Published by
Saidu Medical College

OPEN ACCESS

ISSN (P): 1819-4583
ISSN (E): 3007-9470

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Citation:
Khan AA, Iqbal B, Syed R, Khan S. Chemical Composition and Associated Patient Characteristics of Kidney Stones in Malakand Division, Pakistan: A Cross-Sectional Analysis. *J Saidu Med Coll.* 2026;16(1):86–93.

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Funding:
The authors received no external funding for this study.

Conflicts of Interests:
The authors have declared that no competing interests exist.

Data Sharing Statement:
The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

Received: September 28, 2024
1st Revision: January 18, 2025
2nd Revision: September 25, 2025
3rd Revision: October 07, 2025
4th Revision: December 07, 2025
Accepted: December 11, 2025

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Original Article

Chemical Composition and Associated Patient Characteristics of Kidney Stones in Malakand Division, Pakistan: A Cross-Sectional Analysis

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https://doi.org/10.52206/jsmc.2026.16.1.1088

Abstract

Background: Nephrolithiasis is a prevalent urological disorder and a growing public health concern worldwide. The development of kidney stones is influenced by multiple demographic, clinical, and lifestyle factors, including age, gender, socioeconomic status, hydration habits, obesity, dietary practices, and comorbid conditions such as diabetes and hypertension. Pakistan lies within the global "stone belt," where the burden of kidney stone disease is particularly high.

Objective: This study aimed to analyze the chemical composition of kidney stones and to describe the distribution of demographic characteristics, clinical history, and lifestyle exposures among patients with nephrolithiasis from the Malakand Division of Khyber Pakhtunkhwa, Pakistan.

Methodology: A descriptive cross-sectional study was conducted over four months at the Swat Institute of Medical Sciences, Pakistan. Adult patients (≥18 years) with imaging-confirmed kidney stone disease were enrolled using a consecutive sampling approach. Sociodemographic data, clinical history, and lifestyle factors were collected through structured interviews. Retrieved kidney stones were analyzed using standardized colorimetric and titrimetric wet chemical methods.

Results: A total of 121 patients were included, with a mean age of 37.5 years; 62% were male. Kidney stones were most prevalent among individuals aged 30–50 years (54.5%), those with lower educational attainment (81.8%), and participants from middle socioeconomic backgrounds (51.2%). Commonly reported characteristics included inadequate water intake (69.4%), high dietary sodium consumption (61.2%), frequent tea intake (55.4%), and a personal history of kidney stones (65.3%). Calcium oxalate was the most frequently identified stone type (61.2%), followed by mixed stones (23.1%), calcium phosphate (7.4%), struvite (4.1%), uric acid (3.3%), and cystine (0.8%).

Conclusion: Nephrolithiasis in this population predominantly affects middle-aged men and is commonly associated with modifiable lifestyle factors, particularly inadequate hydration and high dietary sodium intake. Calcium oxalate stones remain the most prevalent type.

Keywords: Chemical Composition, Kidney Stones, Nephrolithiasis, Risk Factors.

Introduction

Nephrolithiasis, commonly referred to as kidney stone disease, is a widespread condition and an important health problem in modern societies [1]. Kidney stones are solid crystalline deposits that form within the renal pelvis and urinary tract as a result of physicochemical imbalances in urine composition [2]. Evidence of nephrolithiasis has been identified in ancient Egyptian mummies, indicating that the condition has afflicted humans for thousands of years [3]. Over the past three decades, the global prevalence of kidney stones has increased substantially, making it a significant contributor to morbidity and healthcare expenditure worldwide [4–7].

The rising incidence of nephrolithiasis has been attributed to multiple factors, including increasing rates of obesity, diabetes mellitus, gout, sedentary lifestyles, and unhealthy dietary patterns [8,9]. As a result, kidney stone disease imposes a considerable economic burden on healthcare systems due to recurrent episodes, hospital admissions, surgical interventions, and long-term complications [10]. Epidemiological data indicate marked geographic variation in prevalence, ranging from 1–5% in Asia, 5–9% in Europe, and 7–15% in North America [11].

Pakistan lies within the "stone belt," a region extending from North Africa through the Middle East to South and Southeast Asia, where urolithiasis is particularly common [11]. Several demographic, socioeconomic, and lifestyle factors have been implicated in stone formation, including male gender, middle age, lower educational level, inadequate hydration, high salt intake, obesity, smoking, hyperlipidemia, diabetes, and hypertension [12–14]. Clinical presentation of kidney stones may range from classic renal colic and hematuria to vague or asymptomatic manifestations such as flank pain, dysuria, nausea, urinary urgency, and lower abdominal discomfort [15].

From a compositional perspective, more than 80% of kidney stones are calcium-based, predominantly calcium oxalate and calcium phosphate stones. Other stone types include uric acid, struvite (magnesium ammonium phosphate), cystine, and less common variants such as cholesterol and carbonate apatite stones. Stones may occur as pure or mixed forms, reflecting complex underlying pathophysiological mechanisms [16,17].

Although multiple studies have examined the risk factors and chemical composition of kidney stones, much of the available literature originates from regions with different environmental, dietary, and socioeconomic contexts. Data specific to northern Pakistan, particularly the Malakand Division, remain limited. Therefore, this study was conducted to describe the chemical composition of kidney stones and to document associated patient characteristics among individuals presenting with nephrolithiasis at the Swat Institute of Medical Sciences. By providing region-specific evidence, this study aims to support clinicians, inform public health strategies, and guide future research on kidney stone disease in Pakistan.

Methodology

Study Design

This was a descriptive, cross-sectional study conducted to characterize the chemical composition of kidney stones and to describe the distribution of demographic, clinical, and lifestyle characteristics among patients with nephrolithiasis. The study design was exploratory in nature and aimed to provide region-specific data from Malakand Division, Khyber Pakhtunkhwa, Pakistan.

Ethics

Ethical approval was obtained from the Ethical Review Board of Saidu Medical College prior to study initiation (Approval No. 134-ERB/024). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment, and confidentiality of patient data was strictly maintained throughout the study process.

Setting

The study was carried out at the Swat Institute of Medical Sciences (SIMS), Swat, Pakistan, a tertiary-care teaching hospital that serves as a major referral center for Malakand Division. Data collection was conducted over a four-month period from March 1 to June 30, 2024.

Participants

All consecutive adult patients (≥18 years) from Malakand Division with a confirmed diagnosis of kidney stone disease, based on ultrasound or computed tomography (CT) scan of the kidneys, ureters, and bladder (KUB), were eligible for inclusion. Patients were excluded if they had secondary causes of nephrolithiasis (such as metabolic disorders or anatomical abnormalities), were pregnant, had incomplete clinical data, or declined participation. A consecutive sampling technique was employed to minimize selection bias and to reflect routine clinical practice.

Variables

The primary variables included sociodemographic characteristics (age, sex, education level, and

socioeconomic status), clinical history (personal and family history of kidney stones, diabetes mellitus, and hypertension), lifestyle factors (daily water intake, tea consumption, soft drink intake, and dietary sodium intake), body mass index (BMI), and the chemical composition of kidney stones. BMI was categorized according to World Health Organization cut-offs, and socioeconomic status was classified based on monthly household income in Pakistani Rupees.

Data Sources/Measurement

Data were collected through structured face-to-face interviews using a predesigned questionnaire, supplemented by review of medical records. Kidney stones obtained after spontaneous passage or surgical removal were transported to the Department of Pathology at SIMS for analysis. Stones were washed, air-dried, coded, and mechanically powdered when required. Chemical composition was determined using standardized colorimetric and titrimetric wet chemical methods with Merck® reagents. Colorimetric analyses were performed on a UV-visible spectrophotometer calibrated daily with standard solutions. Quality control was ensured by running known reference standards with each batch of samples. Stones containing multiple constituents were classified according to the predominant component (≥50% by weight); stones without a dominant component were categorized as mixed.

Bias

To reduce information bias, all interviews were conducted using the same structured questionnaire by trained personnel. Laboratory procedures followed standardized protocols to minimize measurement error and cross-contamination. Consecutive sampling helped reduce selection bias; however, as this was a hospital-based study, referral bias cannot be entirely excluded.

Study Size

As this was an exploratory descriptive study, no formal sample size calculation was performed. All eligible patients presenting during the study period were invited to participate. Of the 150 patients screened, 121 met the inclusion criteria and were included in the final analysis.

Quantitative Variables

Continuous variables such as age and BMI were summarized using means and standard deviations, while categorical variables were expressed as frequencies and percentages. BMI was analyzed as a categorical variable based on predefined clinical cut-offs.

Statistical Methods

Data were entered and analyzed using the Statistical Package for Social Sciences (SPSS), version 29. Descriptive statistics were used to summarize participant characteristics, lifestyle factors, and stone composition. No inferential statistical testing was performed, as the study objective was descriptive rather than analytical.

Results

Participants

During the four-month study period, a total of 150 patients with suspected kidney stone disease were screened at the Swat Institute of Medical Sciences. Of these, 29 patients were excluded due to not meeting the inclusion criteria or declining participation. Consequently, 121 patients were enrolled and included in the final analysis. The participant flow from screening to final inclusion is illustrated in Figure 1. The mean age of the study population was 37.51 ± 11.31 years, with ages ranging across young to older adulthood. Males constituted the majority of participants (62%, n = 75), while females accounted for 38% (n = 46) of the sample (Figure 02).

Descriptive Data

Kidney stone disease was most frequently observed among individuals aged 30–50 years, representing more than half of the study population (54.5%). Patients younger than 30 years constituted 27.3%, whereas those older than 50 years accounted for 18.2%. Regarding body mass index, most participants were classified as having a normal BMI (38.8%) or were overweight (36.4%), while 14.1% were obese and 10.7% were underweight. Socioeconomic assessment showed that over half of the patients belonged to the middle-income group (51.2%), followed by the low-income group (31.4%). Educational status revealed that a large proportion of participants had lower educational attainment, with 81.8% having education up to matriculation level or below, whereas only 18.2% had intermediate or higher education (Table 01).

Outcome Data

Clinical and lifestyle characteristics demonstrated a high prevalence of established nephrolithiasis-related exposures. A personal history of kidney stones was reported by 65.3% of participants, while 46.3% reported a positive family history. Diabetes mellitus was present in 33.0% of patients and hypertension in 22.3%. In terms of lifestyle habits, inadequate daily water intake (<3 liters/day) was reported by 69.4% of participants. More than half of the patients (55.4%) consumed more than one cup of tea daily, and 61.2% reported a high-sodium diet. Daily soft-drink

consumption was less frequent, reported by 28.9% of participants (Table 02). Physical examination of retrieved stones showed that most were irregular or round-to-oval in shape, predominantly hard in consistency (95%), and commonly brown or light brown in color. Stone size most frequently ranged between 10–20 mm (38%) and 5–10 mm (32.2%) (Table 03).

Main Results

Chemical analysis revealed that calcium oxalate was the most prevalent stone composition, identified in 61.2% of cases. Mixed-component stones were the second most common type, accounting for 23.1% of samples. Less frequently observed stone types included calcium phosphate (7.4%), struvite (4.1%), uric acid (3.3%), and cystine stones (0.8%) (Table 04). Overall, the results indicate that nephrolithiasis in this population predominantly affects males in the 30–50-year age group and is commonly associated with inadequate hydration, high dietary sodium intake, frequent tea consumption, and a prior personal history of kidney stones. Calcium-based stones, particularly calcium oxalate, were the dominant stone type identified in patients from Malakand Division.

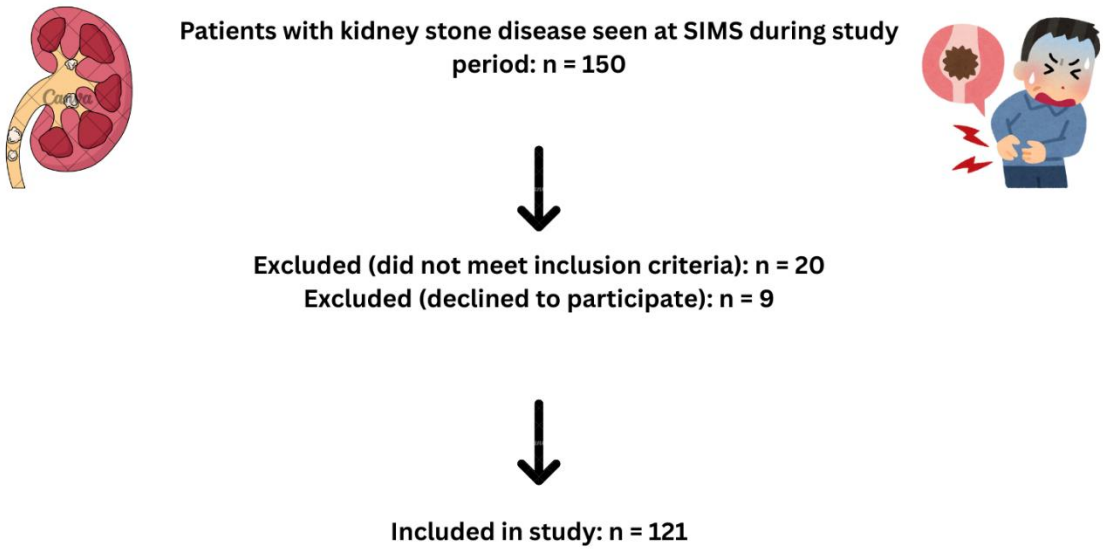


Figure 1: Participant flow diagram showing screening, eligibility, exclusion, and analysis.

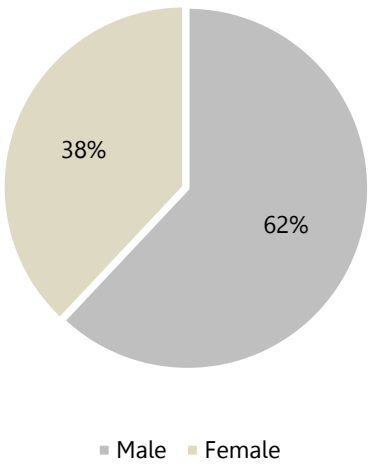


Figure 2: Pie chart depicting the gender of study participants.

Table 1: Sociodemographic information of the participants.

Variable	Frequency	Percentage
Age distribution		
Less than 30 years	33	27.3%
30-50 years	66	54.5%
Greater than 50 years	22	18.2%
Body mass index (BMI)		
Underweight	13	10.7%
Normal	47	38.8%
Overweight	44	36.4%
Obese	17	14.1%
Socioeconomic status		
Low	38	31.4%
Middle	62	51.2%
Upper	21	17.4%
Education		
Primary	27	22.3%
Middle	23	19%
Matric	49	40.5%
Intermediate or above	22	18.2%

Table 2: Clinical history and lifestyle habits of study participants.

Variable	Frequency	Percentage
Family history		
Yes	56	46.3%
No	65	53.7%
Personal history		
Yes	79	65.3%
No	42	34.7%
Diabetes		
Yes	40	33%
No	81	67%
Hypertension		
Yes	27	22.3%
No	94	77.7%
Daily water consumption		
Sufficient	37	30.6%
Insufficient	84	69.4%
Daily tea intake		
One cup or less	54	44.6%
More than one cup	67	55.4%
Daily soft drink intake		
Yes	35	28.9%
No	86	71.1%
High sodium diet		
Yes	74	61.2%
No	47	38.8%

Table 3: Physical examination of stones.

Frequency	Percentage	Frequency
Shape Of Stones		
Irregular	55	45.5%
Irregular To Oval	6	5.0%
Round	6	5.0%
Round To Oval	54	44.6%
Consisitency Of Stones		
Hard	115	95%
Soft	3	2.5%
Very Hard	3	2.5%
Color Of Stones		
Black	12	9.9%
Black And Clay	9	7.4%
Brown	39	32.2%
Clay	3	2.5%
Greyish Black	6	5.0%
Light Brown	37	30.6%
White	3	2.5%
Whitish Yellow	3	2.5%
Yellow	6	5.0%
Yellowish White	3	2.5%
Size Of Stones		
1-5 mm	32	26.4%
5-10 mm	39	32.2%
10-20 mm	46	38%
Greater than 20 mm	4	3.3%

Table 4: Chemical composition of stones.

Composition of stone	Number of stones	Percentage
Calcium Oxalate	74	61.2%
Calcium Phosphate	9	7.4%
Uric Acid	4	3.3%
Ammonium Magnesium Phosphate (Struvite)	5	4.1%
Cystine	1	0.8%
Mixed	28	23.1%

Discussion

This study provides a comprehensive descriptive overview of nephrolithiasis in patients from the Malakand Division, focusing on stone composition and associated demographic, clinical, and lifestyle characteristics. Consistent with existing literature, kidney stone disease in our cohort was more prevalent among males, who constituted 62% of the study population. This male predominance aligns with previously reported findings from multiple regions of Pakistan, including Rawalpindi, Lahore, and Karachi, where male prevalence ranged from 54% to over 62% [18–20]. Biological factors such as hormonal differences, higher muscle mass, and greater urinary excretion of stone-forming solutes in men may partially explain this pattern.

Age-wise distribution showed that nephrolithiasis was most common among individuals aged 30–50 years, accounting for more than half of the cases. This finding is consistent with studies from Karachi and Multan that reported a similar age peak [20,21]. The predominance of kidney stones in this economically productive age group has important public health implications, as recurrent stone disease can lead to work absenteeism, reduced quality of life, and increased healthcare costs [10].

In terms of socioeconomic and educational status, the majority of patients belonged to middle or low socioeconomic groups and had lower levels of formal education. Similar associations have been reported in prior Pakistani studies [18,19], suggesting that limited health literacy, restricted access to preventive healthcare, and dietary practices may contribute to stone formation. These findings emphasize the importance of targeted educational interventions, particularly in underserved populations.

A notable observation in this study was the high proportion of patients reporting a personal history of kidney stones (65.3%), highlighting the recurrent nature of nephrolithiasis. Although nearly half of the participants reported a family history of kidney stones, this proportion was lower than that reported in some earlier Pakistani studies [18,21], but comparable to findings from India [22]. This variability may reflect differences in genetic susceptibility, environmental exposures, or recall bias.

Lifestyle factors emerged as prominent characteristics among affected individuals. Inadequate water intake was reported by nearly 70% of participants, reinforcing the well-established role of low urine volume in stone formation [12,13]. High dietary sodium intake and frequent tea consumption were also common, findings that mirror observations from studies conducted in Rawalpindi and Lahore [18,19].

High sodium intake increases urinary calcium excretion, thereby promoting calcium-based stone formation, while excessive tea consumption may increase oxalate load [13,22]. In contrast, soft drink consumption was less prevalent and showed no clear pattern, consistent with mixed findings in the literature [22].

Chemical analysis revealed that calcium oxalate was the most prevalent stone type, accounting for 61.2% of cases, followed by mixed stones. These results are in line with regional and international studies reporting calcium oxalate as the dominant stone composition [23,24]. The presence of mixed stones as the second most common category further underscores the multifactorial nature of nephrolithiasis, where overlapping metabolic and dietary influences contribute to stone formation [25].

While this study adds valuable region-specific data, its descriptive and cross-sectional design limits causal interpretation. The absence of a control group prevents identification of independent risk factors, and the hospital-based setting may limit generalizability to the wider community. Nonetheless, the findings offer important insights into prevalent characteristics among stone formers in northern Pakistan and provide a foundation for future analytical and interventional research.

Conclusion

This study demonstrates that nephrolithiasis in the Malakand Division predominantly affects men aged 30–50 years, particularly those with lower educational attainment and middle socioeconomic status. Commonly observed characteristics among affected patients included inadequate fluid intake, high dietary sodium consumption, frequent tea intake, and a personal history of kidney stones. Calcium oxalate was the most frequently identified stone type, followed by mixed heterogeneous stones.These findings describe the demographic, lifestyle, and compositional profile of kidney stone disease in this region rather than establishing causality. Nonetheless, they highlight the potential value of preventive strategies focused on hydration, dietary modification, and public health education. Future studies employing analytical designs and including metabolic evaluations are warranted to better elucidate causal pathways and to develop targeted interventions for reducing the burden of nephrolithiasis in Pakistan.

Authors' Contributions:

All authors meet the ICMJE criteria for authorship.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.

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