Al-Mukhtar Journal of Sciences 00 (0): 01-14, 2026
Doi: https://doi.org/10.54172/7gw9ep48

Research Article **Open Access**

Urinary tract infection prevalence and related risk factors in patients with type 2 diabetes: a cross-sectional study

Fatima AL Zahra Ali [1], Halemah Mohamed Alashoury [2*], Nawal Jamal Almozughie [3], Aisha ALamine Ali[4], Asma Mohamed Almethnany [5], Hanin M. abulkasim[6] and Khalid A. Alghannay [7]

[1, 3, 4, 5] Department of Medical Laboratory Sciences, Faculty of Medical Technology, Wadi Alshatii University, Libya.

[6] Faculty of medicine, University of Tripoli, Libya.

[7] Department of Biology, Faculty of Education, Wadi Alshatti University, Libya.

***Corresponding author:** h.abulkasim@wau.edu.ly
Department of Medical Laboratory Sciences, Faculty of Medical Technology, Wadi Alshatii University, Libya.

Received:
09 August 2026

Accepted:
26 October 2026

Publish online:
19 November 2026

Abstract

Patients with diabetes have weakened immune systems, making them more vulnerable to infections. Urinary tract infections (UTIs) are among the most common infections in diabetic patients. The study's objective was to investigate the frequency of UTIs and related risk factors among diabetes patients who visited the outpatient clinics in the Al-Qardah Al-Shati region of Libya. Al-Qardah Al-Shati, Al-Kafa'ah Laboratory. Standard microbiology techniques were used to analyze midstream urine samples in the morning. Data on age, sex, smoking habits, type, and duration of diabetes was obtained using a pre-made questionnaire. The most common bacterial isolates were E. coli with (71.4%), followed by Klebsiella (28.5%). The results also showed that 28.6% of males had urinary tract infections, while 71.4% of females did. Additionally, 41.9% of males were not infected, while 58.1% of females were not infected, the results also showed statistically significant differences (P-value <0.05) between type of treatment for diabetes and Urinary tract infection. According to this study, appropriate diabetic management requires routine HBA1c and infection screening, particularly for UTIs.

Keywords: Urinary Tract Infection, E. coli, Klebsiella, HBA1c, Diabetes, Smoking.

INTRODUCTION

Nearly 50% of people worldwide suffer from infections, and urinary tract infections (UTIs) in particular are more common in underdeveloped nations than in developed ones (Geerling & Hoepelman,1999). Patients with long-term diabetes who have inadequate metabolic control are especially susceptible to urinary tract infections (Geerlings, 2008).

By 2030, 350 million people globally are expected to have diabetes (Wild et al., 2004). Among diabetics, infections are a major cause of disease and mortality (Geerlings et al., 2000). Research indicates that among diabetics, urinary tract infections (UTIs) are the most prevalent bacterial illnesses, The American Diabetes Association notes that individuals with type 2 diabetes have a higher risk of recurring infections and UTIs than people without the disease (Geerlings et al., 2008). Patients with diabetes who have symptomatic bacterial UTIs are considered to have a significant condition that has to be diagnosed and treated with appropriate clinical

The Author (s) 2026. This article is distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License [http://creativecommons.org/licenses/by-nc/4.0/], which permits unrestricted use, distribution, and reproduction in any medium, for non-commercial purposes only*, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

care. Additionally, elevated glucose levels in the urine might give bacteria an abundant supply of resources (Geerlings et al., 2000).

As a result, bacteria might proliferate and cause an infection. Additionally, bacteria may be able to colonize the urinary system due to high glucose levels in the urine, Additionally, urinary tract infections in diabetic patients are caused by a variety of processes. Urinary tract infections are thought to be more common in women with diabetes, overweight people with diabetes, and obese people with diabetes (Geerlings et al., 2000). Additional risk factors for UTIs in the general diabetic population include insulin therapy, diabetic nephropathy, and diabetes with hypertension. Diabetes-related urinary tract infections can lead to complications such pyelonephritis, cystitis, renal and perirenal abscesses, urinary sepsis, and bacteremia. Complications from diabetes-related UTIs include prolonged hospital admissions, recurring UTIs, relapse, reinfection, bacteremia, azotemia, and septic shock (Koftieridis et al., 2009). Studies show that women are more susceptible to infection than men, with 40–60% of women experiencing at least one infection in their lifetime (Foxman, 2014). This is because the urethra is short and close to the rectum, which makes it easier for germs to spread (Köves & Wullt, 2016).

Type 2 diabetes is one of the biggest risk factors for urinary tract infections among diabetics, especially in elderly patients (Nitzan et al., 2015) Poor glycemic control. Because of anatomical differences, women are more vulnerable than men (Geerlings, 2008). diabetes for a long time. Nephropathy and neuropathy are examples of long-term diabetes consequences (Papp & Zimmern, 2023). Bacteremia, abscesses, and renal issues are among the major consequences that urinary tract infections in diabetics can cause, for those with diabetes who suffer urinary tract infections, early diagnosis and prompt treatment are crucial.

This study intends to determine the prevalence of urinary tract infections among individuals with diabetes in the Al-Qardah Al-Shatti area and investigate risk factors linked to urinary tract infections due to the paucity of research on the subject in some areas.

MATERIALS AND METHODS

Research Subject

The investigation was carried out in the Libyan region of Al-Qardah Al-Shatti. Al-Qardah Al-Shatti, Al-Kafa'ah Laboratory.

Study Population

The participants for the study sample consisted of 50 individuals with diabetes, aged 20 to 80 year There were thirty ladies, with a mean age of sixty-four, and twenty males, with a mean age of sixty-one.

Limitations of the study

Firstly: Geographical scope: The Al-Qardah Al-Shatti region was the site of the study, where questionnaires were distributed and clinical and bacteriological tests were performed on diabetic patients visiting the Al-Kafa’ah Laboratory in the Al-Qardah Al-Shatti area.
Secondly: Temporal Scope: The investigation was carried out between August 16, 2025, and October 16, 2025.

Sample Collection

Patients with diabetes were asked for their informed consent before 5 mL of venous blood samples were taken. The blood samples were collected using sterile medical syringes and transferred to spe-

cial tubes containing the anticoagulant (EDTA) to measure blood parameters, while the remaining blood was placed in tubes without an anticoagulant. The samples were then centrifuged using a centrifuge at a speed of 3,000 rpm for 5 minutes to separate the blood and obtain serum which was used to measure fasting blood sugar (FBS) levels.

Urine dipstick tests were used in the laboratory to quickly identify the presence of glucose, protein, blood, and nitrite. Midstream urine samples were also obtained in sterile containers after patients were instructed on the proper sample collection technique. In order to isolate and identify the causative bacterial agents, the urine samples were subsequently directly inoculated onto a variety of culture medium, including blood agar, MacConkey agar, and CLED agar.

Isolates of bacteria

Sample collection and Identification

Early in the morning, midstream urine samples were taken from all diabetic patients using sterile collection containers. Following a 24- 48h incubation period at 37°C, the samples were cultured by inoculating several selective media with 100 microliters of urine.

After the bacterial isolates were cultured and purified on different culture media (MacConkey agar, blood agar, and CLED), the morphological features of the isolated bacterial colonies—including their size, shape, consistency, color, edges, and elevation—were analyzed.

Bacterial isolates that had been grown on the medium for 18 to 24 hours were used to create smears, which were then stained with Gram stain and inspected under a light microscope to see how the cells reacted to the stain in terms of form, organization, and color.

biochemical Identification

1. Catalase Test

A single drop of 3% catalase reagent is put to a sterile, dry slide containing a 24-hour-old developing colony on MacConkey media. Catalase enzyme synthesis is demonstrated by the formation of bubbles on the glass slide's surface. One easy technique for differentiating various types of bacteria is the catalase test. It is based on the identification of the catalase enzyme, which converts hydrogen peroxide ($H2O_2$) into oxygen and water. Catalase-positive staphylococci and catalase-negative streptococci can be distinguished with this test. (Forbes et al., 2017).

API 20E (Analytical Profile Index) System

The API system is one of the standard commercial systems for bacterial diagnosis, based on a set of mini-biochemical tests. The strip consists of several small wells containing dried reagents for different tests, and this system is widely used in the diagnosis of enterobacteria, pseudomonas, and Gram-positive cocci (Cheesbrough, 2006).

Following the manufacturer’s instructions, a pure bacterial suspension was prepared from the sample. The wells of the API strip were then filled with this bacterial suspension, and some of the wells were covered with mineral oil. The strip was then placed in an incubator at 37°C for 24–48 hours.

In order to precisely identify the type of bacteria, the reactions are interpreted in accordance with the system's manual and transformed into a numerical code that is compared with a database.

Statistical Analysis

The data were coded, tabulated, and analyzed using SPSS version 27 for statistical analysis of the current study's findings. Frequencies and percentages were utilized to express qualitative data, and the connection between variables was examined using the Chi-square test. The Mann-Whitney U

test was used to investigate the link between quantitative variables and data having a non-normal distribution. Quantitative data were expressed as the median and interquartile range (Q1–Q3). Q1 represents the 25th percentile, Q3 represents the 75th percentile, and the interquartile range (IQR) is reported as Q1–Q3. When the P-value was less than the 5% significance level ($P < 0.05$), differences were considered statistically significant in all tests. Microsoft Excel was used to make graphical representations.

RESULTS

Urine sample culture testing is the basis for the laboratory diagnosis of urinary tract infections (UTIs). Fifty urine samples from patients with type 2 diabetes—twenty men and thirty women—were used in this investigation. As seen in Figure 1, the findings indicated that 14% of the participants had UTIs and 86% did not.

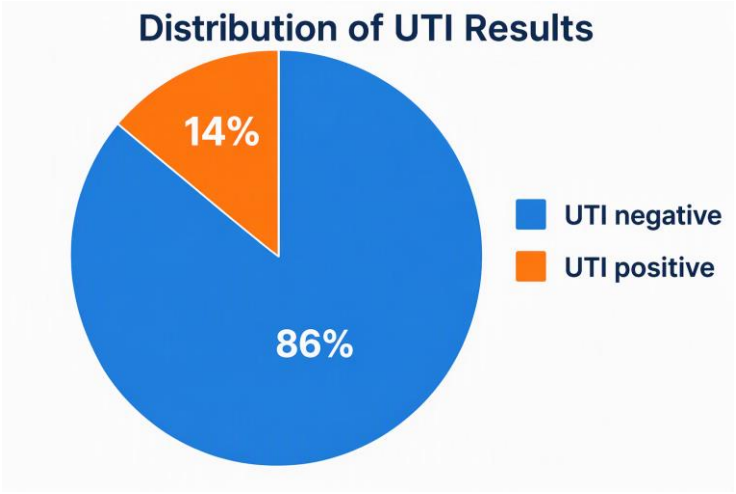


Figure: (1). Percentage of diabetic patients with and without urinary tract infections

The results also showed that 28.6% of males had urinary tract infections, while 71.4% of females did. Additionally, 41.9% of males were not infected, while 58.1% of females were not infected This is illustrated in Figure 2.

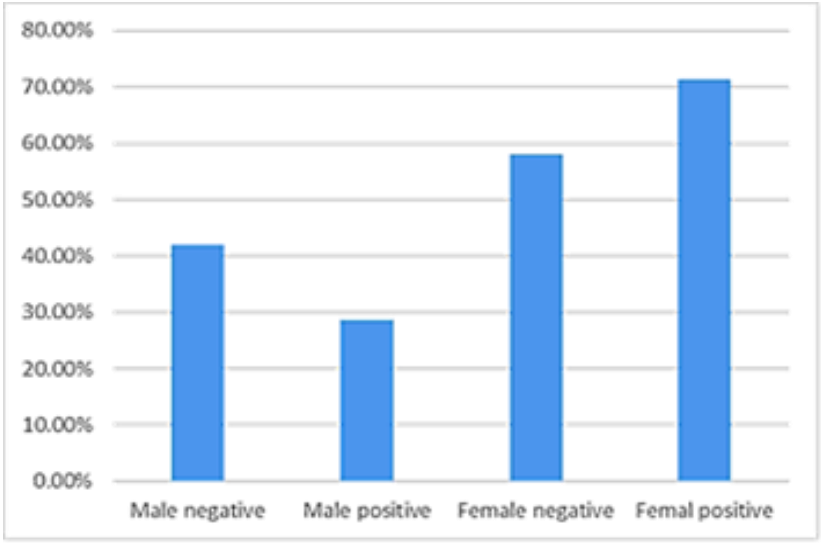


Figure: (2). Percentage of males and females with and without urinary tract infections

The results showed that the data followed a non-normal distribution; therefore, the results were presented using the median and the first and third quartiles (Q1 and Q3), which together form the interquartile range.

The Relationship Between Urinary Tract Infections and Age

With regard to the age variable, the results indicate that the median age of individuals with urinary tract infections was 56 (53–75), while the median age of those without infections was 55 (48–70). as shown in Table 1.

Table:(1). Proportional Distribution of Urinary Tract Infections and Non-Infections by Age

Variable	UTI positive	UTI negative	Total	P. value	Mann Whitney U Test
Age	56(53-57)	55(48-70)	55(48-70)	0.54	128.50

Based on the findings, we discovered that E. coli and Klebsiella were the bacterial species that were isolated from the urine cultures of the study participants and caused urinary tract infections (Table 2).

Table:(2). Numerical and Percentage Distribution of Bacteria Isolated from Urine Samples

Bacterial Isolated	Number	Percentage (%)
E.coli	5	71.4
Klebsiella	2	28.5
Total	7	100

The Relationship Between Smoking and Urinary Tract Infections in Diabetic Patients:

According to the questionnaire collected from the patients in the study, the percentage of individuals with urinary tract infections was 0% among smokers and 100% among nonsmokers, while the percentage of individuals without urinary tract infections was 9.3% and 90.7% among non-smokers. as shown in Table 3.

Table:(3). The Relationship Between Smoking and Urinary Tract Infections in Patients with Diabetes

Smoking	UTI positive n (%)	UTI negative n(%)	Total	P. value	Chi square Test
Yes	0	4(9.3%)	4(8)	0.40	0.12
No	100	39(90.7%)	46(92)		

Urinary tract infections with body mass index in patients with diabetes:

Based on their body mass index (BMI), patients were separated into two groups: those with a BMI below 30 and those with a BMI higher than 30. According to the findings, approximately 57.1% of patients with UTIs had a BMI below 30, and about 42.9% had a BMI over 30. In contrast, about 72.1% of patients without UTIs had a BMI below 30, and approximately 27.9% had a BMI over 30. As indicated in Table 4.

Table:(4). The Relationship Between Body Mass Index and Urinary Tract Infections in Patients with Diabetes

BMI	UTI positive n (%)	UTI negative n (%)	Total	P. value	Chi square Test
>30	4(57.1%)	31(72.1%)	35(70)	0.42	0.11
<30	3(42.9%)	12(27.9%)	15(30)		

The Relationship Between Urinary Tract Infections and Diabetes Type in Patients

According to the findings, about 16.3% of diabetic patients without urinary tract infections had type 1 diabetes and about 73.7% had type 2 diabetes, whereas about 14.3% of diabetic patients with urinary tract infections had type 1 diabetes and about 85.7% had type 2 diabetes. As indicated in Table 5.

Table:(5). The Relationship Between Type of Diabetes and Urinary Tract Infections

Types of Diabetes	UTI positive n (%)	UTI negative n (%)	Total	P. value	Chi square Test
Type 1	1(14.3%)	7(16.3%)	8(16)	0.89	0.02
Type 2	6(85.7%)	36(83.7%)	42(84)		

The Relationship Between Urinary Tract Infections and Diabetes Duration in Patients

According to the findings, approximately 46.5% of patients without urinary tract infections had diabetes for less than ten years, and approximately 53.5% had diabetes for more than ten years. In contrast, approximately 28.6% of diabetic patients with UTIs had diabetes for less than ten years, and approximately 71.4% had diabetes for more than ten years. As showed in Table 6.

Table:(6). Relationship Between Urinary Tract Infections and Diabetes Duration in Patients

Duration of Diabetes	UTI positive n (%)	UTI negative n(%)	Total	P. value	Chi square Test
>10 years	2(28.6%)	20(46.5%)	22(44)	0.37	0.13
< 10 years	5(71.4%)	23(53.5%)	28(56)		

Urinary tract infections in diabetic patients and the type of diabetes treatment they receive

According to the findings, about 28.6% of patients with UTIs were taking oral diabetes medication, and approximately 71.4% were receiving injectable diabetes medication. In contrast, about 72.1% of patients without UTIs were taking oral medication, and approximately 27.9% were receiving injectable medication. As seen in Table 7.

Table:(7). Urinary tract infections in diabetic patients and the type of diabetes treatment they receive

Type of medicine for Diabetes	UTI positive n (%)	UTI negative n (%)	Total	P. value	Chi square Test
Tablet	2(28.6%)	31(72.1%)	33(66)	0.02*	0.32
Injection	5(71.4%)	12(27.9%)	17(34)		

*Significant differences

The Relationship Between Diabetic Patients' Blood Pressure and Urinary Tract Infections

The findings indicated that 18.8% of people without urinary tract infections had high blood pressure, while approximately 81.4% did not, and that 28.6% of patients with urinary tract infections had high blood pressure, while approximately 71.4% did not. As showed in Table 8.

Table:(8). The Relationship Between Diabetic Patients' Blood Pressure and Urinary Tract Infections

Blood presser	UTI positive n (%)	UTI negative n (%)	Total	P. value	Chi square Test
Yes	2 (28.6%)	8(16.8%)	10 (20)	0.54	0.09
No	5(71.4%)	35(81.4%)	40(80)		

Urinary tract infections with marital status in patients with diabetes

The findings revealed that although 79.1% of diabetic patients without infections were married, 11.6% were single, 2.3% were divorced, and 7% were widowed, around 100% of those with UTIs

were married, and 0% were single, divorced, or widowed. As showed in Table 9.

Table:(9). Urinary tract infections with marital status in patients with diabetes

Marital Status	UTI positive n (%)	UTI negative n (%)	Total	P. value	Chi square Test
Married	7(100%)	34(79.1%)	41(82)	0.61	0.19
Un married	0	5(11.6%)	5(100)		
Divorced	0	1(2.3%)	1(2)		
Widow	0	3(7%)	3(6)		

Blood glucose levels in diabetic patients with and without urinary tract infections are related: Based on the data, we discovered that patients with UTIs had lower fasting blood glucose (FBS) levels than patients without UTIs, whose median FBS was 147 (114–202), with a median value of 139 (124–197). As showed in Table 10.

Table:(10). Blood glucose levels in diabetic patients with and without urinary tract infections are related

Variable	UTI positive	UTI negative	Total	P. value	Chi square Test
Fasting blood sugar	139(124-197)	147(114-202)	143(114-200)	0.70	136.50

DISCUSSION

Urinary tract infections (UTIs) are thought to be associated with diabetes, and it is widely known that individuals with diabetes have a higher risk of UTI complications and that the urinary system is the predominant site of infection. In recent years, UTIs have been identified as one of the diseases contributing to the growing cost burden on the healthcare system. UTIs are highly prevalent in individuals with diabetes globally. (Sarafidis et al., 2020). Additionally, data indicates that UTIs are the most prevalent type of bacterial infection in diabetics. (Nitzanoe et al., 2015).

This study aimed to identify the bacteria causing urinary tract infections in urine samples from diabetes patients, determine the bacteria's antibiotic sensitivity and resistance, and evaluate the influence of specific risk factors on infection. Fifty patients with diabetes who were regular visitors to the Al-Kafa'a Laboratory in the Al-Qardah Al-Shatti area participated in this study.

The findings, which indicated that 14% of diabetic patients had UTIs while 86% of diabetic patients did not, are in line with the findings of three studies carried out in Ethiopia, which found that 14% of diabetic patients had UTIs. (Feleke et al., 2007) and 13.8% (Nigussie, 2017). Additionally, our study's findings were comparable to those of two other studies: one in Ethiopia that indicated a prevalence of 17.8% and another in India that found a prevalence of 17.5% among diabetes patients (Laway et al., 2021). (Gizaehew et al., 2012). Nevertheless, this study's findings were at contrast with a study carried out in Egypt, where urinary tract infections were highly common—about 51.3%. (Dalia et al., 2020). The prevalence was 39.3% in a Saudi Arabian study (Anas et al., 2023), 35% in a Kuwaiti study (Sewify et al., 2016), and 68% in a Sudanese study (Hamdana et al., 2015). Urinary tract infections are less common in diabetes individuals, with prevalences of 9.7% in the US (Nichol et al., 2023), 11.6% in Addis Ababa (Assefa et al., 2008), and 11% in China, according to other studies. (Hek et al., 2018).

Neuropathy in the autonomic nerve system, which results in reduced bladder function, incomplete bladder emptying, and urine stasis—creating an environment conducive to bacterial growth—may be the cause of the higher prevalence of UTIs in diabetic patients (Yus et al., 2014).

Patients with diabetes also have immune dysfunction, including decreased levels of prostaglandin E, thromboxane B2, leukotriene B4, and T-cell-mediated immune response, as well as impaired white blood cell adhesion, chemotaxis, and phagocytosis. These conditions increase the risk of infection in general and urinary tract infections in particular. Furthermore, increased urine glucose levels foster the growth of germs.

The P-value in this study was more than 0.05, indicating that there was no correlation between the incidence of urinary tract infections and age. These results are in line with those of a study carried out in Chennai, India, which also discovered no association between age and the frequency of UTIs (Kothai et al., 2018). Additionally, they are consistent with the results of two Saudi Arabian research (Alrubeaan et al., 2013) and (Boyko EJ et al., 2002; Borouman et al., 2006). The results of this investigation were also different from those of the research done by Tektook et al. (2017) in Baghdad and Dalia in Egypt (Dalia et al., 2020), where the findings showed a significant association between the frequency of UTIs and age.

Based on the gender variable, we discovered that the prevalence of UTIs among diabetes patients was 71.4% higher in women than in men, who had a frequency of 28.6%. The results of our study were consistent with those of many other studies, including one conducted in Egypt (Dalia et al., 2020), where the prevalence in women was 54% compared to 45% in men. They also align with the results of studies conducted in both Iraq (Tektook et al., 2017) and Saudi Arabia (Al-Rubeaan et al., 2013), as well as the study by Abdulla et al. (2015) 2015) and a number of international studies (Jaspan et al., 1997; Osullivan DJ et al., 1969; Vejlsaard et al., 1966). It is also consistent with the study conducted in India (Kothai et al., 2018).

Because women's urethras are anatomically shorter than males', urinary tract infections are more common in females than in males. Furthermore, urinary tract infections can be easily caused by bacteria that move from the rectum to the urethra (Njunda Al et al., 2012). The incidence of UTIs is also higher in females than in males due to risk factors like pregnancy, frequent sexual activity, a small urethra, and bacterial colonization of the perineal area, including S. aureus and E. coli (Pargavib et al., 2011). The increased incidence of urinary tract infections in females compared to males may also be caused by low levels of the natural Lactobacillus bacteria, a drop in the pH of the vaginal surface, poor personal hygiene, a small urethra, and proximity to the anus. (Anas 2023).

According to the findings of this study, E. coli accounted for 71.4% of urinary tract infections in diabetes individuals, whereas Klebsiella accounted for 28.5%. The results of this study are in line with numerous previous studies, such as one by Dalia et al. (2020), which discovered that E. coli and Klebsiella were the most frequent bacteria causing UTIs in diabetic individuals. Additionally, these results align with research conducted in Ethiopia (Mohammedaman et al., 2019), India (Kthai et al., 2018), Boyko et al. (2002), and Janifer et al. (2009) (Papazafiropoulou et al., 2010). Additionally, they agree with the findings of studies carried out in Iraq (Heyam Emad et al., 2022), eastern Libya (Eisa Omar, 2021), Greelings SG., 2008, and Abdulla MC et al., 2015. One of the most prevalent bacterial species that cause urinary tract infections in both diabetes and non-diabetic people is E. coli.

According to Eto Ds et al. (2007), the increased prevalence of E. coli is explained by the fact that the bacterium is a normal resident of the gut and that poor personal hygiene can also result in fecal contamination. Additionally, the bacteria's unique structure makes it easier for it to invade the epithelial cells lining the urinary tract and keeps it from being flushed out with urine.

Urinary tract infections were more common in patients with type 2 diabetes (85.7%) than in those

with type 1 diabetes (14.3%), according to this study. These results are in line with a study done in Egypt by Dalia et al. (2020), which found that 46.5% of people had type 1 diabetes and 93.35% had type 2. They are also consistent with another study carried out in Egypt (Adly et al., 2015), which discovered that E. coli was the most often isolated bacterium from urine samples and that the prevalence of urinary tract infections was 77.7% in type 2 diabetes and 64.2% in type 1 diabetes.

Urinary tract infections are more common in people who have had diabetes for more than ten years (71.4% of cases) than in those who have had diabetes for less than ten years (28.6%). These results are in line with those of Dalia et al. (2020), who discovered that the prevalence of UTIs was 27.27% in patients with diabetes for less than ten years and 72.7% in those with diabetes for more than ten years. Additionally, our study's findings are in agreement with those of Abdulla et al. (2015), who discovered that individuals with diabetes for more than ten years had a higher risk of UTIs than those with diabetes for less than ten years.

The findings of this study contrast those of a study by Al-Rubeaan et al. (2013), which discovered that patients' risk of urinary tract infections is unaffected by the duration of their diabetes.

The long-term effects of diabetes on the immune system and autonomic nervous system, as well as bladder and peripheral neuropathy and renal papillary necrosis, are thought to be the cause of urinary tract infections in patients with chronic diabetes. (Nawa Z M., 2008).

Patients in this study were categorized as married, single, divorced, or widowed based on their marital status. Married people had the highest prevalence of UTIs (100%). The findings of this study were in accordance with a study carried out in Saudi Arabia by Anas Elyas et al., 2023, which found that married people had the greatest incidence of UTIs.

Patients in this study were divided into two groups according to their body mass index (BMI): those with a BMI of less than 30 and those with a BMI of more than 30. 57.1% of those with urinary tract infections had a BMI of less than 30, whereas 42.9% had a BMI of more than 30. The findings of this study were at contrast with those of a study carried out in Saudi Arabia (Anas et al., 2023), which discovered that 52.5% of individuals with diabetes had a BMI of more than 30 and 36% had a BMI of less than 30. Diabetic patients in this study were divided into two groups according to the type of diabetes treatment they were receiving: oral medicine and insulin injections. According to our study, 21.4% of patients received insulin injections, whereas 28.6% of patients took oral medication. (Anas et al., 2023).

Additionally, the patients were divided into two groups according to whether or not they had hypertension: those with hypertension (28.6%) and those without (71.4%). These findings were consistent with those of Anas et al. (2023), who found that 16.6% of participants had high blood pressure and 52.4% did not. We suggest carrying out a larger investigation with more diabetic individuals.

CONCLUSION

14% of patients with diabetes had a UTI. With the exception of the type of diabetes treatment, which was statistically significant, other risk factors were not significantly linked to UTIs. E. Coli and Klebsiella were the most frequently isolated microbes, in that order. According to this study, appropriate diabetic management requires routine HBA1c and infection screening, particularly for UTIs. Based on the results of the culture, patients should be informed about the proper usage of antibiotics. It is necessary to implement a stewardship program to justify the usage of antibiotics.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to the entire personnel of Al-Kafa'ah Laboratory in Al-Qardah Al-Shatti.

Duality of interest: Regarding this manuscript, the authors declare that they have no conflicting interests.

Author contributions: Fatima, Nawal, Aisha, Hanin. developed the theoretical formalism, performed the analytic calculations and performed the numerical simulations. Halemah contributed to the final version of the manuscript. Halemah, Asma and Khalid. supervised the project.

Funding: No specific funding was received for this work.

REFERENCES

Geerlings, S. E., & Hoepelman, A. I. (1999). Immune dysfunction in patients with diabetes mellitus (DM). *FEMS immunology and medical microbiology*, *26*(3-4), 259–265. https://doi.org/10.1111/j.1574-695X.1999.tb01397.x

Geerlings, S. E., Brouwer, E. C., Gaastra, W., Verhoef, J., & Hoepelman, A. I. M. (1999). Effect of glucose and pH on uropathogenic and non-uropathogenic Escherichia coli: studies with urine from diabetic and non-diabetic individuals. *Journal of medical microbiology*, *48*(6), 535–539. https://doi.org/10.1099/00222615-48-6-535

Geerlings, S. E., Stolk, R. P., Camps, M. J., Netten, P. M., Collet, T. J., Hoepelman, A. I., & Diabetes Women Asymptomatic Bacteriuria Utrecht Study Group (2000). Risk factors for symptomatic urinary tract infection in women with diabetes. *Diabetes care*, *23*(12), 1737–1741. https://doi.org/10.2337/diacare.23.12.1737

Abdulla, M. C., Jenner, F. P., & Alungal, J. (2015). Urinary tract infection in type 2 diabetic patients: risk factors and antimicrobial pattern. *International Journal of Research in Medical Sciences*, 3(10), 2576–2579. https://doi.org/10.18203/2320-6012.ijrms20150793

Adly, N., Ragab, Y., Hashem, A., & Ahmady, A. (2015). Effect of diabetes on occurrence of urinary tract infection and asymptomatic bacteriuria among diabetic and ketoacidosis patients in Egypt. *Int Res J Microbiol*, *6*, 27-36. https://doi.org/http:/dx.doi.org/10.14303/irjm.2015.139

Al-Rubeaan, K. A., Moharram, O., Al-Naqeb, D., Hassan, A., & Rafiullah, M. R. (2013). Prevalence of urinary tract infection and risk factors among Saudi patients with diabetes. *World journal of urology*, *31*(3), 573–578. https://doi.org/10.1007/s00345-012-0934-x

Ahmed, A. E., Abdelkarim, S., Zenida, M., Baiti, M. A. H., Alhazmi, A. A. Y., Alfaifi, B. A. H., Majrabi, R. Q. M., Khormi, N. Q. M., Hakami, A. A. A., Alqaari, R. A. M., Alhasani, R. A., Alajam, R. A., Alshehri, M. M., Alenazi, A. M., Alqahtani, B., Alshamrani, M., Alhowimel, A., & Abdelwahab, S. I. (2023). Prevalence and Associated Risk Factors of Urinary Tract Infection among Diabetic Patients: A Cross-Sectional Study. *Healthcare (Basel, Switzerland)*, *11*(6), 861. https://doi.org/10.3390/healthcare11060861

Assefa, A., Asrat, D., & Woldeamanuel, Y. (2008). G/Hiwot Y, Abdella A, Melesse T. Bacterial profile and drug susceptibility pattern of urinary tract infection in pregnant women at Tikur Anbessa Specialized Hospital Addis Ababa, Ethiopia. *Ethiop Med J*, *46*(3), 227-235.

Boroumand, M. A., Sam, L., Abbasi, S. H., Salarifar, M., Kassaian, E., & Forghani, S. (2006). Asymptomatic bacteriuria in type 2 Iranian diabetic women: a cross sectional study. *BMC women's health*, *6*, 4. https://doi.org/10.1186/1472-6874-6-4

Boyko, E. J., Fihn, S. D., Scholes, D., Chen, C. L., Normand, E. H., & Yarbro, P. (2002). Diabetes and the risk of acute urinary tract infection among postmenopausal women. *Diabetes care*, *25*(10), 1778–1783. https://doi.org/10.2337/diacare.25.10.1778

Boyko, E. J., Fihn, S. D., Scholes, D., Chen, C. L., Normand, E. H., & Yarbro, P. (2002). Diabetes and the risk of acute urinary tract infection among postmenopausal women. *Diabetes care*, *25*(10), 1778–1783. https://doi.org/10.2337/diacare.25.10.1778

Cheesbrough, M. (2006). *District laboratory practice in tropical countries* (Vol. 2). Cambridge university press, South Africa, 1-434.

Dalia E. Desouky, Hala M. Gabr, Mohammed El-Helbawy, and Hanan M. Hathout. (2020). Urinary Tract Infection: Prevalence, Risk Factors, Bacterial Etiologies and Antimicrobial Resistance Profile among Egyptian Diabetic Patients: Urinary Tract Infection: Prevalence, Risk Factors, Bacterial Etiologies and Antimicrobial Resistance Profile among Egyptians. (2020). *European Journal of Medical and Health Sciences*, 2(4). https://doi.org/10.24018/ejmed.2020.2.4.390

Eisa S Omar (2021). Comparative Study: The Incidence of Urinary Tract Infection in diabetic Patients in the Eastern Region of Libya and their Antibiotics Sensitivity Pattern, *Sirte University Scientific Journal (Applied Sciences)*, 11 (2), https://doi.org/10.37375/susj.v11i2.811

Eto, D. S., Jones, T. A., Sundsbak, J. L., & Mulvey, M. A. (2007). Integrin-mediated host cell invasion by type 1-piliated uropathogenic Escherichia coli. *PLoS pathogens*, *3*(7), e100. https://doi.org/10.1371/journal.ppat.0030100

Feleke, Y., Mengistu, Y., & Enquselassie, F. (2007, 2007/04//). Diabetic infections: clinical and bacteriological study at Tikur Anbessa Specialized University Hospital, Addis Ababa, Ethiopia. *Ethiopian medical journal*, *45*(2), 171-179. http://europepmc.org/abstract/MED/17642174

Forbes, B. A., Sahm, D. F., Weissfeld, A. S., & Bailey, W. R. (2007). *Bailey & Scott's diagnostic microbiology* (12th ed.). Elsevier Mosby.

Foxman, B. (2014) Urinary Tract Infection Syndromes: Occurrence, Recurrence, Bacteriology, Risk Factors, and Disease Burden. Infectious Disease Clinics of North America, 28, 1-13. https://doi.org/10.1016/j.idc.2013.09.003

Geerlings S. E. (2008). Urinary tract infections in patients with diabetes mellitus: epidemiology, pathogenesis and treatment. *International journal of antimicrobial agents*, *31 Suppl 1*, S54–S57. https://doi.org/10.1016/j.ijantimicag.2007.07.042

Yismaw, G., Asrat, D., Woldeamanuel, Y., & Unakal, C. (2012, 01/01). Urinary Tract Infection: Bacterial etiologies, drug resistance profile and associated risk factors in diabetic patients attending Gondar University Hospital, Gondar, Ethiopia. *European Journal of Experimental Biology*, *2*, 889-898.

Hamdan, H. Z., Kubbara, E., Adam, A. M., Hassan, O. S., Suliman, S. O., & Adam, I. (2015). Urinary tract infections and antimicrobial sensitivity among diabetic patients at Khartoum, Sudan. *Annals of clinical microbiology and antimicrobials*, *14*, 26. https://doi.org/10.1186/s12941-015-0082-4

He, K., Hu, Y., Shi, J. C., Zhu, Y. Q., & Mao, X. M. (2018). Prevalence, risk factors and microorganisms of urinary tract infections in patients with type 2 diabetes mellitus: a retrospective study in China. *Therapeutics and clinical risk management*, *14*, 403–408. https://doi.org/10.2147/TCRM.S147078

Al Qurabiy, H. E., Abbas, I. M., Hammadi, A. A., Mohsen, F. K., Salman, R. I., & Dilfy, S. H. (2022). Urinary tract infection in patients with diabetes mellitus and the role of parental genetics in the emergence of the disease. *Journal of medicine and life*, *15*(8), 955–962. https://doi.org/10.25122/jml-2021-0331

Janifer, J., Geethalakshmi, S., Satyavani, K., & Viswanathan, V. (2009). Prevalence of lower urinary tract infection in South Indian type 2 diabetic subjects. *Indian journal of nephrology*, *19*(3), 107–111. https://doi.org/10.4103/0971-4065.57107

Alebiosu, C. O., Osinupebi, O. A., & Olajubu, F. A. (2003). Significant asymptomatic bacteriuria among Nigerian type 2 diabetics. *Journal of the National Medical Association*, *95*(5), 344–349.

Gnanamoorthy, K., R, V., & Suthakaran, P. K. (2018, 07/04). Clinical and Microbiological Profile of Urinary Tract Infections in Diabetic Patients. *Journal of Evidence Based Medicine and Healthcare*, *5*, 2110-2112. https://doi.org/10.18410/jebmh/2018/437

Klein, R. D., & Hultgren, S. J. (2020). Urinary tract infections: microbial pathogenesis, host-pathogen interactions and new treatment strategies. *Nature reviews. Microbiology*, *18*(4), 211–226. https://doi.org/10.1038/s41579-020-0324-0

Laway, B. A., Nabi, T., Bhat, M. H., & Fomda, B. A. (2021). Prevalence, clinical profile and follow up of asymptomatic bacteriuria in patients with type 2 diabetes-prospective case control study in Srinagar, India. *Diabetes & metabolic syndrome*, *15*(1), 455–459. https://doi.org/10.1016/j.dsx.2020.12.043

Mama, M., Manilal, A., Gezmu, T., Kidanewold, A., Gosa, F., & Gebresilasie, A. (2018). Prevalence and associated factors of urinary tract infections among diabetic patients in Arba Minch Hospital, Arba Minch province, South Ethiopia. *Turkish journal of urology*, *45*(1), 56–62. https://doi.org/10.5152/tud.2018.32855

Nawaz, M., Khan, A. A., Khan, S., Sung, K., & Steele, R. (2008). Isolation and characterization of tetracycline-resistant Citrobacter spp. from catfish. *Food microbiology*, *25*(1), 85–91. https://doi.org/10.1016/j.fm.2007.07.008

Nichols, G. A., Brodovicz, K. G., Kimes, T. M., Déruaz-Luyet, A., & Bartels, D. B. (2017). Prevalence and incidence of urinary tract and genital infections among patients with and without type 2 diabetes. *Journal of diabetes and its complications*, *31*(11), 1587–1591. https://doi.org/10.1016/j.jdiacomp.2017.07.018

Nigussie, D., & Amsalu, A. (2017). Prevalence of uropathogen and their antibiotic resistance pattern among diabetic patients. *Turkish journal of urology*, *43*(1), 85–92. https://doi.org/10.5152/tud.2016.86155

Nitzan, O., Elias, M., Chazan, B., & Saliba, W. (2015). Urinary tract infections in patients with type 2 diabetes mellitus: review of prevalence, diagnosis, and management. *Diabetes, metabolic syndrome and obesity : targets and therapy*, *8*, 129–136. https://doi.org/10.2147/DMSO.S51792

Nitzan, O., Elias, M., Chazan, B., & Saliba, W. (2015). Urinary tract infections in patients with type 2 diabetes mellitus: review of prevalence, diagnosis, and management. *Diabetes, metabolic syndrome and obesity : targets and therapy*, *8*, 129–136. https://doi.org/10.2147/DMSO.S51792

L. Njunda, A., C. Assob, N., D. Nsagha, S., P. Nde, F., L. Kamga, F., F. Nkume, A., E. Kwenti, T., & F. Nkume, A. (2012). Uropathogens from diabetic patients with asymptomatic bacteriuria and Urinary tract infections. *Scientific Journal of Microbiology*, 1(6), 141-146. Retrieved from https://sjournals.com/index.php/sjm/article/view/1408

O'sullivan, D. J., Fitzgerald, M. G., Meynell, M. J., & Malins, J. M. (1961). Urinary tract infection. A comparative study in the diabetic and general populations. *British medical journal*, *1*(5228), 786–788. https://doi.org/10.1136/bmj.1.5228.786

Papazafiropoulou, A., Daniil, I., Sotiropoulos, A., Balampani, E., Kokolaki, A., Bousboulas, S., Konstantopoulou, S., Skliros, E., Petropoulou, D., & Pappas, S. (2010). Prevalence of asymptomatic bacteriuria in type 2 diabetic subjects with and without microalbuminuria. *BMC research notes*, *3*, 169. https://doi.org/10.1186/1756-0500-3-169

Pargavi, B., Mekala, T., Selvi, A. T., & Moorthy, K. (2011). Prevalence of urinary tract infection (UTI) among diabetics patients in Vandavasi, Tamil Nadu, India. *Int J Bio Tech*, *2*, 42-45.

Sarafidis, P. A., & Ortiz, A. (2019). The risk for urinary tract infections with sodium-glucose cotransporter 2 inhibitors: no longer a cause of concern?. *Clinical kidney journal*, *13*(1), 24–26. https://doi.org/10.1093/ckj/sfz170

Sewify, May, Nair, Shinu, Warsame, Samia, Murad, Mohamed, Alhubail, Asma, Behbehani, Kazem, Al-Refaei, Faisal, Tiss, Ali, Prevalence of Urinary Tract Infection and Antimicrobial Susceptibility among Diabetic Patients with Controlled and Uncontrolled Glycemia in Kuwait, *Journal of Diabetes Research*, 2016, 6573215, 7 pages, 2016. https://doi.org/10.1155/2016/6573215

Tektook, N. K., Al-Lehibi, K. I., & Al-Husseinei, R. K. (2017). Prevalence Some Pathogenic Bacteria Causing UTI in Diabetic Patients In / Specialized Center For Endocrinology and Diabetes of Baghdad City–Iraq. *Medical Journal of Babylon*, *14*, 260-266. https://doi.org/https://doi.org/10.25271/sjuoz.2019.7.4.629

Vejlsgaard R. (1966). Studies on urinary infection in diabetics. I. Bacteriuria in patients with diabetes mellitus and in control subjects. *Acta medica Scandinavica*, *179*(2), 173–182.

Yu, S., Fu, A. Z., Qiu, Y., Engel, S. S., Shankar, R., Brodovicz, K. G., Rajpathak, S., & Radican, L. (2014). Disease burden of urinary tract infections among type 2 diabetes mellitus patients in the U.S. *Journal of diabetes and its complications*, *28*(5), 621–626. https://doi.org/10.1016/j.jdiacomp.2014.03.012