Population-based dietary risks for kidney stones

Implications for dietary counseling and prevention

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Cite as: Black AJ, Moussaoui G, Forbes CM. Population-based dietary risks for kidney stones: Implications for dietary counseling and prevention. *Can Urol Assoc J* 2025;19(3):E75-9. http://dx.doi.org/10.5489/cuaj.8913

Published online November 4, 2024

ABSTRACT

INTRODUCTION: In the context of the increasing incidence of kidney stones, we aimed to assess the percentage of the population who are eating an at-risk diet for kidney stones and to understand the baseline diet for future counseling.

METHODS: The 2015 Canadian Community Health Survey, a national, cross-sectional instrument administered by Statistics Canada and Health Canada, was queried. Intake of relevant nutrients was compared to dietary risk factors for kidney stone formation. Factors associated with nutrient intake were analyzed in a multivariable regression.

RESULTS: Data for 14 275 participants was included, of whom 24% consumed >2.5 L of fluid per day and 9.4% consumed 1000–1200 mg of dietary calcium; 53.9% consumed too much sodium but 61% of the population had the recommended protein intake. Ninety-nine percent (99%) of the population had at least one dietary risk factor for kidney stone formation, while 92% had two or more risk factors. Fluid, sodium, calcium, and protein intake increased significantly with education level, income, and if employed ($p<0.05$ for all); however, fluid, protein, and sodium intake were lower in patients with hypertension and heart disease ($p<0.05$ for all).

CONCLUSIONS: While only a subset of the population will develop stones, this study shows that 99% of the population has a diet that elevates the risk of stone disease. As the incidence of kidney stones increases, population-based dietary interventions should be considered. Furthermore, clinicians may use these data to understand the average diet as a starting point for questioning and counseling patients.

INTRODUCTION

The incidence of kidney stones is increasing, with approximately one in 10 North Americans developing nephrolithiasis in their lifetime.[1,2] This results in a healthcare cost exceeding $5 billion USD annually, expected to increase by $1.24 billion USD by 2030.[3,4] Lifestyle modifications to prevent kidney stones are an effective way to decrease healthcare expenditure while decreasing the population's morbidity.[5]

Studies dating back to the 1980s demonstrate a strong correlation between diet and kidney stone formation. In 1996, a seminal study by Borghi et al demonstrated that increasing fluid intake for a urine volume of ≥2 L per day decreased five-year kidney stone recurrence from 27% to 12%.[6] Similarly, Curhan et al demonstrated that increasing dietary calcium intake decreases the risk of kidney stones in patients with no prior history of stones.[7-9] Diets with low animal protein, low sodium, high fibre, and <1000 mg of vitamin C supplementation have all been linked to a decreased risk of kidney stone formation.[7,10,11] Therefore, most major urological practice guidelines urge physicians to dedicate time to both dietary assessment and counseling of kidney stone patients.[4,12,13]

Dietary management is usually assessed through the lens of patients who have formed kidney stones, trying to prevent future recurrence of stones;[4] however, improved understanding of the dietary habits of a given population can improve kidney stone prevention through two

KEY MESSAGES

- Most Canadians (99%) have a dietary intake that puts them at risk for kidney stone formation.
- Dietary counseling for kidney stone prevention should focus on fluid and calcium intake, as only 24% and 9.4% of the Canadian population are meeting the respective recommended intakes.
- Patients with comorbidities known to increase the risk of kidney stones had better compliance with recommended dietary intake

mechanisms. First, understanding the percentage of a given population that is eating an "at-risk" diet for kidney stones may allow for population-level dietary interventions, which can help stem the tide of increasing kidney stone prevalence, much of which is thought to be driven by dietary changes.[14] In a society marked by inequality, dietary differences may also be associated with targetable socioeconomic factors that can influence policy decisions.

Second, an understanding of the "average" diet can allow clinicians to focus their limited counseling time on the highest-yield dietary recommendations. Studies have demonstrated a clear desire among urologists to provide dietary counseling, but most have inadequate time to do so.15 Understanding the "starting point" for an average patient can allow urologists to focus questioning and counseling on the areas of greatest need.

In this study, we undertook a population-level assessment of dietary risk factors for kidney stones and geographic and demographic predictors for these risk factors to inform clinicians and policymakers on the North American diet.

METHODS

Population

The 2015 Canadian Community Health Survey (CCHS)–Nutrition, a national, cross-sectional instrument administered by Statistics Canada and Health Canada, was queried. The CCHS uses a multistage cluster sampling design to ensure a representative population in terms of age, sex, geography, and socioeconomic status (SES). Demographics, health characteristics, and dietary intake of Canadians living in British Columbia, Alberta, Manitoba, Saskatchewan, Ontario, Quebec, Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland and Labrador were surveyed. The territories and those living on reserves, military bases, or in institutions such as prisons or care facilities were excluded. The response rate was 61.6%.[16]

Additional detailed information on 2015 CCHS–Nutrition can be found in the user guide.[16] The data integrity has been previously confirmed prior to making the dataset publicly available, so there were no duplicated records and missing data was appropriately labelled and excluded. Our analysis excluded participants <18 years of age (n=6212) and individuals that reported no food items (n=4). No sample size calculation was done, as this was a retrospective review of a large observational database.

Variables

Dietary risk factors for kidney stones were assessed based on previous literature evaluation through the Canadian Urological Association (CUA) guidelines.[4] The dietary variables of interest within the CCHS database were total fluid, calcium, sodium, protein, and vitamin C intake. Total fluid intake was calculated as the sum of all consumed beverages, including alcohol and dairy. While the CUA guidelines recommend a urine output of 2.5 L per day to decrease stone formation, this is difficult to equate to fluid intake, as insensible water losses and food fluid content are not captured; however, the European Association of Urology (EAU) guidelines specify that fluid intake should be 2.5–3 L per day.[4,12,13] Therefore, a fluid intake cutoff of 2.5 L/day was used in our analysis.

Similarly, the CUA guidelines recommend a low animal protein diet, while the EAU guidelines specify 0.8–1.0 g/kg/day.[4,12,13] Our sample had a mean weight of 78 kg, thus a cutoff of 80 g of animal protein per day was used. Calcium, sodium, and vitamin C cutoffs were taken directly from the CUA guidelines.[4]

Statistical analysis

Population demographic, dietary risk factors for kidney stone formation, and supplement intake were examined using descriptive statistics. The sum of each individual's dietary risk factors was used to calculate the percentage of the population eating at risk. The association between participant comorbidities (hypertension, heart disease, diabetes, osteoporosis, and elevated body mass index [BMI]), as well as socioeconomic factors (education, income, employment, and food security) and nutrient intake were examined using Chi-squared test. All statistical analysis was performed using SPSS-v.25 (IBM Corp., Armonk, NY, U.S.). A p-value <0.05 was considered significant.

Table 1. Population demographics

Demographic	n (%)
Age (years, mean ± SD)	51±19
Male	6633 (47%)
BMI (mean ± SD)	28±6
≥150 minutes of physical activity per week	6233 (44%)
Comorbidities	
Hypertension	3336 (23%)
Diabetes	1259 (9%)
Heart disease	938 (7%)
Level of education	
Less than high school diploma	2320 (16%)
High school diploma	3857 (27%)
Trade/college certificate or diploma	4623 (33%)
Bachelor's degree or above	3381 (24%)
Household Income	
$0–19 999	1600 (11%)
$20 000–39 999	2959 (21%)
$40 000–5 9999	2528 (18%)
$60 000–99 999	3441 (24%)
$10 0000+	3740 (26%)
Average nutrient intake ± SD	
Fluid (mL)	1960±1097
Calcium (mg)	784±506
Protein (g)	78±42
Sodium (mg)	2709±1545
Vitamin C (mg)	94.6±98
Food security	
Food secure	12 913 (91%)
Moderately food insecure	881 (6%)
Severely food insecure	426 (3%)

BMI: body mass index; SD: standard deviation.

RESULTS

A total of 14 275 individuals were included in our analysis. Dietary data were available for 14 271 participants, demographics and socio-economic status for ≥14 220, and comorbidities for ≥13 858. The exceptions were supplements and osteoporosis, both of which only had data for between 7508–7680 participants.

The population was 47% male, with a mean age of 51±18.8 years. Further details on demographics and nutrient intake are outlined in Table 1.

Only 24% of the population consumed >2.5 L of fluid per day (Table 2). Dietary calcium consumption was low, with 75% consuming <1000 mg and only 9.4% in the recommended 1000–1200 mg range. Most patients (53.9%) consumed too much sodium, but 61% of the population had a protein intake that would not increase their risk for kidney stones. Ninety-nine percent of the population had at least one dietary risk factor for kidney stone formation, while 92% had two or more risk factors.

As seen in Figure 1, fluid, sodium, calcium, and protein intake increased significantly with education level, income, and if employed. Participants with food insecurity were

Table 2. Population's dietary intake

Nutrient	Amount	n (%)
Fluid	≥2500 mL	3462 (24%)
Calcium		
	<1000 mg	10656 (75%)
	1000–1200 mg	1340 (9.4%)
	>1200 mg	2279 (16%)
Sodium	≤2300 mg	6583 (46%)
Protein	≤80 g	8721 (61%)
Vitamin C	<1000 mg	14271 (100%)
Takes a supplement containing: (% of population)		
	Calcium	3621 (54%)
	Magnesium	3084 (47%)
	Vitamin C	3841 (57%)
	Vitamin D	4947 (73%)
	Vitamin B6	3162 (47%)
Number of dietary risk factors for kidney stone formation		
	0	56 (0.4%)
	1	1123 (7.9%)
	2	5832 (41%)
	3	4845 (34%)
	4	2419 (17%)

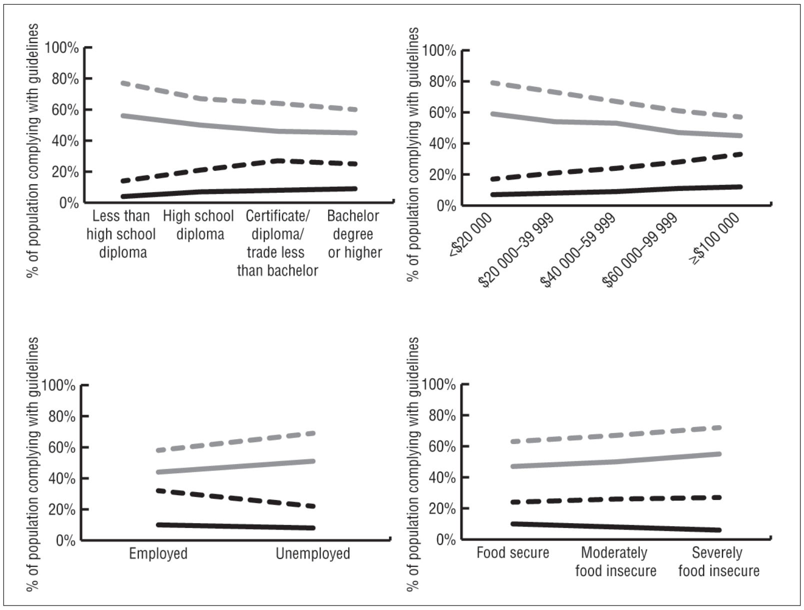

Figure 1. The percentage of the population who have a nutrient intake in accordance with kidney stone prevention guidelines stratified by education, income, employment, and food security. The grey dotted line represents protein intake (≤80 g/day), grey solid represents sodium intake (<2300 g/day), black dotted represents fluid intake (≥2.5 L/day), and black solid represents calcium (1000–1200 mg/day). All trends are significant (p<0.05) except for fluid intake stratified by food security.

more likely to have low dietary protein, sodium, and calcium but had no significant differences in fluid intake.

Hypertension, heart disease, and osteoporosis were all associated with a lower intake of fluid, protein, and sodium, while an elevated BMI was associated with increased intake of fluid and sodium ($p<0.05$ for all).

Supplements are common, with 57% of the population taking a supplement containing vitamin C, 47% vitamin B6, 54% calcium, and 46% magnesium.

DISCUSSION

For decades it has been clear that diet impacts kidney stone formation; however, adherence to dietary recommendations is low among stone formers.[17] Patients require further education to understand the importance of and how to make changes, but healthcare providers are limited by time.[15,17] Most research on kidney stone prevention diets focuses on a post-hoc assessment of diets in patients who form stones. Given the rising incidence of kidney stones, we focused instead on population-level dietary risk factors for kidney stones in North America, to help inform policy and general dietary counseling.[1] Kidney stone formation is a complex interplay of genetic and environmental factors, with a given "at-risk" diet causing stone formation in some patients and not others; however, the general dietary habits of the population may be associated with an increased risk for the population overall, especially for first-time stone formers without prior dietary counseling

Our study suggests that most adults have fluid intake that puts them at risk for kidney stone formation, with only 24% reaching the recommended 2500 mL. Even fewer adults (9.4%) consumed 1000–1200 mg of calcium. Arguably, fluid and calcium are the dietary interventions with the largest effect on kidney stone recurrence, with a decrease in five-year stone recurrence from 27% to 12% when increasing fluid intake to ≥2 L per day, and from 38% to 20% with a normal calcium, low-protein, low-salt diet compared to a low-calcium diet.[6,18] This suggests that kidney stone counseling should primarily be focused on increased fluid and appropriate calcium intake. Specifically, knowing that calcium intake is generally too low can help healthcare providers guide patients to increase calcium intake to meet the recommended 1000–1200 mg of calcium per day. Meanwhile, 100% of patients had a dietary vitamin C intake of <1000 mg, so this is less important to include in counseling, although it did not capture vitamin C intake from supplements.

Socioeconomic status, inferred by looking at education level, income, employment status, and food security, was associated with increased protein, sodium, and calcium intake. It has been demonstrated that people with a higher SES are more likely to have healthy dietary habits, while low SES diets often contain high intakes of highly processed foods and insufficient nutrients.[19] Dairy products and high-protein items like lean meats are very costly, so it is not surprising that a higher SES is associated with a higher calcium and protein intake. Sodium intake, on the other hand, has been shown to be higher in people with a low SES.[20] This discrepancy may be due to reporting bias, as participants were responsible for reporting their own nutrient intake. If high sodium intake in low SES is largely coming from processed foods, individuals may be unaware of the quantity of sodium they are truly consuming.[20]

Interestingly, participants with comorbidities known to increase the risk of kidney stones, such as heart disease and hypertension, all had better compliance with recommended fluid, calcium, protein, and sodium intake than their counterparts. This may be because these patients have already received dietary counseling to address their comorbidities, which likely overlap with kidney stone recommendations. Despite this finding, it has been previously established that these diseases are associated with kidney stone formation.[4] This suggests that the link between these diseases is not necessarily dietary and may have alternative pathophysiologic mechanisms.

Limitations

This study does have limitations inherent to an analysis of an observational database and, as a survey study, is limited by reporting bias. An analysis of the specific dietary differences for the subset of the population that forms kidney stones would have been useful but was not linked to the available dataset. Additionally, correlation to serum and urine chemistries would have been valuable; however, the large sample size and representative sampling technique used by the CCHS allows for robust population-based conclusions to be drawn as to epidemiologic dietary risk factor for kidney stones.

The CCHS database also does not distinguish between animal and plant protein intake. While guidelines specify that diets should be low in specifically animal protein, this may be because the large historical dietary studies only looked at animal protein intake. Smaller studies comparing animal and plant protein diets demonstrate that exclusively vegetarian intake produces a different urinary effect that may increase the risk of uric acid stones, but likely has a similar risk of the more common calcium oxalate or phosphate stones.[21,22] In fact, a recent paper suggests that plant-based meat products actually have higher lithogenic risk than animal protein sources.[23] Robust evidence directly comparing the incidence of kidney stones with animal vs. plant-based proteins does not exist; therefore, we feel that using overall dietary protein intake is justified.

CONCLUSIONS

This study shows that 99% of this North American population is eating a diet that elevates the risk of stone disease. As the incidence of kidney stones increases, prevention will be crucial in preventing population morbidity and increased healthcare expenditure. Efficient and effective patient counseling will be key, but population-based dietary interventions should also be considered. Given that poor fluid and calcium intake is widespread among the population, further research examining whether these could be feasibly increased on a population level to counteract the overall rising incidence of kidney stones should be explored.

COMPETING INTERESTS. The authors do not report any competing personal or financial interests related to this work.

This paper has been peer reviewed.

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