Original Article

Nephrolithiasis, stone composition, meteorology, and seasons in Malta: Is there any connection?

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Abstract

Context: The effect of seasons and meteorology on the incidence of nephrolithiasis has been studied in various regions around the globe, but seldom in the Mediterranean.

Aims: This retrospective analysis aims at investigating these putative effects in the Maltese Islands, whose climate is typically Mediterranean, followed by a systematic review of the literature.

Materials and Methods: Submission rate and chemical composition of all kidney stones after spontaneous passage or surgical removal between January 2009 and December 2011 were analyzed according to seasons and corresponding meteorology.

Results: A total of 389 stones were analyzed. A higher stone submission rate was observed in summer compared to winter (31.6% vs. 20.8%, $P = 0.0008$) and in the warm period compared to the cold period (57.1% vs. 42.9%, $P = 0.0001$). Significant correlation was established between the monthly number of stones and mean monthly maximum temperature ($r = 0.50$, $P = 0.002$), mean monthly temperature ($r = 0.49$, $P = 0.003$) and mean monthly Humidex ($r = 0.49$, $P = 0.007$). Humidex was found to be an independent predictor for stone submission ($\beta = 0.49$, $P = 0.007$). The majority of stones contained calcium (83.3%), combined with oxalate (77.6%), phosphate (14.7%), and carbonate (2.8%). Some stones (11.8%) contained a mixture of >1 negatively charged molecules. Urate (11.6%), cysteine (4.6%), and ammonium-magnesium-phosphate (0.5%) constituted the rest. There was no association between chemical composition and seasons. Literature review included 25 articles. Higher ambient temperature and warm seasons were the most commonly encountered risk factors for both presentation and etiology of nephrolithiasis.

Conclusions: A significant positive correlation was noted between ambient temperature and stone submission rate, which was significantly higher during the warm months in Malta.

Key Words: Ambient temperature, kidney stones/calculi, meteorology, nephrolithiasis, seasons

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INTRODUCTION

Nephrolithiasis is a multifactorial disease, primarily influenced by the patient's genetic constitution, diet, and water intake. Albeit to a lesser degree, various studies worldwide have also implicated meteorology and seasons in this complex process. Nonetheless, there is a paucity of data in the Mediterranean, and

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any association with the chemical composition has been mostly overlooked. The primary aim of this analysis is to investigate the effects of seasons and meteorology, on the incidence of nephrolithiasis and chemical composition of kidney stones in the Maltese Islands, which feature typical Mediterranean climate. This is followed by a systematic review of published literature.

MATERIALS AND METHODS

Geography and climate

The Maltese archipelago consists of two habitable islands; Malta and its smaller sister island Gozo. It is located in the center of the Mediterranean Sea, 93 km south of Sicily and 288 km north of Libya. The two islands are separated by a 7 km stretch of Mediterranean Sea, but are very well connected. They feature a total area of 316 km^2, 250 km of coastline and a maximum elevation of 253 m. The climate is typically Mediterranean, characterized by hot, dry summers and mild, wet winters with insignificant climate variability between the two islands. The warmest months are May to October while the coldest being November to April. During the study period, the mean temperatures in winter (January to March), spring (April to June), summer (July to September), and autumn (October to December) were 13.0°C, 19.7°C, 26.2°C, and 17.5°C, respectively. Mater Dei Hospital is the main university hospital and provides acute care for the vast majority of the Maltese population, which is close to half a million.

Data collection

This is a retrospective analysis with most data collected using the hospital electronic laboratory data system. All kidney stones submitted to the Biochemistry Department at Mater Dei Hospital between the January 01, 2009 and December 31, 2011 were included. Kidney stones are either self-submitted by patients after spontaneous passage or submitted for analysis after removed by surgical intervention. Patients are routinely instructed to bring any spontaneously passed stones for analysis Kidney stone submission was selected in favour to renal colic presentations, as this allowed us to look at the stone chemical composition and any associated seasonal variation. Data collection included gender, race, age of the patient at the time of stone submission, the month and year of stone submission and the chemical composition of the stone. Only the first submitted stone for each patient was included. In the laboratory, stones are subjected to a standard washing and fragmentation technique. Light microscopy is employed to examine crystal morphology and a semi-quantitative chemical analysis, using a series of reagents, is subsequently performed to determine the stone chemical composition.

The mean monthly temperatures, mean monthly maximum temperatures, mean monthly relative humidity and Humidex values for the years 2009–2011 were obtained from the Malta International Airport Meteorological Office. Humidex is a calculated value of the perceived air temperature, similar to the heat index, and it takes into consideration air temperature together with dew point. Humidex values for the month of January and February were not always calculated as the dry bulb temperature was <20°C. The overall frequency of stone submission was subsequently analyzed according to seasons, cold/warm periods and correlated with the corresponding meteorological data. The same procedure was employed to identify any potential climatic influence on the stone chemical composition.

Data analysis

Statistical analysis was performed using SPSS Statistics for Windows, Version 21.0. (IBM Corp.). Results for categorical data are summarized using absolute numbers and percentages. Continuous normally distributed data are reported as means ± standard deviation. Categorical variables were analyzed using Chi-square and Fisher's two-tailed exact test. Bonferroni method was employed to adjust for multiple comparisons. Student's *t*-test and ANOVA were applied to compare parametric continuous data as appropriate. Pearson moment correlation was utilized to investigate for any linear correlation between the monthly number of stones and the mean monthly temperatures and humidity. Step-wise multivariate linear regression was used to investigate which climatic parameters can predict nephrolithiasis. The value of $P < 0.05$ was considered statistically significant unless otherwise specified.

Literature search

Literature search was conducted using Ovid MEDLINE, EMBASE, Scholar and PubMed. The following subject headings were utilized; "kidney/renal stones/calculi, nephrolithiasis, lithiasis, colic, seasons, weather, climate, meteorology, temperature, humidity, occupation, urate/uric acid, cysteine, calcium, oxalate, and phosphate." The search was limited to studies published in English from 1970 onward and related only to adult population. Studies were screened based on their title and abstract.

RESULTS

Baseline characteristics

A total of 389 spontaneously passed and surgically removed kidney stones were submitted for analysis during the years 2009–2011. Of these, 32.4% (n = 126), 29.8% (n = 116) and 37.8% (n = 147) were submitted in 2009, 2010, and 2011, respectively. The mean age of patients at stone submission was 47.8 ± 14.8 years and included four pediatric patients (range: 11–14 years). Males composed 75.58% (n = 294) of all the patients, approximating a 3:1 male to female ratio. All patients were of Maltese race.

Overall incidence of nephrolithiasis

The incidence of stone submission was equally highest in July and August (12.1%). The monthly temperatures, relative humidity, Humidex values, and stone frequency for the years 2009–2011 are summarized in Table 1. The distribution of stone submission varied significantly between seasons, with 20.8% being submitted in winter, 23.7% in spring, 31.6% in summer and 23.9% in autumn (chi-square: 13.34, degrees of freedom: 3, P=0.004). Post-hoc analysis was subsequently performed to investigate which seasons differed significantly, and in order to adjust for multiple comparisons, the alpha value was lowered to 0.013 using the Bonferroni method. Stone submission was significantly higher in summer compared to winter (31.6% vs. 20.8%, P=0.0008). Summer compared to spring (31.6% vs. 23.7%, P=0.016), summer compared to autumn (31.6% vs. 23.9%, P=0.02) and winter compared to autumn (20.8% vs. 23.9%, P=0.34) did not reach the pre-set alpha value of 0.013. Comparing the warm and cold periods, stone submission rate was higher in the warm period when compared to the cold period (57.1% vs. 42.9%, P = 0.0001) [Table 2]. A positive linear correlation was established between the total number of monthly stones per year and the respective mean monthly maximum temperature (r = 0.50, P = 0.002), mean monthly temperature (r = 0.49, P = 0.003), and mean monthly Humidex values (r = 0.49, P = 0.007). There was no significant correlation between the number of kidney stones and mean monthly relative humidity (r = –0.25, P = 0.15) [Figure 1]. The linear regression model predicted the number of stones significantly well (R^2 = 0.24, P = 0.007) and was best explained by Humidex. Humidex was found to be an independent predictor for nephrolithiasis (β = 0.49, P = 0.007).

Biochemical composition of stones

The majority of stones contained calcium (83.3%), combined with negatively charged molecules such as oxalate (77.6%), phosphate (14.7%), and carbonate (2.8%). A number of calcium stones (11.8%) contained a mixture of more than one negatively charged molecules. Urate (11.6%), cysteine (4.6%), and ammonium-magnesium-phosphate (0.5%) stones constituted a minority of stones [Table 3]. None of the stones was drug associated. Calcium phosphate stones occurred more commonly in females when compared to males (27.4% vs. 12.6%, P = 0.001). The rest of all chemical constituents occurred in analogous fashion across gender. There was no association between the chemical composition and seasons [Table 2].

Literature search

Evaluation of search results identified a total of 27 eligible articles. Two of these exclusively investigated geographical

Table 1: Cumulative number of kidney stones by the month of submission together with the respective ranges of mean monthly temperature, mean monthly maximum temperature, mean monthly humidex, and mean monthly relative humidity for the years 2009-2011

Month	Mean monthly temperature (°C)	Mean monthly maximum temperature (°C)	Mean monthly humidex	Mean monthly RH (%)	Cumulative number of stones (%)
January	12.9-13.2	15.5-16.0	[a]	74-84	23 (5.9)
February	11.3-13.8	14.1-16.7	21.5[b]	72-79	27 (6.9)
March	13.0-14.1	16.3-17.0	23.8-24.4	77-81	31 (8.0)
April	16.4-17.0	18.5-20.4	21.7-23.8	76-82	32 (8.2)
May	18.9-20.6	22.7-25.5	23.9-25.8	68-72	27 (6.9)
June	22.9-23.7	27.0-28.5	28.2-28.6	66-70	33 (8.5)
July	26.7-27.0	31.2-32.4	31.8-33.1	57-68	47 (12.1)
August	26.8-27.3	31.6-31.7	32.7-34.9	65-70	47 (12.1)
September	24.0-25.2	27.0-29.3	30.1-31.0	71-74	29 (7.5)
October	20.1-20.6	23.2-23.4	26.2-28.9	72-79	39 (10.0)
November	16.9-18.2	19.9-20.9	25.1-25.3	74-79	39 (10.0)
December	14.1-15.6	16.6-18.0	22.6-24.6	73-76	15 (3.9)

[a]Humidex is not calculated when dry bulb temperature is <20°C, [b]Humidex available only for 2009 as dry bulb temperature was <20°C for 2010 and 2011. RH: Relative humidity

Table 2: Cumulative number and chemical composition of stones by season and cold/warm periods for the years 2009-2011

Variable	Winter	Spring	Summer	Autumn	*P*	Cold period	Warm period	*P*
Age (n±SD)	47.4±16.5	45.3±14.9	49.8±13.5	47.8±14.6	0.18	47.6±15.9	48.0±13.9	0.78
Gender: Male (%)	54 (66.7)	68 (73.9)	97 (79.9)	75 (80.6)	0.14	128 (76.6)	166 (74.8)	0.72
Number of stones (%)	81 (20.8)	92 (23.7)	123 (31.6)	93 (23.9)	0.004	167 (42.9)	222 (57.1)	0.0001
Chemical composition (%)								
Calcium containing	70 (86.4)	77 (83.7)	97 (78.9)	80 (86.0)	0.45	142 (85.0)	182 (82.0)	0.49
Calcium oxalate	64 (79.0)	74 (80.4)	88 (71.5)	76 (81.7)	0.28	135 (80.8)	167 (75.2)	0.22
Calcium phosphate	14 (17.3)	19 (20.7)	14 (11.4)	10 (10.8)	0.16	24 (14.4)	33 (14.9)	1.00
Calcium carbonate	4 (4.9)	2 (2.2)	3 (2.4)	2 (2.2)	0.72	6 (3.6)	5 (2.3)	0.54
Urate	9 (11.1)	7 (7.6)	20 (16.3)	9 (9.7)	0.25	19 (11.4)	26 (11.7)	1.00
Cysteine	2 (2.5)	8 (8.7)	5 (4.1)	3 (3.2)	0.25	5 (3.0)	13 (5.9)	0.23

SD: Standard deviation

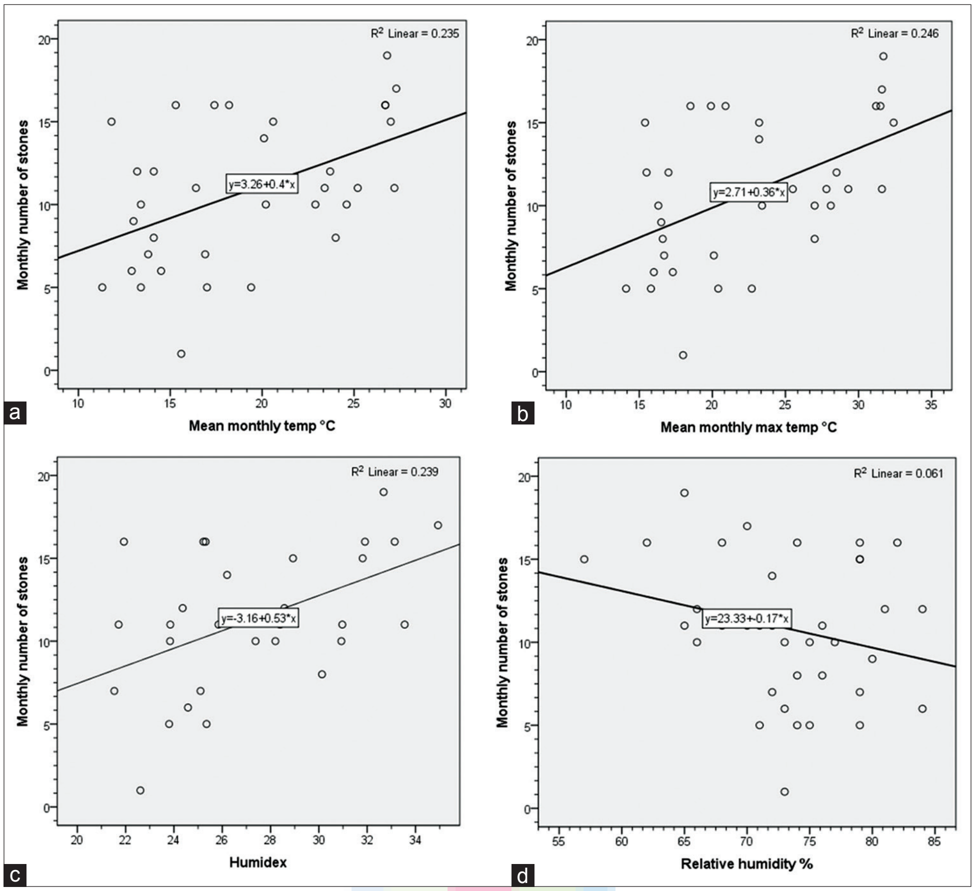

Figure 1: Scatter graphs demonstrating the correlation of monthly cumulative number of stones and: (a) mean monthly temperature, (b) mean monthly maximum temperature, (c) Humidex, (d) mean relative humidity

Table 3: Stone chemical composition

Chemical composition	*n* (%)
Calcium containing	324 (83.3)
Calcium oxalate	302 (77.6)
Calcium phosphate	57 (14.7)
Calcium carbonate	11 (2.8)
Mixed: Oxalate/phosphate/carbonate	46 (11.8)
Urate	45 (11.6)
Cysteine	18 (4.6)
Ammonium magnesium phosphate "struvite"	2 (0.5)
Drug associated	Nil

Calcium stones containing a combination of >2 negatively charged molecules

distribution of kidney stones and thus excluded. A total of 25 articles are included in this literature search, and their main outcome/s is/are summarized in Table 4 according to the year of publication.[1-25] The majority of the studies were retrospective. Only six studies investigated the potential association between the stone chemical composition and ambient temperature.

DISCUSSION

Nephrolithiasis is a relatively common condition worldwide. It has been estimated to be the primary cause of end-stage kidney disease (ESKD) in 2.1–3.2% of patients maintained on dialysis in two European countries[26,27] and 0.2% of patients requiring dialysis according to the United States Renal Data System.[28] A number of patients do not reach ESKD but are still left with significant chronic kidney disease.[29]

The association between ambient temperature, along with various other meteorological parameters and the incidence of nephrolithiasis, has been studied in various climates and geographical locations worldwide. A number of studies suggested that higher ambient temperature and warm seasons are at least partially associated with increased incidence of stone formation and passage. This was noted consistently in studies carried out in the United States (US),[4,5,12,17,21] Italy,[1,6,14] Taiwan,[8,9,19] Saudi Arabia,[18,20] Iran,[15] and Korea.[2] In the Maltese Islands, the incidence of spontaneous passage and surgically removed stones was concordantly higher during the warmer periods, and indeed, Humidex was found to be an independent predictor. Conversely, conflicting results were demonstrated in studies performed in the United Kingdom[24,25] and New Zealand[10,11] One study carried out in the United Arab Emirates has failed to identify any significant association.[13]

Table 4: Summary of all the articles included in the literature search with their respective main outcome(s)

Study	Country	Methodology (year/s studied)	Measured variable	Main outcome(s)
Condemi *et al.*, 2015[1]	Cuneo Northern Italy	Retrospective (2007-2010)	ED RC	Poisson regression model showed significant correlation with thermal parameter ($P<0.03$). No association with RH, atmospheric pressure and total radiation
Park *et al.*, 2015[2]	Korea	Retrospective (2006-2010)	Urinary tract stone attacks	Peak attacks July-September ARIMA regression adjusting for trends and seasonality showed ambient temperature was the only factor associated with the stone attack ($P=0.04$)
Lieske *et al.*, 2014[3]	US	Retrospective (2010)	First stone submitted by patients	CaOx and UA stones were more commonly submitted in the summer months (July-August; $P<0.001$). Other type of stones were not influenced by season
Sirohi *et al.*[4]	US Manhattan	Retrospective (2007-2012)	ED RC (ICD-9 codes)	Lowest monthly RC rate in February (28.8) and highest in August (43.8). Positive correlation between monthly RC and temperature ($r=0.399$, $P<0.01$). No significant correlation with RH, precipitation and atmospheric pressure
Tasian *et al.*[5]	US Atlanta, Chicago, Dallas, Los Angeles, Philadelphia	Retrospective (2005-2011)	KS presentation (surgical procedure, hospital admission, emergency room or outpatient visits)	Relative risk for daily mean temperature of 30°C versus 10°C was 1.38 in Atlanta (95% CI: 1.07-1.79), 1.37 in Chicago (95% CI: 1.07-1.76), 1.36 in Dallas (95% CI: 1.10-1.69), 1.11 in Los Angeles (95% CI: 0.73-1.68), and 1.47 in Philadelphia (95% CI: 1.00-2.17) with estimated lags of ≤3 days
Cervellin *et al.*, 2012[6]	Parma, Northern Italy	Retrospective (2002-2010)	ED RC	Peak in summer especially July. Positive correlation with mean daily temperature ($r=0.93$, $P<0.0001$) and negative correlation with mean daily H ($r=-0.82$; $P<0.0001$)
Eisner *et al.*, 2012[7]	US Boston, Lebanon, Nashville, Scottsdale	Retrospective	24-h urine composition	Multivariate linear regression showed that increasing temperature was associated with increasing urine Ca ($\beta=11.3$, 95% CI: 2.2–20.0), super-saturation of CaOx ($\beta=0.6$, 95% CI: 0.2–0.9), super-saturation of CaP ($\beta=0.14$, 95% CI: 0.03–0.2), and decreasing urine sodium ($\beta=-5.2$, 95% CI: −10.3–−0.1)
Lin *et al.*, 2014[8]	Northern Taiwan	Retrospective (2006-2011)	ESWL	Multivariate linear regression showed temperature ($\beta=1.438$, 95% CI: 3.703–9.144, $P<0.001$) and atmospheric pressure ($\beta=0.803$, 95% CI: 0.790–5.428, $P=0.010$) to be independently related to monthly ESWL
Chen *et al.*, 2008[9]	Taiwan	Retrospective (1999-2003)	ED RC Taiwan National Health Insurance Research Database	Significant peak July–Septembe ($P<0.001$). Significant association with ambient temperature ($r=0.517$, $P<0.001$), atmospheric pressure ($r=-0.485$, $P<0.001$), hours of sunshine ($r=0.276$, $P<0.05$). After statistical adjustment for trends and seasonality, ambient temperature was the sole factor having any positive association
Lo *et al.*, 2010[10]	Auckland New Zealand	Retrospective (1997-2007)	RC presentation in Auckland hospitals	Poisson regression model showed positive association with temperature ($P<0.001$) and hours of sunshine ($P=0.004$). H was not a significant factor ($P=0.14$). Peak RC in February + March (warmest months January-February)
Davidson *et al.*, 2009[11]	Christchurch, New Zealand	Prospective (2001-2012)	X-ray report keywords: "stone/s, calculus/calculi"	No significant difference in incidence by season. Statistical analysis not reported
Fakheri and Goldfarb 2009[12]	US - 47 states	Re-analysis Letter to the editor (1981)	KS prevalence	Positive correlation with temperature. Increasing temperature associated with increasing KS mostly in men. Percentage rate increase by 0.15 ($r^2=0.37$) in men and 0.04 ($r^2=0.51$) in women/unit increase in the Fahrenheit temperature
Freeg *et al.*, 2012[13]	United Arab Emirates	Retrospective (2007-2009)	RC, US confirmed	No significant correlation to atmospheric temperature and RH (Spearman $r=-0.2$; $P=$NS)

Contd...

Table 4: Contd...

Study	Country	Methodology (year/s studied)	Measured variable	Main outcome (s)
Boscolo-Berto *et al.*, 2008[14]	Padova, Italy	Retrospective (2003)	ED RC	Positive correlation with maximum temperature (r=0.75; P<0.005) and negative correlation with minimum H (r=−0.7, P<0.01) 2 weeks preceding colic
Safarinejad 2007[15]	Iran - 30 counties	Cross-sectional (2005)	Self-administered questionnaire	Association with mean annual temperature (OR: 2.27; 95% CI: 1.73–4.31), and sunlight index (OR: 1.66; 95% CI: 1.25–2.23)
Atan *et al.*, 2005[16]	Brazil	Retrospective cross-sectional (March 1999-December 2002)	Incidence of urolithiasis in males exposed to heat in a steel plant	Urolithiasis rate was higher in hot-area versus room-temperature (8% vs. 0.9%; P<0.001). Hypocitraturia (55.8% vs. 28%, P=0.03) and low urine volumes (79.4% vs. 48%, P=0.01) were commoner in the hot-area versus room-temperature group
Chauhan *et al.*, 2004[17]	New Jersey, US	Retrospective (1996-2002)	ED RC (n=30,358)	Positive correlation with ambient temperature (r=0.42; 95% CI: 0.23–0.59; P=0.001)
Khan *et al.*, 2004[18]	Riyadh, Saudi Arabia	Prospective (2000-2001)	Stones removed surgically or other means	A clear stone season corresponding to hot summer months. Statistics not reported
Lee *et al.*, 2002[19]	Taiwan	Cross-sectional 1994-1996	Postal questionnaire	Peak number of stones between June and August statistics not reported
al-Hadramy 1997[20]	Saudi Arabia	Retrospective (1992-1994)	ED diagnosed RC in males	Peak incidence in summer (July-August). Positive correlation to temperature (r=0.67, P<0.0001) and negative correlation to atmospheric pressure (r=−0.64; P<0.0001). No significant correlation to RH
Soucie *et al.*,[21]	US nationwide	Cross-sectional (1982)	Self-reported/ physician-diagnosed KS	Independent association with Ambient temperature (OR: Ranged from 1.0 to 1.5 across regions for males and 1.0-1.7 for females) and sunlight indices (OR: Ranged from 0.9 to 1.2 across regions for males and 1.0-1.7 for females)
Baker *et al.*, 1993[22]	South Australia	Retrospective (1977-1991)	KS passed	No significant seasonal variation with CaOx or CaP stones. Uric acid stones increased by 69% in summer (P<0.001) and 62% in autumn (P<0.01). Infection stones decreased by 27% in spring (P<0.05) and 37% in summer (P<0.01)
Borghi *et al.*, 1993[23]	Northern Italy	Retrospective	Prevalence of stone disease in machinists exposed to heat at a glass plant	Prevalence of nephrolithiasis was significant higher in machinists when compared to controls (8.5% vs. 2.4%; P=0.03). Incidence of UA stones was high (38.8%) in those exposed to heat. UA concentration (722±195 vs. 482±184 mg/l; P<0.001), UA supersaturation (8.67±3.49 vs. 4.15±2.7; P<0.001) and SG (1026±4 vs. 1021±6, P<0.005) were higher in those exposed to heat compared to controls respectively
Power *et al.*, 1987[24]	England + Wales – 18 towns	Prospective (1980-1990)	KS incidence (case registers)	No significant correlation to mean daily hours of sunshine (r=0.37) and mean daily maximum temperature (r=−0.18), P=NS
Robertson *et al.*, 1975[25]	Leeds, Great Britain	Retrospective cross-sectional	Analysis of 24 h urine collections from male idiopathic calcium stone-formers	Rate of stone passage (excluding surgically removed stones) was 50% higher in summer versus winter. Significant variation in the urinary excretion of calcium and oxalate, with a maximum during summer and a minimum in winter. Significant increase in the saturation of urine with CaOx

ED: Emergency Department, RC: Renal colic, KS: Kidney stones, RH: Relative humidity, CaOx: Calcium oxalate, CaP: Calcium phosphate, ESWL: Extracorporeal shockwave lithotripsy, CI: Confidence interval, OR: Odds ratio, UA: Uric acid, ARIMA: Autoregressive integrated moving average, NS=Not significant

Looking at other meteorological parameters, at least five studies have established a significant association between sunshine (measured as sunshine index or hours) and the risk of nephrolithiasis.[10,15,21,25] Two studies have established a significant negative correlation between relative humidity and nephrolithiasis,[6,14] and three studies have suggested a possible negative association between atmospheric pressure and renal colic.[8,9,20]

When interpreting these results, it is important to consider that many studies were conducted in different time periods, had disparate baseline characteristics and employed nonidentical stone detection methods. In addition, there were substantial differences in the methodologies applied. The most frequently measured variable was renal colic episodes, which is by no means equivalent to self-reported or spontaneously passed stones. Many patients suffering from nephrolithiasis may be entirely asymptomatic[30] or may never spontaneously pass a stone. One particular study reports only radiologically confirmed stones,[13] whereas another one reports extracorporeal shock wave lithotripsy rates.[8] Two studies were conducted by means of self-administered questionnaires.[15,19] Considerable selection bias is noted in the study conducted in Saudi Arabia, were all female patients were excluded.[20] Data with this respect remains rather elusive and makes comparison of published work rather challenging. Moreover, climates and meteorological conditions are dictated by a number of closely related variables. For instance, sunshine hours, ultraviolet radiation, ambient temperature, and heat index are all closely interrelated and consequently can give rise to spurious relationships. Occupation[16,23] and seasonal changes such as diet,[31] physical activity,[32] and leisure habits[33] should all be taken into account. To further complicate matters, Boscolo-Berto and colleagues suggested that stone formation might actually precede renal colic or stone passage by a number of weeks,[14] whereas Tasian *et al.* estimated a time lag of 3 days between high-temperature exposure and kidney stone presentation.[5]

Studies investigating the association between stone chemical composition and seasons are indeed sparse. In the Maltese Islands, there was no association between seasons and stone composition. In a study conducted in South Australia, the incidence of uric acid stones increased significantly during summer and autumn, whereas infection stones decreased significantly during spring and summer.[22] In addition, a significantly higher incidence of uric acid stones together with higher uric acid super-saturation was identified amongst workers exposed to high heat stress in a glass plant in Northern Italy.[23] In the same study, no significant variation was observed with calcium oxalate or calcium phosphate stones. Conversely, a significant variation in the urinary excretion of calcium and oxalate, with a maximum during summer and a minimum in winter was observed in a study conducted in the UK.[25] Increasing temperature was also associated with higher urine calcium and super-saturation of calcium oxalate and calcium phosphate in the US.[7] In Brazil, individuals exposed to a hot environment in a steel factory had significant hypocitraturia but no hyperuricosuria.[16] Finally, a study conducted in the US revealed a higher rate of both calcium oxalate and uric acid stones submitted during the summer period (July and August).[3] Considering the evidence available to date, it is rather difficult to draw any conclusions with regards to stone composition and any association with seasons.

Limitations

This analysis contains some important limitations. First, as with many retrospective studies, collecting detailed patient characteristics may prove to be challenging. Although this was a nationally representative sample, the number of kidney stones studied is relatively small. One has to consider that although the Maltese Islands have the highest population density in the European Union, the total population is slightly less than half a million. As mentioned earlier, we opted to analyze kidney stone submission rate in favor to renal colic rate as this allowed us to look at the stone chemical composition. However, one has to appreciate that stone submission rate is by no means a surrogate measurement of renal colic or stone formation. The technique currently employed at our hospital for stone chemical analysis is less accurate when compared to infrared spectroscopy. Finally, as with many similar studies, we could not adjust for the several potential seasonal and/or meteorological confounders.

CONCLUSIONS

This is the first nationally representative sample investigating the association between stone submission rate (after spontaneous passage or surgical removal), chemical composition and seasons in the Maltese Islands. The analysis established a significant linear correlation between the ambient temperature and stone submission rate. Humidex was found to be an independent predictor for stone submission. Summer and the warm months (especially July and August) were associated with significantly higher rate of stone submission. After considering all the evidence available in our literature search, we found no convincing association between stone chemical composition and ambient temperature or seasonality. Although it is difficult to draw any conclusions, current literature suggests a reasonably strong association between ambient temperature and the incidence of nephrolithiasis. Although stone formation is a multifactorial and complex process, it seems that seasons do play some role after all.

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Conflicts of interest

There are no conflicts of interest.

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