# Seasonal Variations in Urinary Calculi Attacks and Their Association With Climate: a Population Based Study

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**Purpose:** In this nationwide population based study we used 5-year data on urinary calculi patient visits to emergency departments in Taiwan to investigate the seasonal variation in urinary calculi attacks and the association with 5 climatic parameters.

**Materials and Methods:** Comprehensive details on total admissions to emergency departments were obtained from the Taiwan National Health Insurance Research Database (1999 to 2003), providing monthly urinary calculi attack rates per 100,000 of the population. Subgroups of urinary calculi incidences were created based on gender and 3 age groups (18 to 44, 45 to 64 and 65 years old or older). Following adjustment for time trend effects, evaluation of the monthly urinary calculi attack rates and the effects of climatic factors was performed using auto-regressive integrated moving average regression methodology.

**Results:** The seasonal trends in the monthly urinary calculi attack rates revealed a peak in July to September, followed by a sharp decline in October, with the auto-regressive integrated moving average tests for seasonality demonstrating significance for each gender group, for each age group and for the whole sample (all $p < 0.001$). Although significant associations were found between ambient temperature, atmospheric pressure and hours of sunshine vis-à-vis monthly urinary calculi attack rates for the total population, after adjustment for trends and seasonality, ambient temperature was found to be the sole major factor having any positive association with the monthly attack rates.

**Conclusions:** We conclude that seasonal variations do exist in the monthly urinary calculi attack rates for all age and gender populations, and that following time series statistical adjustment, only ambient temperature had any consistent association with monthly attack rates.

*Key Words: urinary calculi, seasons, climate*

Urinary calculi is a common disease, the earliest recorded example of which was bladder and kidney stones found in Egyptian mummies circa 4800 BC. UC represents the primary diagnosis in the United States for almost 2 million visits to clinics, more than 600,000 emergency room visits and more than 177,000 hospitalizations, representing an annual expenditure of approximately US$2 billion.[1]

An epidemiological study of the disease which was performed on 10,567 patients in Taiwan using a postal questionnaire indicated that 8.93% of the Southern Taiwanese population may have encountered at least 1 UC episode.[2] Therefore, there would seem to be an urgent requirement in Taiwan to determine effective ways of preventing such attacks.

Several prior studies have reported meteorological factors having some influence on the incidence of UC attacks. However, while some reported a positive association between such incidences and ambient temperature,[3–5] others reported an inverse relationship.[6–9] Thus, the association between UC attacks and climatic parameters has yet to be determined.

Furthermore, such studies have invariably tended to use selective data that were limited, for example, to specific hospitals or population subgroups. This may account for such inconsistencies across studies. The nonrepresentative nature of such data sources also limits the generalizability of their findings to the population as a whole.

Using a 5-year population based data set comprising 1999 to 2003 nationwide emergency department records, this study sets out to determine the seasonal variations in UC attacks among different age and gender groups in Taiwan. We further examine the associations between meteorological

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Nothing to disclose.

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parameters (ambient temperature, relative humidity, atmospheric pressure, rainfall and total hours of sunshine) and monthly UC attack rates.

To the best of our knowledge this is the first nationwide population based study to investigate the dependence of UC attack rates on meteorological conditions. Thus, we believe that the results may help clinicians/researchers to identify specific weather conditions triggering the onset of UC attacks.

## METHODS

### Emergency Department Visits

This study used 1999 to 2003 data on emergency department visits for UC obtained from the NHIRD published by the National Health Research Institute in Taipei. The NHIRD covers all inpatient and outpatient medical benefit claims for virtually the entire Taiwanese population of approximately 23 million people, and includes registries of contracted medical facilities, board certified physicians, catastrophic illness patients, details of inpatient and ambulatory care orders, monthly claims summaries for inpatient and ambulatory care claims, and total expenditure on prescriptions dispensed at contracted pharmacies. This database, which provides primary diagnoses from the ICD-9-CM, is possibly the largest and most comprehensive population based health care database currently available anywhere.

### Study Sample

All department visits for UC attacks in Taiwan between 1 January 1999 and 31 December 2003 were identified from the database by a principal diagnosis of UC (ICD-9-CM codes 592.0, 592.1, 592.9, or 788.0). We assumed that the emergency department visit date was the date of the UC occurrence, since specific information on the latter is unavailable from the NHIRD. Given the universal health care coverage, negligible financial access barriers and the seriously disabling nature of UC, we believe our assumption to be valid.

Since UC attacks on individuals younger than 18 years old are rare, we confined the data to patients 18 years old or older. Furthermore, patients readmitted within 7 days after discharge were regarded as suffering from the same episode. Our study ultimately comprised 270,302 emergency department visits for UC attacks.

### Population Data

The Population Affairs Administration, Ministry of the Interior, releases population data to the public annually. Monthly UC attack rates were defined in this study as the proportion (fraction) of the total monthly emergency department visits for that subgroup of the entire island population, based on a nationwide database. For example, for females the UC rate was calculated per 100,000 females.

### Meteorological Data

Meteorological data, comprising monthly ambient temperature, relative humidity, atmospheric pressure, rainfall and hours of sunshine were obtained from 19 CWB observation stations. Although the CWB has 26 stations scattered throughout the island, the meteorological data from 7 stations was discarded, since they are located in mountainous regions with sparse populations.

By excluding the mountain weather stations, the resultant data more closely represent the conditions to which the majority of the population is exposed. The monthly mean values were calculated by averaging the monthly data from the 19 stations. Since Taiwan is a relatively small island, with a total land area of slightly less than 36,200 square kilometers, we used monthly mean values for the climatic data to explore the associations with UC attack rates.

### Statistical Analysis

Monthly UC attack rates per 100,000 of the population were calculated for 60 months, by gender and age groups (18 to 44, 45 to 64 and 65 years old or older). The prior UC studies have tended to use only univariate statistical analyses to document the relationships with weather. However, given the high correlation between the meteorological parameters of each season, we argue that univariate analysis is unsuitable for identifying any significant contributory factors. Since seasonality is a general component of time series patterns, as in earlier analogous studies,[10,11] ARIMA methodology was used to describe the univariate time series as a function of its past values to test for the presence of seasonality.

The cross-correlation coefficients were used to examine the direction and strength of the relationships between climatic factors and monthly UC attack rates. ARIMA regression methodology was also adopted to evaluate the effects of climatic and monthly factors on UC attack rates after adjusting for the time trend effect. The dummy variable monthly factors included in the model ran from January to December, with a specific month being given a value of 1, while the remaining months were given values of 0. The time trend was a (1 to 60) count variable according to the time series.

Considering the parsimony of the models, only statistically significant independent variables were included in the regression models. To select the models that best fit the data from the family of ARIMA models generated, we used the AIC and the SC (lower values indicate better fit). All p values of $<0.05$ were considered statistically significant in this study.

## RESULTS

### Monthly UC Attack Rates

Throughout the period of this study, from January 1999 to December 2003, the total number of UC visits to emergency departments in Taiwan was 270,302, comprising of 39,870 visits in 1999, 53,348 in 2000, 58,759 in 2001, 59,419 in 2002 and 58,906 in 2003, with respective monthly visit rates of 14.8, 19.7, 21.7, 22.0 and 21.8 per 100,000 of the population.

Across the entire study period the monthly UC attack rates per 100,000 of the population ranged from a low of 4.8 in January 1999 to a high of 44.3 in August 2001, with a mean of 23.1 (SD 9.4). The mean monthly UC attack rate was 34.9 for males and 11.0 for females (tables 1 and 2).

### Seasonality

The seasonal variations in the monthly UC attack rates for each gender and age group are illustrated in figures 1 and 2,

TABLE 1. *UC visits to emergency departments and meteorological factors, 1999–2003*

| | Monthly Mean | SD | Min | Max |
|---|---|---|---|---|
| UC/100,000 of population by age: | | | | |
| 18–44 | 24.0 | 10.6 | 4.4 | 46.1 |
| 45–64 | 26.1 | 10.0 | 6.5 | 50.5 |
| 65 or Older | 11.9 | 3.9 | 2.9 | 20.4 |
| UC/100,000 of population by gender: | | | | |
| Male | 34.9 | 14.6 | 6.9 | 44.3 |
| Female | 11.0 | 4.1 | 2.5 | 68.7 |
| Total | 23.1 | 9.4 | 4.8 | 19.2 |
| Meteorological factors: | | | | |
| Ambient temperature (C)* | 23.2 | 4.1 | 16.2 | 29.3 |
| Relative humidity (%) | 78.1 | 2.8 | 70.3 | 83.1 |
| Atmospheric pressure (hPa) | 999.5 | 4.9 | 990.7 | 1,007.9 |
| Rainfall (mm) | 174.9 | 72.6 | 63.2 | 527.0 |
| Sunshine (hrs) | 158.2 | 128.2 | 20.8 | 890.0 |

* Ambient temperature is mean of daily (24-hour) temperature averaged during each month. Mean shown here is that of all 12 months during the 5 year study.

TABLE 2. *Demographic characteristics and principal diagnoses of patients with urinary calculi visiting emergency departments*

| | Total No. Sampled Pts (%) | Total No. Whole Population (%) |
|---|---|---|
| Year: | | |
| 1999 | 39,870 (14.8) | 22,092,387 (19.7) |
| 2000 | 53,348 (19.7) | 22,276,672 (19.9) |
| 2001 | 58,759 (21.7) | 22,405,568 (20.0) |
| 2002 | 59,419 (22.0) | 22,520,776 (20.2) |
| 2003 | 58,906 (21.8) | 22,604,550 (20.2) |
| Gender: | | |
| Male | 206,978 (76.6) | 57,146,900 (51.1) |
| Female | 63,324 (23.4) | 54,753,053 (48.9) |
| Age group: | | |
| 18–44 | 161,250 (59.7) | 47,373,068 (42.3) |
| 45–64 | 89,518 (33.1) | 22,556,493 (20.2) |
| 65 or Older | 19,534 (7.2) | 9,879,171 (8.8) |
| Principal diagnoses (ICD-9-CM): | | |
| Calculus of kidney (592.0) | 49,640 (18.4) | |
| Calculus of ureter (592.1) | 66,048 (24.2) | |
| Urinary calculus (unspecified) (592.9) | 122,968 (45.5) | |
| Renal colic (788.0) | 31,646 (11.9) | |

which demonstrate fairly similar seasonal patterns between the monthly UC attack rates for each gender and age group.

The ARIMA tests for seasonality were found to be significant for each gender group, each age group and for the whole sample (all p <0.001), with the seasonal trends showing a peak in monthly emergency department visit rates in July to September, followed by a sharp decline in October.

## Climatic Influences

The mean monthly figures for the 5 climatic parameters across the 5-year study period were temperature (23.2C), relative humidity (78.1%), atmospheric pressure (999.5 hPa), rainfall (174.9 mm), and monthly hours of sunshine (158.2 hours). The cross-correlation coefficients revealed that the monthly UC attack rates had significant associations with ambient temperature, atmospheric pressure and hours of sunshine (table 3).

The monthly UC attack rates revealed significant associations between ambient temperature and the 6 population groups of the total group (r = 0.517, p <0.001), males (r = 0.528, p <0.001), females (r = 470, p <0.001), 18 to 44-year-olds (r = 0.476, p <0.001), 45 to 64-year-olds (r = 0.598, p <0.001) and 65 years or older group (r = 0.454, p <0.001).

Similarly the cross-correlation coefficients revealed significant associations between atmospheric pressure and monthly UC attack rates for the total group (r = –0.485, p <0.001), males (r = –0.492, p <0.001), females (r = –0.447, p <0.001), 18 to 44 year-olds (r = –0.422, p <0.001), 45 to 64-year-olds (r = –0.600, p <0.001) and 65 years or older group (r = –0.501, p <0.001).

Similar associations were also demonstrated between sunshine hours and the total group (r = 0.276, p <0.05), males (r = 0.276, p <0.05), females (r = 0.266, p <0.05), 18

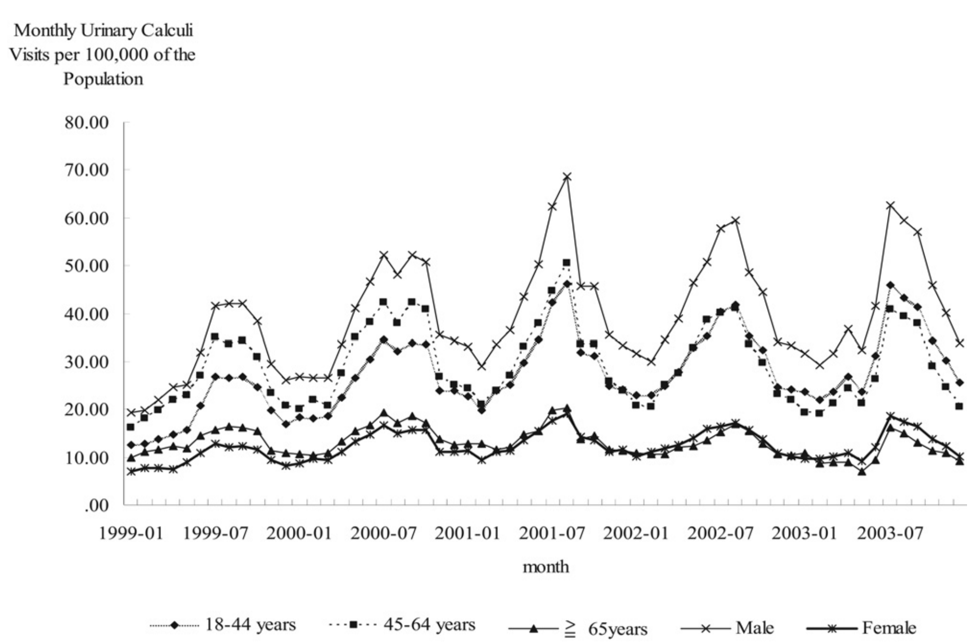


FIG. 1. Monthly UC attack rates per 100,000 of population in Taiwan by age and gender groups, 1998 to 2003

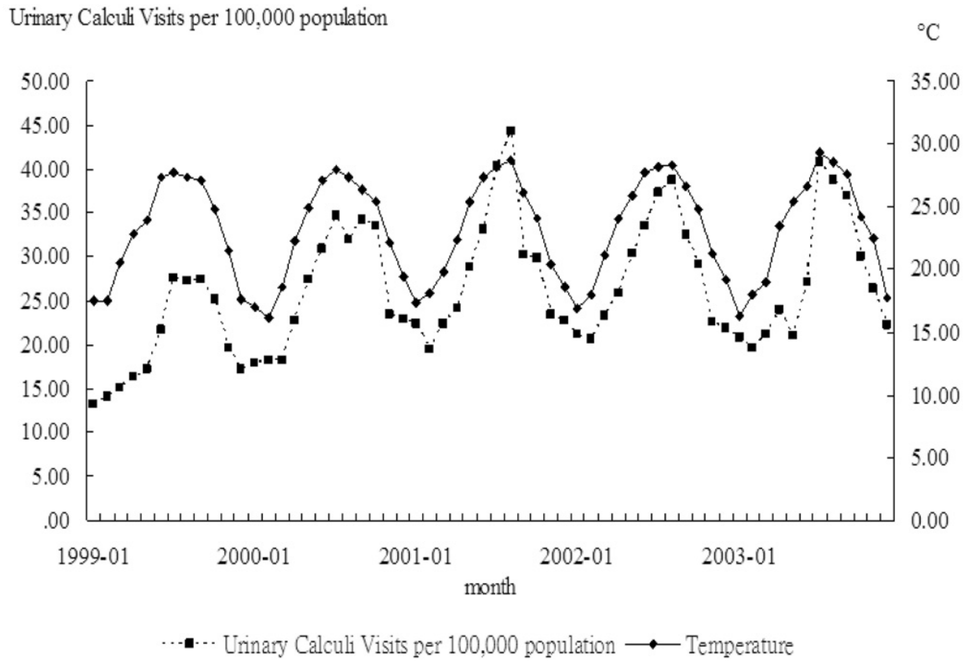


FIG. 2. Time series of monthly UC attack rates per 100,000 of population and mean temperature levels

to 44-year-olds (r = 0.233, p <0.05), 45 to 64-year-olds (r = 0.348, p <0.01) and 65 years or older group (r = 0.325, p <0.01).

While the climatic parameters of relative humidity and rainfall were not found to have any significant association with monthly UC attack rates, after adjustment for seasonality, month and trend, the results of the ARIMA regression models (tables 4 and 5) revealed that the monthly rates had significant associations with ambient temperature for the 6 populations of the total group (p <0.001), males (p <0.01), females (p <0.01), 18 to 44-year-olds (p <0.001), 45 to 64-year-olds (p <0.01) and the 65 years or older group (p <0.01).

Although significant associations were discernible between atmospheric pressure and monthly UC attack rates in the cross-correlation coefficients, just 2 populations, the 18 to 44-year-olds (p <0.05) and 65 years or older group (p <0.05), were found to be significant. Another interesting finding from ARIMA regression models was that there were significant declining trends in the monthly UC attack rates for 3 populations, females, 45 to 64-year-olds and the 65 years or older age groups, although these trends were not easy to discern visually when plotted on the graphs in figure 1.

## DISCUSSION

It is already well recognized that some acute conditions, such as asthma and angina, are provoked by climatic conditions, and although no ideal methodology currently exists for the estimation of the true incidences of UC attacks, an approach based upon total emergency department visits from a comprehensive nationwide database is useful for relevant comparisons.

We have found striking and definitive seasonal variations in the monthly UC attack rates for all populations, with the highest UC attack rates being discernible between July and September, while the lowest were found in February (which, in addition to being the shortest month of the year, is also associated with cooler temperature in Taiwan).

In their discussion on seasonal variations in UC attack rates, Al-Dabbagh and Fahadi excluded females from analysis

TABLE 3. *Crude correlations between climatic factors and monthly UC attack rates in Taiwan, 1999–2003*

| Emergency Admissions for UC/100,000 of Population | Temperature | Relative Humidity | Rainfall | Hrs Sunshine | Pressure |
|---|---|---|---|---|---|
| Gender: | | | | | |
| Male | 0.528* | −0.118 | −0.065 | 0.276† | −0.492* |
| Female | 0.470* | −0.120 | −0.107 | 0.266† | −0.447* |
| Age group: | | | | | |
| 18–44 | 0.476* | −0.161 | −0.071 | 0.233† | −0.422* |
| 45–64 | 0.598* | −0.026 | −0.059 | 0.348‡ | −0.600* |
| 65 or Older | 0.454* | −0.020 | −0.158 | 0.325‡ | −0.501* |
| Overall | 0.517* | −0.118 | −0.075 | 0.276† | −0.485* |

* p <0.001.
† p <0.05.
‡ p <0.01.

TABLE 4. *ARIMA regression results of seasonal and meteorological effects on monthly UC attack rates in Taiwan by gender*

| Independent Variables | Male* | | Female* | | Overall | |
|---|---|---|---|---|---|---|
| | β | *t* Value | β | *t* Value | β | *t* Value |
| Intercept | −640.507 | −1.42 | −235.848 | −1.70 | −512.160 | −1.79 |
| AR1 | 0.744 | 4.04* | −0.545 | −3.20† | 0.761 | 4.21* |
| SAR12 | 0.182 | 1.24 | 0.419 | 5.82* | 0.206 | 1.44 |
| MA1 | −0.196 | −0.80 | 0.997 | 6.72* | −0.251 | −1.02 |
| Atmospheric pressure | 0.628 | 1.43 | 0.238 | 1.75 | 0.503 | 1.80 |
| Ambient temperature | 1.859 | 3.31† | 0.593 | 3.38† | 1.282 | 3.62* |
| Relative humidity | 0.078 | 0.33 | 0.005 | 0.08 | 0.061 | 0.41 |
| Rainfall | 0.006 | 0.25 | 0.003 | 0.72 | 0.005 | 0.34 |
| Hrs sunshine | −0.007 | −1.38 | −0.000 | −0.21 | −0.004 | −1.09 |
| July | 15.242 | 3.26† | 4.408 | 2.65‡ | 9.830 | 3.30† |
| August | 14.947 | 3.24† | 4.062 | 2.44‡ | 9.436 | 3.22† |
| September | 9.935 | 2.40‡ | 3.213 | 2.11‡ | 6.397 | 2.43‡ |
| Trend | 0.027 | 0.20 | −0.077 | −2.28‡ | −0.007 | −0.08 |
| AIC | 5.583 | | 3.001 | | 4.671 | |
| SC | 6.287 | | 3.706 | | 5.376 | |
| $R^2$ | 0.936 | | 0.929 | | 0.936 | |

AR1 refers to autoregressive correlation (lag 1). SAR12 refers to seasonal autoregressive correlation (lag 12). MA1 refers to moving average (lag 1). The reference month was January. Selection of the final parameters was based on the lowest AIC and SC.
* p <0.001.
† p <0.01.
‡ p <0.05.

because they considered them less susceptible to UC attacks than males.[3] However, we have observed seasonal variations among females, although the monthly UC attack rates among females were still lower than those for males. Our data also revealed that female UC attacks increased about 32% throughout the period of this study.

An increase in incidences of UC with ambient temperature among a given population has been well documented in Japan,[4] the United States[12] and Australia,[13] while increased stone formation has also been reported among military personnel transferred between temperate and hot climates.[14] It has been generally assumed that such an association is attributable to the effect of seasonal variations in temperature on urinary volume, since it is supposed that, due to excessive perspiration and dehydration, the higher summer temperatures will produce more concentrated urine than in winter, and consequently, an increased risk of crystalluria. We have also found that monthly UC attack rates were positively and significantly associated with ambient temperature, thereby providing support for these studies.

In apparent support of this assumption, higher UC incidences are often reported among populations living in hot climates, with increased incidences among certain groups, such as military personnel moving between temperate and hotter climates.[14,15] Nevertheless, while higher incidences of UC are commonly associated with countries with hot climates, this is not necessarily the case for all such countries. For example, occurrences of UC are quite low in Nigeria[16] and among the Bantu of South Africa,[17] but extremely high in the oil rich states of the Arabian Gulf, such as Kuwait and Saudi Arabia.[18]

Interestingly with the gradual increase in global ambient temperature due to the greenhouse effect,[19] there is a general expectation that there will be a corresponding increase in UC. However, our findings suggest a declining trend among female patients with UC, as well as those in the 45 to 64 and 65 years

TABLE 5. *ARIMA regression results of meteorological effects on monthly UC attack rates in Taiwan by age group*

| Independent Variables | 18–44 Yrs | | 45–64 Yrs | | 65 Yrs or Older | |
|---|---|---|---|---|---|---|
| | β | *t* Value | β | *t* Value | β | *t* Value |
| Intercept | −647.391 | −2.18* | −188.937 | −0.52 | −259.734 | −2.11* |
| AR1 | 0.758 | 4.18† | −0.377 | −2.05* | 0.489 | 2.47* |
| SAR12 | 0.218 | 1.60 | 0.369 | 4.48† | 0.285 | 2.85‡ |
| MA1 | −0.257 | −1.03 | 0.997 | 6.76† | 0.378 | 1.72 |
| Atmospheric pressure | 0.631 | 2.19* | 0.192 | 0.54 | 0.272 | 2.27* |
| Ambient temperature | 1.373 | 3.75† | 1.280 | 2.76‡ | 0.562 | 3.18‡ |
| Relative humidity | 0.080 | 0.52 | 0.104 | 0.60 | −0.047 | −0.83 |
| Rainfall | 0.009 | 0.54 | −0.002 | −0.18 | −0.016 | −2.48* |
| Hrs sunshine | −0.002 | −0.60 | −0.006 | −1.68 | −0.004 | −3.38‡ |
| July | 10.624 | 3.43‡ | 11.210 | 2.58* | 6.421 | 3.69† |
| August | 10.122 | 3.32‡ | 11.223 | 2.62* | 6.088 | 3.53‡ |
| September | 6.612 | 2.40* | 9.067 | 2.26* | 3.797 | 2.35* |
| Trend | 0.082 | 0.89 | −0.231 | −2.53* | −0.141 | −3.06‡ |
| AIC | 4.735 | | 5.058 | | 3.232 | |
| SC | 5.440 | | 5.762 | | 3.937 | |
| $R^2$ | 0.946 | | 0.927 | | 0.913 | |

AR1 refers to autoregressive correlation (lag 1). SAR12 refers to seasonal autoregressive correlation (lag 12). MA1 refers to moving average (lag 1). The reference month was January. Selection of the final parameters was based on the lowest AIC and SC.
* p <0.05.
† p <0.001.
‡ p <0.01.

or older groups ($p < 0.05$). Therefore, there must be some other factor with a much stronger influence on UC attacks. More data would seem to be required to facilitate a followup examination of the UC trend among these populations.

Fujita first noted that falling air pressure seemed to influence the incidence of urinary colic.[4] However, such a significant relationship with atmospheric pressure disappears after adjustment under the ARIMA model. Parry and Lister further proposed that increased exposure to sunlight was the most likely cause of hypercalciuria resulting in UC formation.[20] In this study, although we have found that hours of sunlight had a significant influence on UC attacks among the 65 years or older group (a result which is compatible with the findings of Chauhan et al[5]), after adjustment for other factors, such a significant relationship between sunshine hours and monthly UC attack rates was not observed among other gender and age groups.

Davalos showed that renal calculi attacks were quite common in the warm, dry section of Ecuador, while they were quite rare in the warm, moist section of the country,[21] theorizing that due to excessive sweating in such climates, the excretion of waste products via routes other than the kidneys was responsible for the low incidence of renal calculi in these areas. However, we have found no significant relationship between relative humidity and monthly UC attack rates. Thus, we postulate that ambient temperature is the primary meteorological factor influencing UC attacks.

This study has 2 inherent limitations. It can only identify seasonality for stone passage rather than stone formation. The NHIRD data set used cannot allow us to calculate the period between stone formation and passing. Further study is still needed to explore the mechanisms and duration of time required for an asymptomatic stone to pass.

In addition, renal colic is common after extracorporeal SWL due to passage of fragments, and this could potentially compromise the findings of this study. However, before people receive extracorporeal SWL they must show some symptoms/signs that allow physicians to make a diagnosis of urolithiasis. Therefore, to minimize the possible confounding factor of extracorporeal SWL we limited study subjects to those making first time emergency visits. If a patient was readmitted within 7 days of the first visit it was regarded as the same episode.

## CONCLUSIONS

Our study has used ARIMA methodology to investigate whether any relationship exists between weather conditions and monthly UC attack rates, fitting the models with the monthly UC attack rate time series. This method has been widely used to examine associations between climate and incidences of other diseases. Of the 5 meteorological factors ambient temperature and atmospheric pressure are obvious contributory factors having significant associations with the monthly UC attack rates. However, after time series statistical adjustment ambient temperature is found to be the primary factor. Ambient temperature is easy to observe and predict. Thus, no matter how complicated the etiologies for UC are, we simply suggest paying greater attention to increasing temperature and ensuring a corresponding increase in fluid intake.

**Abbreviations and Acronyms**

| | | |
|---|---|---|
| AIC | = | Akaike information criterion |
| ARIMA | = | auto-regressive integrated moving average |
| CWB | = | Taiwan Central Weather Bureau |
| NHIRD | = | Taiwan National Health Insurance Research Database |
| SC | = | Schwarz criterion |
| SWL | = | shock wave lithotripsy |
| UC | = | urinary calculi |

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