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Time trends in reported prevalence of kidney stones in the United States: 1976–1994[1]

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Background. A body of evidence establishes that the occurrence of kidney stone disease has increased in some communities of industrialized countries. Information on recent temporal trends in the United States is lacking and population-based data on epidemiologic patterns are limited.

Study objective was to determine whether kidney stone disease prevalence increased in the United States over a 20-year period and the influence of region, race/ethnicity, and gender on stone disease risk.

Methods. We measured the prevalence of kidney stone disease history from the United States National Health and Nutrition Examination Survey (II and III), population-based, cross-sectional studies, involving 15,364 adult United States residents in 1976 to 1980 and 16,115 adult United States residents in 1988 to 1994.

Results. Disease prevalence among 20- to 74-year-old United States residents was greater in 1988 to 1994 than in 1976 to 1980 (5.2% vs. 3.8%, $P < 0.05$), greater in males than females, and increased with age in each time period. Among 1988 to 1994 adults, non-Hispanic African Americans had reduced risk of disease compared to non-Hispanic Caucasians (1.7% vs. 5.9%, $P < 0.05$), and Mexican Americans (1.7% vs. 2.6%, $P < 0.05$). Also, age-adjusted prevalence was highest in the South (6.6%) and lowest in the West (3.3%). Findings were consistent across gender and multivariate adjusted odds ratios for stone disease history, including all demographic variables, as well as diuretic use, tea or coffee consumption, and dietary intake of calcium, protein, and fat did not materially change the results.

Conclusion. Prevalence of kidney stone disease history in the United States population increased between 1980 and 1994. A history of stone disease was strongly associated with race/ethnicity and region of residence.

[1] **See Editorial by Goldfarb, p. 1951.**

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During the past 25 years, numerous reports have suggested that the frequency of kidney stone disease in westernized societies has been rising [1–5]. Residents of the United States are estimated to have a 10% to15% chance of being diagnosed with a kidney stone during their adult lives [1, 6]. Kidney stones are not usually quiescent [7], typically causing patients considerable pain and suffering. In addition, costs for the diagnosis and treatment of kidney stones are not trivial [8], resulting in a substantial financial burden. More precise knowledge about the epidemiology of kidney stones could potentially contribute to improved planning for disease prevention. Unfortunately, current population-based data on the frequency of kidney stones in the United States are limited [1, 9, 10] and published studies describing recent national time trends are not available.

Epidemiologic investigations of kidney stones in selected United States communities have shown that the disease is more common in males than in females, uncommon in African Americans, and incidence in men increases with age, peaking in the age group of those 40 to 59 years old [11–14]. Ecologic studies demonstrate that residents of southern locations are more likely to have a history of kidney stones compared to residents of other regions [9, 12, 14]. Such findings are congruent with theories about the formation of kidney stones, since higher average temperatures and greater sun exposure could result in oversaturation of stone-forming salts in the urine [15]. Other reports suggest that kidney stones are associated with dietary calcium, protein, and salt intake [16–18], dehydration, and warm climates.

Goals of the present study are to compare national estimates of the prevalence of kidney stones disease in adults living in the United States during two time periods, 1976 to1980 and 1988 to1994, and to evaluate the association of self-reported history of kidney stones with gender, age, race, and geographic residence.

METHODS

Study population

The National Health and Nutrition Examination Survey (NHANES) is conducted periodically in a probability sample of the civilian noninstitutionalized United States population to determine the health status of the population. Information on sociodemographic factors, health-related behaviors, medical history, use of medications, and food consumption were collected during standardized interviews of participants in the second (NHANES II) and the third (NHANES III) surveys. NHANES II participants, ages 6 months to 74 years, were interviewed between 1976 and 1980 and NHANES III participants, aged 2 months and older, were interviewed between 1988 and 1994. Interviewed participants totaled 25,286 persons in NHANES II and 33,994 persons in NHANES III. Oversampling of some high-risk populations (e.g., the elderly, children, and low-income populations) occurred in both surveys to enable reliable estimates in these groups. Our analyses were limited to adults between 20 and 74 years of age with information on lifetime occurrence of kidney stones. These study populations consisted of 15,364 adult participants in NHANES II (7059 males and 8273 females) and 16,115 adult participants in NHANES III (7605 males and 8500 females).

Variables

Adult participants who responded "yes" to the question "Have you ever had a kidney stone?" were considered to have had an episode of kidney stones in life. Age was defined as the participant's age at the time of the interview, and gender was based on interviewer observation. Race (Caucasian, African American, other) was based on interviewer observation in NHANES II and self-reports in NHANES III. Self-reports of race/ethnicity in NHANES III also enabled respondents to be categorized as non-Hispanic Caucasian, non-Hispanic African American, Mexican American, and other ethnicity. Interviewers in NHANES III were shown all prescription and nonprescription medications taken by a participant; any medication that was subsequently coded as a "diuretic" defined a diuretic user.

Information on food and beverage consumption was collected from NHANES III participants during a scheduled comprehensive medical examination. The quantity of plain drinking water consumed was reported in fluid ounces using standardized measurement devices. Responses to questions on frequency of coffee and tea consumed in the past month were categorized into none, $<$1 cup/day, 1 to 2 cups/day and $>$2 cups/day. A 24-hour dietary recall was completed through an automated data collection, coding, and interview system at the time of the medical examination. Translation of foods consumed into dietary nutrient intake values [19] was based on United States Dietary Association food composition databases [20]. Quantitative estimates for intake of total energy (kilocalories), dietary calcium (milligrams), protein (grams), and total fat (grams) were available for NHANES III participants whose dietary recall was considered complete and reliable. A linear regression model, with energy intake as the independent variable and nutrient intake as the dependent variable, was used to obtain energy-adjusted nutrient intakes in accordance with recommended procedures [21].

Regions

A geographic region code, assigned by NHANES III operations staff, identified the location of the participant's residence at the time of the interview. The regions of the United States and corresponding states were the Northeast (Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania); the South (Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, and Texas); the Midwest (Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, North Dakota, and South Dakota); and the West (Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii).

Statistical analysis

Estimates of percent prevalence and standard errors were computed using methods that incorporate the complex survey design and weight the sample appropriately to account for unequal probability of selection of sample persons and nonresponse. These procedures generated disease prevalence estimates for the total civilian, noninstitutionalized population of the United States. For subpopulation comparisons, prevalence estimates were age-adjusted by direct standardization to the 1980 Census population for ages 20 to 29 years, 30 to 39 years, 40 to 49 years, 50 to 59 years, and 60 to 74 years. Assessment of temporal changes in prevalence of lifetime kidney stone disease was based on 95% confidence interval (CI) estimates of the difference between time-period prevalence estimates. Definitions of the boundaries for the South, Midwest, and West regions differed between the two surveys and did not permit comparisons of regions across time.

Odds ratios (OR) were adjusted simultaneously for potential confounders by multivariate logistic regression analysis, with history of kidney stones (yes or no) as the dependent variable in the model. Categorical independent terms included in the basic model were age (three categories), race/ethnicity (four categories), and region (four categories). The basic model was expanded to in-

Table 1. Percent prevalence[a] of a history of kidney stones (±SE) in United States adults by gender, age group, and time period (NHANES II, 1976 to 1980; NHANES III, 1988 to 1994)

	Males			Females		
Age Group *years*	1976 to 1980	1988 to 1994	Difference (95% CI)[b]	1976 to 1980	1988 to 1994	Difference (95% CI)[b]
20–29	0.9 ± 0.31	1.3 ± 0.42	0.4 (−0.6, 1.4)	1.4 ± 0.36	2.0 ± 0.51	0.6 (−0.6, 1.9)
30–39	4.2 ± 0.51	3.6 ± 0.75	−0.6 (−2.4, 1.1)	2.0 ± 0.37	3.0 ± 0.57	1.0 (−0.8, 2.8)
40–49	6.9 ± 0.99	9.5 ± 1.45	2.6 (−0.8, 6.1)	2.2 ± 0.40	4.2 ± 0.70	**2.0 (0.4, 3.5)**
50–59	7.5 ± 1.26	9.6 ± 1.17	2.1 (−1.3, 5.4)	5.3 ± 0.64	7.0 ± 1.10	1.7 (−0.7, 4.3)
60–69	8.3 ± 0.66	11.1 ± 1.68	2.8 (−0.8, 6.3)	4.2 ± 0.48	5.6 ± 0.88	1.4 (−0.6, 3.3)
70–74	6.7 ± 0.86	13.3 ± 1.81	**6.6 (2.7, 10.5)**	3.7 ± 0.68	6.9 ± 1.38	**3.2 (0.2, 6.3)**
All ages[c]	4.9 ± 0.42	6.3 ± 0.56	**1.4 (0.05, 2.8)**	2.8 ± 0.17	4.1 ± 0.27	**1.3 (0.7, 1.5)**

[a] Crude unadjusted prevalence
[b] Difference is prevalence in 1988 to 1994 minus prevalence in 1976 to 1980); 95% CI denotes the (lower limit, upper limit) of the 95% CI estimate of the difference. Bold type indicates that the difference was statistically significant at $P < 0.05$
[c] Persons 20 to 74 years of age

clude the following independent variables: diuretic use (yes or no); tea consumption frequency (four categories); coffee consumption frequency (four categories); energy-adjusted dietary calcium intake (quartiles); energy-adjusted total fat intake (quartiles); energy-adjusted protein intake (quartiles); and quantity of drinking water (quartiles). All statistical analyses were performed using SAS [22] and SUDAAN, statistical software for analysis of data from complex sample surveys [23].

RESULTS

Time trends

The lifetime prevalence of kidney stones in 20- to 74-year-old adults in the United States significantly increased from 3.2% (±0.21) in 1976 to 1980 to 5.2% (±0.34) in 1988 to 1994 ($P < 0.001$). Prevalence estimates by age decade and gender for each time period are presented in Table 1. In both time periods, progressive rises in kidney stone prevalence with age occurred until age 70 in men and age 60 in women. Kidney stone prevalence was greater in 1988 to 1994 than in 1976 to 1980 for every decade of age, although statistically significant increases were observed only in 70- to 74-year-old males (6.7% vs. 13.3%, $P < 0.001$), 70- to 74-year-old females (3.7% vs. 6.9%, $P = 0.024$), and 40- to 49-year-old females (2.2% vs. 4.2%, $P = 0.028$). However, the overall rate of kidney stone disease increased significantly in the total male population (4.9% ± 0.42% vs. 6.3% ± 0.56%, $P = 0.046$) and the total female population (2.8% ± 0.17% vs. 4.1% ± 0.27%, $P < 0.001$) between 1976 and 1980 and 1988 and 1994.

When broader age groupings were constructed to examine gender and race group effects, the previously observed time period increases in prevalence occurred in adults 20 to 39 years old, 40 to 59 years old, and 60 to 74 years old of each gender and each race, as shown in Figure 1. Rates of kidney stone disease were significantly greater among males who were 40 to 59 years old and 60 to 74 years old than among comparable aged females in 1976 to 1980 (7.2% vs. 3.7%, $P = 0.004$; 7.9% vs. 4.1%, $P < 0.001$) and in 1988 to 1994 (9.5% vs. 5.3%, $P < 0.001$; 11.7% vs. 6.0%, $P < 0.001$). A significantly greater percent of Caucasians compared with African Americans reported having had kidney stones in 1976 to 1980 (4.2% ± 0.23% vs. 1.4% ± 0.25%, $P < 0.001$) and in 1988 to 1994 (5.8% ± 0.40% vs. 1.9% ± 0.18%, $P < 0.001$). Similar patterns of greater prevalence among Caucasian adults compared to African American adults 20 to 39 years old, 40 to 59 years old, and 60 to 74 years old were observed in each time period. Although overall prevalence of kidney stones among Caucasians significantly increased between the two time periods ($P < 0.001$), there was no significant change in overall prevalence among African Americans ($P = 0.105$). Rate increases of 31% among Caucasian males (5.4% ± 0.46% vs. 7.1% ± 0.65%) and 45% among Caucasian females (3.1% ± 0.19% vs. 4.5% ± 0.33%) occurred from 1976 to 1980 to 1988 to 1994.

Risk factor assessment

Separate analyses in the 1988 to 1994 population revealed the impact of geographic region of residence and race/ethnicity on lifetime prevalence of kidney stones in the United States. Residents of the South had higher age-adjusted lifetime prevalence (6.6% ± 0.48%) compared to residents of the West (3.3% ± 0.36%, $P < 0.001$), and the Midwest (4.6% ± 0.70%, $P = 0.019$) but not the Northeast (5.1% ± 0.77%, $P = 0.098$). Figure 2 displays age-adjusted rates of kidney stone disease by gender within region. Differences between age-adjusted rates in the South and the West were significant among males (8.1% ± 0.81% vs. 3.7% ± 0.70%, $P < 0.001$) and females (5.3% ± 0.34% vs. 3.1% ± 0.65%, $P < 0.003$). Also, females in the South had a significantly

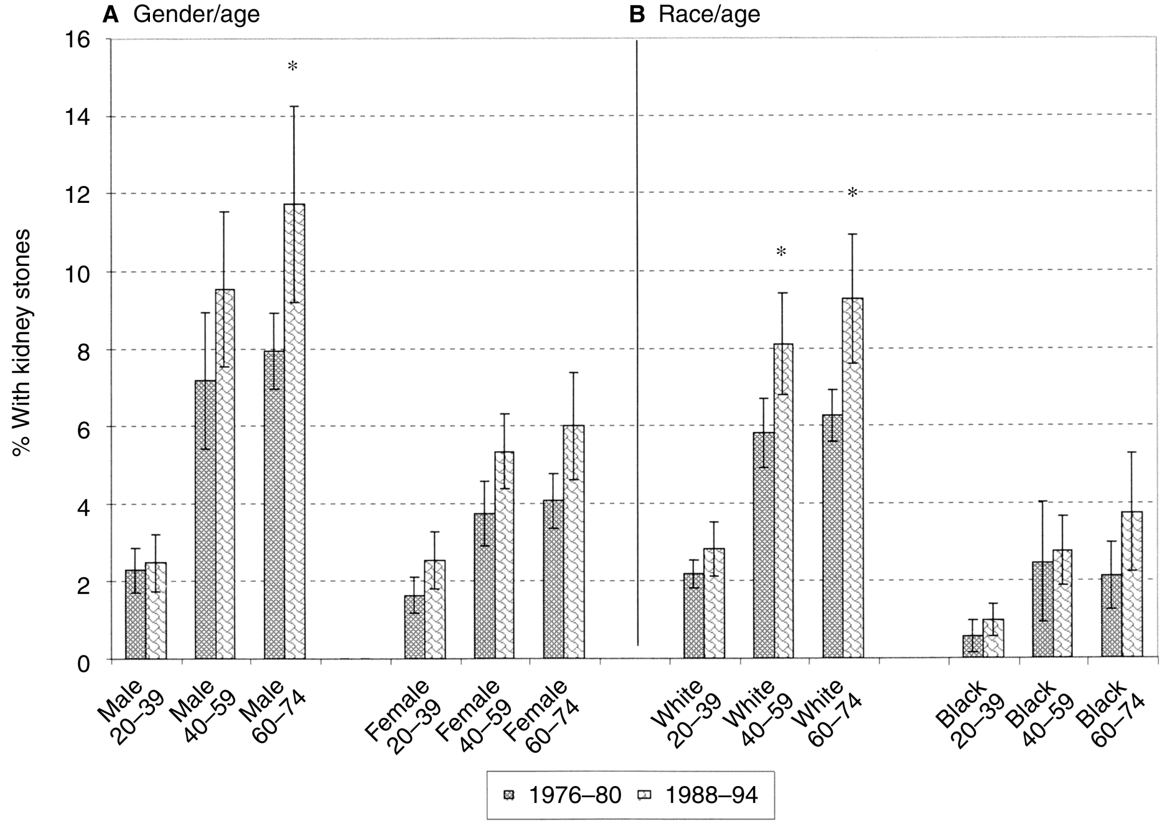

Fig. 1. Percent prevalence of history of kidney stones for 1976 to 1980 and 1988 to 1994 in each age group for each gender (*A*) and each race group (*B*). Error bars denote the 95% confidence interval. *Statistically significant time period difference.

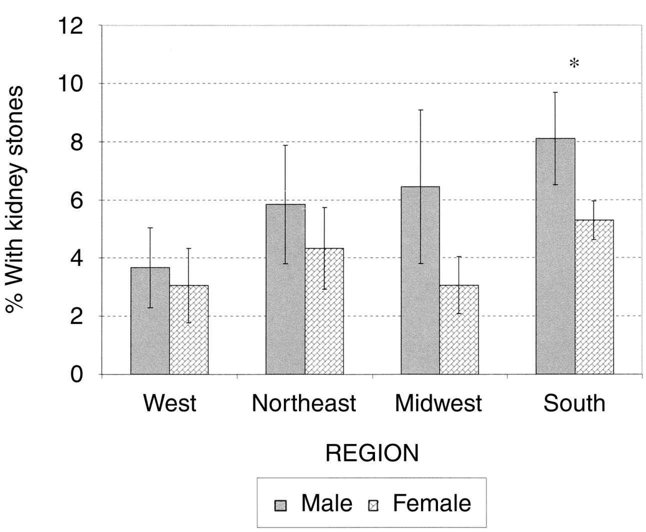

Fig. 2. Age-adjusted prevalence of kidney stones in the 1988 to 1994 United States adult population by gender within regions. Error bars denote the 95% confidence interval. *Statistically significant gender difference.

greater age-adjusted rate of kidney stone disease compared to those in the Midwest region (3.1% ± 0.50%, $P < 0.001$).

The percent of non-Hispanic Caucasians with a history of kidney stones in the 1988 to 1994 population (5.9% ± 0.43%) was significantly greater than the percent of non-Hispanic African Americans (1.7% ± 0.16%, $P < 0.001$) and the percent of Mexican Americans (2.6% ± 0.19%, $P < 0.001$) who reported having had the disease. In addition, Mexican Americans had a higher lifetime prevalence of kidney stones compared to non-Hispanic African Americans ($P < 0.001$). Odds ratios for kidney stone disease were estimated using a multivariate logistic regression model that included race/ethnicity, region of residence, and age as independent variables. Compared to non-Hispanic Caucasians, the adjusted odds of stones for men and women, respectively, were: non-Hispanic African Americans, 0.23 (95% CI = 0.2 to 0.3) and 0.35 (95% CI = 0.2 to 0.5); and Mexican Americans, 0.62 (95% CI = 0.5 to 0.9) and 0.64 (95% CI = 0.5 to 0.9). Similarly, adjusted odds ratios in Mexican Americans compared to non-Hispanic African Americans were 1.80 (95% CI = 1.2 to 2.8) among women and 2.74 (95% CI = 1.8 to 4.1) among men (data not shown).

The multivariate adjusted odds ratios of stone disease associated with region of residence, age, race/ethnicity, and diuretic use are shown in Table 2. The significant association of residential region and stone disease prevalence found in age-adjusted analyses, persisted after ad-

Table 2. Percent prevalence and adjusted odds ratio [95% confidence interval (CI)] of kidney stone disease history in relation to region of residence, age, race/ethnicity, and use of diuretics among adults 20 to 74 years of age in 1988 to 1994 United States population

	Male				Female			
Independent variable	No	% with stones	Odds ratio[a]	95% CI	No	% with stones	Odds ratio[a]	95% CI
Region								
South	2906	7.5	1.0		3207	5.2	1.0	
Northeast	840	6.7	0.81	0.5–1.4	1066	4.4	0.77	0.5–1.2
Midwest	1226	6.3	0.72	0.4–1.2	1431	3.3	0.57	0.4–0.8
West	1658	4.0	0.50	0.3–0.8	1827	3.3	0.57	0.4–0.9
Age *years*								
20–39	3011	2.5	1.0		3624	2.5	1.0	
40–59	2008	9.5	3.99	2.8–5.7	2294	5.3	1.80	1.2–2.7
60–74	1611	11.7	5.08	3.5–7.5	1616	6.0	2.26	1.4–3.6
Race/ethnicity								
Non-Hispanic Caucasian	2420	7.4	1.0		2796	4.6	1.0	
Non-Hispanic African American	1900	1.8	0.24	0.2–0.3	2312	1.7	0.35	0.2–0.5
Mexican American	2055	3.0	0.62	0.5–0.9	2094	2.4	0.64	0.5–0.9
Diuretic use								
No	6248	5.9	1.0		6878	3.9	1.0	
Yes	379	15.6	1.7	1.0–3.2	659	7.6	1.5	1.0–2.5

[a] The odds ratios associated with each variable were estimated using a logistic regression model that included age group, race/ethnicity, region of residence, and use of diuretics as independent variables.

justment for the other variables. The odds ratios for men in the West, as well as women in the West and Midwest regions, compared to residents in the South of similar gender were significantly reduced. Diuretic use had a marginally significant association with history of kidney stone disease in males (OR = 1.74; 95% CI = 1.0 to 3.2) and in females (OR = 1.50; 95% CI = 1.0 to 2.5), after adjustment for age, race/ethnicity, and region. The effect of dietary intake of calcium, total fat, protein, and consumption of tea, coffee, and plain drinking water on risk estimates of stone disease history was also examined. Incorporating one of these factors, along with diuretic use, as independent variables expanded the basic model. The six expanded models produced adjusted odds ratios for region, race/ethnicity, and age group that were substantially identical to the tabled risk estimates (data not shown). Moreover, no independent association with risk of stone disease was observed for these variables at any level, with the exception of highest intake of dietary calcium in males (OR = 0.59; 95% CI = 0.41 to 0.85 for the fourth quartile compared to the first quartile of dietary calcium intake).

DISCUSSION

To our knowledge, this is the only study to describe temporal trends for the past 20 years in the occurrence of kidney stone disease in the United States population. Our results on lifetime history of kidney stones were based on data from the NHANES II and III, which were nationwide probability sample surveys with high survey participation rates, and planned coverage of all domiciles that ensured diversity in socioeconomic levels of participants.

The lifetime prevalence of a history of kidney stones among adults in the United States increased significantly by 37% between 1976 to 1980 and 1988 to 1994. Stratified analysis by age group revealed statistically significant increased prevalence in 60- to 74-year-old Caucasians, but not in African Americans of comparable ages and increased prevalence of stone disease in most age groups regardless of gender or race. Several factors may have contributed to these observed elevations in prevalence. Better detection and/or diagnosis of kidney stones in the later time period compared to the earlier time period could have been a contributing factor. The temporal trend may also reflect differential survival experiences with disproportionately higher mortality prior to 1976 compared to subsequent years, among individuals affected with stone disease. Perhaps some of the increase is due to changes in health related behaviors (e.g., increased soft drink consumption) between the two time periods. In any case, our findings in the United States population are consistent with study results in other Westernized societies [2, 4, 5], where temporal trends in kidney stone disease have been examined.

Among adult residents of the United States in 1988 to 1994, lifetime kidney stone disease prevalence was significantly greater in men 40 years of age and older, than similarly aged women, as it was in previous United States community studies [1, 9]. After adjustment for age, region, and diuretic use, the risk of stone disease in both males and females was significantly lower among non-Hispanic African Americans and Mexican Americans compared to non-Hispanic Caucasians. Others have reported that the prevalence of kidney stones in African Americans is less than half that found among Caucasians [9, 13], which is in accordance with our finding.

The reduced risk of stone disease in Mexican American men and women compared to non-Hispanic Caucasians is consistent with previous findings in Hispanics compared to Caucasians [9]. However, observed rates of stone disease among Mexican Americans in the present study (3.2% of males and 2.4% females who were Mexican American had a history of kidney stones), were lower than reported rates of 6.7% in males and 3.2% in females who were Hispanic [9]. These divergent results could well be attributable to aspects of life-style that are different between Mexican Americans and the general population of Hispanics and diminished risk of kidney stone disease. Also, different participant selection procedures may partially account for the inconsistent findings. In the prior study [9], health association volunteers selected friends, neighbors, or relatives from residential urban areas with potentially a concentration of affluent life-styles, whereas our study participants were randomly selected from all residents of the United States. An inverse relationship between the frequency of kidney stones and indicators of socioeconomic level has been previously reported [11].

Geographic variation in the prevalence of kidney stone disease has been documented in several cohort studies, and is reported to be greatest in the Southeastern area of the United States [9, 14]. Our results could be broadly interpreted as supportive of prior studies, even though discrepancies between the definitions of the regions used in these studies and the present study (eight states that we included in the South region were incorporated in other regions in the cohort studies) make comparisons problematic. None of the personal risk factors that we studied appeared to account for the observed regional variation in lifetime prevalence of kidney stones. However, current information on exposures of interest may be incorrect for the relevant time period of stone formation, since a diagnosis of stone disease could result in an individual changing his/her dietary habits [16].

Factors that may play a role in increasing risk of kidney stone disease include water hardness [24], sunlight and heat [25], dietary consumption of animal protein [26, 27], and certain comorbid conditions [28]. Possible mechanisms involving several of these factors have been advanced to explain why living in more southern locations in the United States confers greater risk of stone formation [24–26]. However, we were limited in our ability to examine these hypothesized associations due to lack of data. Our data were cross-sectional and our finding that dietary protein intake in 1988 to 1994 had little effect on regional variation in stone disease history may have resulted from altered food consumption after an episode of stones or our use of a measure that combined protein from all dietary sources. It should be noted that a previous study of women residents of three Midwest communities in the United States with differing mineral content of their water supply, reported that residence in the high-calcium water community was not associated with a higher prevalence of renal stones [29]. Thus, the most likely explanation for the geographic variation in risk of kidney stone disease remains unclear.

The use of diuretics has been associated by other investigators with the formation of stones, most probably reflecting the use of thiazides as a treatment for kidney stones [18]. The marginally positive association between diuretic use and a history of kidney stones found in our study cannot be clearly interpreted since the type of diuretic, loop vs. thiazide, is not identified in the NHANES data set.

Limitations in our study include use of self-reported history without confirmation from medical record review. Since identical questions and standardized interview procedures were used to ascertain disease history in both surveys, we cannot envision a mechanism whereby the data could have been disproportionately affected by questionnaire bias. However, recall bias might have influenced the quality of information provided by study subjects. It is also possible that more frequent renal ultrasound studies due to different care patterns and technical advances might have caused a slight increase of kidney stone detection in NHANES III.

CONCLUSION

The lifetime prevalence of kidney stones in United States adults was significantly greater in 1988 to 1994 compared to 1976 to 1980. Risk patterns for kidney stones in 1988 to 1994 were strongly associated with race/ethnicity and region of residence, suggesting an influential role for genetic and environmental factors, respectively, in disease occurrence. The fact that the age- and gender-specific prevalence appears to be increasing emphasizes the importance of environmental factors. Future studies should target environmental risk factors with the ultimate goal of reversing the growth of kidney stone disease.

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