the incidence of stones has remained elusive. Some studies have estimated a 12-month incidence at various time points in past decades. The highest of these was found to be 1,116 per 100,000 employees covered by 2 large

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insurance companies in the year 2000.[6] The lowest of these was found using a cohort in second half of the 1900s located in Rochester, Minnesota and found the yearly rate to be 102 per 100,000.[7] A prior study within the same population described the trends of kidney stones from 1984 to 2012 and found a rise in the incidence of stones over this time period (254 per 100,000 in 2012).[8] This study also discussed the important distinction between symptomatic and asymptomatic stones, which have increasingly become evident on imaging methods such as computerized tomography in recent years. While all of these studies provide important epidemiologic data, they cannot be extrapolated to the entire U.S. population as they are bound to the regions in which they were carried out, and include different age ranges of participants. Additionally, the increasing incidence of nephrolithiasis provides even more reason to update these findings.[4,8]

A study published in early 2021 in *The Journal of Urology®* used The Medical Expenditure Panel Survey and reported a 12-month incidence in the United States to be 0.9% in 2015, an increase from 0.6% in 2005.[9] Given the limitations and variance of these studies, we conducted an analysis of the incidence, which is newly available in the NHANES, and prevalence of nephrolithiasis including the patient factors that may influence these numbers. NHANES is designed to make nationally representative estimates, giving it great value for this type of epidemiology research.[10]

MATERIAL AND METHODS

Study Population

The NHANES began in 1999 surveying a nationally representative, complex, stratified multistage probability sample of the U.S. population in 2-year cycles.[11] For this study, information on kidney stone history from the 2015–2016 and 2017–2018 cycles were combined into one data set. This included 11,288 participants aged 20 years of age or older. We further excluded those missing data on any of the characteristics identified in our methods (767). Our final analytical study population included 10,521 participants, representing a total population of 304,403,337 individuals after weighting.

Assessment of Kidney Stones

The prevalence of nephrolithiasis was assessed by the question, "Have you ever had a kidney stone?" The 12-month incidence of symptomatic nephrolithiasis was assessed by the question, "In the past 12 months, have you passed a kidney stone?" Like other questionnaire data in the NHANES database, these questions were asked in the home by trained interviewers, using the Computer-Assisted Personal Interview system. This system assists interviewers to define key terms and utilizes built-in systems to reduce data-entry errors.[10]

Assessment of Sociodemographic and Lifestyle Characteristics

Self-reported sociodemographic characteristics were obtained from the "demographics" data set, including information on age and race. We further stratified age into groups 20–29, 30–39, 40–49, 50–59, 60–69, 70–79 and 80+. Race was categorized as Mexican American, other Hispanic, nonHispanic White, nonHispanic Black, nonHispanic Asian, other including multiracial. Mexican American and other Hispanic were later combined into the category "Hispanic" in order to increase statistical power. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared from the physical examination data and categorized using the National Institutes of Health and World Health Organization classification as less than 18.5, 18.5–24.9, 25–29.9 and 30 or above.[12] Smoking status was assessed by the question, "Have you smoked at least 100 cigarettes in life?" and categorized as yes/no. Diabetes, hypertension, hypercholesterolemia and gout were assessed using the "have you ever been told by a doctor or health professional that you have the condition" questions. Diabetes was categorized as yes, no or borderline. Hypertension, hypercholesterolemia and gout were categorized as yes/no.

Statistical Analysis

Survey analysis procedures were used to account for the complex sampling design of the NHANES sample. We estimated the weighted prevalence and 95% confidence intervals of ever having a kidney stone and having a kidney stone in the past 12 months, overall and by demographic, lifestyle and clinical characteristics. Any strata with fewer than 10 participants were excluded from the analysis. In addition, we generated age-standardized values making use of the projected U.S. population at risk in December 2016, the middle of the study period. We used Poisson regression accounting for survey weights to estimate risk ratios (RRs) and 95% CIs for the association between demographic, lifestyle and clinical factors, and ever having kidney stones and having kidney stone in the past 12 months, respectively. STATA/SE™, version 13.0 was used for all statistical analysis. Statistical significance was defined as $p < 0.05$.

RESULTS

The overall 12-month incidence of symptomatic nephrolithiasis is estimated to be 2.1%, 95% CI 1.5–2.7, or 2,054 per 100,000 individuals, while the prevalence of at least 1 episode of previous nephrolithiasis was 11.0%, 95% CI 10.1–12.0. Age-standardized estimates for 12-month incidence and prevalence were 2.1, 95% CI 1.7–2.3, and 11.0%, 95% CI 10.6–11.3, respectively. Table 1 shows the proportions of participants who have ever had a kidney stone or passed a kidney stone in the past 12 months in the United States by demographic or associated risk factor included in the analysis.

Table 1 and the figure both show the relationship between the percentage of participants who reported having had a previous kidney stone and those who have passed a stone in the previous 12 months. No obvious trend exists in regard to age and incidence; however, the prevalence of ever having a kidney stone peaked in subjects aged

Table 1. *Estimated proportions of participants who have ever had a kidney stone or passed a kidney stone in the past 12 months in the United States by demographics and associated risk factors*

	Unweighted No. Available for Analysis in Each Subgroup	Ever Had Kidney Stone	Passed Kidney Stone in Past 12 Mos
% (95% CI)	10,521	11.0 (10.1—12.0)	2.1 (1.5—2.7)
Mean yrs age (standard error)		53.6 (0.6)	48.3 (1.6)
% Yrs age group at stone event (95% CI):			
20—29	1,685	8.4 (6.6—10.6)	12.9 (7.1—22.4)
30—39	1,721	12.8 (10.5—15.5)	23.6 (16.5—32.5)
40—49	1,665	17.6 (14.7—21.0)	15.9 (9.0—26.5)
50—59	1,745	22.9 (18.6—27.8)	23.4 (14.6—35.3)
60—69	1,931	21.4 (17.9—25.3)	13.7 (6.1—28.0)
70—79	1,093	11.4 (8.8—14.6)	9.4 (5.0—16.7)
80+	681	5.6 (4.2—7.3)	—
% Gender (95% CI):			
Male	5,479	54.1 (49.2—58.5)	54.7 (46.3—62.9)
Female	5,042	45.9 (41.5—50.4)	45.3 (37.1—53.7)
% Race (95% CI):			
Hispanic	2,798	12.1 (9.1—15.9)	10.5 (6.7—15.9)
NonHispanic White	3,528	72.9 (67.6—77.7)	74.6 (65.6—81.9)
NonHispanic Black	2,349	6.8 (5.1—9.0)	4.8 (2.3—9.6)
NonHispanic Asian	1,393	2.8 (2.0—4.0)	3.5 (1.9—6.3)
Other	453	5.3 (3.4—8.1)	6.7 (2.6—16.2)
Mean kg/m^2 BMI (standard error)		31.0 (0.3)	31.7 (0.7)
% kg/m^2 BMI (95% CI):			
<18.5	157	0.7 (0.3—1.6)	—
18.5—24.9	2,656	17.5 (14.5—20.9)	17.3 (10.5—27.0)
25—29.9	3,378	31.6 (27.9—35.6)	27.6 (20.6—36.0)
30+	4,330	50.1 (45.2—55.0)	53.8 (44.0—63.4)
% Smoked 100 cigarettes in life (95% CI):			
Yes	4,402	49.8 (45.4—54.2)	42.7 (40.7—44.7)
No	6,119	50.2 (45.8—54.6)	57.3 (55.3—59.3)
% Diabetes (95% CI):			
Yes	1,585	19.3 (16.1—23.0)	19.3 (16.1—23.1)
No	8,653	77.1 (73.5—80.3)	77.1 (73.5—80.3)
Borderline	283	3.6 (2.57—5.04)	—
% Hypertension (95% CI):			
Yes	3,898	46.1 (40.1—52.1)	48.4 (34.9—62.2)
No	6,623	53.9 (47.9—59.8)	51.6 (37.8—65.1)
% High cholesterol (95% CI):			
Yes	3,665	42.9 (38.5—47.5)	41.9 (32.6—51.9)
No	6,856	57.1 (52.5—61.5)	58.1 (48.1—67.4)
% Gout (95% CI):			
Yes	564	7.5 (5.6—10.0)	7.5 (3.8—14.1)
No	9,957	92.5 (90.0—94.4)	92.5 (85.9—96.2)

Percentages not shown for subgroups with <10 participants reporting an incident stone per NHANES reporting guidelines.

60—69. Table 2 shows multivariable risk ratios according to subject characteristics. We found that increasing BMI was associated with an increased prevalence of kidney stones, while females and Hispanic, Black and Asian races as compared to White race were associated with a lower risk of stones. Further, Hispanic or Black race were associated with a lower 12-month stone incidence, while hypertension was associated with an increased incidence of stones.

DISCUSSION

We found a 12-month incidence of kidney stones of 2,054 per 100,000. The rate of passing a kidney stone was also shown to be lower in those of Black, Hispanic or Asian race as compared to White. Not all factors associated with increased prevalence of stones were also associated with incidence. Of note, diabetes did not have a statistically significant relationship with the 12-month incidence of stones, while hypertension did. This perhaps suggests that historical risk factors which contribute to stone prevalence may play less of a role in incident stones, although this also may be an artifact of the relatively low number of incident events leading to reduced power to detect differences.

Even with the large amount of data available for analysis, there were some limitations to our study. First, this study is methodologically different than a traditional cohort study used to find incidence of an event, as we relied on retrospective self-report to generate these estimates. As such, what is referred to as the "12-month incidence" would more accurately be described as the prevalence of reported incident stones within the past 12 months. Further, participants are asked about "passing" a kidney stone within the past 12 months, which would not account for asymptomatic kidney stones diagnosed during this time. Our findings represent only the incidence of symptomatic kidney stones within the population. In addition, the unique pathophysiological mechanisms of different types of kidney stones are not accounted for due to the nature of the questioning in the NHANES surveys.

Recall bias may be present in our study due to the inability of participants to remember the exact timing of stone passage. In a previous questionnaire study by Curhan et al, kidney stones were confirmed on imaging in 97% of survey participants, with the remaining 3% actually having bladder stones.[13] This suggests directly asking patients about their kidney stone history is in large part methodologically sound.

Our findings suggest the 12-month incidence of nephrolithiasis is twice that of a recent report, as well much higher than reports from a decade ago.[6,7,9,14,15] These data are representative of the entire United States population and include more recent data than previous studies, giving them high generalizability. Similar to our study, the work of Tundo et al, with data up to 2015, is also in theory representative of the entire United States population.[9] We made use of NHANES, while they utilized the Medical Expenditure Panel Survey. Both of these questionnaires survey households and attempt to generalize findings to the larger population. We both

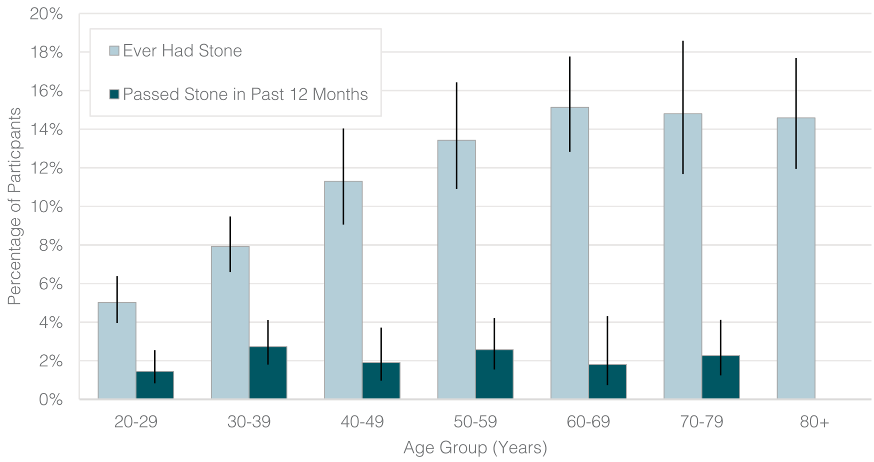

Figure. Incidence and prevalence of kidney stones by age group. Weighted proportion of participants who have had a kidney stone in their life and the proportion who have passed a stone in the previous 12 months by age. Bars represent 95% confidence intervals. Incidence of passing a stone in the past 12 months in subjects 80+ not shown as <10 unweighted subjects reported an incident stone in this age group.

used surrogate questionnaires to define incidence, with our definition being self-reported passing of a stone while Tundo et al used self-reported diagnosis of a stone within their defined time period. The similarities in these methods gives our studies similar strengths and limitations. We know from NHANES that the prevalence of stones has increased by ~50% over the past 2 decades.[4] This raises the question of whether this high incidence is due to a rapid rise in incidence or a combination of other identified limitations. Monitoring these trends over time will be important.

Our findings have significant implications. If these findings are due to a persistent increase in stone incidence over recent years and this trend continues, there is the potential need for substantially increased resource utilization. This would mean an increase in the number of emergency department visits, urology consults and the need for

Table 2. *Multivariate Poisson regression assessing the risk ratio of kidney stone prevalence or incidence with the indicated subject characteristic*

	RR: Ever Had Kidney Stone	95% CI	p Value	RR: Passed a Kidney Stone within Past 12 Mos	95% CI	p Value
Yrs age group (referent 20—29):						
30—39	1.44*	1.12—1.85	0.004	1.66*	1.65—1.67	<0.001
40—49	1.94*	1.18—3.19	0.001	1.04	0.73—1.48	0.830
50—59	2.11*	1.46—3.05	<0.001	1.16*	1.12—1.20	<0.001
60—69	2.12*	1.23—3.66	0.007	0.66	0.28—1.52	0.320
70—79	2.01*	1.32—2.05	0.001	0.77*	0.61—0.98	0.030
80+	2.03*	1.40—2.95	<0.001	—	—	—
Female (referent male)	0.83*	0.80—0.85	<0.001	0.87	0.72—1.04	0.120
Race (referent nonHispanic White):						
Hispanic	0.76*	0.63—0.90	0.002	0.56*	0.50—0.62	<0.001
NonHispanic Black	0.52*	0.44—0.62	<0.001	0.32*	0.25—0.41	<0.001
NonHispanic Asian	0.51*	0.47—0.57	<0.001	0.59*	0.37—0.94	0.030
Other	1.06	0.64—1.77	0.818	1.16	0.68—0.98	0.580
kg/m^2 BMI (referent 18.5—24.9):						
<18.5	0.84	0.37—1.91	0.677	—	—	—
25—29.9	1.26*	1.21—1.32	<0.001	1.25*	1.15—1.35	<0.001
30+	1.44*	1.12—1.84	0.004	1.60	0.64—4.00	0.310
Smoked >100 cigarettes (referent no)	1.11	0.96—1.28	0.147	1.10	0.49—2.45	0.820
Diabetes (referent no):						
Yes	1.37	0.86—1.93	0.184	1.45	0.56—3.73	0.4401
Borderline	1.47*	1.17—1.84	<0.001	—	—	—
Hypertension (referent no)	1.29	0.86—1.93	0.222	1.79*	1.19—2.71	0.006
High cholesterol (referent no)	1.00	0.86—1.16	0.980	1.24*	1.24—1.24	<0.001
Gout (referent no)	1.16	0.75—1.80	0.503	1.36	0.87—2.11	0.170

RR, risk ratio of kidney stone event as compared to defined referent while controlling for the other specified variables making use of a multivariate Poisson regression incorporating robust error variance.
* p <0.05 for association with ever having had or passed a kidney stone as compared to the indicated referent group. Ratios not shown for subgroups with <10 participants reporting an incident stone.

interventions such as lithotripsy or placement of stents. Further, this study highlights the critical need to understand why these trends exist and the importance of dietary and pharmacological efforts in preventing stone recurrence. In addition, understanding the role of community efforts aimed at primary disease prevention may be of interest, given the prevalence of the disease.

CONCLUSIONS

Population-level data describing kidney stone incidence are limited. Using data from a large, national survey, we found a 12-month incidence of 2,054 per 100,000, substantially higher than previously reported. This could have large impacts on the allocation of resources both within the hospital and within the community in order to combat modifiable kidney stone risk factors. Further research is needed to analyze additional contributing factors to this trend in order to improve disease prevention. A future nationally representative cohort study that confirms these findings would also be helpful, as our methods simply allow us to provide an estimate based on survey data.

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