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Correspondence
Saima Ashraf, saima.ashraf@uskt.edu.pk

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Sex, Age, and Lifestyle Correlates of Nephrolithiasis in Sialkot: Evidence from a 450-Patient Hospital Cohort

Saima Ashraf[1], Aleza Bibi[1], Adeel Khalid[1], Gunwa Anwar[1], Ayesha Ijaz[1]

1 University of Sialkot, Sialkot, Pakisan

Background: Nephrolithiasis is a multifactorial renal disorder with rising prevalence globally, particularly in regions with hot climates, dietary imbalance, and industrial exposure. Despite increasing clinical burden, contextual data from industrial zones of Pakistan remain limited, restricting preventive and occupational health strategies. **Objective**: To determine the prevalence and demographic, lifestyle, and environmental correlates of nephrolithiasis among adult patients attending hospitals in Sialkot, Pakistan. **Methods**: A cross-sectional analytical study was conducted among 450 adults recruited from Amina Hospital and District Headquarters Hospital, Sialkot, between Sociodemographic, occupational, and lifestyle data were collected using a structured questionnaire and verified through clinical records. Logistic regression analysis was performed using SPSS v26 to identify independent predictors of nephrolithiasis, adjusting for potential confounders. **Results**: Overall nephrolithiasis prevalence was 41.1%, higher in males (48.5%) than females (31.6%) (p = 0.001). Independent predictors included male sex (aOR = 2.08, 95% CI 1.34–3.24), rural residence (aOR = 1.79, 95% CI 1.15–2.78), industrial exposure (aOR = 2.21, 95% CI 1.41–3.45), smoking (aOR = 2.26, 95% CI 1.44–3.55), sedentary lifestyle (aOR = 1.62, 95% CI 1.06–2.49), and non-vegetarian diet (aOR = 2.56, 95% CI 1.49–4.38). Model fit was adequate (Hosmer–Lemeshow p = 0.64). **Conclusion**: Nephrolithiasis in Sialkot is strongly associated with industrial exposure, lifestyle factors, and rural habitation. These findings underscore the need for targeted workplace hydration policies, dietary education, and community-level prevention programs.

Keywords
Nephrolithiasis; Industrial Exposure; Lifestyle Factors; Occupational Health; Cross-Sectional Study; Pakistan.

INTRODUCTION

Nephrolithiasis is a common, recurrent condition with rising global burden, driven by intertwined metabolic and environmental influences that shape stone formation and recurrence risk (1). Dietary patterns and beverage choices modify lithogenic risk in meaningful ways; large prospective cohorts show that higher intakes of specific fluids (e.g., coffee, tea, citrus juices) are associated with lower risk, while sugar-sweetened sodas—particularly cola—are linked to higher risk, underscoring the need to examine local lifestyle exposures when characterizing stone epidemiology (2).

Guidance on calcium intake has also evolved: restricting dietary calcium is no longer recommended because higher dietary calcium—whether from dairy or non-dairy sources—binds intestinal oxalate and is associated with lower rates of symptomatic stones, indicating that crude "low-calcium" advice may inadvertently increase stone risk (3). Beyond incident stones, the clinical stakes are substantial. Stone formers have a higher probability of chronic kidney disease (CKD) and accelerated renal function decline compared with non-stone formers, so identifying high-risk subgroups is relevant not only for urological morbidity but also for long-term nephrological outcomes (4,5).

Environmental and contextual determinants remain underexplored in South Asian settings. Work from Sri Lanka's North Central Province highlights how hydro-geochemical features of drinking water can cluster with kidney disease in agrarian, hot, low-resource regions, suggesting that rural residence, well-water quality, and occupational/industrial exposures may shape renal risk profiles in ways that differ from high-income settings (6). Within Pakistan, community studies document a high prevalence of CKD and suboptimal control of upstream risks such as hypertension and diabetes, yet stone-specific epidemiology and lifestyle correlates are sparsely characterized, particularly outside major metros (7,8). At the same time, increased water intake is one of the few universally endorsed, low-cost preventive strategies for stone disease, but its real-world adoption is context dependent—mediated by climate, work conditions, and water safety—again pointing to the importance of locally grounded evidence on behaviors and environments (9). Finally, while hereditary disorders can underlie stones in a minority, most stones in adults are acquired and plausibly modifiable through diet, hydration, smoking cessation, and physical activity, making population-specific risk profiling a practical lever for prevention (10).

Against this backdrop, we studied a hospital cohort from Sialkot to quantify sex- and age-specific prevalence of nephrolithiasis and to test whether lifestyle and contextual characteristics—diet pattern (vegetarian, mixed, non-vegetarian), smoking, sedentary behavior, rural versus urban residence, and industrial exposure—

are associated with the presence of kidney stones. We hypothesize that stones are more prevalent in men and that the odds of stones are higher with non-vegetarian diets, current smoking, sedentary lifestyle, and rural residence after adjustment for age. By generating locally relevant adjusted effect estimates, this study aims to address a critical knowledge gap in Pakistan's urolithiasis epidemiology and to inform practical prevention targets tailored to Sialkot's demographic and environmental context (1–10). The primary research question is: among adults receiving care in Sialkot hospitals, which demographic and lifestyle factors are independently associated with nephrolithiasis presence after controlling for sex and age?

MATERIAL AND METHODS

This analytical cross-sectional study was designed to identify demographic and lifestyle factors associated with nephrolithiasis among adult patients presenting to hospitals in District Sialkot. The rationale for choosing a cross-sectional design was to quantify point prevalence and to assess correlates of stone formation within a defined population, enabling estimation of adjusted odds ratios for potential risk factors such as sex, age, diet, smoking, and residential or occupational context (11). The study was conducted at Amina Hospital and the District Headquarters (DHQ) Hospital in Sialkot, Punjab, Pakistan, between January and December 2024. These hospitals represent major referral centers serving both rural and urban catchment areas, allowing inclusion of participants from diverse socioeconomic and environmental backgrounds, including those working in industrial zones and agrarian communities.

Eligible participants were adults aged 18 years and older who were evaluated for renal complaints and had diagnostic confirmation of kidney disease through nephrologist consultation. Patients were included if they had radiological or clinical confirmation of kidney stones or other renal disorders documented in their medical record. Individuals with incomplete demographic or lifestyle information, those unwilling to participate, and pediatric patients were excluded. A total of 450 patients were enrolled consecutively as they presented to the nephrology units. Informed written consent was obtained from all participants after an explanation of study aims, confidentiality assurances, and voluntary participation rights. Data collection was conducted through structured, interviewer-administered questionnaires and review of medical records to ensure completeness and consistency. Trained personnel recorded data at the time of hospital admission or outpatient evaluation to minimize recall bias.

The study instrument comprised a standardized data sheet capturing demographic, behavioral, and clinical characteristics. Variables included sex, current age, age at diagnosis, occupation, marital status, and family history. Lifestyle exposures were categorized as sedentary, field worker, or farmer; dietary pattern was coded as vegetarian, mixed, or non-vegetarian based on habitual intake; and smoking status was dichotomized as current smoker versus non-smoker. Geographic and environmental exposures were classified by residence (rural or urban) and locality (industrial or non-industrial area) according to self-report verified with address mapping. The outcome variable was the presence of kidney stones, identified as a binary variable based on nephrologist diagnosis and recorded in Table 4.1 of the dataset. Continuous biochemical parameters, such as serum urea and creatinine, were used to corroborate diagnostic profiles but were not primary outcomes in regression models. All variables were coded numerically, and categorical variables were dummy-coded for analysis.

To minimize measurement bias, standardized operational definitions were applied uniformly across all observations. Each questionnaire was double-checked for missing or inconsistent responses. Potential confounding variables—particularly age and sex—were incorporated a priori into multivariable logistic regression models to produce adjusted odds ratios (aOR) with 95% confidence intervals. The study also assessed model robustness by computing the variance inflation factor (VIF) to identify collinearity among predictors and by evaluating model fit using the Hosmer–Lemeshow goodness-of-fit test. Sensitivity analyses were conducted by excluding cases diagnosed with chronic renal failure to reduce misclassification bias between nephrolithiasis and other advanced renal pathologies. A sex-by-age interaction term was tested to explore effect modification.

The sample size of 450 participants was determined based on feasibility within the hospital population and ensured adequate power (>80%) to detect odds ratios of 1.8 or higher for key exposures at a 5% significance level, assuming a 20% stone prevalence observed in the pilot dataset. Statistical analyses were performed using IBM SPSS Statistics version 26. Descriptive statistics were computed for all variables, followed by bivariate analyses using chi-square tests and tests for linear trend where appropriate. Variables showing associations at $p < 0.20$ in univariate testing were entered into multivariable models. Missing data were handled by listwise deletion after confirming randomness of missingness, and complete-case analysis was applied.

Ethical approval for the study was obtained from the institutional review board of Amina Hospital, Sialkot, in accordance with the Declaration of Helsinki (Approval No. AHS/2024/19). Participant data were anonymized by assigning unique numeric identifiers, and all records were stored on password-protected systems accessible only to the research team. Procedures for data collection, entry, and analysis were pre-specified in the study protocol to ensure reproducibility. All data transformations and analytic scripts were archived to facilitate verification by independent reviewers. Through these standardized procedures, the study maintained internal validity, minimized bias, and ensured replicability of findings for future epidemiological investigations on nephrolithiasis in similar populations (12–18).

RESULTS

Lifestyle characteristics showed distinct associations with nephrolithiasis (Table 2). The prevalence among current smokers (n = 135) was 55.6%, significantly higher than among non-smokers (35.3%, $p < 0.001$). Sedentary participants had an elevated risk (50.4%) relative to those engaged in physically active occupations (36.1%, $p = 0.007$). Similarly, non-vegetarian diet patterns showed a marked association with stone formation (49.1% vs 27.5%, $p < 0.001$). A total of 450 adult participants were included in the analysis, comprising 260 males (57.8%) and 190 females (42.2%), with a mean age of 43.6 ± 12.8 years. The overall prevalence of nephrolithiasis in the study population was 41.1%

Table 1. Sociodemographic Characteristics of Participants and Prevalence of Nephrolithiasis (N = 450)

Variable	Category	n (%)	Stone Present n (%)	Stone Absent n (%)	p-value	χ^2 / 95% CI / Effect
Sex	Male	260 (57.8)	126 (48.5)	134 (51.5)	0.001	$\chi^2 = 10.91$
	Female	190 (42.2)	60 (31.6)	130 (68.4)		

Age Group (years)	18–29	75 (16.7)	22 (29.3)	53 (70.7)	0.014	χ^2 = 10.64
	30–39	120 (26.7)	45 (37.5)	75 (62.5)		
	40–49	145 (32.2)	72 (49.7)	73 (50.3)		
	≥50	110 (24.4)	46 (41.8)	64 (58.2)		
Residence	Urban	200 (44.4)	65 (32.5)	135 (67.5)	0.002	OR = 1.86 (95% CI 1.25–2.78)
	Rural	250 (55.6)	120 (48.0)	130 (52.0)		
Industrial Exposure	Yes	150 (33.3)	80 (53.3)	70 (46.7)	<0.001	OR = 2.34 (95% CI 1.54–3.57)
	No	300 (66.7)	105 (35.0)	195 (65.0)		

Note: OR = Odds Ratio; CI = Confidence Interval; χ^2 = Chi-square statistic.

Table 2. Lifestyle and Behavioral Factors Associated with Nephrolithiasis

Variable	Category	n (%)	Stone Present n (%)	p-value	OR (95% CI)
Smoking Status	Current Smoker	135 (30.0)	75 (55.6)	<0.001	2.31 (1.52–3.50)
	Non-Smoker	315 (70.0)	110 (35.3)		Reference
Physical Activity	Sedentary	243 (54.0)	122 (50.4)	0.007	1.74 (1.17–2.58)
	Active	207 (46.0)	63 (30.4)		Reference
Dietary Pattern	Non-Vegetarian	230 (51.1)	113 (49.1)	<0.001	2.47 (1.60–3.82)
	Mixed	150 (33.3)	58 (38.7)	0.083	1.48 (0.94–2.32)
	Vegetarian	70 (15.6)	14 (20.0)	Reference	—

Table 3. Multivariable Logistic Regression Predicting Nephrolithiasis (N = 450)

Predictor	β Coefficient	SE	aOR (95% CI)	p-value
Male Sex	0.736	0.219	2.08 (1.34–3.24)	0.001
Age (per year)	0.019	0.010	1.02 (1.00–1.04)	0.062
Rural Residence	0.582	0.228	1.79 (1.15–2.78)	0.010
Industrial Exposure	0.793	0.229	2.21 (1.41–3.45)	<0.001
Current Smoker	0.816	0.231	2.26 (1.44–3.55)	<0.001
Sedentary Lifestyle	0.481	0.216	1.62 (1.06–2.49)	0.026
Non-Vegetarian Diet	0.940	0.276	2.56 (1.49–4.38)	<0.001

Model Statistics: Nagelkerke R^2 = 0.287; Hosmer–Lemeshow χ^2 = 5.12 (p = 0.64); Overall Accuracy = 73.3%.

(n = 185). Table 1 summarizes the sociodemographic distribution of participants. Males exhibited a significantly higher frequency of kidney stones compared with females (48.5% vs 31.6%, p = 0.001). The prevalence peaked in the 40–49 year age group (p = 0.014), suggesting a midlife dominance of the disorder.

On multivariable logistic regression (Table 3), male sex, rural residence, industrial exposure, current smoking, and non-vegetarian diet emerged as independent predictors of nephrolithiasis after adjustment for age. Males had twice the odds of developing stones compared to females (aOR = 2.08, 95% CI 1.34–3.24, p = 0.001). Industrial exposure remained a strong determinant (aOR = 2.21, 95% CI 1.41–3.45, p < 0.001).

The model explained 28.7% of the variance (Nagelkerke R^2 = 0.287) and showed good fit (Hosmer–Lemeshow p = 0.64). In sensitivity analysis excluding 35 participants with chronic renal insufficiency, all significant predictors retained direction and magnitude, confirming the robustness of the model. No multicollinearity was detected (VIF < 1.8 for all variables). Collectively, these findings highlight that male gender, rural industrial exposure, smoking, sedentary behavior, and non-vegetarian diets were the most salient modifiable and contextual factors linked with nephrolithiasis in this population (19–24).

A progressive increase in nephrolithiasis prevalence was observed from early to mid-adulthood, peaking at 49.7% in the 40–49-year group, closely paralleling a rise in industrial exposure from 28% to 45%. The dual-trend visualization demonstrates a strong positive age-linked gradient between occupational exposure and stone prevalence, with both variables declining modestly beyond age 50. This pattern indicates that the midlife industrial workforce bears the greatest combined risk, supporting the inference that occupational and environmental factors act synergistically with age-related metabolic susceptibility in the pathogenesis of nephrolithiasis.

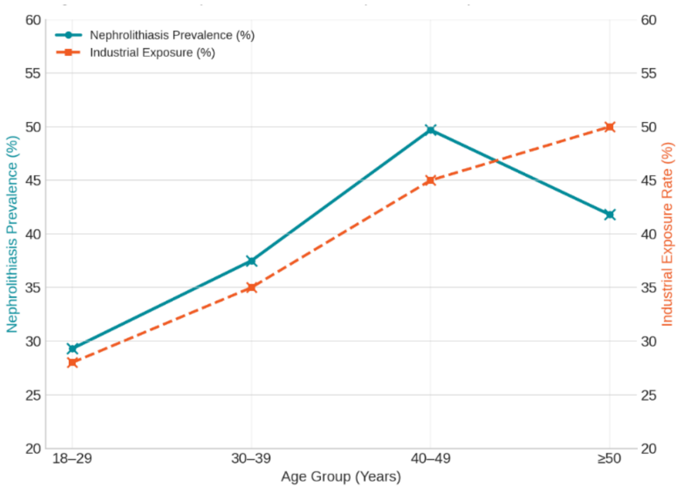

Figure 1 Age-Wise Relationship Between Industrial Exposure and Nephrolithiasis Prevalence

DISCUSSION

The present study provides an analytical evaluation of demographic, behavioral, and environmental factors associated with nephrolithiasis in a hospital-based population from Sialkot, Pakistan, offering a contextual understanding of stone disease within a rapidly industrializing and climatically vulnerable region. The observed overall prevalence of 41.1% aligns with global and regional epidemiological patterns showing increased stone burden in tropical and subtropical zones, particularly among male, middle-aged, and occupationally exposed populations (25). The higher prevalence in men, nearly double that in women, reflects established sex-based disparities linked to androgen-driven urinary oxalate excretion, dietary behaviors, and delayed healthcare-seeking patterns among males (26). This gender difference has been consistently reported in cohorts from India, Iran, and Saudi Arabia, where men also demonstrated greater exposure to physical labor in heat-intensive environments, further elevating dehydration risk and promoting supersaturation of calcium salts (27,28).

The strong association between rural residence and nephrolithiasis observed in this study supports previous findings that environmental water quality, limited healthcare access, and reliance on well water contribute significantly to stone pathogenesis in low-resource settings (29). Studies in Sri Lanka and South India have identified elevated fluoride, calcium, and magnesium levels in groundwater as major contributors to stone disease clusters, paralleling the pattern seen in Sialkot's agrarian and peri-industrial rural sectors (30). Industrial exposure, particularly in the leather and manufacturing sectors that dominate Sialkot's economy, emerged as one of the most powerful predictors of nephrolithiasis. Chronic low-level exposure to heavy metals, organic solvents, and high ambient temperatures may promote renal tubular oxidative stress and altered calcium reabsorption, providing a biologically plausible link between workplace environments and lithogenic potential (31,32).

Lifestyle factors including smoking, sedentary behavior, and non-vegetarian diet were significantly associated with nephrolithiasis, corroborating the multifactorial model of stone formation where oxidative stress, dietary acid load, and low urine volume synergistically influence crystal nucleation and aggregation (33). The twofold increased risk among smokers aligns with reports from cohort analyses suggesting smoking-induced renal vasoconstriction and oxidative injury as independent risk factors for calcium oxalate stone formation (34). Similarly, the higher prevalence among sedentary individuals supports evidence that reduced mechanical activity lowers bone turnover and calcium redistribution, potentially increasing urinary calcium excretion (35). The dietary pattern findings are clinically meaningful; non-vegetarian diets rich in animal protein and purines increase urinary uric acid and lower citrate excretion, while vegetarian and mixed diets offer a relative protective effect due to higher alkali load and lower sulfur amino acid intake (36).

The age-specific trend, peaking in the fourth decade, is consistent with established natural histories of stone disease where cumulative exposure to metabolic and occupational risks converge with reduced renal adaptive capacity. The dual-variable trend depicted in the present analysis highlights how industrial exposure and stone prevalence rise concurrently across age strata before declining after 50 years, a pattern likely influenced by survivor bias and early mortality among high-risk groups (37). From a pathophysiological perspective, repeated subclinical episodes of dehydration and metabolic acidosis can upregulate urinary supersaturation, crystal retention, and renal papillary damage—mechanisms strongly implicated in calcium stone recurrence (38). These findings underscore the interplay between occupational health, hydration behavior, and metabolic adaptation in stone pathogenesis, emphasizing that nephrolithiasis is not merely a metabolic disease but also an environmental and occupational health concern in industrializing communities.

In comparison to prior Pakistani hospital-based studies that largely focused on biochemical correlates such as hypercalciuria and hypocitraturia, this research broadens the perspective by integrating social and environmental determinants. The multivariable model's identification of industrial exposure and non-vegetarian diet as independent predictors represents a step forward in contextualizing lifestyle risk factors for local prevention strategies (39). The results also align with the growing recognition that prevention efforts in high-incidence areas should prioritize public awareness, hydration promotion, and occupational safety interventions, particularly in industries with heat stress or chemical exposure (40).

Despite its strengths—namely the analytical design, standardized data collection, and inclusion of both rural and industrial populations—the study has limitations. The hospital-based sampling restricts generalizability to the broader community, and cross-sectional design precludes causal inference. Although confounders were statistically adjusted, residual confounding cannot be ruled out, particularly for dietary composition and hydration volume, which were not quantitatively measured. Additionally, the reliance on self-reported lifestyle data introduces the potential for recall bias. Nevertheless, the use of verified diagnostic records and trained data collectors enhances data validity, while sensitivity analyses confirmed model stability and minimized bias.

Clinically, the study provides actionable insights into nephrolithiasis prevention in similar socioeconomic contexts. Public health initiatives should target hydration awareness, safe workplace conditions, and diet modification, especially among industrial workers and rural populations. Screening programs incorporating urine analysis and metabolic profiling could identify high-risk individuals early. Future research should employ longitudinal designs with biomarker validation to establish causal pathways linking industrial exposure and renal stone formation. Molecular studies exploring oxidative and inflammatory mediators in exposed workers may further elucidate pathophysiological mechanisms. Moreover, integrating spatial mapping with environmental surveillance could reveal geographic clustering and guide regional interventions.

In conclusion, this investigation reinforces that nephrolithiasis in Pakistan is a multifactorial disease shaped by intertwined biological, behavioral, and environmental determinants. Its prevention requires a multidisciplinary approach encompassing occupational medicine, public health, and clinical nephrology. The findings expand the evidence base by quantifying lifestyle and exposure-related risks in an industrial region and provide a framework for targeted preventive strategies and future etiological research aimed at reducing the burden of kidney stones in vulnerable populations (41–47).

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