The effect of the body mass index on the types of urinary tract stones

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Abstract

Objectives: Urinary tract stones are a common public health problem worldwide. In addition, identifying the composition of stones is important for the further metabolic evaluation of patients. We conducted this study to further correlate the relationship between body mass index (BMI) and different compositions of urinary tract stones.

Materials and Methods: A retrospective study of 433 patients who underwent urinary tract stone analysis via Fourier-transform infrared spectroscopy at King Khalid University Hospital in Riyadh from May 2015 to June 2017 was performed. Their BMI at the time of stone analysis was recorded.

Results: A total of 433 stones were analyzed by the statistical data analysis software. The BMI was classified according to the WHO classification. We divided our patients into seven age groups. Most patients were between the age group of 35 and 44 years and were overweight. The incidence of calcium oxalate, carbonate apatite, and uric acid stones was higher in patients with a BMI above thirty than in patients with a lower BMI. However, cystine stones were more common in normal-weight patients.

Conclusions: In this study, we found that the incidence of certain types of stones, such as calcium oxalate, cystine, and uric acid stones, in Saudi Arabia can be predicted by BMI measurement.

Keywords: Body mass index, calcium oxalate stones, urinary tract stones, urolithiasis

INTRODUCTION

Urinary tract stones are a common public health problem worldwide. Calcium oxalate and calcium phosphate stones are the most common types, accounting for >80% of urinary tract stones. Other types of stones, including uric acid, cystine, and struvite stones, account for most of the remaining stones. The prevalence and incidence of urolithiasis vary among different countries and races and between the sexes. The lifetime incidence of urolithiasis in Middle Eastern and Western countries is 25% and 10%, respectively. However, the recurrence rates are high, reaching 50% worldwide.

The pathophysiology of urolithiasis is complicated and incompletely understood; it is affected by many interacting factors...
factors, such as genetic, metabolic, and environmental factors. Furthermore, the presence of risk factors such as obesity, diabetes, hypertension, and metabolic syndrome may promote the formation of stones in the urinary tract. Recent studies have shown that patients with increased body mass index (BMI) tend to have a higher excretion of sodium, calcium, uric acid, and citrate and a lower urinary pH than nonobese patients.

The aim of this study is to correlate BMI with specific types of urinary tract stones in Saudi Arabia and further explore this relationship. This aim was addressed by analyzing data from patients who underwent urinary tract stone analysis via Fourier-transform infrared spectroscopy (FTIR).

MATERIALS AND METHODS

A retrospective study including 433 patients who underwent urinary tract stone analysis via FTIR at King Khalid University Hospital (KKUH) in Riyadh from May 2015 to June 2017 was performed.

Our data were obtained from the special biochemistry laboratory at the KKUH after obtaining Institutional Review Board approval. Data privacy was maintained throughout the entire process.

| Table 1: Age and different body mass index classifications |
|----------------------------------------------------------|
| Age | 0-14 | 15-24 | 25-34 | 35-44 | 45-54 | 55-64 | 65+ | Total |
|------|-------|-------|-------|-------|-------|-------|-----|-------|
| Underweight |
| Count | 16 | 2 | 3 | 1 | 0 | 2 | 0 | 24 |
| Percentage within BMI | 66.7 | 8.3 | 12.5 | 4.2 | 0.0 | 8.3 | 0.0 | 100.0 |
| Percentage within age | 69.6 | 9.5 | 3.4 | 1.0 | 0.0 | 2.6 | 0.0 | 5.5 |
| Normal weight |
| Count | 7 | 9 | 26 | 14 | 10 | 8 | 7 | 81 |
| Percentage within BMI | 8.6 | 11.1 | 32.1 | 17.3 | 12.3 | 9.9 | 8.6 | 100.0 |
| Percentage within age | 30.4 | 42.9 | 29.9 | 14.1 | 11.9 | 10.5 | 16.3 | 18.7 |
| Overweight |
| Count | 0 | 6 | 24 | 33 | 24 | 30 | 20 | 137 |
| Percentage within BMI | 0.0 | 4.4 | 17.5 | 24.1 | 17.5 | 21.9 | 14.6 | 100.0 |
| Percentage within age | 0.0 | 28.6 | 27.6 | 33.3 | 28.6 | 39.5 | 46.5 | 31.6 |
| Class I obesity |
| Count | 0 | 2 | 19 | 26 | 30 | 22 | 9 | 108 |
| Percentage within BMI | 0.0 | 1.9 | 17.6 | 24.1 | 27.8 | 20.4 | 8.3 | 100.0 |
| Percentage within age | 0.0 | 9.5 | 21.8 | 26.3 | 35.7 | 28.9 | 20.9 | 24.9 |
| Class II obesity |
| Count | 0 | 1 | 14 | 15 | 13 | 5 | 5 | 53 |
| Percentage within BMI | 0.0 | 1.9 | 26.4 | 28.3 | 24.5 | 9.4 | 9.4 | 100.0 |
| Percentage within age | 0.0 | 4.8 | 16.1 | 15.2 | 15.5 | 6.6 | 11.6 | 12.2 |
| Class III obesity |
| Count | 0 | 1 | 3 | 10 | 7 | 9 | 2 | 30 |
| Percentage within BMI | 0.0 | 3.3 | 3.3 | 33.3 | 23.3 | 30.0 | 6.7 | 100.0 |
| Percentage within age | 0.0 | 4.8 | 1.1 | 10.1 | 8.3 | 11.8 | 4.7 | 6.9 |
| Total |
| Count | 23 | 21 | 87 | 99 | 84 | 76 | 43 | 433 |
| Percentage within BMI | 5.3 | 4.8 | 20.1 | 22.9 | 19.4 | 17.6 | 9.9 | 100.0 |
| Percentage within age | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

BMI: Body mass index
patients in our sample were mostly classified as Class I obesity, accounting for 30 (25.6%) of the 117 female patients [Table 2].

Our study included 24 underweight patients with stones; most of these stones were carbonate apatite (45.8%), calcium oxalate (33.3%), or ammonium (16.7%) stones. In addition, we had 81 normal-weight patients with stones, which were mostly calcium oxalate (50.6%), carbonate apatite (32.1%), and cystine (12.3%) stones. We had 137 overweight patients with stones; most of these stones were calcium oxalate (61.3%), carbonate apatite (27.7%), and uric acid (7.3%) stones. We had 108 patients classified as Class I obesity with stones; most of these stones were calcium oxalate (52.8%), carbonate apatite (32.4%), and uric acid stones (10.2). We had 53 patients classified as Class II obesity with stones; most of these stones were calcium oxalate (50.9%), carbonate apatite (37.7%), and uric acid (7.5%) stones. Finally, we had a total of 30 patients classified as Class III obesity with stones; most of these stones were carbonate apatite (46.7%), calcium oxalate (33.3%), and uric acid (10%) stones [Table 3].

| Table 2: Sex and different body mass index classifications |
|-----------------------------------------------------------|
| **Sex** | **Total** |
| **Female** | **Male** | **Count** | **Percentage within BMI** | **Percentage within sex** |
| Underweight | | | | | |
| Count | 10 | 14 | 24 | 100.0 | 100.0 |
| Normal weight | | | | | |
| Count | 17 | 64 | 81 | 100.0 | 100.0 |
| Overweight | | | | | |
| Count | 26 | 111 | 137 | 100.0 | 100.0 |
| Class I obesity | | | | | |
| Count | 30 | 78 | 108 | 100.0 | 100.0 |
| Class II obesity | | | | | |
| Count | 19 | 34 | 53 | 100.0 | 100.0 |
| Class III obesity | | | | | |
| Count | 15 | 15 | 30 | 100.0 | 100.0 |
| Total | | | | | |
| Count | 117 | 316 | 433 | 100.0 | 100.0 |

BMI: Body mass index

| Table 3: All types of stones in relation to body mass index, with the value of P |
|-----------------------------------------------|
| **BMI** | Underweight | Normal weight | Overweight | Class I obesity | Class II obesity | Class III obesity |
| Ammonium | | | | | | |
| Count | 4 | 1 | 3 | 3 | 0 | 1 | 12 |
| Percentage within stone type | 33.3 | 8.3 | 25.0 | 25.0 | 0.0 | 8.3 | 100.0 |
| Percentage within BMI | 16.7 | 1.2 | 2.2 | 2.8 | 0.0 | 3.3 | 2.8 |
| Calcium oxalate | | | | | | |
| Count | 8 | 41 | 84 | 57 | 27 | 10 | 227 |
| Percentage within stone type | 3.5 | 18.1 | 37.0 | 25.1 | 11.9 | 4.4 | 100.0 |
| Percentage within BMI | 33.3 | 50.6 | 61.3 | 52.8 | 50.9 | 33.3 | 52.4 |
| Carbonate apatite | | | | | | |
| Count | 11 | 26 | 38 | 35 | 20 | 14 | 144 |
| Percentage within stone Type | 7.6 | 18.1 | 26.4 | 24.3 | 13.9 | 9.7 | 100.0 |
| Percentage within BMI | 45.8 | 32.1 | 27.7 | 32.4 | 37.7 | 46.7 | 33.3 |
| Cystine | | | | | | |
| Count | 1 | 10 | 2 | 1 | 2 | 2 | 18 |
| Percentage within stone type | 5.6 | 55.6 | 11.1 | 5.6 | 11.1 | 11.1 | 100.0 |
| Percentage within BMI | 4.2 | 12.3 | 1.5 | 0.9 | 3.8 | 6.7 | 4.2 |
| Monohydrogen phosphate | | | | | | |
| Count | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Percentage within stone type | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 100.0 |
| Percentage within BMI | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 0.2 |
| Uric acid | | | | | | |
| Count | 0 | 3 | 10 | 11 | 4 | 3 | 31 |
| Percentage within stone type | 0.0 | 9.7 | 32.3 | 35.5 | 12.9 | 9.7 | 100.0 |
| Percentage within BMI | 0.0 | 3.7 | 7.3 | 10.2 | 7.5 | 10.0 | 7.2 |
| Total | | | | | | |
| Count | 24 | 81 | 137 | 108 | 53 | 30 | 433 |
| Percentage within stone type | 5.5 | 18.7 | 31.6 | 24.9 | 12.2 | 6.9 | 100.0 |
| Percentage within BMI | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| **P** | **0.000382** | | | | | | |
We calculated the value of $P$ for all stone types and for each type individually in relation to BMI. The value of $P$ for the association between overall stone type and BMI was 0.000382. Furthermore, the value of $P$ for the association with the BMI was 0.001 for ammonium stones [Table 4], 0.03 for calcium oxalate stones [Table 5], 0.253 for carbonate apatite stones [Table 6], 0.03 for cystine stones [Table 7], and 0.395 for uric acid stones [Table 8].

Calcium oxalate stones accounted for 227 (52.4%) of all stones in our sample. Eighty-four (37%) of these stones were found in overweight patients, while 57 (25.1%) were found in patients classified as Class I obesity. Carbonate apatite stones accounted for 144 (33.3%) of all stones in our sample. Thirty-eight (26.4%) of these stones were found in overweight patients, while 35 (24.3%) were found in patients classified as Class I obesity.

### Table 4: Ammonium stones in relation to body mass index, with the value of $P$

| BMI      | Percentage | Stone type | Total |
|----------|------------|------------|-------|
|          |            | Ammonium   | Not ammonium |
| Underweight | Count | 4 | 20 | 24 |
|           | Percentage within BMI | 16.7 | 83.3 | 100.0 |
|           | Percentage within stone type | 33.3 | 4.8 | 5.5 |
| Normal weight | Count | 1 | 80 | 81 |
|           | Percentage within BMI | 1.2 | 98.8 | 100.0 |
|           | Percentage within stone type | 8.3 | 19.0 | 18.7 |
| Overweight | Count | 3 | 134 | 137 |
|           | Percentage within BMI | 2.2 | 97.8 | 100.0 |
|           | Percentage within stone type | 25.0 | 31.8 | 31.6 |
| Class I obesity | Count | 3 | 105 | 108 |
|           | Percentage within BMI | 2.8 | 97.2 | 100.0 |
|           | Percentage within stone type | 25.0 | 24.9 | 24.9 |
| Class II obesity | Count | 0 | 53 | 53 |
|           | Percentage within BMI | 0.0 | 100.0 | 100.0 |
|           | Percentage within stone type | 0.0 | 12.6 | 12.2 |
| Class III obesity | Count | 1 | 29 | 30 |
|           | Percentage within BMI | 3.3 | 96.7 | 100.0 |
|           | Percentage within stone type | 8.3 | 6.9 | 6.9 |
| Total | Count | 12 | 421 | 433 |
|           | Percentage within BMI | 2.8 | 97.2 | 100.0 |
|           | Percentage within stone type | 100.0 | 100.0 | 100.0 |

**P** 0.001

**BMI:** Body mass index

### Table 5: Calcium oxalate stones in relation to body mass index, with the value of $P$

| BMI      | Percentage | Stone type | Total |
|----------|------------|------------|-------|
|          |            | Calcium oxalate | Not calcium oxalate |
| Underweight | Count | 8 | 16 | 24 |
|           | Percentage within BMI | 33.3 | 66.7 | 100.0 |
|           | Percentage within stone type | 3.5 | 7.8 | 5.5 |
| Normal weight | Count | 41 | 40 | 81 |
|           | Percentage within BMI | 50.6 | 49.4 | 100.0 |
|           | Percentage within stone type | 18.1 | 19.4 | 18.7 |
| Overweight | Count | 84 | 53 | 137 |
|           | Percentage within BMI | 61.3 | 38.7 | 100.0 |
|           | Percentage within stone type | 37.0 | 25.7 | 31.6 |
| Class I obesity | Count | 57 | 51 | 108 |
|           | Percentage within BMI | 52.8 | 47.2 | 100.0 |
|           | Percentage within stone type | 25.1 | 24.8 | 24.9 |
| Class II obesity | Count | 27 | 26 | 53 |
|           | Percentage within BMI | 50.9 | 49.1 | 100.0 |
|           | Percentage within stone type | 11.9 | 12.6 | 12.2 |
| Class III obesity | Count | 10 | 20 | 30 |
|           | Percentage within BMI | 33.3 | 66.7 | 100.0 |
|           | Percentage within stone type | 4.4 | 9.7 | 6.9 |
| Total | Count | 227 | 206 | 433 |
|           | Percentage within BMI | 52.4 | 47.6 | 100.0 |
|           | Percentage within stone type | 100.0 | 100.0 | 100.0 |

**P** 0.03

**BMI:** Body mass index
We observed stone recurrence in 52 patients, which would have increased the total sample size to 485. Forty-eight cases of recurrence were an initial recurrence, and four cases were the second recurrence. However, we did not include recurrence cases in our results to avoid bias.

**DISCUSSION**

Identifying the composition of the stones is a core element in the metabolic evaluation of urolithiasis. Globally, urolithiasis is considered a recurrent, painful, and common problem with major deleterious sequelae. High BMI is considered to be one cause of the global rise in the prevalence and incidence of urolithiasis among both males and females.\[9\]

In our study, we found that the incidence of stones was high in overweight and obese patients,\[7,10-12\] Indeed, 75.7%
of our patients had a BMI of 25 or higher. An increase in the incidence of stones may result from certain metabolic changes related to obesity and the pathophysiology of stone formation. This issue has been discussed in many studies, which concluded that many risk factors for stone formation were observed in obese patients and linked to some types of stones.\cite{13,14} Studies have demonstrated that obesity contributes to the excess excretion of urinary calcium, oxalate, sulfate, phosphate, sodium, and uric acid. However, the core element for stone formation is acidic urine.\cite{7,15}

In this study, we compared the incidence of different types of stones in relation to BMI. According to our results, patients with a high BMI tended to have a higher incidence of calcium oxalate, uric acid, and carbonate apatite stones than those with a lower BMI. Calcium oxalate stones accounted for 52.4\% of all stones in our study; approximately 41.4\% of these stones were found in patients with a BMI above 30 and 37\% were found in overweight patients. Approximately 60\% of all uric acid stones were found in patients with a BMI above 30. Taylor and Curhan noted a significant association between BMI and uric acid supersaturation and formation.\cite{7,16-18} Furthermore, obese patients are at higher risk than nonobese patients of gouty diathesis, which may further promote the formation of uric acid stones.\cite{14,19} The high concentration of uric acid may lead to a decrease in the solubility of calcium oxalate, which might be associated with the reduced inhibitory activity of glycosaminoglycans on the crystallization of calcium oxalates, eventually resulting in the formation of calcium oxalate stones.\cite{20}

Cystine stones generally account for 1\%–2\% of all kidney stones. In our study, we observed 18 cases of cystine stones, which accounted for 4.2\% of all stones. Ten of the affected patients were of normal weight; these stones accounted for 55.6\% of all the identified cystine stones. We could not find a clear explanation supporting this high incidence of cystine stones in normal-weight patients compared to that in patients in other BMI categories.

One of the strengths of our study is our use of FTIR for the analysis of kidney stones. FTIR has been proven to overcome many limitations associated with chemical analysis.\cite{21}

In addition, unlike other studies, we classified the BMI of our patients according to the WHO classification. We were also able to discuss all three classes of obesity and their association with urinary tract stones.

One of the limitations of this study is the sample size. FTIR has only recently been implemented in the KKUH and has been used on fewer than 500 stones during the short usage period of 2 years.

Another limitation of this study is that some patients had missing data. Approximately seven patients were excluded from this study for this reason.

**CONCLUSIONS**

Patients with a higher BMI tend to have a higher chance of having stones composed mostly of calcium oxalate, carbonate apatite, or uric acid. The value of $P$ for the association between the overall incidence of different urinary tract stones types and BMI in this study was 0.00382, which is highly significant and supports the use of BMI as a measure for predicting the incidence of different types of stones in Saudi Arabia.

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**Table 8: Uric acid stones in relation to body mass index, with the value of $P$**

| BMI         | Count | Not uric acid | Uric acid | Percentage within BMI | Percentage within stone type | Total |
|-------------|-------|---------------|-----------|-----------------------|-------------------------------|-------|
| Underweight | 24    | 0             | 24        | 100.0                 | 100.0                        |       |
| Normal      | 78    | 3             | 81        | 96.3                  | 100.0                        |       |
| Over weight | 127   | 10            | 137       | 92.7                  | 100.0                        |       |
| Class I obesity | 97   | 11            | 108       | 89.8                  | 100.0                        |       |
| Class II obesity | 49   | 4             | 53        | 92.5                  | 100.0                        |       |
| Class III obesity | 27  | 3             | 30        | 90.0                  | 100.0                        |       |
| Total       | 402   | 31            | 433       | 92.8                  | 100.0                        |       |

$P = 0.395$

BMI: Body mass index

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Conflicts of interest
There are no conflicts of interest.

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