

**Research Article**

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The Prevalence of Nephrolithiasis and Associated Risk Factors Among the Population of Baghdad Province, Iraq

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Received Date: July 08, 2025**Published Date: July 16, 2025****Abstract**

This cross-sectional study investigated the prevalence and risk factors of nephrolithiasis among adults in Baghdad Province, Iraq. Using multistage stratified random sampling, we enrolled 2,112 participants aged ≥ 18 years from January 2023 to December 2024. Data collection included structured questionnaires, physical measurements, renal ultrasonography, and biochemical analyses. The overall prevalence of nephrolithiasis was 16.3% (95% CI: 14.8-18.0), with significant demographic variations: males showed higher prevalence than females (19.2% vs 12.8%, $p=0.002$), and adults aged 46-60 years had the highest rates (24.8%). Key modifiable risk factors included low fluid intake ($< 2L/day$, $aOR=2.11$, 95% CI: 1.62-2.75), high sodium consumption ($> 5g/day$, $aOR=1.89$, 95% CI: 1.42-2.51), and obesity ($BMI \geq 30$, $aOR=1.67$, 95% CI: 1.25-2.23). Non-modifiable factors included family history ($aOR=2.15$, 95% CI: 1.63-2.83) and outdoor occupation ($aOR=1.53$, 95% CI: 1.16-2.02).

Spatial analysis revealed district-level clustering, with Al-Sadr City showing the highest prevalence (21.4%), strongly correlated with water hardness ($r=0.82$). Seasonal variation was pronounced, with a 2.61-fold increased incidence rate ratio (95% CI: 2.07-3.29) during summer months. The estimated annual economic burden exceeded \$6.1 million, with productivity losses accounting for 53% of costs. These findings establish Baghdad as a high-risk region for nephrolithiasis, shaped by unique environmental, dietary, and metabolic factors. The study highlights the urgent need for targeted prevention strategies addressing hydration, dietary modifications, and workplace interventions, particularly for high-risk groups and districts.

Keywords: Nephrolithiasis; prevalence; risk factors; Iraq; climate; water hardness

Introduction

Nephrolithiasis, or kidney stone disease, represents a significant and growing global public health challenge, with recent epidemiological studies indicating a steady rise in prevalence across both developed and developing nations due to factors such as dietary changes [1], increasing obesity rates [2], climate change [3], and improved diagnostic techniques [4], where current data suggest approximately 10-15% of the global population will experience at

least one symptomatic kidney stone episode in their lifetime [5], while recurrence rates remain alarmingly high at 50% within five to ten years following the initial episode [6], creating a substantial economic burden on healthcare systems worldwide, particularly in regions with extreme climatic conditions such as the Middle East [7], where high ambient temperatures and arid environments contribute to chronic dehydration, a well-documented risk factor for stone formation [8], and where Iraq, specifically Baghdad Prov-

ince, presents a critical case study due to its unique combination of environmental, socioeconomic, and lifestyle factors that exacerbate nephrolithiasis risk [9], including summer temperatures that frequently exceed 50°C (122°F) [10], leading to excessive fluid loss through perspiration and subsequent urine concentration, which promotes the crystallization of stone-forming minerals such as calcium oxalate [11], uric acid [12], and struvite [13], as demonstrated in recent climatological studies linking heat stress to increased hospital admissions for renal colic [14], while rapid urbanization and dietary shifts over the past two decades have further compounded the problem, with a marked increase in processed food consumption (42% rise since 2010) and animal protein intake (35% increase) [15], both established dietary risk factors for kidney stones [16], alongside a decline in traditional plant-based foods rich in natural stone inhibitors like citrate [17] and phytate [18], creating an imbalanced dietary profile that favors lithogenesis, particularly when combined with inadequate hydration practices, a common issue in Baghdad due to both behavioral factors and infrastructural challenges related to water access [19], where salinity intrusion in the Tigris River and aging distribution systems have led to inconsistent potable water supply [20], discouraging sufficient daily fluid intake, with nearly 60% of Baghdad's adult population consuming less than the recommended 2-3 liters of water per day [21], a critical concern given that low urine volume is one of the strongest predictors of kidney stone formation [11], as confirmed by international cohort studies showing a 40-50% lower incidence of nephrolithiasis among individuals with high fluid intake [22].

Beyond environmental and dietary influences, metabolic disorders such as obesity (38.7% prevalence in Baghdad) [23], diabetes (15.2% prevalence) [24], and hypertension further elevate susceptibility to kidney stones [25], with obesity-related hyperinsulinemia increasing renal calcium excretion [26], while diabetes-induced insulin resistance reduces renal ammonium excretion, leading to acidic urine that favors uric acid stones [12], creating a multifactorial physiological milieu that significantly elevates lithogenic risk, particularly when combined with genetic predisposition, another critical factor in Middle Eastern populations [27], where consanguinity rates exceeding 50% in some Iraqi communities may amplify the inheritance of monogenic disorders such as cystinuria [28,29], and primary hyperoxaluria [30], as well as polygenic traits influencing urinary solute handling [31], though comprehensive genetic epidemiological data specific to Iraq remain scarce [32], highlighting a key knowledge gap this study seeks to address, particularly given the recurrent nature of kidney stones, with approximately half of all patients experiencing a repeat episode within a decade without preventive intervention [6], leading to repeated hospitalizations, surgical procedures, and lost productivity, a cycle that imposes substantial costs on healthcare systems exemplified by the \$10 billion annual expenditure on stone-related care in the United States [33], and one that Iraq's already strained medical infrastructure can ill afford [20], particularly given the high prevalence of comorbid conditions that complicate stone management [23], while the psychological toll of recurrent renal colic, including anxiety and reduced quality of life [34], further amplifies the disease burden, making the development of culturally adapted prevention

strategies a pressing priority [35], one that requires locally relevant data on modifiable risk factors, such as the relative contributions of dietary sodium versus fluid intake in Baghdad's population [36], or the potential protective role of traditional dietary elements like dates and barley water [21], gaps that this study's findings will help fill, thereby informing targeted public health campaigns, clinical practice guidelines, and healthcare policy decisions aimed at reducing the incidence and recurrence of nephrolithiasis in Baghdad and other high-risk regions. This study aims to comprehensively investigate the prevalence and risk factors of nephrolithiasis among Baghdad's adult population through a community-based cross-sectional design.

Methods

Study Design and Population

We conducted a community-based cross-sectional study across Baghdad Province from January 2023 to December 2024. The study employed a multistage stratified random sampling design to ensure representative coverage of Baghdad's diverse population. The sampling framework was based on the most recent Iraqi census data (2020), with stratification by:

- Administrative district (10 districts)
- Urban/rural classification
- Socioeconomic status (using neighborhood-level indicators)

Sample Size Calculation

The sample size was determined using the single population proportion formula:

$$n = (Z^2 \times p \times q) / d^2$$

Where:

Z = 1.96 (95% confidence level)

p = 15% (anticipated prevalence from pilot data)

q = 1-p (85%)

d = 2% (margin of error)

Design effect = 1.5 (for cluster sampling)

Non-response adjustment = 15%

Final required sample size = 2,112 participants

Inclusion Criteria

- Permanent residents of Baghdad Province (≥1 year residence)
- Age ≥18 years
- Willing and able to provide informed consent
- No cognitive impairment affecting participation

Exclusion Criteria

- Pregnancy (due to ultrasound concerns)
- History of renal transplantation

- c) Current participation in other clinical studies
- d) Terminal illness with life expectancy <6 months
- e) Prisoners or institutionalized individuals

Data Collection and Measurements

Data Sources

1. Primary Data:
 - a) Structured interviewer-administered questionnaires
 - b) Physical measurements
 - c) Laboratory tests
 - d) Ultrasound examinations
2. Secondary Data:
 - a) Meteorological records (temperature, humidity)
 - b) Water quality reports from municipal sources
 - c) Health facility records for validation

Assessment of Risk Factors

All measurements followed standardized protocols:

1. Dietary Assessment:
 - a) Validated Iraqi Food Frequency Questionnaire (126 items)
 - b) 24-hour dietary recall (3 non-consecutive days)
 - c) Sodium estimation using local food composition tables
2. Fluid Intake:
 - a) 7-day fluid diary with pictorial aids
 - b) Verification using specific gravity measurements
3. Anthropometrics:
 - a) Weight (SECA 874, calibrated daily)
 - b) Height (Harpender stadiometer)
 - c) Waist circumference (midpoint method)
 - d) Body composition (Tanita MC-980MA)
4. Clinical Measurements:
 - a) Blood pressure (OMRON HEM-7322, triple readings)
 - b) Random blood glucose (Accu-Chek Instant)
 - c) Spot urine analysis (Siemens Clinitek Novus)
5. Ultrasound Examination:
 - a) Performed by certified radiologists
 - b) Mindray DP-50 with 3.5MHz convex probe
 - c) Standardized protocol including:
 - a. Kidney dimensions

- b. Stone characteristics (size, location, number)
- c. Hydronephrosis grading

Statistical Analysis

1. Descriptive Statistics:
 - a) Prevalence estimates with 95% CIs
 - b) Demographic characteristics
 - c) Risk factor distributions
2. Analytical Statistics:
 - a) Univariable logistic regression for initial screening
 - b) Multivariable logistic regression (forward selection)
 - c) Adjustment for potential confounders:
 - a. Age
 - b. Sex
 - c. District
 - d. Socioeconomic status
 - d) Effect modification assessment
 - e) Population attributable fraction calculations
3. Advanced Analyses:
 - a) Structural equation modeling for pathway analysis
 - b) Spatial analysis (SaTScan for clustering)
 - c) Machine learning approaches (random forest)

Statistical Software

All analyses were conducted using:

- a) SPSS 28.0 for basic statistics
- b) R 4.2.1 for advanced modeling
- c) ArcGIS Pro 3.0 for spatial analysis
- d) Mplus 8.8 for structural equation modeling

Ethical Considerations

- a) Approval obtained from Baghdad University Institutional Review Board (Ref: MED-2022-087)
- b) Written informed consent from all participants
- c) Data anonymization and secure storage
- d) Voluntary participation with right to withdraw
- e) Referral system for abnormal findings
- f) Community engagement through local leaders

Quality Assurance Measures

- a) Pretesting of all instruments
- b) Training and certification of data collectors

- c) Daily equipment calibration
- d) Random verification of 10% data entries
- e) Periodic data quality audits
- f) Standard operating procedures for all measurements
- d) Secure backup procedures
- e) Data dictionary with coding schemes

Results

The sample distribution shows adequate representation across age groups, with predominance of middle-aged participants (31-45 years, 40.0%), reflecting Baghdad's demographic pyramid. The slight male predominance (54.8%) aligns with household sampling where males were more available for interviews. District distribution matches population proportions, ensuring geographic representativeness for subsequent prevalence estimates (Table 1). The overall prevalence of 16.3% confirms Baghdad as a high-risk region, with significantly increasing odds by age (aOR=3.12 for 46-60 vs 18-30 years, $p<0.001$). The male predominance (aOR=1.53) persists after adjustment, suggesting biological or occupational risk factors requiring investigation (Table 2). low fluid intake (PAF=38.2%) and high sodium consumption (PAF=32.7%) emerge as leading modifiable risks, supporting targeted interventions. The obesity association (aOR=1.67) persists after adjustment, suggesting metabolic pathways in stone formation (Table 3).

Pilot Study

A pilot study (n=150) was conducted in November 2022 to:

- a) Test field procedures
- b) Estimate prevalence for sample size
- c) Validate questionnaires
- d) Refine training materials

Data Management

- a) Redcap electronic data capture system
- b) Double data entry for 10% random sample
- c) Range and consistency checks

Table 1: Demographic Characteristics of Study Participants (n=2,112).

Characteristic	Category	n (%)	95% CI
Age (years)	18-30	687 (32.5)	30.5-34.6
	31-45	845 (40.0)	37.9-42.1
	46-60	452 (21.4)	19.7-23.2
	>60	128 (6.1)	5.1-7.2
Sex	Male	1,158 (54.8)	52.7-56.9
	Female	954 (45.2)	43.1-47.3
District	Central	423 (20.0)	18.3-21.8
	Al-Karkh	381 (18.0)	16.4-19.7
	Al-Rusafa	396 (18.8)	17.1-20.5

Table 2: Prevalence of Nephrolithiasis by Demographic Factors.

Factor	Category	Prevalence % (n/N)	p-value	aOR (95% CI)
Overall	-	16.3 (344/2,112)	-	-
Age	18-30	8.7 (60/687)	<0.001	1.00 (Ref)
	31-45	17.2 (145/845)		2.01 (1.46-2.77)
	46-60	24.8 (112/452)		3.12 (2.21-4.40)
	>60	21.1 (27/128)		2.87 (1.72-4.78)
Sex	Male	19.2 (222/1,158)	0.002	1.53 (1.17-2.00)
	Female	12.8 (122/954)		1.00 (Ref)

Table 3: Association Between Modifiable Risk Factors and Nephrolithiasis.

Risk Factor	Category	aOR (95% CI)	p-value	PAF %
Fluid intake	<2L/day	2.11 (1.62-2.75)	<0.001	38.2
	≥2L/day	1.00 (Ref)		
Sodium intake	>5g/day	1.89 (1.42-2.51)	<0.001	32.7
	≤5g/day	1.00 (Ref)		
BMI	≥30	1.67 (1.25-2.23)	0.001	24.5
	<30	1.00 (Ref)		

The final model identifies six independent predictors, with family history showing strongest association (aOR=2.15). Outdoor work (aOR=1.53) confirms environmental heat exposure as a unique local risk. The model's discrimination (AUC=0.78) suggests good predictive ability for clinical use (Table 4). This composition analysis reveals sex-specific patterns, with struvite stones more common in females (14.3% vs 8.1%, $p<0.05$), possibly reflecting differential UTI prevalence. The age-related increase in uric acid stones (24.0% in ≥ 40 y vs 15.2%, $p<0.05$) suggests acquired metabolic changes,

while outdoor workers show expected predominance of calcium oxalate stones (65.5%) likely reflecting dehydration effects. These findings guide targeted prevention - increased hydration for outdoor workers versus metabolic evaluation for older adults with uric acid stones (Table 5). The spatial analysis identifies significant clustering in Al-Rusafa and Al-Sadr City, where prevalence correlates strongly ($r=0.82$, $p<0.01$) with combined environmental stressors: higher temperatures ($+2.3^{\circ}\text{C}$ vs mean), elevated water hardness ($430\pm 25\text{mg/L}$ vs $340\pm 18\text{mg/L}$), and socioeconomic disadvantage.

Table 4: Multivariable Model of Significant Risk Factors.

Variable	aOR	95% CI	p-value
Age (per 10y)	1.32	1.18-1.48	<0.001
Male sex	1.41	1.09-1.83	0.009
Fluid <2L/day	1.97	1.52-2.56	<0.001
Sodium >5g/day	1.72	1.30-2.28	<0.001
Family history	2.15	1.63-2.83	<0.001
Outdoor work	1.53	1.16-2.02	0.003

Table 5: Stone Composition Analysis by Demographic Groups.

Composition	Male (n=185)	Female (n=98)	Age <40 (n=112)	Age ≥ 40 (n=171)	Outdoor Workers (n=87)
Calcium Oxalate	62.7%	58.2%	59.8%	61.4%	65.5%
Uric Acid	22.2%	18.4%	15.2%	24.0%*	19.5%
Struvite	8.1%	14.3%*	9.8%	9.4%	7.0%
Cystine	7.0%	9.1%	15.2%	5.3%*	8.0%

* $p<0.05$ compared to reference group.

These findings justify district-specific interventions like water softening programs in high-risk areas (Table 6). Stone formers show significantly higher metabolic comorbidity burdens, with obesity demonstrating the highest population attributable risk (39.5%). The metabolic syndrome prevalence (47.1% vs 29.3%, $p<0.001$) suggests insulin resistance as a unifying pathway (Table 7). Environmental focus, summer shows 2.61-fold higher stone episode rates (95% CI:2.07-3.29) coinciding with extreme tempera-

tures (41.3°C) and low humidity. This temporal pattern confirms dehydration as a key mechanism and suggests timing preventive education campaigns before summer peaks (Table 8). The annual economic burden exceeds \$6 million, with productivity losses (53% of total) representing the largest component. This justifies investment in prevention programs, where a 20% reduction in incidence could save \$1.2 million annually, supporting cost-effectiveness of proposed interventions (Table 9).

Table 6: Spatial Distribution of Nephrolithiasis Prevalence.

District	Prevalence %	Mean Temp ($^{\circ}\text{C}$)	Water Hardness (mg/L)	Poverty Rate (%)
Al-Karkh	14.2	38.2	320	28.5
Al-Rusafa	18.7*	39.5*	410*	35.2*
Al-Mansour	12.9	37.8	290	22.1
Al-Sadr City	21.4*	40.1*	450*	42.7*

* $p<0.01$ for high-prevalence clusters.

Table 7: Comorbidity Patterns Among Stone Formers.

Condition	Stone Formers (n=344)	Non-Formers (n=1,768)	p-value	Population Attributable Risk
Hypertension	42.4%	28.1%	<0.001	31.2%
Diabetes	38.7%	22.5%	<0.001	28.9%
Obesity	51.2%	36.8%	<0.001	39.5%
Metabolic Syndrome	47.1%	29.3%	<0.001	35.8%

Table 8: Seasonal Variation in Symptomatic Episodes.

Season	Cases/1000	Mean Temp (°C)	Humidity (%)	Adjusted IRR
Winter	8.2	15.4	68	1.00 (Ref)
Spring	12.7	25.1	52	1.55 (1.22-1.96)
Summer	21.4*	41.3*	31*	2.61 (2.07-3.29)
Autumn	14.1	28.7	45	1.72 (1.35-2.19)

IRR = Incidence Rate Ratio.

*p<0.001 vs other seasons.

Table 9: Economic Impact Analysis.

Cost Category	Mean Cost (USD)	Annual Cases	Total Burden (USD)
Hospitalization	420	3,200	1,344,000
Outpatient Care	85	8,500	722,500
Lost Productivity	1,150	2,800	3,220,000
Medications	75	11,200	840,000
Total	-	-	6,126,500

Discussion

Our findings demonstrate a representative sample distribution across Baghdad's population strata. The predominance of middle-aged participants (40.0% aged 31-45 years) reflects Iraq's demographic pyramid where 58% of the population is aged 15-49 [37]. The male predominance (54.8%) aligns with regional household surveys where males are more likely to participate in health studies [32]. These demographic characteristics ensure our prevalence estimates are generalizable to Baghdad's adult population. The overall prevalence of 16.3% significantly exceeds rates from neighboring countries like Jordan (11.2%) [38], but remains lower than Kuwait (18.9%) [39]. The strong age gradient supports global data on increasing stone risk with age [34], while the persistent male predominance contrasts with recent Western studies showing gender parity [40], suggesting cultural or occupational factors unique to our setting. Our finding that low fluid intake (PAF=38.2%) exceeds sodium impact (PAF=32.7%) contrasts with similar Middle Eastern studies emphasizing dietary sodium [41].

This likely reflects Baghdad's extreme summer temperatures [14], and water access challenges [19]. The obesity association (aOR=1.67) aligns with metabolic syndrome pathways identified in Gulf populations [42]. The final model's discrimination (AUC=0.78) compares favorably with recent prediction tools from Turkey (AUC=0.72) [43], and Saudi Arabia (AUC=0.75) [7]. The strong family history association (aOR=2.15) supports genetic studies from Qatar showing high heritability [27]. Outdoor work's significance (aOR=1.53) highlights an occupation risk needing workplace interventions. The sex-specific patterns mirror global trends for struvite stones in females [12], while the age-related uric acid increase matches metabolic studies from the UAE [44]. The outdoor workers' calcium oxalate predominance (65.5%) exceeds construction workers in Qatar (58%) [39], suggesting more severe dehy-

dration in Baghdad's harsher climate. The district-level clustering correlates strongly ($r=0.82$) with water hardness measurements exceeding WHO guidelines [19]. Al-Sadr City's 21.4% prevalence represents a 47% excess versus Baghdad's average, comparable to high-risk zones in Egypt's Nile Delta [45].

These findings support targeted water quality interventions. The metabolic syndrome prevalence (47.1%) exceeds rates from Kuwait (38.2%) [42], and Western populations (34.5%) [46], suggesting accelerated cardio renal metabolic dysfunction. The high PAR for obesity (39.5%) supports integrated prevention strategies addressing both conditions [23]. The summer IRR=2.61 exceeds Mediterranean climate patterns (IRR=1.8-2.0) [3], and matches only desert regions like Arizona (IRR=2.5) [8]. This confirms climate change may exacerbate Baghdad's stone burden as temperatures rise [14]. The \$6.1 million annual burden represents 12% of Baghdad's urology budget [15], exceeding diabetes-related kidney disease costs (9%). The productivity losses (53% of costs) match construction sector studies from Qatar [39], justifying workplace prevention programs.

Conclusion

This comprehensive study conclusively demonstrates that Baghdad Province represents a hyper endemic region for nephrolithiasis, with an alarmingly high prevalence of 16.3% among adults that significantly exceeds neighboring countries and approaches the highest global rates, driven by a unique convergence of extreme environmental conditions (summer temperatures exceeding 50°C and high water hardness in multiple districts), ongoing dietary transitions (increased processed food and sodium consumption), and rising metabolic comorbidities (obesity prevalence of 51.2% among stone formers), creating a distinctive risk profile that differs from both Western and regional patterns, as evidenced by the early age of onset (peak prevalence in 46-60 year-olds, 5-7 years

younger than Western populations) and strong male predominance (aOR=1.53) likely reflecting both biological factors and occupational exposures among outdoor workers (65.5% calcium oxalate stones).

Our findings reveal that low fluid intake (PAF=38.2%) and high sodium consumption (PAF=32.7%) represent the most significant modifiable risks, while the substantial economic burden (\$6.1 million annually, with 53% from productivity losses) underscores the urgent need for preventive interventions, particularly given the 2.61-fold increased risk during summer months that highlights climate vulnerability. These results provide a robust evidence base for implementing targeted public health strategies including district-specific water quality improvements, workplace hydration programs, and integrated metabolic screening, while also contributing to global understanding of stone disease in extreme climate regions facing accelerating climate change impacts, though we acknowledge limitations including the cross-sectional design and potential underestimation of asymptomatic cases that future longitudinal studies should address through ongoing surveillance and cost-effectiveness analyses of prevention approaches in this high-risk population.

Limitation of This Study

Despite the significant contributions of this study, several limitations must be acknowledged: the cross-sectional design precludes causal inferences and assessment of stone recurrence patterns, while reliance on ultrasonography may have underestimated the true prevalence by missing small or asymptomatic stones; self-reported dietary and lifestyle data introduce potential recall bias that could be mitigated in future studies through objective measures like 24-hour urine collections; although we employed random sampling, selection bias may persist due to differential participation rates across demographic groups; the lack of genetic testing limits our understanding of hereditary contributions to stone formation in this population; environmental exposures were assessed at the district level rather than individually, potentially obscuring important local variations; our economic impact estimates, while comprehensive, may not fully capture informal sector losses; and finally, the findings may not be generalizable to all Iraqi regions due to Baghdad's unique urban and climatic characteristics, suggesting the need for multicenter studies to better understand the national burden of nephrolithiasis.

Conflict of Interest

None

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