ORIGINAL RESEARCH

Differences in the Food Consumption Between Kidney Stone Formers and Nonformers in the Swiss Kidney Stone Cohort

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Objective: Diet has a major influence on the formation and management of kidney stones. However, kidney stone formers' diet is difficult to capture in a large population. Our objective was to describe the dietary intake of kidney stone formers in Switzerland and to compare it to nonstone formers.

Methods: We used data from the Swiss Kidney Stone Cohort (n = 261), a multicentric cohort of recurrent or incident kidney stone formers with additional risk factors, and a control group of computed tomography-scan proven nonstone formers (n = 197). Dieticians conducted two consecutive 24-h dietary recalls, using structured interviews and validated software (GloboDiet). We took the mean consumption per participant of the two 24-h dietary recalls to describe the dietary intake and used two-part models to compare the two groups.

Results: The dietary intake was overall similar between stone and nonstone formers. However, we identified that kidney stone formers had a higher probability of consuming cakes and biscuits (odds ratio (OR) [95% CI] = 1.56[1.03; 2.37]) and soft drinks (OR = 1.66[1.08; 2.55]). Kidney stone formers had a lower probability of consuming nuts and seeds (OR = 0.53[0.35; 0.82]), fresh cheese (OR = 0.54[0.30; 0.96]), teas (OR = 0.50[0.3; 0.84]), and alcoholic beverages (OR = 0.35[0.23; 0.54]), especially wine (OR = 0.42[0.27; 0.65]). Furthermore, among consumers, stone formers reported smaller quantities of vegetables (β coeff[95% CI] = − 0.23[− 0.41; − 0.06]), coffee (β coeff = − 0.21[− 0.37; − 0.05]), teas (β coeff = − 0.52[− 0.92; − 0.11]) and alcoholic beverages (β coeff = − 0.34[− 0.63; − 0.06]).

Conclusion: Stone formers reported lower intakes of vegetables, tea, coffee, and alcoholic beverages, more specifically wine, but reported drinking more frequently soft drinks than nonstone formers. For the other food groups, stone formers and nonformers reported similar dietary intakes. Further research is needed to better understand the links between diet and kidney stone formation and develop dietary recommendations adapted to the local settings and cultural habits.

Keywords: Kidney stones; dietary assessment; nutritional epidemiology

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Introduction

DIET PLAYS A key role in both the formation and management of kidney stones. Previous studies in the US,[1–4] UK,[5,6] and Spain[7,8] identified dietary protective and risk factors linked to the development of kidney stones. Current dietary guidelines to prevent kidney stones include a sufficient fluid intake to reach a urinary volume >2 L/24-h in order to dilute the urine and reduce the concentration of urinary lithogenic components.[9,10] Low sodium, oxalate and protein dietary intakes with a normal calcium intake (1000–1200 mg/day) and a high fruits and vegetables intake can also decrease the risk of kidney stone formation.[9,10] The human diet is multidimensional, complex, and highly variable[11] and cultural factors influence food choices.[12] It is thus important to explore further the associations between dietary factors and the risk of kidney stones to deepen our understanding of the role of diet in nephrolithiasis pathophysiology.

Kidney stones are associated with high morbidity (potential complications include ureteral obstruction or kidney failure) and high costs.[13,14] Kidney stone prevalence reaches 5–10% in Europe and has been increasing worldwide during the last decades.[13,15,16] Primary and secondary prevention based on efficient dietary recommendations has a major role to play to fight this public health problem.[9,17]

The Swiss Kidney Stone Cohort (SKSC) has been launched in 2014 to study the epidemiology and pathogenesis of kidney stone disease in Switzerland.[18] The first Swiss national nutrition survey, menuCH, conducted in 2014–2015, assessed dietary intake in the Swiss general adult population via 24-hour dietary recalls.[19] Given the paucity of data on the diet of kidney stone formers in Switzerland so far, it was of great interest to collect high quality nutritional data specific to kidney stone formers. Here, we described the food consumption of kidney stone formers from the SKSC at baseline and compared it to a group of nonkidney stone formers.

Materials and Methods

Study Population

The SKSC is a multicentric cohort of kidney stone formers covering five centers in the German and French-speaking parts of Switzerland (Berne, Zurich, Basel/Aarau, Lausanne, and Geneva).[18] The cohort includes both incident and recurrent stone formers, recruited from the nephrology outpatient clinics. Inclusion criteria were to have recurrent (>1) stone episodes or an incident episode with other risk factors such as first episode before 25 year old, positive family history, noncalcium oxalate stones, gastrointestinal disorders, metabolic syndrome, osteoporosis, chronic urinary tract infection or chronic renal failure. Participants under 18 years old were not included in the cohort. The same harmonized protocol was used across all centers. Participants were recruited between May 2014 and March 2020.

The SKSC contains a unique set of data, with detailed anthropometric measures, nutritional data, and biological samples. After a baseline examination (≥4 weeks post stone passage or intervention), follow-up visits were conducted at 3 months, 1 year, and then once a year during 3 years. After the 3 years, study nurses checked annually on participants by phone calls. Data collected at each visit included medical and stone history, physical exam, 24-h dietary recalls, 24-h urine collections, and blood samples.

A control group of nonstone formers was recruited in the general adult population, by advertisement (in Geneva, Zurich, Aarau, and Lausanne centers). Controls, unlike kidney stones formers, were seen only for a baseline visit, yet we used the same standard operating procedures for dietary intake and questionnaire data, as well as for urine and blood sample collections. These participants had no kidney stone history and were free of stones, as ruled out by a native computed tomography-scan of the abdomen. Matching for sex and age with SKSC participants was done when possible but in the final sample, the control group includes more women and younger individuals than the SKSC.

Dietary Intake Assessment

At each visit, participants completed two consecutive 24-h dietary recalls (except at the 3 months follow-up visit where only a single 24-h recall was completed), in which participants described and quantified every food and beverage item consumed over the 48-h recall period. Trained dieticians conducted the interviews, using a dedicated and validated software to collect the data, GloboDiet® (GD, formerly EPIC-Soft®, version CH-2016.4.10, International Agency for Research on Cancer, Lyon, France, adapted to the Swiss food market).[20–22] Interviews were distributed over weekdays and weekends and throughout the year, depending on participants' availability and moment of inclusion in the study. For stone formers, 127 interviews (49%) were done during weekdays only, 100 (38%) during weekends only and 34 (13%) were a mix of weekdays and weekends. For nonstone formers, 84 interviews (43%) were done during weekdays only, 93 (47%) during weekends only and 20 (10%) were a mix of weekdays and weekends.

As previously described,[19,22] the 24-h dietary recalls were multiple-pass (recall process organized in standardized steps with probes from the interviewer to help participants remember food and beverages consumed) and automated. We categorized foods or beverages into 19 main food groups (e.g., vegetables, cereals, meat, fish and seafood, nonalcoholic beverages), based on food groups precoded by GD. These food groups are further divided into several subgroups. Specific descriptors allow a highly standardized

Table 1. Characteristics of the Participants With Two 24-h Dietary Recalls at Baseline

		SKSC (n = 261)	Nonkidney stone formers (n = 197)	*P* value*
Women, n (%)		93 (36%)	90 (46%)	.03
Age (years), mean [min, max]	All	47.3 [19,79]	43.4 [20,81]	<.01
	Men	48.2 [20,79]	45.7 [22,81]	.15
	Women	45.6 [19,73]	40.6 [20,62]	<.01
German speaking part, n (%)		148 (57%)	109 (55%)	.77
Education level 53 missing (33 SKSC, 20 nonformers)	Low	27 (12%)	3 (2%)	<.01
	Middle	131 (57%)	72 (40%)	
	High	70 (31%)	102 (58%)	
BMI (kg/m^2), mean (SD) 3 missing (2 SKSC, 1 nonformers)	All	26.6 (4.7)	25.2 (4.4)	<.01
	Men	26.7 (4.5)	26 (3.8)	.15
	Women	26.2 (5.2)	24.2 (4.9)	<.01
Total calorie intake (kcal/24h), mean (SD)†	All	2015 (658)	2065 (629)	.41
	Men	2203 (628)	2274 (648)	.38
	Women	1674 (572)	1817 (508)	.08
Total protein intake (g/24h), mean (SD)†	All	76 (28)	80 (33)	.22
	Men	84 (28)	88 (37)	.34
	Women	62 (23)	70 (25)	.03
Total carbohydrates intake (g/24h), mean (SD)†	All	215 (84)	208 (77)	.38
	Men	235 (86)	229 (82)	.55
	Women	178 (66)	184 (63)	.58
Total fat intake (g/24h), mean (SD)†	All	88 (34)	90 (35)	.50
	Men	95 (33)	98 (39)	.45
	Women	76 (33)	81 (29)	.28

*The two groups were compared using the chi-square test for categorical variables and the two sample t-test for continuous variables.
†Calculated using the mean intake of the two 24-h dietary recalls for each participant.

description of foods and recipes.[19,20] Furthermore, a picture book, also including typical Swiss recipes, helped participants to quantify the amounts of foods and beverages consumed.[23] Macronutrients (energy, protein, carbohydrates and fat) intakes were calculated by GD for each interview.

Vegetables are an important source of oxalate in the diet. As oxalate plays a major role in the physiopathology of kidney stones, we were interested in detailing the consumption of vegetables depending on their oxalate content. We categorized vegetables based on their oxalate content using the table from the Harvard T.H Chan School of Public Health as reference.[24] Based on this reference table, we associated an oxalate content category to 51 out of the 104 vegetables available in GD (49%). There are seven different oxalate content categories: very high (n = 8 vegetables), high (n = 3 vegetables), moderate (n = 11 vegetables), low (n = 3 vegetables), very low (n = 11 vegetables), little/none (n = 15 vegetables), unknown (for the vegetables that could not be associated with an oxalate content category (n = 53 vegetables).

For beverages, we used the Food and Agriculture Organization of the United Nations (FAO) database[25] for the density of the different liquids. As the density of most beverages was close to 1, we applied a general conversion factor of 1g = 1 mL for the nonalcoholic and alcoholic beverages.

Statistical Analysis

To compare characteristics of stone and nonstone formers, we used the chi-square test for categorical variables and the two-sample t-test for continuous variables.

Whenever participants did not consume a given food or beverage during the two baseline recalls, they were labeled as nonconsumers (and attributed a consumption value of zero) for this specific food or beverage group.

For each participant, we calculated the mean consumption of the two consecutive 24-h dietary recalls from baseline to describe the dietary intake, by macronutrients, food groups, and subgroups, in the stone and nonstone formers groups. We generated mean consumed quantities considering all the participants, both consumers and nonconsumers.

We also compared the dietary intake between stone formers and nonstone formers. Some of the food groups had a large proportion of nonconsumers and presented a skewed distribution. As linear regression models do not fit well such data, we therefore used two-part models[26] to compare the dietary intakes between the two groups. The two-part model estimates separately 1) the association of the kidney stone status (stone formers coded as 1 and nonformers as 0), taken as the independent variable of interest, with the probability of consumption (consumers coded as 1 and nonconsumers coded as 0), as the dependent variable of interest, in a logistic regression model and 2) the association of kidney stone status with the quantities reported by consumers,

Table 2. Description of Mean Food Consumption for all Participants (Consumers and Nonconsumers), by Sex

	Mean consumption, g (SE)*			
	Men		Women	
	Stone formers (n = 168)	Nonstone formers (n = 107)	Stone formers (n = 93)	Nonstone formers (n = 90)
Potatoes	45 (5)	49 (7)	45 (6)	39 (6)
Vegetables	138 (8)	188 (19)	154 (11)	214 (15)
Legumes (pulses)	4 (2)	9 (3)	4 (2)	3 (1)
Fruits	148 (11)	133 (13)	139 (12)	168 (17)
Nuts and seeds	6 (1)	10 (2)	5 (1)	10 (2)
Dairy products (all subgroups†)	241 (15)	263 (19)	195 (19)	228 (19)
Milk	100 (12)	114 (16)	70 (13)	66 (11)
Substitute milks (soy, coconut)	12 (5)	14 (5)	11 (8)	31 (11)
Yogurt	47 (6)	41 (7)	47 (8)	57 (12)
Fresh cheese	14 (4)	17 (5)	8 (3)	16 (4)
Cheese	43 (3)	51 (5)	35 (4)	37 (4)
Cereals	261 (12)	255 (12)	175 (10)	182 (10)
Meat	119 (7)	115 (9)	78 (7)	81 (8)
Fish and seafood	34 (4)	26 (4)	26 (5)	29 (4)
Eggs	19 (2)	23 (3)	15 (2)	20 (3)
Oils and fat	19 (1)	22 (2)	21 (2)	20 (2)
Sugar, chocolate, and sweets	36 (3)	38 (4)	32 (4)	31 (3)
Cakes and biscuits	49 (6)	41 (6)	32 (6)	29 (5)
Nonalcoholic beverages (mL) (all subgroups†)	2269 (66)	2125 (82)	2008 (71)	2133 (98)
Juices	75 (11)	80 (16)	75 (16)	66 (12)
Soft drinks	211 (27)	158 (26)	145 (29)	126 (34)
Coffee	233 (20)	296 (26)	229 (22)	233 (22)
Tea	36 (9)	114 (30)	45 (14)	156 (29)
Infusions	114 (22)	100 (30)	207 (36)	179 (36)
Water (tap and bottled)	1583 (72)	1360 (86)	1298 (74)	1369 (100)
Alcoholic beverages (mL) (all subgroups†)	152 (19)	277 (40)	43 (11)	116 (17)
Wine	61 (9)	107 (17)	21 (7)	77 (15)
Beer	85 (14)	159 (37)	20 (8)	32 (9)
Spirits	3 (2)	0.3 (0.3)	0.07 (0.05)	0.2 (0.2)
Spices and sauces	39 (3)	34 (3)	33 (4)	30 (3)
Soups	39 (8)	33 (9)	44 (10)	50 (12)
Dietetic and sports food	5 (2)	10 (6)	0.3 (0.15)	3 (1)
Savory snacks	11 (2)	12 (3)	14 (3)	10 (3)

*Calculated using the mean intake of the two 24-h dietary recalls for each participant, standard error (SE).
†Including subgroups not detailed in this table.

taken as the dependent variable of interest, in a linear regression model. In both models, we included as covariables age, sex, body mass index (BMI), linguistic region (French-speaking or German-speaking part of Switzerland), mean energy intake, and education level (coded as low [secondary school], middle [high school, apprenticeship] and high [university degree]). We used a log-transformation of the dependent variable (mean consumed quantity) to better approximate a symmetric and normal distribution of the residuals. Furthermore, we decided that a minimum of 50 consumers and nonconsumers (logistic regression) and 50 consumers (linear regression) in a food group was needed to have enough information in the data to run the regression model. We considered two-sided p value $<.05$ as statistically significant in our analyses.

As the education level was missing in 53 participants (11.5%) and BMI in 3 participants (0.6%), we used multiple imputations by chained equations. Ten complete datasets were generated using a regression model for the BMI and an ordered logit model for the education level. All variables included in the two-part models were used as potential predictors.

Finally, we compared the macronutrients' intake to the values obtained in menuCH,[19] using a t-test with a normal approximation. This comparison was done as a quality check regarding the data collection and to evaluate if the intake was similar between the two studies.

Table 3. Influence of the Kidney Stone Status on the Probability of Consumption and Differences in the Mean Dietary Consumption Between Kidney Stone Formers and Nonformers

		Step 1 (consumption yes/no)			Step 2 (consumed quantities among consumers)		
		Logistic regression*			Linear regression*		
	Consumers, n (%)	OR	95% CI	*P* value	Coeff†	95% CI	*P* value
Potatoes	217 (47.4)	1.06	0.70; 1.59	.79	−0.08	−0.28; 0.13	.46
Vegetables	436 (95.2)	NA‡	NA	NA	−0.23	−0.41;-0.06	**.009**
Legumes (pulses)	46 (10)	NA	NA	NA	NA	NA	NA
Fruits	354 (77.3)	0.87	0.53; 1.45	.60	0.008	−0.18; 0.2	.94
Nuts and seeds	158 (34.5)	0.53	0.35; 0.82	**.004**	−0.26	−0.67; 0.16	.22
Dairy products	446 (97.4)	NA	NA	NA	−0.09	−0.26; 0.09	.34
Milk	268 (58.5)	0.93	0.61; 1.4	.71	−0.12	−0.44; 0.2	.45
Substitute milks	47 (10.3)	NA	NA	NA	NA	NA	NA
Yogurt	186 (40.6)	1.07	0.71; 1.61	.75	−0.06	−0.3; 0.18	.61
Fresh cheese	65 (14.2)	0.54	0.30; 0.96	**.036**	0.45	−0.14; 1.03	.13
Cheese	373 (81.4)	0.76	0.45; 1.28	.31	−0.02	−0.21; 0.18	.88
Cereals	455 (99.3)	NA	NA	NA	0.05	−0.06; 0.16	.35
Meat	405 (88.4)	0.52	0.26; 1.02	.06	−0.02	−0.19; 0.15	.83
Fish and seafood	187 (40.8)	0.92	0.61; 1.4	.70	0.20	−0.05; 0.45	.11
Eggs	225 (49.1)	0.82	0.55; 1.23	.35	0.04	−0.22; 0.30	.77
Oils and fat	430 (93.9)	NA	NA	NA	−0.04	−0.22; 0.13	.64
Sugar, chocolate, sweets	391 (85.4)	1.09	0.6; 1.97	.78	−0.008	−0.23; 0.21	.94
Cakes and biscuits	251 (54.8)	1.56	1.03; 2.37	**.038**	0.07	−0.16; 0.30	.56
Nonalcoholic beverages (mL)	458 (100)	NA	NA	NA	0.04	−0.04; 0.12	.34
Juices	233 (50.9)	1.33	0.89; 1.99	.17	−0.08	−0.55; 0.38	.72
Soft drinks	183 (40)	1.66	1.08; 2.55	**.02**	−0.27	−0.57; 0.03	.075
Coffee	344 (75.1)	0.83	0.52; 1.33	.44	−0.21	−0.37;-0.05	**.011**
Tea	95 (20.7)	0.50	0.3; 0.84	<**.01**	−0.52	−0.92;-0.11	**.012**
Infusions	135 (29.5)	1.24	0.79; 1.95	.35	0.01	−0.21; 0.41	.53
Water (tap and bottled)	443 (96.7)	NA	NA	NA	0.11	−0.04; 0.26	.17
Alcoholic beverages (mL)	218 (47.6)	0.35	0.23; 0.54	<**.001**	−0.34	−0.63;-0.06	**.02**
Wine	153 (33.4)	0.42	0.27; 0.65	<**.001**	−0.29	−0.59; 0.006	.05
Beer	95 (20.7)	0.74	0.45; 1.21	.23	−0.18	−0.47; 0.12	.24
Spirits	15 (3.3)	NA	NA	NA	NA	NA	NA
Spices and sauces	442 (96.5)	NA	NA	NA	0.18	−0.12; 0.48	.23
Soups	116 (25.3)	0.92	0.58; 1.46	.74	0.26	−0.37; 0.88	.42
Dietetic and sports food	48 (10.5)	NA	NA	NA	NA	NA	NA
Savory snacks	115 (25.1)	0.93	0.58; 1.48	.75	0.001	−0.39; 0.39	.1

*Kidney stone formers coded as 1 and nonformers as 0. Models were adjusted for age, sex, body mass index, linguistic region, mean energy intake, and education level.

†The dependent variable (mean consumption) has been log-transformed.

‡NA in the logistic regression: less than 50 participants in the consumers or nonconsumers group; NA in the linear regression: less than 50 participants in the consumers group.

The analyses are based on a database extraction done in December 2020 and were performed with Stata 16 (Stata Corporation, College Station, TX, USA). To produce the figures, we used the package ggplot2 (Wickham, 2016) from the software R, version 4.1.1 (R Core Team, 2021).

Results

There were 261 participants in the SKSC and 197 participants in the nonkidney stone formers group that had complete data to be analyzed (Table 1). The two groups differed in their proportion of men and women, mean age, education level, and BMI, as well as the protein intake in women.

The mean consumed quantities (in grams) for the different food groups and subgroups are shown in Table 2. Those values represent the mean consumption at the group level, including both consumers and nonconsumers, and allow identifying central elements of the diet for the group. For instance, the mean consumption of food groups such as vegetables, fruits, dairy products, cereals, meat, and beverages at the group level is higher than other food groups such as legumes, nuts and seeds, dietetic and sports food and savory snacks. Furthermore, this table allows comparing the absolute amount of each food group consumed by stone formers with the ones consumed by nonstone formers. For vegetables, male nonstone formers consumed, on average, 188 g/day, whereas male stone

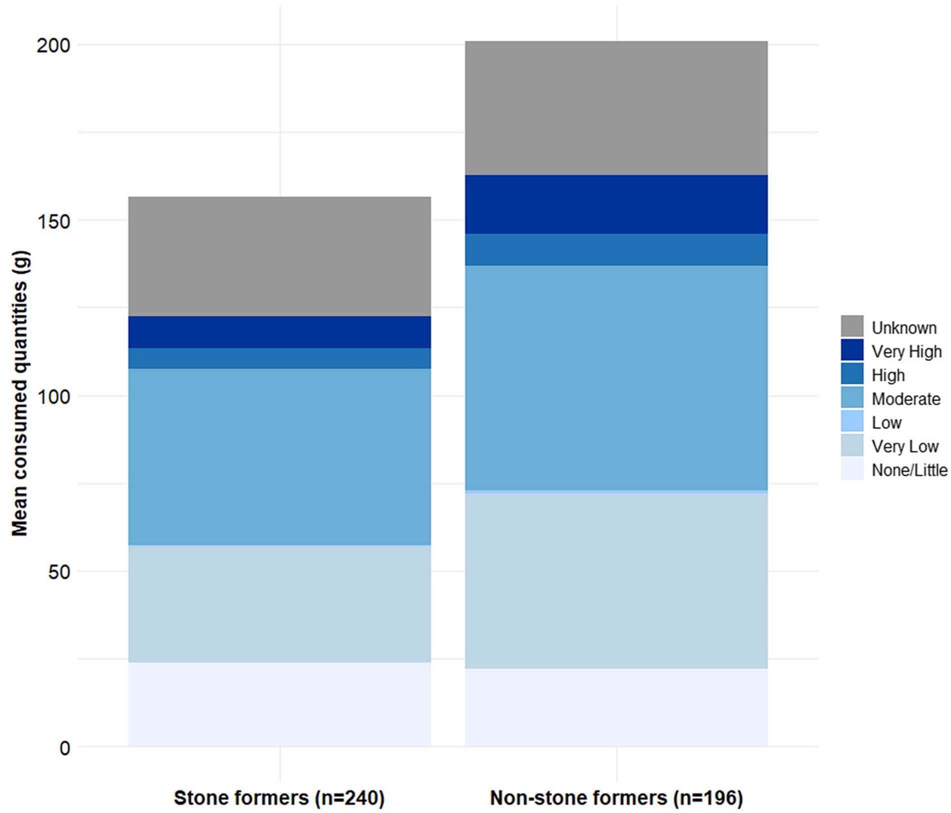

Figure 1. Mean consumed quantities of vegetables, among consumers, by oxalate-content categories. None/Little (n = 15 vegetables), Very Low (n = 11 vegetables), Low (n = 3 vegetables), Moderate (n = 11 vegetables), High (n = 3 vegetables), Very High (n = 8 vegetables) and Unknown (for the vegetables that could not be associated with an oxalate content category (n = 53 vegetables).

formers 138 g/day, which gives an absolute difference (50 g/day) that is a relevant difference from a public health nutrition perspective. A similar comment can be made for vegetable consumption by women.

Table 3 shows the number of consumers for the different food groups, representing the participants who consumed at least once an item from a given food group during the two 24-h dietary recalls. Kidney stone status was significantly associated with the probability of consuming nuts and seeds, fresh cheese, cakes and biscuits, soft drinks, teas as well as alcoholic beverages and wine (Table 3). Kidney stone formers had a higher probability of consuming cakes and biscuits (odds ratio (OR) 95% confidence interval [95% CI] = 1.56[1.03; 2.37]) and soft drinks (OR[95% CI] = 1.66[1.08; 2.55]). However, they had a lower probability of consuming nuts and seeds (OR[95% CI] = 0.53 [0.35; 0.82]), fresh cheese (OR[95% CI] = 0.54[0.30; 0.96]), teas (OR[95% CI] = 0.50[0.3; 0.84]) and alcoholic beverages (OR[95% CI] = 0.35[0.23; 0.54]), the latter through a lower consumption of wine (OR[95% CI] = 0.42[0.27; 0.65]), but not of beer.

Among consumers, stone formers reported smaller amounts of vegetables (β coeff[95% CI] = −0.23 [− 0.41; − 0.06]), coffee (β coeff[95% CI] = −0.21[− 0.37; − 0.05]), teas (β coeff[95% CI] = −0.52[− 0.92; − 0.11]) and alcoholic beverages (β coeff[95% CI] = − 0.34[− 0.63; − 0.06]) than nonformers (Table 3). Quantities reported by the consumers for other food groups were not significantly different between stone and nonstone formers (Table 3).

The mean consumed quantities for the different vegetables, based on their oxalate content category, are shown in Figure 1. The low categories (none/little, very low, and low) represent 37% of the total consumption for the stone formers and 36% for the nonstone formers, the moderate category represents 32% of the total consumption in both groups and the high categories (high and very high) represent 9% of the total consumption for the stone formers and 13% for nonstone formers.

There were both qualitative and quantitative differences in the consumption of beverages. Figure 2 shows the percentage of consumers by beverage category for the stone formers and nonstone formers. Water and coffee were the most often consumed beverages. There were more stone formers reporting the consumption of soft drinks and more nonstone formers reporting the consumption of tea

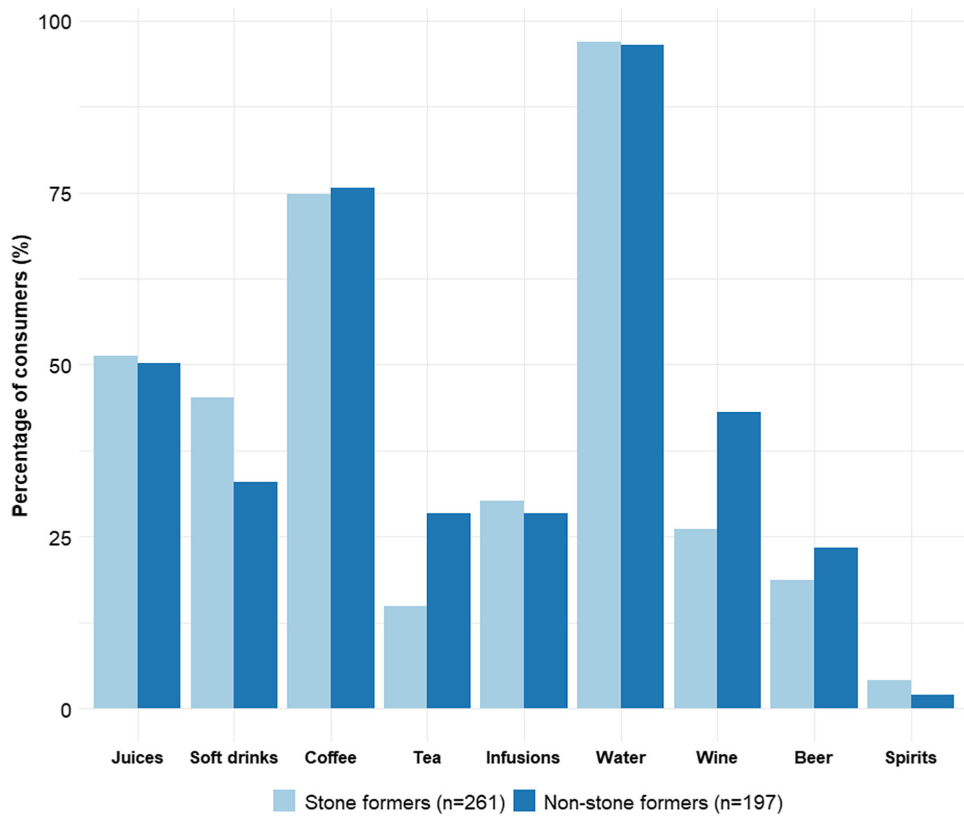

Figure 2. Percentage of consumers in the stone and nonstone formers groups, by beverage category.

and wine. Mean consumed quantities for nonalcoholic and alcoholic beverages are reported in Figure 3. Both nonstone and stone formers had a high mean fluid intake over 2000 mL, however nonstone formers reported higher quantities of tea, coffee, and alcoholic beverages (especially wine) than stone formers.

Daily energy intake was slightly higher in menuCH (mean ± standard error: 2185 ± 16.6 kcal), than in stone formers (2015 ± 40.7 kcal, $P < .001$) and nonstone formers (2065 ± 44.8 kcal, $P = .01$). The protein intake was higher in menuCH (82.7 ± 0.7 g/day) than in stone formers (76 ± 1.7 g/day, $P < .001$) but similar to that of nonstone formers (80 ± 2.3 g/day $P = .27$). The carbohydrates intake was higher in menuCH (230.4 ± 2.1 g/day) than in stone formers (215 ± 5.2 g/day, $P < .01$) and nonstone formers (208 ± 5.5 g/day, $P < .001$). Finally, the mean fat intake was similar in menuCH (89.7 ± 1.2 g/day) than in stone formers (88 ± 2.1 g/day, $P = .48$) and nonstone formers (90 ± 2.5 g/day, $P = .91$).

Discussion

Overall, in our sample, the diets of kidney stone formers and nonformers were similar but we mainly identified some differences in the consumption of vegetables and beverages between the two groups. We found that kidney stone formers consumed smaller amounts of vegetables, coffee, tea, and alcoholic beverages than nonstone formers and reported more frequently the consumption of soft drinks and cakes and biscuits. In contrast, nonstone formers reported more frequently the consumption of nuts and seeds, fresh cheese, tea, and wine compared to stone formers.

An important strength of this study is the collection of two 24-h dietary recalls for both groups. Indeed 24-h dietary recalls are considered the least biased tool in the category of self-reported dietary assessment methods.[27] Moreover, the use of the software GloboDiet® (GD), which has been validated in European dietary surveys,[20,21,28,29] allows for a precise and standardized characterization of dietary intake. Finally, the quality controls applied in GD and the possibility for multilanguages use[22,29] make it a reliable tool in the multicentric setting of the SKSC.

Yet, like all self-report methods, 24-h dietary recalls are subject to errors and biases[27,30-32] and have been shown to poorly estimate total energy intake.[27,31,33] 24-h dietary recalls contain both random errors, due to day-to-day variation in the diet of individuals, and systematic errors,[27] such as the consistent underreporting of certain foods and beverages (e.g., fats, sweets).[33] Random errors induce a greater variance in the measures and can lead to inaccurate usual intake distributions. However, regarding the mean intake, a study identified that single recalls or the average of two 24-h dietary recalls estimated correctly population estimates of mean intakes and were not inferior to estimates

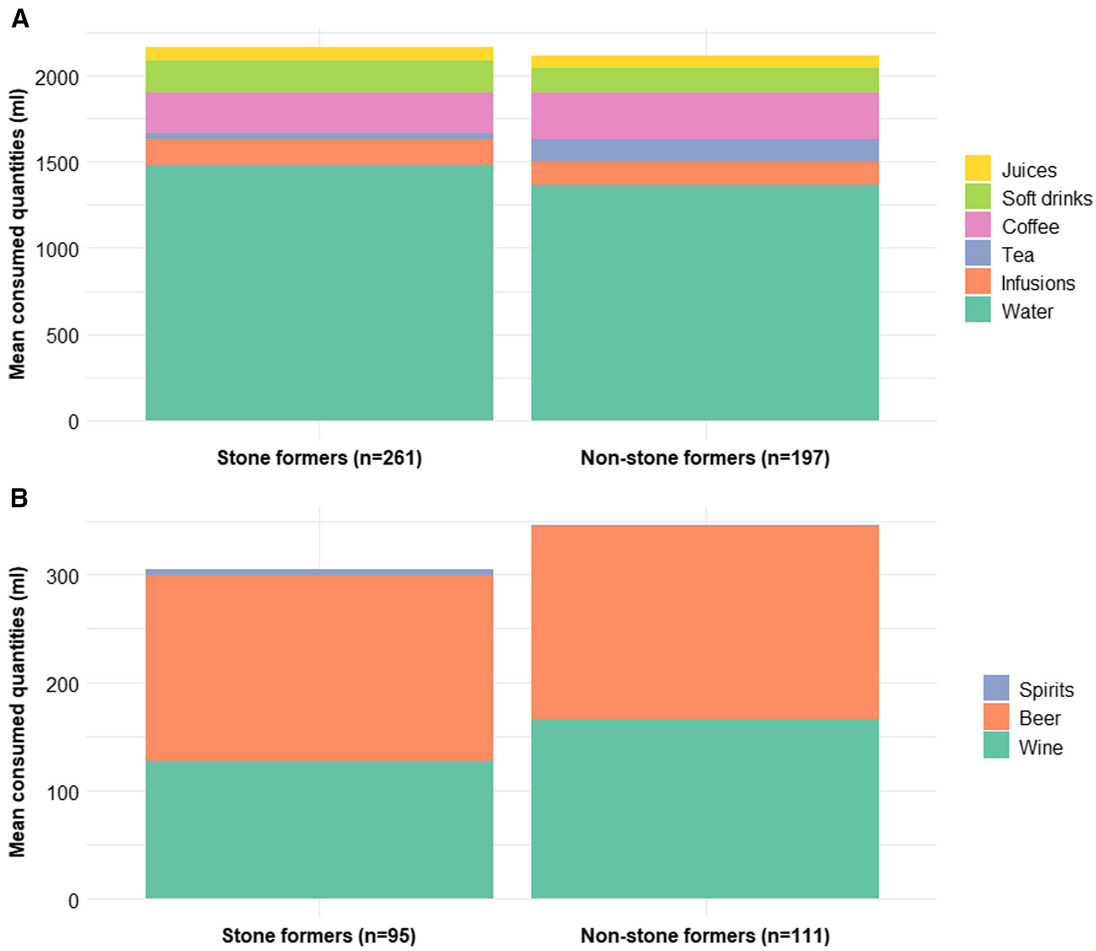

Figure 3. Mean consumed quantities of nonalcoholic (A) and alcoholic (B) beverages, among consumers.

using other more sophisticated models for this specific purpose.[34] In our study, as we worked with the mean consumption and not the usual intake, results should thus be less impacted by such errors. Finally, as 24-h dietary recalls focus on a single day (usually the previous day), the magnitude of systematic errors is less important than with other methods.[32]

Furthermore, the SKSC included both incident and recurrent stone formers. In the context of a stone event, after metabolic evaluation and during their follow-up, kidney stone formers usually receive dietary recommendations. These recommendations can be general, such as increasing their liquid intake or avoiding high oxalate content foods and beverages.[9,35] Recommendations can also specifically target urinary risk factors (e.g., hypercalciuria or hypocitraturia) identified after a metabolic evaluation with an analysis of 24-h urine composition.[9,35] It is thus possible that some recurrent stone formers had already modified their diet at the baseline visit, while others did not.

The results of this study are consistent with the literature. We found that nonstone formers consumed more vegetables than stone formers. The impact of vegetable consumption on stone formation is complex. Studies showed a protective effect of vegetables on the risk of kidney stones[36–42] but some types of vegetables, such as leafy greens, were identified as risk factors.[43,44] Indeed, leafy greens have a high content of oxalates and can thus increase the risk of oxalate-based stones, the most common stone type.[9,45] As intestinal absorption of oxalate can be influenced by the presence of calcium, it is also interesting to note that we observed no significant difference in the quantities of dairy products (one of the major source of calcium in the diet) reported by the consumers.

Vegetables interact with other elements of the diet and their impact on kidney stone formation needs to be considered in the context of the whole diet. Some studies identified that diets such as the Mediterranean, DASH (Dietary Approaches to Stop Hypertension), or vegetarian diets (characterized by a high intake of vegetables, fruits, nuts, and legumes and a low/no intake of red meat) were associated with a reduced risk of kidney stones.[2,5,8,35,46,47]

Moreover, vegetables are an important source of various elements, such as fibers, potassium, phytates, citrate, or oxalates among others. However, depending on their combination and balance with other foods and beverages, these elements might have a different impact on the risk. For instance, the impact of high fiber diets was inconsistent: studies identified high fiber diets as protective,[6,39] without effect,[48] or at increased risk[49] for kidney stone formation. Fibers can decrease the urinary excretion of oxalate and calcium by binding minerals and fats in the gastrointestinal tract[17] but if a fiber-rich diet is associated with a low calcium intake, the result can thus be a lowered urinary calcium excretion and higher oxalate concentration.[35] Another example is green tea. Tea is known to contain oxalates, which could put tea in the "at-risk" category but overall, due to components such as antioxidants and other phytochemicals, green tea has been shown to be protective against kidney stone formation.[17] Finally, investigators also highlighted the importance of the balance between different components of the diet, showing that a higher animal protein-to-potassium (mainly derived from vegetables and fruits) ratio was associated with a higher risk.[50]

Insufficient fluid intake is one of the most important risk factors for kidney stone formation.[9] Some beverages seem to be protective while others increase the risk but these effects are still debated.[9] Previous studies showed that tea,[6,42,51-54] coffee,[6,51-53,55] and alcoholic beverages[6] such as beer[49,51,53,56] or wine[51-53] were associated with a decreased risk. However, studies also identified that total fluid intake was the main protective factor, independently of the beverage category,[43] or that alcohol was increasing the risk.[57-59] Overall, it seems that urine dilution is key but different beverages may have properties leading to either a decreased or an increased risk.

As mentioned, stone formers were not naive when they entered the cohort and may have received and already implemented some dietary recommendations. In that context, interpretation of the low consumption of tea and other oxalate containing food should be exerted with caution. In addition, we still identified qualitative and quantitative differences for beverages between nonformers and formers, despite the fact that increasing volume intake is one of the main dietary recommendations for kidney stone prevention. This could reveal a difficulty to implement these recommendations in the day-to-day life.

Finally, regarding the comparison of macronutrients' intake with menuCH, there were some significant differences in energy intake, protein intake and carbohydrates intake between menuCH and the SKSC. However, the scales and ranges of the energy and macronutrients intakes are close between the two studies and not clinically relevant.

This study is the first to describe the diet of kidney stone formers in Switzerland, where the diets in the French and German-speaking regions are known to substantially differ.[19] As kidney stones are becoming more prevalent, it is of key importance to better understand the dietary characteristics of kidney stone formers in order to build dietary recommendations that take the local settings and cultural habits into account. This description of the food intake is thus a first step toward understanding kidney stone formers diet' specificities and can inform future studies. Yet, as mentioned before, self-report methods are prone to errors and biases. Therefore, future research combining objective nutritional biomarkers such as sodium, potassium, or urea excretion in 24-h urine collections and data collected with self-report methods will help evaluate the impact of diet on kidney stone formation in Switzerland.

Practical Implications

This study helps define points of action in the prophylaxis of kidney stones in Switzerland. We found that stone formers consumed fewer vegetables and had a tendency to drink more soft drinks and less tea/coffee and alcoholic beverages. As recommended in the existing literature[9,10,35] and in accordance with the present results, health professionals should encourage stone formers to eat a diet rich in vegetables, dairy products and limited in meat and salt. Additionally, a high intake of beverages (with a preference for water and nonsweetened beverages) is indicated to dilute the urine and limit its saturation in lithogenic components.

Credit Authorship Contribution Statement

Constance Legay: Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Tanja Haeusermann:** Writing – review & editing. **Jérôme Pasquier:** Formal analysis, Writing – review & editing. **Angeline Chatelan:** Methodology, validation, Writing – review & editing. **Daniel G. Fuster:** Writing – review & editing. **Nasser Dhayat:** Writing – review & editing. **Harald Seeger:** Writing – review & editing. **Alexander Ritter:** Writing – review & editing. **Nilufar Mohebbi:** Writing – review & editing. **Thomas Ernandez:** Writing – review & editing. **Catherine Stoermann Chopard:** Writing – review & editing. **Florian Buchkremer:** Writing – review & editing. **Stephan Segerer:** Writing – review & editing. **Grégoire Wuerzner:** Writing – review & editing. **Nadia Ammor:** Writing – review & editing. **Beat Roth:** Writing – review & editing. **Carsten A. Wagner:** Writing – review & editing. **Olivier Bonny:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Murielle Bochud:** Conceptualization, Methodology, Supervision, Writing – review & editing.

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