

NARRATIVE REVIEW

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Scoping review on managing the bladder and preventing urinary tract infections (UTIs) in athletes with spinal cord injuries

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Abstract

Background This research aimed to identify evidence-based protocols for the safe management of bladder infections and the prevention of UTIs in athletes who have spinal cord injuries (SCI), as they are constantly at high risk of developing UTIs again.

Study design Scoping review

Methodology Four databases were searched (PubMed, Scopus, Web of Science, and Science Direct) for pertinent literature. The non-randomized controlled studies (non-RCT) and randomized controlled trials (RCT) that described the application of any particular measure to properly manage bladder and avoid urinary tract infections (UTIs) in people with spinal cord injuries (SCIs) were chosen.

Results Forty-nine articles were screened for the effectiveness of weekly oral cyclic antibiotics, bacterial interference, coated catheter types, and patient education in preventing UTIs in SCI were shown in 20 RCT and 29 non-RCT researches. Concerns were raised about cranberry supplements and low-dose antibiotic prophylaxis, which is unreliable and leads to the emergence of germs that are resistant to many drugs.

Conclusion According to the scoping review, WOCA is the most effective antibiotic regimen. The proven methods for treating UTIs in SCI patients include coated catheters, bacterial interference, bladder irrigation, and patient education. Moreover, there is a great deal of variation in the research about the efficacy of cranberries. The best option for safe bladder management and preventing UTIs in SCIs is to use suprapubic and coated intermittent catheters (ICs). When a urine bag is full, it should be changed out for a fresh one, and patients should be told to employ spontaneous voiding if that's not an option.

Keywords Bladder control, Intermittent catheter (IC), Prevention, SCI, UTI

Positioning

This research paper presents a comprehensive study on bladder care and UTI prevention in athletes with spinal cord injuries (SCI) [1]. UTIs are a common and long-lasting issue, affecting the quality of life and financial burden. Athletes with SCI are also susceptible to chronic UTIs due to their sports lifestyle, travel, and bladder control practices [2, 3]. The choice of catheters for bladder management depends on the degree of SCI. Some people support using cranberry tablets to reduce UTI symptoms, but there is a lack of evidence [4]. Probiotics and other

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dietary strategies can also help lower the risk of UTIs. Antibiotic resistance is linked to recurrent UTIs, and the treatment of persistent UTIs is threatened by this resistance [5, 6]. The scoping study aims to find online data to develop evidence-based recommendations for safe bladder management and UTI prevention in SCI athletes [7].

Introduction

The National Spinal Cord Injury Statistical Centre (NSCISC) reports that the USA experiences 17,700 instances of spinal cord injury (SCI) annually [2]. Urinary tract infections (UTIs) are more common in people with SCI, with clinically significant UTIs defined as having 105 bacteria/ml of recently passed urine [8]. Factors such as increased intravesical pressure, using catheters, and inadequate voiding exacerbate symptomatic UTIs. Frequent high-dose antibiotic use also contributes to the spread of infections [1].

UTIs are the primary source of morbidity for many SCI patients throughout their lifetimes [9]. Genitourinary sickness accounted for 7.6% of all illnesses and injuries sustained by athletes competing in the London 2012 Paralympic Games. UTIs are the most prevalent of all genitourinary issues [10, 11].

Safe bladder management is a top priority for those with spinal cord injuries. Disposable catheters, known as clean intermittent catheters (CICs), are the safest way to lower the risk of UTIs [12]. However, they can occasionally cause pain and discomfort and negatively affect patient satisfaction. Recurrent use of the same intermitter catheter (IC) by athletes from poor nations, like Brazil, Columbia, and South Africa, resulted in CA-UTI (Catheter-associated-UTI) [13, 14]. Athletes from wealthy countries, like the USA, Canada, and Sweden, did not reuse their catheters, but those who did experience three to four urinary tract infections annually [3].

Nutritional components to prevent UTIs, such as using cranberry juice or pills, have inconsistent research about their efficacy [15]. Methenamine salts, vitamin C, and D-mannose sugar are suggested as helpful in halting the growth of bacteria in the bladder. Additional evidence-based research is necessary to consider these components as effective dietary interventions [16, 17].

Travel to national and international championships is a common occurrence for professional SCI athletes, who purposefully dehydrate to reduce the need for catheterization while traveling [18]. A team physician's guidance should be followed when administering antibiotic prophylaxis, but the literature does not advise using antibiotic prophylaxis to treat UTIs in patients with SCI [5, 19].

The Australian Paralympic Position provides general guidelines for safe bladder management for athletes with SCI, but they do not address the use of probiotics,

bacterial interference, or different types of catheters to reduce the risk of UTIs [20, 21]. This scoping review aims to locate research based on RCT and non-RCT trials to identify safe bladder control strategies for athletes with SCI to avoid UTI.

Methodology

A systematic framework for conducting scoping reviews was established by Arksey and O'Malley [22]. The author of this scoping study carefully examined Arksey and O'Malley's recommendations, which outline a five-step procedure that begins with (1) identification of the research issue. (2) Locating pertinent research. (3) Study selection. (4) Data visualization; and 5) Outlining the findings. Additionally, Levac and colleagues' clarification of scoping review criteria [23] was taken into consideration when making comments to improve the quality of this scoping review. To preserve methodological transparency, PRISMA-Scr [24] reporting guidelines—which are the thing that systematic reviews prefer to report and the extension of meta-analysis for scoping reviews—were also adhered to.

Identification of research questions

Bladder control involves athletes using external devices like CIC and indwelling catheters to assist urination. Prevention involves medical and dietary interventions for UTI treatment and prevention. The research question aims to identify bladder management and UTI prevention strategies based on evidence to reduce UTI episodes in athletes with spinal cord injuries.

Locating pertinent research

Using the following set of keywords, four databases (PubMed, Scopus, Web of Science, and Science Direct) were searched for relevant literature on bladder, management/synonyms, prevention/synonyms, UTI, and spinal cord injuries.

Study selection

Following a search using the terms listed above. The completed search results were downloaded and then subjected to additional screening using the inclusion/exclusion criteria listed below.

Criteria for inclusion

- Studies, both controlled and uncontrolled, unequivocally state that individuals with neurogenic bladder syndrome (SCI) should utilize specific types of catheters, food supplements, or medications to regulate their bladders and avoid urinary tract infections.

Criteria for exclusion

- Research on animals
- Research that fails to provide a clear explanation of how a particular type of catheter, nutritional supplement, or medication is used to prevent or treat urinary tract infections in individuals with spinal cord injuries.
- Research articles written in languages other than English.
- Research that was done prior to 2000.
- Protocols for studies and research on children.
- Research on hospitalized patients' bladder care and UTI prevention.
- Research on UTI prevention in the fields of multiple sclerosis, stroke, geriatrics, and spina bifida.

After conducting the aforementioned keyword search and taking into account the basic search parameters, 535 research publications from all websites (PubMed, Scopus, Web of Science, and Science Direct) were found.

Data charting

Levac and colleagues recommend data charting for obtaining information from research. They suggest grouping retrieved studies into RCT and non-RCT groups for precise answers [23]. Each group details specific dietary guidelines, catheter designs, or antibiotic regimens to control bladder and prevent UTI bouts, as outlined in the final investigations.

Below is a flowchart that details the amount of articles and the literature choices.

Results collection and summarizing findings

Levac and associates proposed dividing the fifth stage into three sections: data analysis, results reporting, and result interpretation. They highlighted the importance of summary tables for research and careful examination of data [23]. The descriptive summary tables were divided into cohorts to address specific topics. This method helps develop recommendations for safe bladder management and UTI prevention for people with spinal cord injury. It also informs athletes with SCI and their carers about these guidelines to manage their bladder and prevent recurrent UTI bouts.

Data analysis

Identification and selection of study

(1) Medication measurements; (2) nutritional guidelines; (3) safe catheter type; (4) bacterial interference; and (5) the education of patients are the criteria used to group the studies. The research findings from RCT-based and non-RCT-based studies were to be compared. We have

split them into two distinct groups in order to better analyze and comprehend them. It would provide us with a clear understanding of evidence-based practice and help future researchers choose between an RCT and a non-RCT methodological approach when they conduct further research on evidence-based bladder management and UTI prevention techniques in individuals with spinal cord injury (Fig. 1).

Four hundred fifty-one studies did not meet the requirements for inclusion. The application of certain precautions to avoid UTIs or properly manage the bladder was not mentioned. Certain non-randomized controlled trials were eliminated due to their broad focus on UTIs and lack of participant recruitment or intervention implementation. Additional information regarding the excluded research is available in Table 1.

The following summary tables provide further details about the listed studies. There are distinct summary tables for RCT and non-RCT research.

Results

Medicinal measures to manage UTI in SCI

Eleven non-RCT studies and five RCTs looked into the usage of various antibiotic kinds and regimens to treat UTI in people with SCI. Below is a more detailed explanation of those measures (Tables 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11).

Weekly oral cyclic antibiotics: (WOCA)

Two antibiotics are alternately administered once a week as part of WOCA [10]. Four WOCA studies—3 non-randomized and 1 randomized—out of a total of 16 investigations demonstrated extremely encouraging outcomes of the WOCA regimen in the treatment of UTI in SCI without a discernible increase in the growth of multidrug-resistant bacteria. According to a 6-month RCT trial [10], WOCA was successful in treating UTI in patients with SCI. Three other non-RCT investigations, two of which were cross-sectional studies [45] and the other one was a prospective observational research [46, 47], yielded comparable results.

Bladder irrigation

To prevent the growth of bacterial colonies, bladder irrigation entails putting an antibiotic solution inside the bladder [44]. Three non-RCT studies were conducted, and the results of all three indicated that bladder irrigation is a safe and efficient way to reduce symptomatic UTI episodes in patients with SCI and that it effectively stopped the growth of bacterial colonies. Of these three investigations, one was a systematic review [41] and the other two were prospective clinical trials [44, 50]. These trials supported bladder irrigation with gentamicin [41], povidone-iodine [44], and chlorhexidine [50].

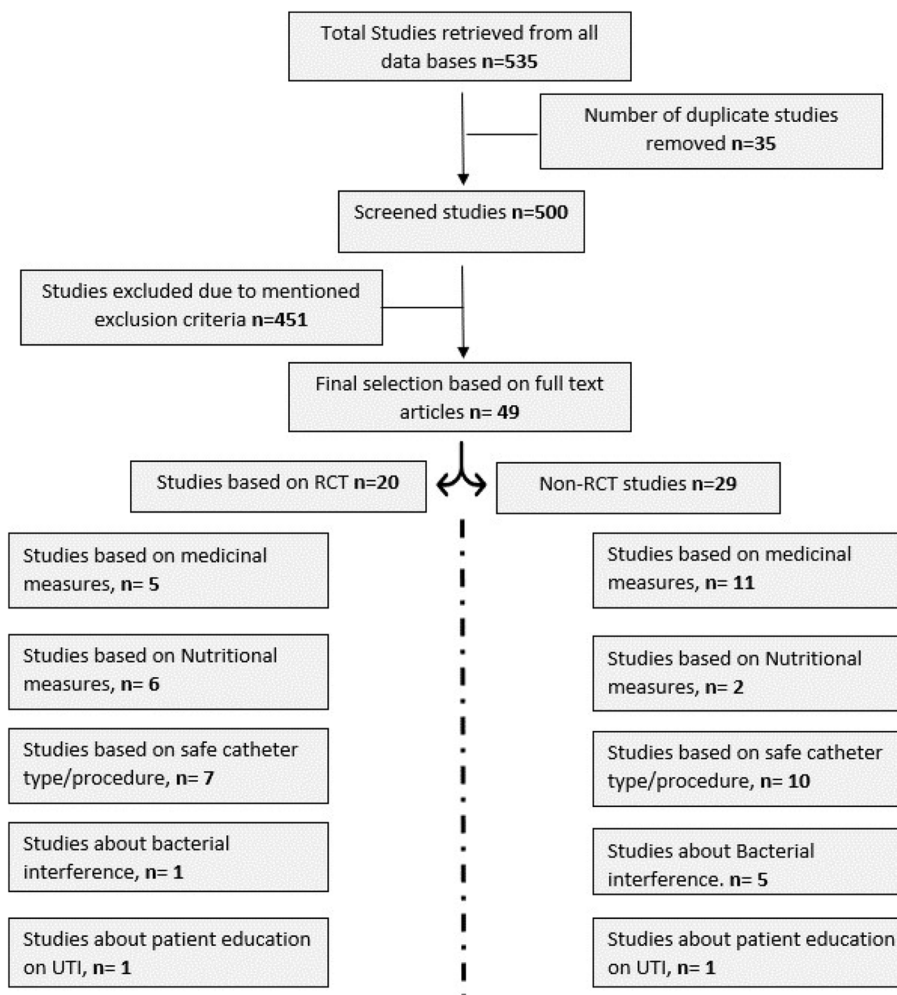


Fig. 1 Flow chart for selecting data

Antibiotics prophylaxis (ABP)

Continuous low-dose ABP was the basis of five studies to prevent UTI in people with SCI. Out of five studies, three recommended using trimethoprim, cephalexin, and nitrofurantoin as an ABP against UTIs in SCI [27, 42, 48]. However, these three investigations similarly came to the conclusion that multi-drug resistance bacteria were developed as a result of the prolonged ABP [27, 42, 48]. A non-RCT prospective observational investigation [40], the fourth trial in this group, found that ongoing low-dose ABP did not aid in the treatment of UTIs in SCI patients, but rather contributed to the development of antibiotic resistance. The systematic review [49] based on ABP was the fifth study. Additionally, this study came to the conclusion that the data do not support treating UTI in SCI with ABP. Another RCT [28] came to the conclusion that SCI patients’ UTI symptoms might be effectively alleviated by using methenamine and methylene blue.

Long vs short course of antibiotic regimen

Three trials [25, 26, 43] looked at the effectiveness of a long course of antibiotics versus a short course of antibiotics in treating UTI symptoms in people with spinal cord injuries. Regarding regimen selection, the results of these investigations were not entirely uniform. For the treatment of UTIs, one RCT research [26] found that a 14-day regimen including 250 mg of ciprofloxacin was more successful than a 3-day regimen, while another RCT research [25] found that both short course and long courses were equally beneficial. According to the results of a third non-RCT trial [43], treating a UTI with a brief course of antibiotics was successful. It is hard to draw firm conclusions regarding the effectiveness of a long-course versus short-course antibiotic regimen to prevent UTI in SCI due to the heterogeneity of the outcomes.

Table 1 The numbers and reasons for the exclusion of 451 studies

	No. of researches
Research on preventing urinary tract infections in older adults without spinal cord injury.	14
Research on Animals	12
Research on UTI in obstetrics and gynecology	30
Research on different languages other than English	07
Research on UTI having multiple sclerosis disease	11
Researches on UTI in pediatrics	48
Researches on urine culture and microbiology in UTI	76
Researches on research protocol introduction	04
Researches on bladder control during urinary retention	08
Researches on UTI in spina bifida	23
Researches on bladder control in kidney stones	09
Researches on UTI in stroke patients	07
Researches on bladder control during surgical procedures	25
Researches on UTIs in patients with diabetes	02
Researches on radiotherapy of bladder	03
Researches on UTI epidemiology	02
Researches for nurses on managing bladder and UTI awareness	07
Researches on UTI in the period of bladder cancer	11
Researches on UTI that did not give reasonable preventive guidelines	152
All the researches excluded on basis of exclusion criteria	451

Bacterial interference

In order to accomplish colonization, avirulent strains of bacteria are introduced into the bladder through bacterial interference, which is safe for human health [29]. Six investigations in all, including one RCT [29], four non-RCT clinical researches [52, 53, 55, 56], and one retrospective cohort research [54], were based on bacterial interference. Every study that used bacterial interference to treat UTIs in SCI patients had excellent outcomes. Five trials out of six found that *E. coli* strains (HU2117 and 83972) were very effective at colonizing the bladder and preventing UTIs from coming back [29, 52, 54–56]. Based on the application of *Lactobacillus rhamnosus* GG (LGG), the sixth trial [53] found that introducing LGG was both safe and effective in avoiding symptomatologic UTIs in people with SCI.

Program of education for people with SCI

One unique RCT investigation focused on the education of patients and SCI patients' knowledge of UTIs

[30]. This unique study found that following the instructional program, the experimental group had a significant decrease in UTI episodes. Written information regarding self-hygiene, general UTI introduction, and other crucial guidelines to prevent bacterial introduction in perineal areas were distributed to the experimental group. For half a year, this group was also contacted via phone. This study found that educational initiatives contributed to a decrease in UTI episodes. According to the findings of another non-RCT qualitative study [51], most catheter users were unsure of the symptoms and indicators of UTIs and were unsure of when to get medical attention. They also suggested creating a self-help book or booklet with basic UTI prevention advice for individuals with SCIs that is simple to read and comprehend [51].

Nutritional measures

There is a lack of consensus among dietary interventions to treat UTIs in spinal cord injury (SCI) patients. Two non-RCT studies and six RCTs have found inconsistent results [37]. One review disapproved of cranberry supplements, while another found them helpful [38]. There is also disagreement among RCT studies about the efficacy of cranberry therapy. One 6-month RCT found 400 mg of cranberry pills taken twice daily for six months to be highly effective in reducing UTI incidence in SCI patients [39]. Another 2-year RCT found that neither cranberry nor methenamine hippurate helped SCI patients' UTI symptoms [36]. A 4-week RCT refuted the efficacy of cranberry supplementation. Probiotics were also found to be incongruous in two RCTs [8]. One study found probiotics useful in treating UTIs in two SCI patients, while another found no benefit in 207 participants [9].

Catheter type/bladder management technique

Based on the kind of catheter and the method used to manage the bladder, there were seven RCTs and ten non-RCT studies. More information is provided below.

Coated vs non-coated intermittent catheters

Seventeen studies have examined bladder management in patients with spinal cord injuries using coated and non-coated catheters [31]. Results show that hydrophilic-coated intermittent catheters are more effective in preventing urinary tract infections (UTIs) and reducing UTI bouts [32]. However, hydrophilic-coated and non-coated PVC catheters are significantly inferior to gel-lubricated, non-hydrophilic catheters [33]. Silver hydrogel- and silver alloy-coated catheters are more effective than ordinary non-coated PVC catheters. Noble metal alloy-coated foley catheters are more successful than standard foley catheters without coating [35].

Table 2 Features of RCT research based on medical measures

Author, year, and country of research	Objectives of the research	SCI participants	Interventions/methodology	Outcome addressed by intervention/conclusion
Daoruice et al. (2014), USA [25]	To evaluate the efficiency of a brief course of antibiotics in treating CA-UTI in individuals with SCI	The persons with SCI with CA-UTI ($n = 61$). Experimental $n = 33$ Control $n = 28$	The experimental group was given a 5-day antibiotic treatment with catheter exchange while the control group was given a 10-day antibiotic regimen with catheter retention.	It was determined that the effectiveness of a 5-day antibiotic treatment with catheter exchange is equivalent to that of a 10-day regimen with catheter retention.
Dinh et al. (2019), France [10]	To evaluate the effectiveness of weekly oral cyclic antibiotic (WOCA) prophylaxis compared to no prophylaxis on recurrent UTI prevention in SCI people with IC	45 persons with SCI using IC, were randomized to two groups. Control $n = 22$, Experimental $n = 23$.	While the control group received no prophylaxis, the experimental group received self-IC and WOCA prophylaxis for a period of 6 months.	In individuals with SCI who were undergoing CIC and had neurogenic bladder, WOCA prophylaxis effectively avoided UTI. It is noteworthy that it did not result in the development of bacterial resistance within the nasal and stomach microbiota.
Dow et al. (2004), Canada [26]	To determine the effectiveness of ciprofloxacin for 3 days vs 14 days regimen in SCI patients suffering from lower UTI.	60 SCI patients suffering from UTI. Experimental $n = 30$, Control $n = 30$	The subjects were randomized via computer, with one group receiving either a placebo or 250 mg of ciprofloxacin orally b.i.d. for 11 days, while the other group received the medication for 3 days.	When treating symptomatic lower urinary tract infections in patients with spinal cord injury (SCI), a 14-day prescription of 250 mg of ciprofloxacin showed a substantial improvement over a 3-day regimen.
Fisher et al. (2018), UK [27]	To determine clinical potency and cost-effectiveness of continuous low-dose antibiotic prophylaxis to reduce the frequency of UTIs over 12 months in people doing CIC.	404 participants randomized to 2 groups, Experimental group $n = 203$, and control group $n = 201$	During a 12-month period, the experimental group received a daily low dose of antibiotic prophylaxis, while the control group did not receive any antibiotic prophylaxis.	The trial provided reliable proof of the preventative benefits of low-dose antibiotics for CIC patients. However, it is concerning that 12-month prophylaxis resulted in antibiotic resistance. This regimen was found to be financially feasible with only a little additional expenses.
Gama et al. (2020), Brazil [28]	To assess the efficacy of methenamine and methylene blue to avoid UTI in SCI.	A total of 288 SCI individuals were randomized into Group A, $n = 144$ and Group B = 144.	Group A= Methenamine 120 mg + methylene blue 20 mg vs group B=acriflavine 15 mg + methenamine 250 mg+ methylene blue 20 mg + Atropa belladonna 15 mg.	The symptoms of UTI were completely relieved in both urine antiseptic groups.

Table 3 Features of RCT research based on bacterial interference

Author, year, and country of research	Objectives of research	SCI participants	Interventions/methodology	Outcome addressed/conclusion
Darouiche et al. (2011), USA [29]	To assess the efficacy of bacterial intervention versus placebo in neurogenic bladder for the prevention of UTI	A 3:1 ratio was used to randomize 65 adult patients with neurogenic bladder and recurrent UTIs into two groups: experimental ($n = 50$) and control ($n = 15$).	Escherichia coli HU2117 was given to the experimental group, while sterile saline was given to the control group. Urine cultures were taken every week for 3 months, and then every month for a year. No one followed up.	This study demonstrated that giving individuals with SCI the E. Coli HU2117 strain effectively decreased their chance of developing a symptomatic UTI.

New vs old urine bag

It was shown in a quasi-experimental study that it is crucial to replace the pee bag whenever it becomes full [64]. Because used pee bags encourage the growth of bacterial colonies, which in turn lead to UTI symptoms [64]. Their investigation also found that in comparison to the conventional practice of emptying the urine bag, replacing the bags considerably decreased the prevalence of UTIs and bacteriuria [64].

Different types of catheters and UTI incidence

The type of catheter used significantly impacts the frequency of urinary tract infections (UTIs) [48]. Those with SCI who practice spontaneous voiding are less likely to have UTIs compared to indwelling catheter users [50]. Intermittent catheterization (IC) users have a lower incidence of UTIs compared to indwelling catheter users. Supra-pubic catheters are linked to a reduced incidence of UTIs. Intermittent catheterization also reduces bladder emptying, as leftover pee encourages bacterial colon growth, worsening UTIs [27].

Discussion

The scoping review on bladder control and UTI prevention in spinal cord injury patients found agreement on prescription medication and antibiotic regimens. The WOCA regimen and bladder irrigation showed promise, supported by RCT and non-RCT trials. [10]. It is not advised to administer the same antibiotic to these populations for an extended period of time due to the risk of multidrug-resistant bacteria [49, 69]. Antibiotic resistance is a major global issue that threatens the prevention of highly contagious diseases [11, 70]. Our scoping analysis revealed a similar pattern, with multiple studies concluding that low-dose antibiotic prophylaxis contributed to the development of significant antibiotic resistance while not helping to control UTIs in SCI [27, 40, 42, 48].

Recurrent UTIs in SCI are caused by bacterial colonies adhering to the bladder wall as a result of UTIs [71, 72]. These bacterial colonies develop resistance to a variety of available antibiotics as a result of sustained antibiotic

administration [34]. Bladder irrigation has been a popular method to lower bacteriuria in patients with SCI since the 1960s, and it is a safe substitute for conventional antibiotics for this reason [73, 74]. Using antiseptics such as povidone-iodine, chlorhexidine, and neomycin to wash the bladder is known as bladder irrigation [75]. Research indicates that when it comes to managing UTIs in SCI patients, bladder irrigation is more effective than conventional antibiotic prophylaxis (ABP) [74, 76]. This scoping review on bladder irrigation came to similar conclusions [41, 44, 50]. A systematic review [41], two prospective clinical trials [44, 50], and other researches supported the effectiveness of gentamicin [41], povidone-iodine [44], and chlorhexidine [50] in irrigation of bladder for the treatment of UTIs in the SCI patients.

The current body of research indicates that there is disagreement on whether short-term (< 10 days) or long-term (> 10 days) antibiotic regimens are more effective in treating symptomatic UTIs in people with spinal cord injuries [26, 77–79]. Our scoping assessment yielded comparable results for the length of vs. short course of several antibiotic kinds [25, 26, 43]. We are unable to identify the major antibiotic regimen for treating symptomatic UTIs in individuals with SCI due to uncertainties over the effectiveness of a particular regimen. E. Coli HU2117 and 83972 are bacterial strains that are commonly used for this purpose, particularly to treat symptomatic UTIs in SCI [52]. The effectiveness of bacterial interference in treating symptomatic UTIs in SCI has been well-proven in earlier research [80–82]. In patients with SCI, the avirulent strain of *E. coli* 83,972 has proven to be highly successful in colonizing the bladder and preventing UTIs [83]. Promising outcomes for bacterial interference without major negative effects were also observed in our scoping assessment.

A crucial component of any healthcare rehabilitation program is patient education. Simple-to-understand instructions on how to prevent different chronic diseases are the main focus of patient education [84]. Additionally, the significance of this strategy lies in its ability to

Table 4 Features of RCT research based on an educational program for people with SCI

Author, year, and country of research	Objectives of research	SCI participants	Interventions/methodology	Outcome addressed/conclusion
Cardenas et al. (2004), USA [30]	To assess the claim that educational initiatives assist in lowering the incidence and severity of UTIs in individuals with SCI.	56 adult participants were randomized into two groups: a control group (n = 27) and an experimental group (n = 29).	The experimental group was provided with a handbook detailing safe and sanitary methods for managing their bladders, instructions for caring for catheters, advice on maintaining good perineal cleanliness, and a weekly phone call for questions and answers.	The amount of microorganisms in the SCI patient's urine was considerably lower after this educational trial. Additionally, it lessened symptomatic recurring UTI bouts.

Table 5 Features of RCT research based on catheter type or bladder management technique

Author, year, and country of research	Objectives of research	SCI participants	Interventions/methodology	Outcome addressed/conclusion
Bonfill et al. (2017), Spain [31]	To assess silver alloy coated catheters' (SAC) effectiveness in preventing CA-UTI.	There were 246 patients in the control group and 243 in the experimental group out of 489 SCI patients.	Catheters coated with silver alloy were employed by the experimental group, while regular catheters were used by the control group.	The results of this investigation showed that the incidence of symptomatic UTI is not decreased by (SAC) catheters.
Cardenas et al. (2009), USA [32]	To study the efficacy of hydrophilic catheters to lower the incidence of symptomatic UTI in persons with SCI.	56 SCI adults were randomized to experimental $n = 28$, and control group $n = 28$	While the control group employed normal catheters, the experimental group received LoFric® hydrophilic catheters.	Compared to the control group the experimental group received fewer UTI treatments, although the number of UTI encounters was the same for both groups.
Cardenas et al. (2011), USA [33]	To compare the effectiveness of normal non-coated catheters for intermittent catheterization to hydrophilic coated ICs in reducing the incidence of symptomatic UTI in acute SCI.	A total of 224 participants with SCI were randomized to 2 groups, Experimental $n = 108$, and control group $n = 116$	While the control group employed uncoated regular PVC catheters, the experimental group received hydrophilic coated catheters, called SpeediCath®.	When patients with acute SCI use SpeediCath® for IC, patient satisfaction increases and the onset of the first symptomatic UTI is delayed.
De Ridder et al. (2005), Belgium [4]	To evaluate the effectiveness of the standard uncoated PVC catheter versus the hydrophilic catheter SpeediCath® in patients with SCI	123 adults with SCI were randomized into two groups: the experimental group ($n = 61$) and the control group ($n = 62$).	While the control group used a typical uncoated PVC catheter as an IC for a year, the experimental group employed a hydrophilic coated catheter called SpeediCath®.	Compared to non-coated catheters, hydrophilic-coated catheters decreased the incidence of symptomatic UTI episodes; nevertheless, both groups experienced the same number of hematuria and bacteriuria episodes.
Larsen et al. (2021), India [34]	The ability of a noble metal alloy (NMA)-coated foley catheter to shield SCI patients from urinary tract infections.	1000 SCI patients were randomized in 3:1 into 2 groups, experimental $n = 750$, and control group $n = 250$.	An NMA-coated BIP foley catheter was administered to the experimental group, while an uncoated foley catheter was provided to the control group.	This research demonstrates the value of NMA-coated foley catheters in lowering the frequency of CA-UTI and bacteriuria in people with SCI.
Estores et al. (2008), USA [35].	To evaluate the efficacy of silver hydrogel urinary catheters in shielding stroke patients from urinary tract infections.	One person with tetraplegic SCI who has a history of recurrent UTIs	For six months, the sort of indwelling catheter the patient was receiving was concealed from both him and his carers. The typical latex catheter or silver hydrogel.	The patient was on silver hydrogel catheters for six months during which time she did not experience any symptoms of a UTI.
Sirica et al. (2010), Turkey [5]	To evaluate the effectiveness of hydrophilic, gel-lubricated, and traditional PVC catheters in preventing urethral injuries.	Three distinct kinds of catheters were randomly assigned to be used by 25 adult SCI patients.	For self-catheterization, 25 SCI patients were instructed to utilize three different kinds of catheters. The decision to utilize a catheter was made at random. Every catheter was used for 6 weeks in a row.	In terms of reducing urethral micro-trauma and raising patient satisfaction, gel-lubricated non-hydrophilic catheters performed better than hydrophilic and PVC-coated catheters.

Table 6 Features of RCT research based on nutritional guidelines

Author, year, and country of research	Objectives of research	SCI participants	Interventions/methodology	Outcome addressed/conclusion
BB Lee et al (2007), Australia [36]	To find out if cranberry tablets or methenamine hippurate (MH) protect against UTI in people with SCI.	In order to determine the effectiveness of probiotics Lactobacillus reuteri RC-14 and Lactobacillus rhamnosus GR-1 in reducing inflammatory cytokines 21 SCI individuals were randomly divided into the cranberry group and control group.	(1) 800 g cranberry with MH placebo; (2) 1 g MH with cranberry 800 mg; (3) MH 1 g and cranberry 800 mg; and (4) both MG and cranberry placebo were the groups that were employed. For 4 weeks, the participants were instructed to take three 400 mg cranberry tablets every day. Each participant received a 1-week supply of either a cranberry pill or a placebo after every week.	According to the study's findings, MH or cranberry pills had no effect on the frequency of UTIs in people with SCI. In people with SCI, cranberry tablets did not lower bacteriuria, WBC counts, or UTIs.
Linsenmeyer et al. (2016), USA [37]	To determine whether cranberry food supplements are effective in shielding SCI patients from UTIs	47 SCI patients were split into two groups at random and given either a placebo or cranberry tablet.	For 6 months, each group was given a 400-mg cranberry pill or a placebo tablet twice a day. Every month, the patients' signs and symptoms of UTIs were monitored. For a duration of 15 days, both groups were administered daily dosages of either concentrated PAC or placebo.	Cranberry tablets for 6 months dramatically decreased the number of participants with UTIs and the incidence of UTIs. This therapy was more beneficial to patients with higher GFRs. Following PAC treatment, there was a notable decrease in bacteria and an improvement in the quality of the urine in those with SCI.
MU Hess et al. (2008), USA [38]	To assess the impact of cranberry supplement concentrated with proanthocyanidins (PACs) on bacteriuria in people with SCI.	A total of 13 SCI individuals were grouped into the experimental $n = 7$ and the control group $n = 6$.	Two capsules each day, comprising of either Group 1 [RC14-GRI+LGG-BB12], Group 2 [RC14-GRI+placebo], or Group 3 [LGG-BB12+placebo], were taken by each randomized participant, and 4 [Two-Potassium]	Probiotics had no discernible impact on the treatment of UTI in people with SCI.
Sappal et al. (2018), USA [39]	To determine if probiotic treatment reduces the risk of UTI in patients with SCI	A total of 207 SCI individuals were randomized to four distinct groups.	Patients were randomized to receive probiotics or a placebo after obtaining blood samples.	Probiotics have demonstrated encouraging effects in reducing inflammatory cytokines, particularly IL-6, IL-8 and TNF-alpha in people with SCI
Toh et al. (2019), Australia [8]	To determine how well the probiotics Lactobacillus reuteri RC-14 and Lactobacillus rhamnosus GR-1 work to reduce inflammatory cytokines	Two patients with SCI have a history of getting recurrent UTIs.		

Table 7 Features of non-RCT research based on medical guidelines

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of researches included	Interventions/methodology	Outcome addressed/conclusion
Akil et al. (2015), Turkey [40]	To look into using antibiotic prophylaxis (ABP) to treat the symptoms of UTI in people with SCI.	A prospective observational research project.	SCI individuals, n=22	ABP was given to 22 patients in the first year but not in the second.	Regular use of ABP does not prevent the onset of symptomatic UTI. Following ABP the growth of resistant bacteria also increased.
Nieuwkoop et al. (2010), The Netherlands. [41]	To determine the use of CIC to treat UTI in people with SCI by administering intravesical gentamicin.	Systematic review.	8 researches were included in the systematic review.	A thorough search of the literature was done to find clinical studies reporting gentamicin treatment for intravesical UTIs.	Gentamicin intravenous therapy is a safe and efficient way to treat UTI in people with SCI who are undergoing CIC.
Chew et al. (2018), USA [42]	To assess the efficacy of long-term nitrofurantoin usage in veterans with SCI for the prevention of UTIs	Matched pair study.	A total of 122 veterans with SCI.	A matched pairs research design was used, with one group receiving long-term (> 90 days) nitrofurantoin medication and another receiving none at all.	Although nitrofurantoin is not recommended for long-term usage, it may be useful in the long run in preventing UTIs. To completely confirm the effects of such antibiotic use, more research is required.
Dinh et al. (2016), France [43]	To outline the cure rate for febrile UTIs based on various antibiotic regimens.	Retrospective Cohort study.	A total of 112 SCI cases with febrile UTI.	Based on the length of antibiotic treatment, patients were split into three groups: < 10 days, 10–15 days, and > 15 days.	The effectiveness of antimicrobial therapy for shorter than 10 days is supported by the study. To verify it, a randomized control experiment is necessary.
Moussa et al. (2021), Lebanon [44]	Povidone-iodine (PI) bladder irrigation's effectiveness in lowering UTI in patients with neurogenic bladder undergoing CIC will be evaluated.	Prospective trial.	A total of 119 patients with neurogenic bladder suffering from recurrent UTIs.	A total of 119 patients who underwent daily PI bladder irrigation and were undergoing CIC were observed between 2014 and 2020.	For individuals with neurogenic bladder who use CIC, routine intravesical irrigation of the bladder is an excellent way to prevent UTI.
Poirier et al. (2016), France [45]	To assess the effectiveness of weekly oral cycling antibiotics (WOCA) in SCI patients' for the prevention of UTI.	Cross-sectional study.	50 SCI patients who have a history of recurrent UTIs and who use CIC.	Examination of clinical data and cross-sectional evaluation of patients on WOCA regimen.	WOCA is a safe and efficient way to keep individuals with neurogenic bladder from getting UTIs. Bacteria resistant to drugs do not arise from WOCA.
Salomon et al. (2009), France [46]	To evaluate WOCA's ability to protect pregnant SCI women against UTIs.	Prospective observational study.	Total 6 pregnant women with SCI.	A single-center study was conducted from 2004 to 2007. Six SCI women taking WOCA were monitored during their pregnancy.	Pregnant SCI women found that the WOCA regimen was effective in avoiding UTI. They gave birth to healthy children devoid of any gynecological issues.
Salomon et al. (2006), France [47]	To assess WOCA's effectiveness in preventing UTI in SCI patients undergoing CIC.	Prospective observational study.	A total of 38 patients with neurogenic bladder.	WOCA program participants with SCI who were utilizing CIC were monitored over a period of 2 years.	The frequency of UTI recurrence in SCI patients receiving WOCA was decreased. Additionally, there was a decline in hospital stays and a drop in antibiotic usage.

Table 7 (continued)

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of researches included	Interventions/methodology	Outcome addressed/ conclusion
Welk et al. (2022), UK [48]	To assess the impact of antibiotic prophylaxis on the 1-year UTI rate in individuals with neurogenic bladder using current clinical data	A secondary study of a multi-center clinical experiment	A total of 138 patients with neurogenic bladder consuming CIC.	138 patients who had previously taken part in an RCT using low-dose antibiotic prophylaxis to treat symptomatic UTIs were subjected to a secondary analysis.	In patients with neurogenic bladder, a continuous low-dose antibiotic preventive regimen effectively reduced UTI.
Morton et al. (2001), USA [49]	To assess the advantages and disadvantages of using antibiotic prophylaxis to treat UTI in people with SCI.	Systematic literature review.	28 studies were included in the review.	Comprehensive literature search in MEDLINE, EMBASE, and CINAHL.	The literature that is currently available suggests against using antibiotic prophylaxis to treat UTI in people with SCI.
Wilkstom et al. (2018), Sweden [50]	To assess how well chlorhexidine bladder irrigation reduces urinary tract infections and bacteriuria in people with spinal cord injury.	Prospective, non-controlled, multi-centered study.	50 patients with SCI practicing CIC.	During follow-up visits, patients were checked for bacteriuria and other UTI symptoms.	Chlorhexidine bladder irrigation is a useful tactic for treating bacteriuria and preventing UTI in SCI patients undergoing CIC.

Table 8 Features of non-RCT qualitative research based on educational programs for persons with SCI

Author, year, and country of research	Objectives of research	Study Design	SCI participants	Interventions/methodology	Outcome addressed/conclusion
Okamoto et al(2017), UK, [51]	To evaluate the knowledge of IC users regarding UTI symptoms, presentation, and terminologies.	Qualitative analysis	A qualitative investigation involving thirty IC users who took part in semi-structured.	Patients who had taken IC for at least 3 months and had experienced one self-reported UTI since starting IC were interviewed in a semi-structured manner.	Users of IC were unsure of the signs and symptoms of UTIs and when to get medical attention. The creation of a self-help book for SCI patients is necessary.

Table 9 Features of non-RCT research based on bacterial interference

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of studies included	Interventions/methodology	Outcome addressed/conclusion
Darouiche et al. (2001), USA [52]	To assess the effectiveness of bacterial interference in the management of UTI symptoms.	A prospective, non-RCT pilot clinical trial.	44 participants with SCI.	Participants received an injection of E. Coli 83972, a non-pathogenic prototype.	In the vaccinated group, the number of successfully treated UTI episodes decreased from 3.77 to 0.06 incidents per patient-year.
Groah et al. (2019), USA [53]	To evaluate the safety and effectiveness of intravenous Lactobacillus rhamnosus GG (LGG) in neurogenic bladder to avoid UTI.	A prospective, non-RCT clinical trial.	A total of 103 individuals with neurogenic bladder perform CIC on a routine basis.	An 18-month trial, 3 phases trial (6 months each; Baseline, intervention, and washout). Intravesical LGG was given to the participants.	Intravesical LGG given on one's own is safe and well-tolerated in people with neurogenic bladders undergoing CIC.
Krebs et al. (2018), Switzerland [54]	To assess the effectiveness of treating UTI in individuals with SCI with E. coli fractions as part of oral immunomodulation therapy.	Retrospective cohort study.	136 individuals with SCI with a history of frequent UTIs.	A database containing patient records from 2008 to 2016 who received lyophilized lysate containing 18 strains of E. coli was screened.	For those with SCI, oral immunomodulation therapy using Escherichia coli reduces the frequency of recurrent UTI episodes.
Prasad et al. (2009), USA. [55]	To examine the efficacy of E. coli strain 83972-coated catheters to manage UTI in SCI persons.	Non-RCT pilot trial.	A total of 13 participants with SCI with a history of getting recurrent UTI performing CIC.	Every participant was given catheters that had already been infected with E. Coli 83972.	By successfully colonizing the bladder, E. Coli-coated catheters decreased the annual rate of recurrent UTIs from 2.27 to 0.77 per patient.
Traunter et al. (2014), USA. [56]	To determine whether bladder colonization using urinary catheters coated with Escherichia coli HU2117 is an effective way to prevent UTIs.	Prospective clinical trial.	A total of 12 SCI individuals using indwelling catheters with a history of recurrent UTIs.	E. Coli HU2117-coated indwelling catheters were implanted. After 28 days, the study catheters were taken out.	E. Coli HU2117-coated catheters were successful in colonizing bacteria and reduced the frequency of UTIs in people with spinal cord injuries.

Table 10 Features of non-RCT research based on nutritional guidelines

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of studies included	Interventions/methodology	Outcome addressed/conclusion
Luis et al. (2017), Portugal [57]	To assess the connection between cranberry consumption and UTI prevention	Systematic literature review.	A total of 25 studies were included for final review.	A search was conducted through Web of Science, Scielo, PubMed, Scopus, and the Cochrane Library.	Cranberries have been shown in this review and meta-analysis to be useful in lowering the symptoms of UTIs.
Opazo et al. (2016), USA [58]	To assess dietary supplements' effectiveness in keeping people with SCI from getting UTIs.	Systematic literature review.	A total of 18 studies were included in the final screening.	A search was conducted using Google Scholar, Cochrane, Dare, Lilacs, CINAHL, Embase, MEDLINE, OTSeeker, PEDro, PsychINFO, SpeechBITE, Science Direct, and Scopus.	Strong data exists to support the ineffectiveness of cranberry supplements none treating UTIs. Studies have demonstrated the benefits of omega-3 fatty acids and vitamin D.

Table 11 Features of non-RCT research based on catheter type or bladder control technique

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of studies included	Interventions/methodology	Outcome addressed/conclusion
Anderson et al. (2019), Switzerland [59]	To assess UTI risk factors in persons with spinal cord injury.	Prospective cohort study.	A total of 369 patients with SCI with different lesions.	Between 2013 and 2017, patient data was gathered, including information on functional independence and bladder control strategies.	In terms of bladder management, patients were split into three groups: (A) those who used an indwelling catheter (IDC), (B) those who used an IC, and (C) those who went to the toilet on their own.
Banaszek et al. (2020), Canada [60]	To ascertain the effectiveness of silicon catheters (SACC) coated with silver alloy in avoiding CA-UTI.	Quality improvement study.	A total of 302 patients with SCI.	SACC was administered to former LIC users, who were tracked for 3 years for UTI signs and symptoms.	When compared to standard LIC, SACC had encouraging outcomes in lowering the frequency of UTIs in SCI patients.
Bermingham et al. (2012), UK [61]	To assess the best kind of catheter for UTI prevention.	Systematic review.	8 researches were included in the final screening.	A search was conducted using CIC to find RCTs and non-RCTs in Cinahl, Embase, MEDLINE, and the Cochrane library.	UTIs were less common with hydrophilic and gel reservoir catheters than with non-coated catheters.
Mitchell et al. (2021), Australia [62]	To ascertain whether using antiseptics on the urethral entrance before using IC is effective.	Systematic review.	Two articles were selected in the final screening.	A search was conducted using the Cumulative Index to Nursing and Allied Health Literature and MEDLINE (via Ovid).	It is uncertain if using antiseptics on the meatal area before using IC is beneficial. This field requires more investigation.
Rogoni et al. (2017), Italy [63]	To assess coated catheters—hydrophilic and non-hydrophilic—for their ability to prevent urinary tract infections.	Systematic review.	7 researches were included in the final selection.	MEDLINE, PubMed, and Web of Science were searched for RCTs on hydrophilic and non-hydrophilic coated standard PVC catheters in the prevention of UTIs.	Promising outcomes were shown in the reduction of CA-UTI risk with hydrophilic-coated catheters.
Hafizi et al. (2018), Iran [64]	To assess the impact of changing the sterile urine bag every day on the occurrence of CA-UTI and bacteriuria.	Quasi-experimental study.	A total of 200 patients needed the insertion of a Foley catheter.	Patients were split into two groups: (1) catheterization using a standard protocol and (2) catheterization using a sterile urine bag change per day.	Comparing and replacing a sterile pee bag with an empty one is a routine procedure; however, replacing the bag effectively lowers the risk of UTI and bacteriuria.
Hennessey et al. (2018), Australia [65]	To determine which bladder care strategy had the lowest UTI rate.	Prospective observational study.	A total of 143 patients with SCI with indwelling urinary catheter (IUC).	Medical records from 2012 to 2014 were gathered, and information on bladder control strategies and UTI occurrences was examined.	The incidence of UTIs was greater in IUC. Patients should switch to non-IUC bladder treatment as soon as possible once the IUC is removed.
Krebs et al. (2013), Switzerland. [66]	To determine the volume of leftover urine following intermittent catheterization (IC).	Prospective cross-sectional study.	60 men with SCI, experienced in performing IC.	After the participants used IC to empty their bladders twice, ultrasonography was performed right after to check for any leftover pee.	The use of IC demonstrated encouraging results in the bladder, leaving little to no leftover pee.

Table 11 (continued)

Author, year, and country of research	Objectives of research	Study design	SCI participants/no. of studies included	Interventions/methodology	Outcome addressed/ conclusion
Nwardiaro et al. (2007), Nigeria [67]	To analyze UTI incidence in urethral catheterization (UC) versus suprapubic cystostomy (SPC).	Retrospective clinical study.	A total of 125 patients with neurogenic bladder participated in the study.	The clinical records from 1984 to 2005 were examined to see if there was a relationship between the use of UC/SPC and the frequency of UTIs.	Compared to UC, SPC was linked to a decreased incidence of UTIs and a higher quality of life.
Roth et al. (2018) USA [68]	To examine the subjective judgement of patients concerning UTI symptoms.	Prospective observational study.	1479 patients were enrolled in the study.	Patients were divided into three groups according to how they managed their bladders: (A) those who used an indwelling catheter (IDC), (B) those who used an IC, and (C) those who voided on their own.	Among IDC users, the frequency of UTI was higher than that of IC users. The spontaneous voiding group, however, had the lowest incidence rate of UTIs.

enhance patients' quality of life in addition to managing the disease [85]. Numerous studies in the literature have come to the conclusion that patient education can enhance patients' quality of life and aid in the prevention of numerous chronic conditions, including arthritis, fibromyalgia, and high blood pressure [86–89]. Similar results were observed in our review, wherein 1 RCT-based trial [30] found that following a 6-month educational program, patients in the experimental group demonstrated symptoms of reduced UTI. The foundation of this training program was a broad introduction to UTIs, self-hygiene standards, and optimal management of perineal areas in terms of hygiene [30]. A non-RCT qualitative study [51] that examined IC users' awareness of UTI signs and symptoms came to the conclusion that IC users were unclear about these symptoms and indications and were unsure of when to seek medical attention. This study also proposed the creation of a self-help book with simple instructions for maintaining personal hygiene and a broad understanding of urinary tract infections for people with spinal cord injuries [51].

There has been discussion in the literature regarding the role that cranberries play in preventing UTIs in patients with SCI [20]. A similar discrepancy was discovered in our scoping review, wherein data on the usage of cranberry and other food supplements for the treatment of UTIs were reported by 6-RCTs and 2-non-RCTs in very diverse and inconsistent ways. Cranberry was reported to be beneficial for preventing UTIs in patients with spinal cord injury (SCI) in one comprehensive study [57], but it was found to be useless in another [58]. Probiotic use was the subject of similar inconsistent results in 2-RCTs; one study [9] showed that probiotics are useful in preventing UTIs in SCI patients, whereas another study [8] came to the opposite conclusion. Regarding the utilization of cranberry supplementation, other non-RCT studies are likewise inconclusive; one research [38] found it beneficial, while another [36] found it useless. According to one study [39], co-supplementing proanthocyanidins and cranberries can improve the management of UTIs in patients with SCI. Nutritional research faces a significant deal of challenge when multiple authors provide contradicting and inconsistent conclusions on the same subject. This is mostly because of many uncontrollable confounding factors [90].

With over 150 million cases annually, catheter-associated UTIs (CA-UTIs) are the most prevalent healthcare-associated illness. Urinary catheters are thought to be the most extensively used medical equipment worldwide [91]. However, the quality of life for SCI patients has been significantly impacted by recent advancements in catheter quality and material [92]. According to our scoping assessment, there is encouraging evidence that, in

comparison to conventional non-coated PVC catheters, hydrophilic coated [4, 32, 33] and gel-lubricated non-hydrophilic coated catheters [5] offer superior protection against the occurrence of UTIs in SCI. Catheters that are hydrophilic-coated are coated with a particular hydrophilic material that, when combined with water, creates a slick surface that allows the catheter to slide into the urethral canal without creating any damage [93].

Hydrophilic-coated catheters were also linked to less urethral damage and fewer UTI bouts in SCI, according to three systematic reviews [61–63]. In addition to the advantages of hydrophilic coatings, research also shows that silver hydrogel and alloy coatings are more effective than conventional PVC catheters without coatings [35, 60]. Compared to an indwelling catheter (IC) or suprapubic catheter users, the incidence of urinary tract infections (UTIs) is much greater in suprapubic IDC users [31]. However, compared to conventional non-coated foley catheters, foley catheters that are coated with noble metal alloys are significantly more effective in preventing UTIs, according to an RCT trial involving 1000 patients [34]. Urine bags that are used for longer periods of time when an indwelling catheter is in place create bacterial colonies, which then multiply and cause recurrent urinary tract infections [94]. Most of the time, regular antibiotic treatment does not work against these bacterial colonies [10]. According to the results of a quasi-experimental investigation, replacing a full urine bag with an empty one drastically decreased the prevalence of symptomatic UTIs and bacteriuria [64]. Due to the development of bacterial colonies, a lot of people simply empty the pee bag and continue using it, which this study considered malpractice [64].

The literature indicates that the type of catheter used and the frequency of UTIs are strongly correlated [16]. Due to the fact that compared to suprapubic and IC users, indwelling urinary catheter users had the highest risks of urinary tract infections [65, 68]. Additionally, there was little to no remaining pee in the bladder after using IC [66]. Urinary stasis in the bladder causes bacterial colonies to grow, which exacerbates UTIs in SCI. For this reason, it is crucial that the bladder be completely emptied.

Limitations

The development of UTI prevention measures for athletes with SCI is the goal of this review. The author concurs that the public with UTIs is the main target of this study rather than athletes. The author was unable to locate any publication that was exclusively based on evidence-based recommendations for SCI athletes. In order to determine whether athletes with SCI could benefit from these recommendations, the author had to locate evidence-based guidelines for the general public's prevention of UTIs.

Conclusion

According to the scoping review, WOCA is the most effective antibiotic regimen. The proven methods for treating UTIs in SCI patients include coated catheters, bacterial interference, bladder irrigation, and patient education. Moreover, there is a great deal of variation in the research about the efficacy of cranberries. The best option for safe bladder management and preventing UTIs in SCI patients is to use a suprapubic catheter and coated IC. If spontaneous voiding is not possible, a new full urine bag should be provided, and patients should be urged to utilize it.

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Authors' contributions

Qasim Ali, Yang Long, and Maria Naeemi Malhi wrote the introduction and methodology. Qasim Ali, Hamna, and Maria Naeemi Malhi wrote the manuscript with support from Yang Long. Qasim Ali and Muhammad Ali carried out the data collection and analysis. Yang Long helped supervise the project. Qasim Ali, Yang Long, and Muhammad Ali conceived the original idea. Yang Long supervised the project. All authors read and approved the final manuscript.

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Availability of data and materials

By using the reference listed at the conclusion of this review, you can access information online.

Declarations

Ethics approval and consent to participate

I, Qasim Ali, hereby state that my research paper titled, "Scoping review on managing the bladder and preventing urinary tract infections (UTIs) in athletes with spinal cord injuries" is my own work and has not been submitted previously in any journal by me or anywhere else in the country/world. I worked with my Associate professor Mr. Yang Long (Taiyuan University of Technology, CHINA). At any time, if my statement is found to be incorrect, even after my paper publication, you have the right to withdraw and reject my paper.

Consent for publication

The authors gave the consent to publish the research paper.

Competing interests

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