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Age-Related and Pathogen-Specific Variations in C-Reactive Protein Levels Among Urinary Tract Infection Patients

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Abstract

This study evaluated serum C-reactive protein (CRP) levels among urinary tract infected patients attending Madonna University Teaching Hospital in order to determine inflammatory response patterns associated with urinary tract infections. A cross-sectional experimental design was employed involving 105 participants comprising 52 urinary tract infected patients and 53 apparently healthy controls. Serum CRP concentrations were measured using the Enzyme-Linked Immunosorbent Assay method, while statistical analysis was performed using SPSS version 26. The findings demonstrated that UTI patients exhibited significantly higher CRP concentrations compared to healthy controls. Age-related analysis further revealed elevated inflammatory responses among children and adolescents relative to adults. Comparative bacterial analysis showed that Escherichia coli infections produced the highest CRP levels, followed by Proteus mirabilis and Klebsiella pneumoniae. The novelty of this study lies in its integrated evaluation of age-dependent and pathogen-specific inflammatory responses among UTI patients within a Nigerian tertiary healthcare setting. The findings provide important evidence supporting the clinical relevance of CRP as a rapid biomarker for assessing inflammatory severity and host-pathogen interactions in urinary tract infections. The study further contributes to improving biomarker-based infection assessment and inflammatory monitoring in resource-limited clinical environments.

INTRODUCTION

Urinary tract infection (UTI) remains one of the most prevalent infectious diseases affecting both community and hospital populations worldwide, with substantial implications for morbidity, healthcare expenditure, and antimicrobial resistance. UTI is characterized by microbial colonization and inflammation of the urinary system, including the urethra, bladder, ureters, and kidneys. Epidemiological evidence indicates that millions of individuals experience UTIs annually, with women, children, older adults, and immunocompromised patients representing the most vulnerable populations (Foxman et al., 2025; Broughton et al., 2025). The high

recurrence rate and increasing prevalence of multidrug-resistant uropathogens have transformed UTIs into a significant global public health concern (Addis et al., 2021; Ormeño et al., 2022; Silago et al., 2022). Among the bacterial agents responsible for UTIs, *Escherichia coli* remains the predominant pathogen, followed by *Klebsiella pneumoniae* and *Proteus mirabilis*, each exhibiting distinct virulence mechanisms and inflammatory potentials. The persistent burden of UTIs emphasizes the necessity for reliable biomarkers capable of improving diagnostic accuracy, evaluating disease severity, and guiding therapeutic interventions (Mattoo & Spencer, 2024; Dudzik et al., 2025; Baimakhanova et al., 2025; Barguigua et al., 2025; Bharuka et al., 2024; Haghayegh et al., 2024).

Inflammation constitutes a central pathological mechanism in urinary tract infections, as microbial invasion activates both innate and adaptive immune responses (Naskar & Choi, 2024; Kuhn et al., 2023; Behzadi et al., 2023). During bacterial colonization of the urinary epithelium, immune cells release pro-inflammatory cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and interleukin-1β (IL-1β), which subsequently stimulate hepatic synthesis of acute-phase proteins. Among these inflammatory mediators, C-reactive protein (CRP) has emerged as one of the most clinically significant biomarkers of systemic inflammation. CRP is a pentameric acute-phase reactant synthesized primarily by hepatocytes in response to inflammatory cytokine stimulation (Olson et al., 2023; Rizo-Téllez et al., 2023; Potempa et al., 2025). Physiologically, CRP contributes to host defense through complement activation, opsonization of pathogens, and facilitation of phagocytosis. Under inflammatory conditions, serum CRP concentrations may increase dramatically within a short period, making it a highly sensitive indicator of infectious and inflammatory processes (Mouliou, 2023; Johnkennedy & Mercy, 2022; Banait et al., 2022). Previous investigations have demonstrated that elevated CRP levels are associated with bacterial infections, autoimmune disorders, tissue injury, and cardiovascular diseases, thereby highlighting its broad diagnostic relevance.

The clinical significance of CRP in infectious diseases has received considerable scholarly attention over the past decade (Ali et al., 2023; Bhattacharya & Munshi, 2023). Several studies have demonstrated that serum CRP levels correlate strongly with the severity and progression of bacterial infections, including sepsis, pneumonia, and pyelonephritis. In the context of UTIs, elevated CRP levels have been associated with upper urinary tract involvement, severe bacterial invasion, and increased inflammatory response. Researchers such as Pope and Choy reported that CRP serves as an important biomarker for systemic inflammatory reactions and can aid clinicians in distinguishing bacterial infections from non-inflammatory conditions. Similarly, McLellan and Hunstad emphasized that inflammatory biomarkers, including CRP, play a critical role in understanding host-pathogen interactions during UTIs (Rana et al., 2025). These findings support the growing interest in integrating CRP assessment into routine clinical evaluation of urinary tract infections.

Despite extensive investigations on UTIs and inflammatory biomarkers globally, important inconsistencies remain regarding the relationship between CRP levels, patient demographics, and specific bacterial pathogens. Existing literature has largely focused on CRP as a generalized inflammatory marker without adequately examining age-dependent inflammatory variations or pathogen-specific immune responses in UTI patients. Studies involving pediatric and adolescent populations have suggested that immune response dynamics differ substantially across developmental stages, potentially influencing CRP expression patterns during infection. Likewise, evidence indicates that distinct uropathogens possess varying virulence factors that can trigger differential inflammatory responses. However,

comparative analyses evaluating CRP variations among bacterial species responsible for UTIs remain relatively limited, particularly in resource-constrained healthcare settings.

The burden of UTIs in developing countries presents additional clinical and epidemiological challenges. In many African healthcare institutions, delayed diagnosis, limited laboratory infrastructure, poor antimicrobial stewardship, and increasing bacterial resistance contribute significantly to disease complications and recurrent infections (Musa et al., 2023; Aremu et al., 2025). Nigeria, like many low- and middle-income countries, continues to experience a rising prevalence of UTIs among hospital-attending patients. Yet, inflammatory biomarkers such as CRP are not routinely integrated into diagnostic protocols for infection assessment in several tertiary healthcare facilities. This limitation may hinder early identification of severe inflammatory responses and reduce the effectiveness of clinical management strategies. Furthermore, local epidemiological data regarding CRP responses among UTI patients in Nigerian tertiary hospitals remain insufficiently documented (Azeez et al., 2024; Nwamaka et al., 2025; Shinggu et al., 2025).

Previous studies investigating CRP in UTI patients have predominantly originated from Europe, Asia, and North America, where healthcare systems, microbial patterns, and patient demographics differ considerably from sub-Saharan African contexts. Consequently, findings from these regions may not be entirely generalizable to Nigerian populations due to variations in pathogen distribution, environmental exposures, healthcare accessibility, and host immune responses. Although some studies have explored inflammatory markers in infectious diseases within Nigeria, limited empirical evidence exists concerning the evaluation of CRP among UTI patients attending Madonna University Teaching Hospital, Elele, Rivers State. More importantly, prior investigations have not comprehensively examined the relationship between CRP levels, age stratification, and specific bacterial isolates within this population. This gap in knowledge restricts the development of context-specific clinical interpretations of CRP in UTI management.

The present study addresses this research gap by evaluating serum C-reactive protein levels among urinary tract infected patients attending Madonna University Teaching Hospital. Unlike previous studies that primarily focused on generalized inflammatory assessment, this research comparatively examines CRP variations across different age categories and bacterial pathogens, thereby providing a more nuanced understanding of inflammatory dynamics in UTIs. The novelty of this study lies in its integration of pathogen-specific and age-related analyses within a Nigerian tertiary healthcare setting, where such evidence remains scarce. By identifying variations in CRP expression among different bacterial isolates and demographic groups, the study contributes to expanding the clinical applicability of CRP as a biomarker for infection severity and immune response assessment. The findings are expected to strengthen evidence-based diagnostic approaches, improve inflammatory monitoring in UTI patients, and provide foundational data for future research on biomarker-guided infection management in resource-limited settings.

METHODS

This section presents the detailed methodology employed in the research, including the study area, research design, ethical approval, sample collection, laboratory assays, and statistical analysis. The approach adopted in this study was rigorously structured to ensure validity and reliability while adhering to ethical standards and protocols for conducting research in clinical settings.

Study Area

The study was conducted at Madonna University Teaching Hospital (MUTH) Elele, situated in the Ikwerre Local Government Area of Rivers State, South-South Nigeria. This community hospital is located at geographical coordinates 50402 N and 64909 E. The laboratory work for this study took place in the chemical pathology laboratory of Madonna University Teaching Hospital, which provided the necessary facilities for sample analysis and testing of the research parameters.

Research Design

This research follows an experimental and cross-sectional design, focusing on estimating the levels of C-reactive protein (CRP) in patients diagnosed with urinary tract infections (UTIs) at Madonna University Teaching Hospital, Elele. The cross-sectional nature of the study allowed for the simultaneous collection of data across a defined population at a single point in time. This design is suitable for determining the prevalence of CRP in UTI patients and understanding its clinical relevance in such cases.

Ethical Approval and Considerations

The research was approved by the Ethical Committee of Madonna University, Elele, Rivers State. The ethical standards were maintained throughout the study, in accordance with the Good Clinical Practice (GCP) guidelines, as well as the modified Helsinki Declaration. Ethical approval ensured that the study adhered to all necessary protocols for protecting the rights and welfare of participants. Written informed consent was obtained from each subject prior to participation in the study. Furthermore, participants were assured that their names and medical details would remain confidential, as the study adhered strictly to ethical standards regarding privacy and data protection.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were meticulously defined to select a representative sample of patients who would provide meaningful data for the study.

Inclusion Criteria

Subjects included in the study were those with confirmed fungal or bacterial growth on urine culture plates at Madonna University Teaching Hospital. These subjects were diagnosed with UTIs, and their CRP levels were analyzed to assess the association between infection and inflammatory markers.

Exclusion Criteria

Subjects who exhibited no fungal or bacterial growth on the urine culture plates were excluded from the study. These individuals did not meet the diagnostic criteria for UTI, and thus their inclusion would not have contributed to the research objectives focused on infection-related CRP levels.

Sample Collection

Sample collection followed standardized procedures to ensure the accuracy and integrity of the collected specimens. A total of 5 ml of whole blood was drawn from each participant through venipuncture. The blood was introduced into a plain container, carefully labeled with the participant's age and laboratory number to ensure proper identification. Following collection, the blood samples were allowed to clot and retract naturally. Once the clotting process was complete, the serum (supernatant) was separated by centrifugation at 12,000 rpm for five minutes.

The resulting serum was transferred into an Ependorf tube using a micropipette to avoid contamination or loss of sample material. Each serum sample was then labeled

accordingly to ensure traceability. All collected samples were stored at -20°C to preserve their integrity until the time of laboratory analysis.

Laboratory Assay

The laboratory analysis of C-reactive protein (CRP) was performed using the Enzyme-Linked Immunosorbent Assay (ELISA) method. ELISA is a sensitive and widely accepted immunoassay technique used to measure the concentration of CRP in serum samples. The assay involves a series of steps, including antigen-antibody binding, washing, and colorimetric detection, to quantify CRP levels. This method was chosen due to its accuracy, reproducibility, and ability to detect low concentrations of CRP, making it ideal for assessing the inflammatory response in UTI patients.

Statistical Analysis

Data collected from the study were analyzed using the Statistical Package for the Social Sciences (SPSS), version 26, for Windows 10. Descriptive statistics were used to summarize the characteristics of the study population, with results expressed as mean ± standard deviation (SD). The statistical methods applied included the independent Student's T-test to compare two independent groups and one-way analysis of variance (ANOVA) for comparisons among multiple groups. Statistical significance was determined at a p-value of <0.05, with values greater than 0.05 considered not significant. This approach ensured a robust statistical analysis to assess the relationships between CRP levels and UTI patients, and to draw valid conclusions based on the collected data.

RESULTS AND DISCUSSION

This section presents the findings obtained from the evaluation of serum C-reactive protein (CRP) among urinary tract infected patients attending Madonna University Teaching Hospital. The analysis focuses on four major areas. First, the demographic and clinical characteristics of the study participants are presented to provide an overview of the sample distribution. Second, serum CRP concentrations are compared between urinary tract infected patients and apparently healthy control subjects. Third, age-related variations in CRP concentrations among infected patients are examined. Finally, differences in inflammatory responses among bacterial isolates associated with urinary tract infections are analyzed. The findings are presented systematically using tables and analytical interpretation to ensure clarity and consistency. All statistical analyses were performed using SPSS version 26, while CRP concentrations were measured using the ELISA technique.

Participant Characteristics and Distribution of Bacterial Isolates

A total of 105 participants were enrolled in this study, comprising 52 urinary tract infected patients and 53 apparently healthy control subjects. The infected participants were categorized according to age groups and bacterial isolates identified from urine culture analysis. Table 1 presents the demographic and microbiological characteristics of the study population.

Table 1. Demographic and Clinical Characteristics of Study Participants

Variable	Category	Frequency (N)	Percentage (%)
Study Group	Control Subjects	53	50.5
	UTI Patients	52	49.5
Age Category	1–12 Years	18	34.6
	13–18 Years	16	30.8
	19–65 Years	18	34.6
Bacterial Isolates	*Escherichia coli*	24	46.2
	Klebsiella pneumoniae	14	26.9

	Proteus mirabilis	14	26.9

Source: Field and laboratory data obtained from participants attending Madonna University Teaching Hospital, 2025

The results in Table 1 show that the study population was relatively balanced between control subjects and infected patients. Among the UTI patients, the distribution across age categories was fairly comparable, with children aged 1–12 years and adults aged 19–65 years each accounting for 34.6% of infected participants, while adolescents aged 13–18 years represented 30.8%.

The microbiological findings further demonstrated that *Escherichia coli* was the predominant bacterial isolate identified among UTI patients, accounting for 46.2% of all bacterial growths. *Klebsiella pneumoniae* and *Proteus mirabilis* each accounted for 26.9% of isolates. The predominance of *Escherichia coli* confirms its established role as the leading uropathogen responsible for urinary tract infections in both hospital and community settings.

Comparison of CRP Levels Between UTI Patients and Healthy Controls

The primary objective of this study was to evaluate whether urinary tract infected patients demonstrated significantly elevated serum CRP levels compared to healthy control subjects. The findings are presented in Table 2.

Table 2. Comparison of Serum C-Reactive Protein Levels Between Control and UTI Groups

Parameter	Group	N	Mean ± SD (mg/L)	Minimum	Maximum	F-value	P-value
C-Reactive Protein	Control	53	3.08 ± 1.28	1.20	5.80	231.812	0.000*
	UTI Patients	52	20.75 ± 8.35	8.10	38.60		

Source: ELISA-based serum CRP analysis among study participants, 2025

The findings presented in Table 2 reveal a substantial elevation in serum CRP concentrations among urinary tract infected patients compared to apparently healthy controls. The mean CRP level among control subjects was 3.08 ± 1.28 mg/L, while UTI patients demonstrated a significantly higher mean concentration of 20.75 ± 8.35 mg/L. Statistical analysis using the independent Student's t-test showed a p-value of 0.000, indicating a highly significant difference between the two groups. The ANOVA result further confirmed this variation with an F-value of 231.812.

The descriptive statistics also revealed substantial variation in CRP concentrations among infected participants, with values ranging from 8.10 mg/L to 38.60 mg/L. By comparison, control subjects demonstrated considerably lower and more stable CRP concentrations, ranging from 1.20 mg/L to 5.80 mg/L. This marked disparity confirms the existence of systemic inflammatory activation among patients with urinary tract infections.

The elevated CRP concentrations observed among infected patients reflect activation of the acute-phase inflammatory response triggered by bacterial invasion of the urinary tract. Increased production of inflammatory cytokines likely stimulated hepatic synthesis of CRP, resulting in significantly higher serum levels compared to healthy individuals. These findings support the clinical relevance of CRP as a sensitive biomarker for inflammatory activity associated with UTIs. The elevated CRP concentration among UTI patients compared to healthy controls is further illustrated in Figure 1.

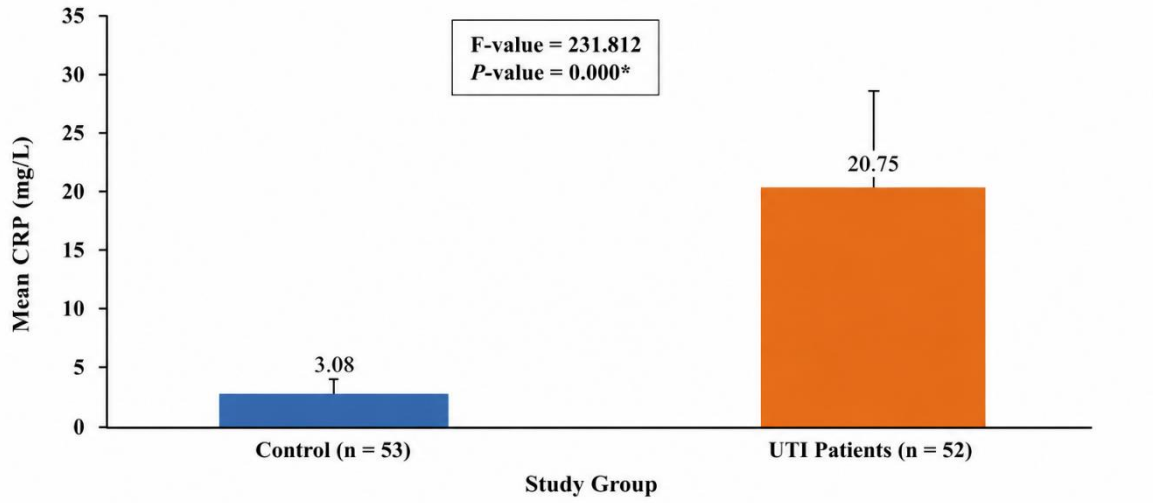

Figure 1. Mean Serum CRP Levels Between Control and UTI Groups

Source: Laboratory analysis of study participants using ELISA method, 2025

Figure 1 illustrates the comparison of mean serum C-reactive protein (CRP) levels between urinary tract infected patients and apparently healthy control subjects. The findings demonstrate that UTI patients exhibited substantially higher CRP concentrations (20.75 mg/L) compared to the control group (3.08 mg/L). The error bars represent the standard deviation within each study group, indicating variability in inflammatory responses among participants. Statistical analysis revealed a highly significant difference between the two groups (p = 0.000; F = 231.812), confirming that urinary tract infections are associated with marked systemic inflammatory activation. These findings support the clinical relevance of CRP as an important biomarker for assessing inflammatory response in UTI patients.

Age-Related Variations in CRP Concentrations

The study further investigated whether inflammatory responses differed significantly across age groups among UTI patients. Participants were grouped into children (1–12 years), adolescents (13–18 years), and adults (19–65 years). The results are summarized in Table 3.

Table 3. Serum C-Reactive Protein Levels Across Different Age Groups Among UTI Patients

Age Group	N	Mean ± SD (mg/L)	Minimum	Maximum	F-value	P-value
1–12 Years	18	20.68 ± 8.87	9.40	36.20	10.74	0.000
13–18 Years	16	21.75 ± 8.17	10.80	38.60		
19–65 Years	18	9.75 ± 10.03	2.50	28.40		

Source: Statistical analysis of CRP concentrations according to age categories among UTI patients, 2025

Table 3 demonstrates significant differences in serum CRP levels across the three age categories. Adolescents aged 13–18 years exhibited the highest mean CRP concentration of 21.75 ± 8.17 mg/L, followed closely by children aged 1–12 years with a mean concentration of 20.68 ± 8.87 mg/L. Adults aged 19–65 years demonstrated a substantially lower mean concentration of 9.75 ± 10.03 mg/L.

The ANOVA analysis revealed a statistically significant variation in CRP levels among age groups, with a p-value of 0.000 and an F-value of 10.74. These findings indicate

that age significantly influences inflammatory responses among patients with urinary tract infections.

The descriptive statistics further revealed that adolescents recorded the highest maximum CRP concentration of 38.60 mg/L, suggesting stronger inflammatory activation within this group. Children also demonstrated elevated inflammatory responses, with CRP values reaching up to 36.20 mg/L. Adults, however, exhibited lower overall CRP concentrations despite confirmed urinary tract infections.

The observed differences may reflect developmental and immunological variations across age groups. Younger individuals generally possess more reactive immune responses during acute infections, which may contribute to increased cytokine release and subsequent CRP synthesis. The lower CRP concentrations observed among adults may indicate differences in immune regulation, infection severity, or host adaptation mechanisms.

Distribution of CRP Levels Among Different Bacterial Isolates

The study additionally evaluated whether specific bacterial pathogens produced varying inflammatory responses as reflected by serum CRP concentrations. Table 4 presents the distribution of CRP levels according to bacterial growth categories.

Table 4. Serum C-Reactive Protein Levels Among Different Bacterial Isolates

Bacterial Growth Category	N	Mean ± SD (mg/L)	Minimum	Maximum
No Growth (Control)	53	3.08 ± 1.28	1.20	5.80
Escherichia coli	24	27.93 ± 5.10	18.40	38.60
Klebsiella pneumoniae	14	12.99 ± 4.08	7.10	22.50
Proteus mirabilis	14	15.51 ± 4.05	8.60	24.30

Table 5. Post Hoc Analysis

Comparison	P-value
No Growth vs Escherichia coli	0.000
Klebsiella pneumoniae vs Proteus mirabilis	0.054
Escherichia coli vs Proteus mirabilis	0.000

Source: Urine culture and serum CRP analysis among bacterial growth categories, 2025

The findings in Table reveal considerable differences in inflammatory responses among bacterial isolates associated with urinary tract infections. Patients infected with *Escherichia coli* demonstrated the highest mean CRP concentration of 27.93 ± 5.10 mg/L. By comparison, patients infected with *Proteus mirabilis* showed a mean concentration of 15.51 ± 4.05 mg/L, while those infected with *Klebsiella pneumoniae* recorded a mean concentration of 12.99 ± 4.08 mg/L.

The post hoc analysis indicated a statistically significant difference between the control group and the *Escherichia coli* group (p = 0.000). Similarly, CRP levels associated with *Escherichia coli* infections differed significantly from those associated with *Proteus mirabilis* infections (p = 0.000). However, the comparison between *Klebsiella pneumoniae* and *Proteus mirabilis* did not demonstrate statistical significance (p = 0.054), suggesting relatively similar inflammatory responses between these bacterial species.

The markedly elevated CRP concentrations observed among *Escherichia coli*-infected patients indicate that this pathogen may induce more severe inflammatory activation than other bacterial isolates evaluated in this study. The maximum CRP concentration associated with *Escherichia coli* infections reached 38.60 mg/L, which was considerably higher than values observed for other bacterial groups.

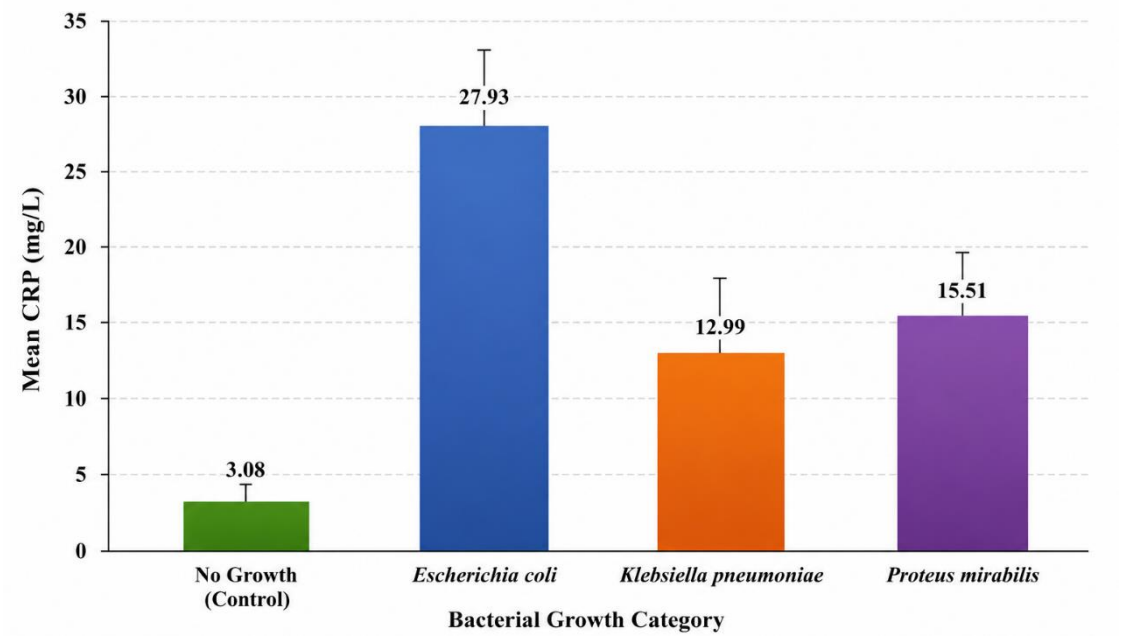

Figure 3. Comparative CRP Levels Among Different Uropathogens

Source: Urine culture and serum CRP laboratory analysis (2025).

These findings suggest that variations in bacterial virulence factors and host-pathogen interactions contribute significantly to differences in inflammatory responses during urinary tract infections. The relatively lower CRP concentrations associated with *Klebsiella pneumoniae* and *Proteus mirabilis* indicate less pronounced systemic inflammatory activation compared to *Escherichia coli* infections.

Inflammatory Response Dynamics and Clinical Relevance of CRP in Urinary Tract Infections

The present study demonstrated significantly elevated serum C-reactive protein (CRP) levels among urinary tract infected patients compared to apparently healthy control subjects, indicating substantial systemic inflammatory activation during urinary tract infections (UTIs). This finding supports the established role of CRP as an acute-phase inflammatory biomarker released in response to bacterial invasion and cytokine stimulation. Previous studies have similarly reported that CRP concentrations increase markedly during bacterial infections due to activation of inflammatory pathways involving interleukin-6 and tumor necrosis factor-alpha (Pope & Choy, 2021; Jarczak & Nierhaus, 2022). The current findings are also consistent with Kuhn et al. (2023), who explained that bacterial colonization of the urinary tract stimulates host immune responses capable of inducing significant inflammatory protein synthesis. The significantly higher CRP concentrations observed among UTI patients therefore confirm the close relationship between urinary tract infections and systemic inflammatory activity.

The age-related variation in CRP concentrations observed in this study further expands existing knowledge regarding inflammatory responses during UTIs. Children and adolescents demonstrated significantly higher CRP levels than adults, suggesting that inflammatory activity differs across developmental stages. This observation corresponds with findings reported by Medina and Castillo-Pino (2019), who noted that younger populations frequently exhibit stronger inflammatory reactions during acute bacterial infections because of heightened innate immune responsiveness. Similarly, Shaikh et al. (2023) identified elevated inflammatory biomarker expression among pediatric UTI patients compared to older individuals.

However, the current findings differ from some adult-centered investigations that reported relatively stable CRP responses across age categories. These discrepancies may reflect variations in immune maturation, microbial exposure, nutritional status, and environmental conditions between study populations. The present study therefore contributes important regional evidence demonstrating that age significantly influences inflammatory responses among UTI patients in Nigerian clinical settings.

Another important finding of this study was the substantial variation in CRP concentrations among bacterial isolates associated with urinary tract infections. Patients infected with *Escherichia coli* exhibited significantly higher CRP levels than those infected with *Klebsiella pneumoniae* and *Proteus mirabilis*. This observation aligns with previous studies identifying *E. coli* as the predominant and most virulent uropathogen responsible for severe inflammatory responses in UTIs (Zhou et al., 2023; Whelan et al., 2023). According to Pokharel et al. (2023), *E. coli* possesses multiple virulence factors, including adhesins, toxins, and fimbriae, which enhance bacterial colonization and stimulate stronger immune activation. The markedly elevated CRP concentrations associated with *E. coli* infections in this study therefore indicate more intense host-pathogen interaction and inflammatory stimulation compared to other bacterial species. In contrast, the relatively lower CRP levels observed among *Klebsiella pneumoniae* and *Proteus mirabilis* infections suggest comparatively moderate inflammatory activation. These findings strengthen the argument that bacterial virulence significantly influences inflammatory biomarker expression during urinary tract infections.

The novelty of this study lies in its integrated evaluation of CRP variations across both age groups and bacterial isolates within a tertiary healthcare institution in Nigeria. While previous studies largely focused on generalized inflammatory responses during UTIs, the present study comparatively examined pathogen-specific and age-dependent inflammatory patterns. This multidimensional assessment contributes to existing literature by providing context-specific evidence regarding inflammatory response dynamics among UTI patients in resource-limited healthcare environments.

From a theoretical perspective, the findings reinforce inflammation-based models of host-pathogen interaction by demonstrating that inflammatory responses vary according to both microbial pathogenicity and host physiological characteristics. Practically, the study highlights the clinical relevance of CRP as a rapid and accessible biomarker for assessing inflammatory severity in urinary tract infections. The observed pathogen-specific variations in CRP concentrations may support clinical decision-making by assisting healthcare professionals in identifying patients at greater risk of severe inflammatory complications.

The implications of this study extend to laboratory medicine and infectious disease management, particularly in developing countries where advanced diagnostic technologies may be limited. CRP measurement may serve as a cost-effective adjunctive tool for evaluating infection severity, monitoring treatment response, and improving early clinical intervention among UTI patients. Nevertheless, several limitations should be acknowledged. The cross-sectional design limited causal interpretation of the findings, while the relatively small sample size reduced generalizability beyond the study population. Additionally, the study focused exclusively on CRP and did not assess other inflammatory biomarkers such as procalcitonin, interleukin-6, or erythrocyte sedimentation rate. Future studies should therefore adopt multicenter longitudinal designs involving larger populations and broader inflammatory biomarker profiling. Further investigations examining antimicrobial resistance patterns and molecular characterization of uropathogens

may also provide deeper insights into inflammatory mechanisms associated with urinary tract infections.

CONCLUSION

This study demonstrated that urinary tract infected patients exhibited significantly elevated serum C-reactive protein (CRP) concentrations compared to apparently healthy individuals, confirming the strong association between urinary tract infections and systemic inflammatory activation. The findings further revealed that inflammatory responses varied across age groups and bacterial isolates, with children and adolescents showing higher CRP levels than adults, while *Escherichia coli* infections produced the highest inflammatory response among the evaluated uropathogens. These observations highlight the important role of host-related and pathogen-related factors in determining inflammatory severity during urinary tract infections.

The study contributes theoretically to the understanding of host-pathogen inflammatory dynamics by demonstrating that CRP expression is influenced not only by infection status but also by bacterial virulence and developmental immune differences. Practically, the findings support the clinical utility of CRP as a rapid and accessible biomarker for evaluating infection severity and inflammatory progression in UTI patients, particularly in resource-limited healthcare settings. Despite these contributions, the study was limited by its cross-sectional design, relatively small sample size, and focus on a single inflammatory biomarker. Future studies should therefore involve multicenter longitudinal investigations with larger populations and expanded inflammatory profiling, including cytokine analysis and antimicrobial resistance assessment, to provide broader insight into inflammatory mechanisms associated with urinary tract infections.

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