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Research Article

Diagnostic Role of Urinary Nitrites and Leukocyte Esterase in Detection of UTI in Children

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Abstract

Background: Urinary tract infections (UTI) are common in children and pose a significant public health concern, particularly in low-resource settings like Bangladesh. Rapid, cost-effective diagnostic tools such as urinary nitrite and leukocyte esterase dipstick tests offer an alternative to traditional urine culture, which is often time-consuming and resource-intensive. This study aimed to evaluate the diagnostic accuracy of urinary nitrite and leukocyte esterase tests in detecting UTI in children. *Methods:* This cross-sectional study was conducted at Shaheed Suhrawardy Medical College Hospital, Dhaka, Bangladesh, from July 2019 to December 2019. A total of 200 children, including 100 cases with proven UTI by culture or microscopy and 100 controls, were enrolled. Urinary nitrite and leukocyte esterase tests were performed on urine samples, with urine culture used as the gold standard. Sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were calculated to assess diagnostic performance. *Results:* The urinary nitrite test demonstrated a sensitivity of 75.56% and a specificity of 97.00%, with an overall accuracy of 90.34%. The PPV was 91.89%, and the NPV was 89.81%. The leukocyte esterase test showed a sensitivity of 88.89% and a specificity of 82.00%, with an accuracy of 84.14%, PPV of 68.97%, and NPV of 94.25%. Compared with urine R/E, the urinary nitrate test had strong specificity (97.00%) but moderate sensitivity (47.78%), while the leukocyte esterase test maintained high sensitivity (86.67%) and reliable NPV (87.23%). *Conclusion:* Both urinary nitrite and leukocyte esterase dipstick tests are effective rapid screening tools for diagnosing UTI in children, with high specificity and sensitivity, respectively. Their combined use can enhance diagnostic accuracy, particularly in settings where access to culture testing is limited. These findings support the implementation of dipstick tests as a reliable first-line diagnostic method for pediatric UTI.

Keywords

Urinary Tract Infection, Urinary Nitrite, Leukocyte Esterase, Pediatric UTI, Diagnostic Accuracy, Urine Culture, Bangladesh

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1. Introduction

Urinary tract infections (UTI) are among the most common bacterial infections in children, with a significant impact on global public health. They account for a substantial proportion of pediatric hospital visits and are associated with considerable morbidity if left untreated. The prevalence of UTI in children varies globally, with higher rates reported in developing countries like Bangladesh due to factors such as limited access to healthcare and inadequate sanitation practices [1]. In South Asia, including Bangladesh, data suggests that UTI are prevalent in up to 8% of febrile infants and young children, contributing to a high burden of pediatric morbidity and mortality [2]. Early and accurate diagnosis of UTI in children is critical to prevent serious complications like renal scarring, hypertension, and chronic kidney disease, which can have lasting consequences on child's health and development [3, 4]. The primary causative agents of pediatric UTI are Gram-negative uropathogens, predominantly Escherichia coli, followed by Proteus mirabilis and Klebsiella species [5, 6]. These pathogens colonize the urinary tract and lead to inflammation and infection, primarily through the production of virulence factors such as fimbriae, toxins, and biofilm formation that enhance their ability to adhere to the urothelial cells [7]. Escherichia coli, in particular, is known for its ability to form intracellular bacterial communities, which play a crucial role in the persistence and recurrence of infections in pediatric patients [8]. Additionally, Proteus mirabilis has been noted for its urease activity and other virulence factors that contribute to stone formation and complicated UTI. Factors such as poor hygiene, low socioeconomic status, and limited healthcare access in Bangladesh exacerbate the risk of these infections in children, making them a significant public health concern in this region [9]. Traditionally, the gold standard for diagnosing UTI has been urine culture, which provides detailed information about the specific pathogens and their antibiotic sensitivities. Although highly accurate, urine culture is time-consuming, requires well-equipped laboratory facilities, and is often not feasible in resource-limited settings like rural areas of Bangladesh [10]. These limitations underscore the need for rapid, cost-effective diagnostic tools that can be used at the point of care to initiate timely treatment. In such contexts, rapid diagnostic tests using urinary nitrites and leukocyte esterase dipsticks have emerged as valuable alternatives [11]. These tests provide quick results by detecting nitrites, which are produced by nitrate-reducing bacteria like Escherichia coli, and leukocyte esterase, an enzyme released by white blood cells as a response to infection [12]. Their biochemical basis makes these dipstick tests particularly useful as screening tools in low-resource settings, where they can significantly reduce diagnostic delays and treatment initiation time [13]. Studies have demonstrated varying levels of sensitivity and specificity for these dipstick tests in pediatric populations, depending on factors such as the age of the child and the presence of congenital anomalies in the urinary tract. For example, in infants under six months of age, leukocyte esterase dipsticks have shown a sensitivity of 92% and specificity of 89.7%, whereas in older children, the sensitivity improves to 96.4% with a specificity of 95.8% [14]. When used in combination, the sensitivity and specificity of nitrite and leukocyte esterase tests in detecting UTI can reach up to 94.7% and 99.5%, respectively, significantly enhancing their diagnostic accuracy compared to when used individually [14]. However, despite these promising results, conflicting evidence exists regarding their reliability in cases with low bacterial load or infections caused by non-nitrate-reducing pathogens, leading to false-negative results [15, 16]. False-negative and false-positive results in dipstick testing pose significant challenges in clinical decision-making, especially in pediatric cases where the prompt initiation of treatment is crucial to prevent complications. For instance, nitrite tests have been reported to have lower sensitivity in identifying infections caused by bacteria that do not reduce nitrates, which could result in missed diagnoses if relied upon solely. On the other hand, leukocyte esterase tests, while highly specific, have been known to yield false-positive results in the presence of conditions like proteinuria or contaminated samples, potentially leading to unnecessary treatment [17]. The implications of such diagnostic inaccuracies are particularly severe in children with underlying congenital abnormalities of the kidney and urinary tract (CAKUT), where delayed treatment of a UTI can rapidly escalate to renal damage or sepsis [18]. Given these limitations, the combination of urinary nitrites and leukocyte esterase tests serves as a valuable screening approach in low-resource settings like Bangladesh. Their rapid turnaround time and ease of use at the point of care make them suitable for widespread implementation, especially in rural areas where advanced laboratory facilities are scarce. Moreover, the high negative predictive value of these tests when both parameters are negative makes them effective in ruling out UTI, thereby reducing the need for costly and time-consuming urine cultures in cases where the clinical suspicion is low [19]. Nonetheless, caution must be exercised in interpreting the results of these tests, and confirmatory urine culture remains essential for accurate diagnosis, especially in complex cases or when dipstick tests yield ambiguous results [20]. In conclusion, while the rapid diagnostic capabilities of urinary nitrites and leukocyte esterase tests have transformed the initial screening process for pediatric UTI, there remain significant gaps in their accuracy and reliability that necessitate further investigation. The findings from this study aim to provide a comprehensive evaluation of these tests' diagnostic value in the Bangladeshi pediatric population, emphasizing their potential role in enhancing UTI management in low-resource settings.

2. Methods

This cross-sectional analytic study was conducted in the Department of Pediatrics (both inpatient and outpatient) at

Shaheed Suhrawardy Medical College Hospital, Dhaka, Bangladesh, from July 2019 to December 2019. The study population comprised 200 children aged 2-12 years, with 100 cases diagnosed with clinical features suggestive of urinary tract infection (UTI), with urine R/E or culture positive, and 100 controls without UTI, selected using a purposive sampling method. Inclusion criteria for cases included children with clinical signs of UTI and positive urine culture or microscopy, while controls consisted of otherwise healthy children without UTI. Exclusion criteria encompassed children who had received antibiotics within the last 48 hours and those whose urine samples were collected using bag specimens or suprapubic aspiration. Urine samples were tested for nitrites and leukocyte esterase using dipstick tests, with positivity indicated by a color change within specific timeframes (nitrites within 60 seconds and leukocyte esterase within 2 minutes). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using standard formulas. Urine culture and urine leukocyte esterase were used as the gold standards, separately. Data were analyzed using the Statistical Package for Social Science (SPSS) version 23.0, with results expressed as mean, standard deviation, frequency, and percentage. Statistical significance was assessed using chi-square tests and Student's t-tests where applicable, with a p-value <0.05 considered significant. Ethical considerations included obtaining informed written consent from guardians, maintaining patient confidentiality, and ensuring no environmental harm during the study process.

3. Results

Table 1. *Distribution of baseline characteristics among the participants (N=200).*

Variables	Case (n=100)		Control (n=100)		p-value
	n	%	n	%	
Age					
2-5 years	40	40.0%	30	30.0%	0.182
6-12 years	60	60.0%	70	70.0%	
Mean ±SD	6.68 ±2.78		7.20 ±2.73		0.184
Sex					
Male	36	36.0%	38	38.0%	0.884
Female	64	64.0%	62	62.0%	
Residence					
Rural	42	42.0%	38	38.0%	0.17
Urban	28	28.0%	40	40.0%	
Urban-Slum	30	30.0%	22	22.0%	

The age distribution was similar between cases and controls, with no significant difference (p=0.182). The mean age of cases was 6.68 ±2.78 years, and for controls, it was 7.20 ±2.73 years (p=0.184). Sex distribution was also comparable, with 36% of cases and 38% of controls being male (p=0.884). In terms of residence, 42% of cases were from rural areas compared to 38% of controls, but this difference was not significant (p=0.17).

Table 2. *Distribution of clinical presentation among the case group participants (n=100).*

Clinical Presentation	n	%
Fever	74	74.0%
Abdominal pain	49	49.0%
Dysuria	40	40.0%
Frequency of Micturition	42	42.0%
Vomiting	36	36.0%
Malodorous Urine	22	22.0%
Hematuria	8	8.0%
Crying during Micturition	14	14.0%
Failure to thrive	12	12.0%

Among the 100 case group participants, the most common clinical presentation was fever, reported by 74% of the participants. Abdominal pain was present in 49%, followed by dysuria in 40%, and increased frequency of micturition in 42%. Vomiting was reported by 36% of participants, while 22% had malodorous urine. Hematuria was observed in 8% of cases, crying during micturition in 14%, and failure to thrive in 12% of participants.

Table 3. *Distribution of hematological lab finding among the participants (N=200).*

CBC	Case (n=100)		Control (n=100)		p-value
	n	%	n	%	
<4000/mm^3	6	6.0%	18	18.0%	0.001
4000-11000/mm^3	41	41.0%	52	52.0%	
>11000/mmm^3	53	53.0%	30	30.0%	

A significantly higher proportion of cases (53%) had a white blood cell (WBC) count greater than 11,000/mm^3 compared to 30% of controls. Additionally, 6% of the cases had a WBC count below 4,000/mm^3, while 18% of controls fell into this category. The majority of participants in both groups had WBC counts within the normal range (4,000-11,000/mm^3), with 41% of cases and 52% of controls. Overall, the difference was statistically significant.

Table 4. Distribution of urinary lab findings among the participants (n=100).

Laboratory findings	n	%
Urine C/S		
Positive	45	45.0%
Negative	55	55.0%
Urine R/E (pus cells)		
Positive (pus cell >5/HPF)	90	90.0%
Negative (pus cell ≤5/HPF)	10	10.0%

Table 4 shows that urine culture was positive in 45% of the cases, while 55% had a negative culture. Urinalysis (urine routine examination) revealed that 90% of the cases had elevated pus cell counts (>5/HPF), while only 10% had pus cell counts within the normal range (≤5/HPF).

Table 5. Cross-tabulation showing concurrent diagnosis by urinary nitrate holding culture test as the gold standard (N=145).

Urinary Nitrate	Urine Culture Sensitivity		Total
	Culture Positive (n=45)	Control (n=100)	
Urinary Nitrate Positive	34 (TP)	3 (FP)	37
Urinary Nitrate Negative	11 (FN)	97 (TN)	108

Table 5 presents the cross-tabulation of urinary nitrate results with urine culture, using the culture test as the gold standard. Among the 45 culture-positive cases, 34 were correctly identified as true positives (TP) by the urinary nitrate test, while 11 were false negatives (FN). Out of the 100 controls, 97 were true negatives (TN), and 3 were false positives (FP). Overall, the urinary nitrate test demonstrated a good capacity to identify true positives and true negatives when compared to the culture standard.

Figure 1 illustrates the diagnostic performance of urinary nitrate testing, using urine culture as the gold standard. The sensitivity of the test was 75.56%, indicating its ability to correctly identify positive cases. The specificity was notably high at 97.00%, reflecting a strong ability to correctly identify negatives. The overall accuracy of the urinary nitrate test was 90.34%, with a positive predictive value (PPV) of 91.89%, showing a high likelihood that positive test results were true positives. The negative predictive value (NPV) was 89.81%, indicating that negative test results were reliably true negatives.

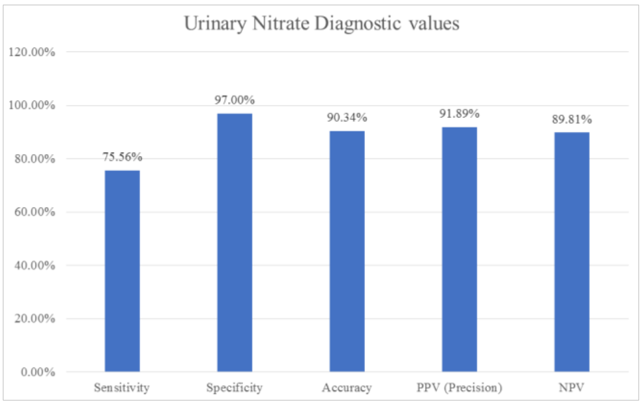

Figure 1. Diagnostic value of urinary nitrate holding culture test as the gold standard.

Table 6. Cross-tabulation showing concurrent diagnosis by urinary leukocyte esterase holding culture test as the gold standard (N=145).

Urinary Leukocyte Esterase	Urine Culture Sensitivity		Total
	Culture Positive (n=45)	Control (n=100)	
Urinary Leukocyte Esterase Positive	40 (TP)	18 (FP)	58

Urinary Leukocyte Esterase	Urine Culture Sensitivity		Total
	Culture Positive (n=45)	Control (n=100)	
Urinary Leukocyte Esterase Negative	5 (FN)	82 (TN)	87

Table 6 displays the cross-tabulation of urinary leukocyte esterase results compared to urine culture, using the culture test as the gold standard. Among the 45 culture-positive cases, 40 were correctly identified as true positives (TP) by the leukocyte esterase test, while 5 were false negatives (FN). Of the 100 controls, 82 were true negatives (TN), and 18 were false positives (FP). This suggests that the urinary leukocyte esterase test has a good ability to correctly detect positive cases but shows a moderate rate of false positives compared to the urinary nitrate test.

Figure 2 presents the diagnostic performance of the urinary leukocyte esterase test, using urine culture as the gold standard. The test showed a sensitivity of 88.89%, indicating a strong ability to correctly identify true positive cases. The specificity was 82.00%, reflecting its effectiveness in accurately detecting true negatives, although slightly lower than the specificity seen with the urinary nitrate test. The overall accuracy of the leukocyte esterase test was 84.14%. The positive predictive value (PPV) was 68.97%, indicating a moderate probability that a positive result was a true positive, while the negative predictive value (NPV) was high at 94.25%, suggesting that negative results were reliably accurate.

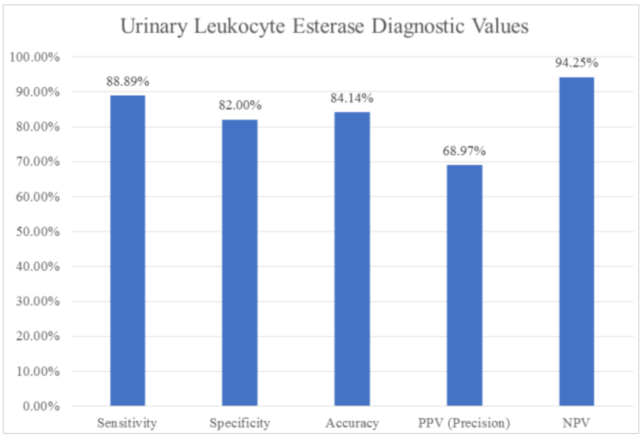

Figure 2. *Diagnostic value of urinary leukocyte esterase holding culture test as the gold standard.*

Table 7. *Cross-tabulation showing concurrent diagnosis by urinary nitrate holding urine R/E as the gold standard (N=190).*

Urinary Nitrate	Urinary R/E sensitivity		Total
	R/E pus cell >5/HPF (n=90)	Control (n=100)	
Urinary Nitrate Positive	43 (TP)	3 (FP)	46
Urinary Nitrate Negative	47 (FN)	97 (TN)	144

Table 7 presents the cross-tabulation of urinary nitrate results compared to urine routine examination (R/E), using the presence of pus cells (>5/HPF) as the gold standard. Among the 90 cases with positive R/E findings, 43 were correctly identified as true positives (TP) by the urinary nitrate test, while 47 were false negatives (FN). Of the 100 controls, 97 were true negatives (TN), and 3 were false positives (FP). These results suggest that while the urinary nitrate test demonstrates a high rate of correctly identifying true negatives, it has a considerable number of false negatives when compared to urine R/E.

Figure 3 illustrates the diagnostic performance of urinary nitrate testing, using urine routine examination (R/E) as the gold standard. The sensitivity of the test was 47.78%, indicating a moderate ability to correctly identify true positives, which reflects a significant rate of false negatives. The specificity was high at 97.00%, showing strong accuracy in detecting true negatives. The overall accuracy of the test was 73.68%, and the positive predictive value (PPV) was 93.48%, indicating a high likelihood that a positive result was a true positive. The negative predictive value (NPV) was 67.36%, suggesting that the test was less reliable in confirming negative cases.

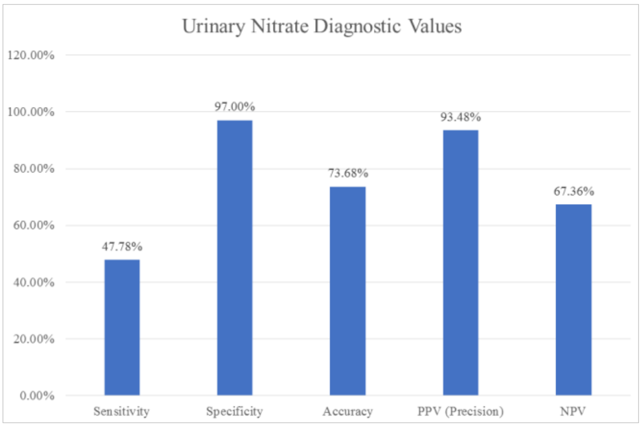

Figure 3. *Diagnostic value of urinary nitrate holding urinary R/E as the gold standard.*

Table 8 presents the cross-tabulation of urinary leukocyte esterase results compared to urine routine examination (R/E), using the presence of pus cells (>5/HPF) as the gold standard. Among the 90 cases with positive R/E findings, 78 were correctly identified as true positives (TP) by the leukocyte esterase test, while 12 were false negatives (FN). Of the 100 controls, 82 were true negatives (TN), and 18 were false positives (FP). These results indicate that the urinary leukocyte esterase test has a high rate of correctly identifying true positives but also shows a moderate level of false positives compared to urine R/E.

Table 8. *Cross-tabulation showing concurrent diagnosis by urinary leukocyte esterase holding urine R/E as the gold standard.*

Urinary Leukocyte Esterase	Urine Culture Sensitivity		Total
	R/E pus cell >5/HPF (n=90)	Control (n=100)	
Urinary Leukocyte Esterase Positive	78 (TP)	18 (FP)	96
Urinary Leukocyte Esterase Negative	12 (FN)	82 (TN)	94

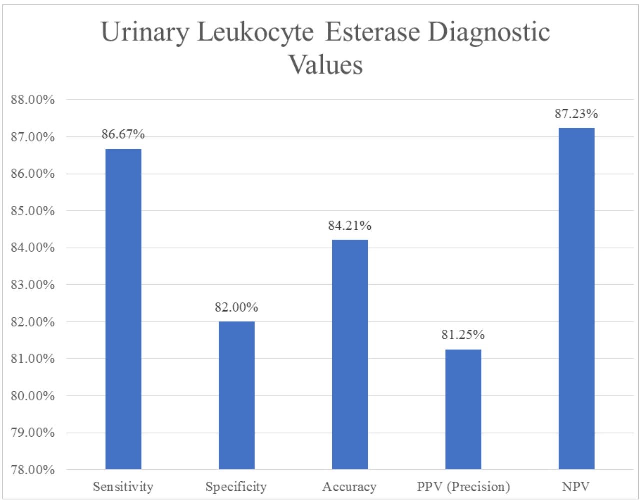

Figure 4. *Diagnostic value of urinary leukocyte esterase holding urinary R/E as the gold standard.*

Figure 4 shows the diagnostic performance of urinary leukocyte esterase testing, using urine routine examination (R/E) as the gold standard. The test demonstrated a sensitivity of 86.67%, indicating strong ability to correctly identify true positives. The specificity was 82.00%, reflecting its effectiveness in detecting true negatives. The overall accuracy was 84.21%, and the positive predictive value (PPV) was 81.25%, suggesting a good likelihood that a positive result was a true positive. The negative predictive value (NPV) was 87.23%, indicating that negative results were reliably accurate.

4. Discussion

The current study aimed to evaluate the diagnostic role of urinary nitrites and leukocyte esterase in the detection of urinary tract infections (UTI) in children, using urine culture and routine examination (R/E) as gold standards. Analysis of the baseline characteristics revealed no significant differences in age, sex, or residential distribution between cases and controls, suggesting that these factors did not bias the prevalence of UTI within the studied cohort. However, the 64% female prevalence among the case groups shows the higher incidence of infection among females. Another important factor is that very few (only 28%) of the control group were from urban areas, which suggest higher incidence of UTI in rural and semi-rural areas. These findings are consistent with previous research that showed comparable age and sex distributions among pediatric UTI cases, with no marked disparity between urban and rural settings [21, 22]. In terms of clinical presentation, fever was identified as the most common symptom, present in 74% of the cases, followed by abdominal pain (49%) and dysuria (40%). This pattern aligns with findings from other studies that also reported fever and abdominal pain as predominant symptoms among pediatric UTI patients, emphasizing the systemic nature of the infection [23]. Less common symptoms such as malodorous urine and hematuria were also observed, which further support the heterogeneity of clinical presentations as noted in other studies across different regions [24]. The study's hematological findings showed a significantly higher proportion of elevated white blood cell (WBC) counts (>11,000/mm³) among cases (53%) compared to controls (30%), demonstrating a significant association (p=0.001). Elevated WBC counts have been frequently associated with UTI, indicating a systemic inflammatory response, which is consistent with previous findings highlighting leukocytosis as a common hematological marker in pediatric UTI cases [25]. The urinary nitrate test, when compared to urine culture, showed a high specificity (97.00%) and an overall accuracy of 90.34%, but only moderate sensitivity (75.56%). The positive predictive value (PPV) was 91.89%, indicating strong reliability when the test is positive, while the negative predictive value (NPV) was 89.81%, suggesting reliable exclusion of UTI when negative. Similar trends were observed in other studies, where the nitrate test was found to have high specificity but varying sensitivity, often due to the test's dependence on the presence of nitrate-reducing bacteria like *Escherichia coli* [26, 27]. The diagnostic performance of the urinary leukocyte esterase test showed a sensitivity of 88.89% and specificity of 82.00% when compared to urine culture, with an accuracy of 84.14%, a PPV of 68.97%, and an NPV of 94.25%. These findings suggest that the leukocyte esterase test is effective in identifying true positives and negatives, though there is a moderate rate of false positives. The study's results are supported by similar findings from previous research, which reported comparable sensitivity and specificity values for leukocyte esterase, noting its usefulness as a rapid diagnostic tool despite some limitations in precision [11, 28]. When comparing urinary nitrate tests to urine R/E, the results indicated strong specificity (97.00%) but limited sensitivity (47.78%), which resulted in a considerable number of false negatives. These findings suggest that while the test can reliably confirm the presence of a UTI when positive, it may miss cases where nitrate-reducing bacteria are not present. Previous studies have also highlighted this limitation, noting that the nitrate test is more likely to miss infections caused by organisms that do not reduce nitrate, leading to lower sensitivity [29, 30]. Similarly, the urinary leukocyte esterase test compared to urine R/E showed robust sensitivity (86.67%) and a high NPV (87.23%), indicating its effectiveness in ruling out UTI. This is consistent with the findings from other studies, where leukocyte esterase showed high sensitivity and NPVs, making it a reliable option for screening and exclusion of UTI in clinical settings [13, 31]. Overall, the findings from this study highlight the utility of urinary dipstick tests as cost-effective, rapid screening tools, particularly in low-resource settings where urine culture may not be readily available. While both urinary nitrate and leukocyte esterase tests demonstrated high specificity, their sensitivity varied, and the combination of both tests may offer enhanced diagnostic accuracy, as suggested by other research [32]. Further studies, especially those considering diverse populations and varying clinical presentations, are necessary to optimize the use of these diagnostic tools in different healthcare settings.

Limitations of the Study

The study was conducted in a single hospital with a small sample size. So, the results may not represent the whole community.

5. Conclusion

The present study demonstrates that urinary nitrite and leukocyte esterase dipstick tests can serve as valuable diagnostic tools for the detection of urinary tract infections (UTI) in children, particularly in low-resource settings where urine culture facilities may not be readily accessible. The urinary nitrate test exhibited high specificity, making it reliable for confirming positive cases, though its moderate sensitivity highlights the potential for false negatives. The leukocyte esterase test showed robust sensitivity and high negative predictive value, making it effective for ruling out UTI. Combining these tests could improve overall diagnostic accuracy, providing a cost-effective and rapid screening method. While these tests cannot replace urine culture, they offer an efficient alternative for initial diagnosis and treatment decisions, especially in rural or under-resourced healthcare settings. Further research is recommended to optimize the use of these diagnostic tools across diverse pediatric populations.

Abbreviations

UTI	Urinary Tract Infections
PPV	Positive Predictive Value
NPV	Negative Predictive Value

Ethical Approval

The study was approved by the Institutional Ethics Committee.

Funding

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Conflicts of Interest

The authors declare no conflicts of interest.

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