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Urinary tract infections are common and have an impact on performance in elite wheelchair athletes: a cross-sectional study of self-reported data

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Summary

STUDY AIMS: Wheelchair athletes may be at risk of urinary tract infections, especially those with spinal cord injury. A urinary tract infection can lead to a loss of training hours and reduced performance in athletes. We assessed the self-reported occurrence of urinary tract infections and the impact of urinary tract infections on training and performance in elite wheelchair athletes. We also evaluated the prophylactic measures used, as reported by the athletes.

METHODS: Data were collected from September 2022 to August 2023 at an institute specialised in examining wheelchair athletes. All wheelchair athletes active in international and/or national competitions who attended one of the routine checkups at the institute during the study period were included. The number of self-reported urinary tract infections during the previous 12 months was collected, including symptoms associated with urinary tract infections, prophylaxis, and impact on training and performance. The method of bladder voiding was assessed by catheter use, either "Yes" (intermittent and indwelling) or "No" (no catheter use at all).

RESULTS: Eighty-one athletes were included (mean ± standard deviation age 35 ± 11 years; 24 females; 67 with spinal cord injury; 56 using a catheter). Prophylaxis was used by 38 (47%) athletes; the most common was natural supplements, including cranberry juice and D-mannose. Thirty-six (44%) athletes had had at least one urinary tract infection during the previous 12 months. Athletes were more likely to have had at least one urinary tract infection if they had spinal cord injury (34 [94%] vs 2 [6%] athletes, $p = 0.013$) or were using a catheter (32 [89%] vs 4 [11%] athletes, $p = 0.001$). A urinary tract infection resulted in 4±6 lost training days and impaired performance.

CONCLUSION: Urinary tract infections are common in elite wheelchair athletes and have a negative impact on training volume and performance. About half of the athletes use prophylaxis. Athletes with spinal cord injury or who use a catheter are especially at risk of urinary tract infections.

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Introduction

For athletes, illness can have a substantial impact on training and performance [1]. Para athletes have a higher risk of illness than Olympic athletes [2]. During several winter and summer Paralympic Games between 2012 and 2022, genitourinary illness was the fourth most commonly reported illness after respiratory, skin and gastrointestinal illnesses [2–4]. Genitourinary illness, which includes urinary tract infections, accounted for 7–11% of all events [2–4]. Symptoms of urinary tract infections in athletes with spinal cord injury include fever, malaise, increased spasticity and autonomic dysreflexia [5]. This makes urinary tract infections particularly burdensome for these athletes, potentially leading to decreased performance and missed training days, and ultimately affecting competition results.

Individuals with a neurogenic bladder, including those with spinal cord injury, spina bifida, cerebral palsy and multiple sclerosis, are at increased risk of developing a urinary tract infection [6, 7]. Depending on the bladder evacuation method, 10% to 50% of individuals with spinal cord injury experience recurrent urinary tract infections [8]. Impaired bladder storage and voiding function, intermittent catheterisation and catheter reuse are associated with an increased risk of urinary tract infections [5, 9–11]. Dehydration may also play a role, especially in athletes [2]. Several prophylactic measures can be taken to prevent urinary tract infections, including the intake of antibiotics or natural supplements, such as cranberry products [5, 12]. Nevertheless, evidence for the effectiveness of urinary tract infection prophylaxis is inconsistent [5]. Frequent bladder voiding by catheterisation has also been identified as an important preventive factor for urinary tract infections [5]. On the other hand, frequent catheterisation has been associated with an increased risk of cross-infection [5]. This highlights the complexity and multifactorial nature of this issue.

Although several studies have demonstrated an increased prevalence of urinary tract infections in individuals with spinal cord injury, findings in elite wheelchair athletes are rare. One study in international elite wheelchair athletes found that athletes who reused their catheters experienced more urinary tract infections [11]. Another study in international elite athletes with spinal cord injury using intermittent catheterisation found that 63% had experienced at least one urinary tract infection during the previous 12 months [10]. Besides knowledge regarding the occurrence of urinary tract infections, there is a lack of knowledge regarding the use of prophylaxis, potential causes and the impact of urinary tract infections on the performance of wheelchair athletes. The primary objective of this cross-sectional, retrospective, self-report study was to evaluate the occurrence of urinary tract infections in elite wheelchair athletes in the previous 12 months. We also evaluated the self-reported impact of urinary tract infections on performance and training. Additionally, we evaluated measures of prophylaxis implemented and potential reasons for the occurrence of urinary tract infections as reported by the athletes.

Methods

Design, setting and population

We used a cross-sectional study design and adhered to the STROBE guidelines [13]. Data were collected from September 2022 to August 2023 at the Institute of Sports Medicine at the Swiss Paraplegic Centre, specialised in examination of wheelchair athletes. Wheelchair athletes include all athletes who compete in a variety of wheelchair sports. Wheelchair athletes who are members of the national team in their respective sport visit our institute at least once a year for a standardised medical examination and performance test. All the data analysed in this study were collected during these routine checkups. Compared to studies in able-bodied individuals, studies in wheelchair athletes are often limited by a small sample size – this is further complicated by the large variation in disease and classification categories. To maximise the sample size and diversity of the study population, all wheelchair athletes active in international and/or national competitions who attended one of these regular checkups at our institute during the study period were included. The time frame for data collection was chosen to resemble a full cycle of tests at our institute, i.e. at least one test performed in all our athletes.

Data collection

Only one checkup for each athlete was included in the analyses. The following individual characteristics were collected from the athletes' in-house medical files: sex, age, height, body mass, body mass index (BMI), regular use of medication, diagnosis, spinal cord injury lesion level, degree of impairment following the American Spinal Injury Association Impairment Scale (AIS), year of spinal cord injury onset and method of bladder emptying. All further parameters were collected using an in-house standardised questionnaire as part of the regular performance checkup of the athletes presenting to our institute. The questionnaire was completed together with the athlete, which provided the opportunity to resolve any issues or questions directly and resulted in no missing data. The following sports and urinary tract infection parameters were collected using questionnaires: type of sports, time spent at elite level, duration and number of weekly training sessions, total number of urinary tract infections in the previous 12 months, the month of manifestation, prophylaxis, potential reasons, symptoms, duration of symptoms, treatment and number of training days lost due to urinary tract infections. The impact of urinary tract infections on training volume and performance was assessed on a 5-point Likert scale ranging from "No impact at all" to "No participation possible". Urine specific gravity was assessed from a 10 ml urine sample. The urine samples were handled and analysed according to routine clinical procedures in our in-house laboratory.

Data preparation

The diagnosis was categorised by presence of spinal cord injury, either "Yes" or "No". The neurological level of spinal cord injury, the highest sensorimotor lesion level, was categorised as "tetraplegia" (C1–C8) or "paraplegia" (T1 or lower) [14]. The degree of sensory impairment was categorised as "complete" (A) or "incomplete" (B–D) [14]. The voiding method was categorised by use of catheterisation, either "Yes" (intermittent or indwelling catheter) or "No" (no catheter use at all), as any form of catheterisation increases the risk of urinary tract infections [15]. The type of sports was categorised as "Endurance" (cycling and wheelchair racing), "Team" (basketball and rugby) or "Skill" (alpine skiing, badminton, curling, fencing, shooting, table tennis, tennis and Wheelchair MotoCross [WCMX]). The occurrence of urinary tract infections was categorised as "None" (no urinary tract infections) or "At least one" (≥1 urinary tract infection), given that the occurrence of one urinary tract infection in athletes is already clinically relevant in terms of potential training disruptions and decreased performance. Prophylactic measures were categorised as "Natural supplements" (e.g. cranberry, vitamin C), "Hydration" (plenty or additional fluids), "Hygiene" (e.g. washing hands, appropriate catheter handling) or "Medication" (e.g. Uro-Vaxom®, methionine). Urine specific gravity was categorised as "Hydrated" (≤1.020 g/ml) or "Dehydrated" (>1.020 g/ml) [16].

Data analyses

Following the central limit theorem, parametric methods were applied. Data were reported as mean and standard deviation (SD) as well as count and percentage. Differences in the occurrence of urinary tract infections and the use of urinary tract infection prophylaxis between different groups (spinal cord injury yes/no and catheter yes/no) were evaluated using Pearson's chi-squared test. Differences in missed training days, and the number and duration of urinary tract infections between different groups (spinal cord injury yes/no and catheter yes/no) were evaluated using the independent t-test. A Bonferroni correction was applied to the Pearson's chi-squared and the independent t-tests, resulting in a significance level of $p \leq 0.013$. A binary logistic regression was run to evaluate the effects of relevant predictors (sex, age, spinal cord injury, spinal cord injury duration, catheter use, training frequency, urinary tract infection prevention) on the occurrence of at least one urinary tract infection, entering all predictors into the model at once. One model was calculated with data from all athletes and a second model was calculated with data from athletes with spinal cord injury only. The Hosmer-Lemeshow test was used to assess the goodness of fit of the models. For the models, a p-value of ≤0.05 was considered statistically significant. Analyses were performed with Stata statistical software release 17.0 (StataCorp LLC, College Station, TX, USA).

Ethics approval

All participants provided written informed consent. The study was performed in accordance with the standards of ethics outlined in the Declaration of Helsinki and national laws and was approved by the local ethics committee on 23 June 2023 (EKNZ, Basel, Switzerland, project-ID: 2023-01180).

Results

Athlete characteristics

Data were analysed from 81 athletes, ranging in age from 15 to 64 years (table 1). Some athletes had just joined the elite squad for the first year, while others had been competing at the elite level for up to 38 years. Most athletes were active in either basketball (n = 14, 17%) or cycling (n = 14, 17%). Forty-two (52%) athletes had a traumatic spinal cord injury, whereas other diagnoses included neural tube defect (n = 17, 21%), multiple sclerosis (n = 3, 4%), amputation (n = 3, 4%) or further diagnoses (n = 16, 20%) such as cerebral palsy or Guillain-Barré syndrome. Fifty-six (69%) athletes were using a catheter for bladder emptying of whom 52 (93%) were using intermittent catheterisation. Most of the athletes had spinal cord injury (n = 67, 83%), most of whom were using a catheter (n = 55, 82%). One athlete was dehydrated at the time of data collection and had a urine specific gravity of 1.025 g/ml.

Urinary tract infections

Thirty-six (44%) athletes had experienced at least one urinary tract infection in the previous 12 months. Athletes with spinal cord injury (p = 0.013) and those using a catheter (p = 0.001) experienced urinary tract infections more often compared to athletes without spinal cord injury and those not using a catheter (table 2). In athletes with spinal cord injury and using a catheter, 31 (56%) had experienced at least one urinary tract infection. Of all athletes, 38 (47%) were using at least one type of urinary tract infection prophylaxis (table 2). Natural supplements, including cranberry juice and D-mannose, were used most often (figure 1). Of the athletes using prophylactic measures, twenty-five (69%) had experienced at least one urinary tract infection.

Of the athletes who had experienced urinary tract infections, 13 (36%) reported one, while 2 reported having had 12 urinary tract infections. Urinary tract infections lasted a mean of 7 ± 5 days (table 2 and 3), with a range from 1 to 20 days. Thirty-four (94%) athletes with urinary tract

Table 1:
Athlete characteristics. Data are presented as mean (standard deviation) or count (percentage). Percentages may not total 100 due to rounding.

		Overall (n = 81)	Spinal cord injury?		Using a catheter?	
			Yes (n = 67)	No (n = 14)	Yes (n = 56)	No (n = 25)
Sex	Female	24 (30%)	15 (22%)	9 (64%)	15 (27%)	9 (36%)
	Male	57 (70%)	52 (78%)	5 (36%)	41 (73%)	16 (64%)
Age (years)		35 ± 11	35 ± 11	33 ± 12	35 ± 12	36 ± 11
Height (cm)		173 ± 13	174 ± 12	166 ± 13	173 ± 13	172 ± 13
Body mass (kg)		68 ± 15	68 ± 16	70 ± 14	67 ± 16	70 ± 14
BMI (kg/m²)		22.9 ± 4.4	22.3 ± 4.0	25.6 ± 5.7	22.4 ± 4.0	23.9 ± 5.2
Diagnosis	Traumatic spinal cord injury	42 (52%)	42 (63%)	–	34 (61%)	8 (32%)
	Neural tube defect	17 (21%)	17 (25%)	–	15 (27%)	2 (8%)
	Multiple sclerosis	3 (4%)	–	3 (21%)	1 (2%)	2 (8%)
	Amputation	3 (4%)	–	3 (21%)	–	3 (12%)
	Other*	16 (20%)	8 (12%)	8 (57%)	6 (11%)	10 (40%)
Time since spinal cord injury (years)		18 ± 10	18 ± 10	–	17 ± 10	18 ± 13
Lesion level	Tetraplegia	18 (27%)	18 (27%)	–	11 (20%)	7 (58%)
	Paraplegia	49 (73%)	49 (73%)	–	44 (80%)	5 (42%)
Sensory impairment	Complete	36 (54%)	36 (54%)	–	31 (56%)	5 (42%)
	Incomplete	31 (46%)	31 (46%)	–	24 (44%)	7 (58%)
Sport	Endurance**	27 (33%)	26 (39%)	1 (7%)	22 (39%)	5 (20%)
	Team***	22 (27%)	14 (21%)	8 (57%)	10 (18%)	12 (48%)
	Skill****	32 (40%)	27 (40%)	5 (36%)	24 (43%)	8 (32%)
Weekly training	Duration (h)	9 ± 5	10 ± 5	8 ± 5	10 ± 5	8 ± 4
	Sessions (#)	5 ± 3	6 ± 3	5 ± 3	6 ± 3	5 ± 2
Elite level athlete (years)		5 ± 7	6 ± 7	3 ± 4	6 ± 7	4 ± 5

BMI: body mass index.

* “Other” diagnosis = cerebral palsy, functional neurological disorder, Guillain-Barré syndrome and lower limb deficiency.

** Endurance sports = cycling and wheelchair racing.

*** Team sports = basketball and rugby.

**** Skill sports = alpine skiing, badminton, curling, fencing, shooting, table tennis, tennis and Wheelchair MotoCross (WCMX).

infections had experienced at least one symptom. General malaise (28%), fever (25%) and pain (23%) were the most commonly reported symptoms, followed by spasm (13%) and incontinence (11%). Twenty-three (64%) athletes had received antibiotic treatment for their urinary tract infection. The urinary tract infections caused a mean loss of 4 ± 6 training days (table 3). Stress (34%), air travel (28%) and training intensity (17%) were the most commonly reported potential causes of the urinary tract infection, followed by competition (10%), nutrition (7%) and altitude (3%). Sixteen athletes did not mention a particular cause for their urinary tract infection. Most athletes mentioned that their urinary tract infection had at least some negative effect on their training volume (53%, figure 2A) or performance (61%, figure 2B).

In both logistic regression models (all athletes, only athletes with a spinal cord injury), the use of prophylaxis ($p \leq 0.02$) was associated with higher odds of having at least one urinary tract infection (tables 4 and 5). None of the other investigated parameters were significant predictors ($p \geq 0.06$, tables 4 and 5).

Discussion

This is the first study to investigate the occurrence of self-reported urinary tract infections in elite wheelchair athletes and their impact on performance and training. Thirty-six (44%) athletes had experienced at least one urinary tract infection during the previous 12 months. Urinary tract infections were more common in athletes with spinal cord injury and those using a catheter to empty their bladder. Most athletes experienced a reduction in training volume and performance due to urinary tract infections.

Urinary tract infections were common among our wheelchair athletes: 44% reported having had at least one urinary tract infection during the past 12 months. In this subgroup, 36% reported one infection episode (the most common frequency). In another cohort of international athletes with spinal cord injury using intermittent catheterisation, 63% reported having had at least one urinary tract infection during the past 12 months, with a median of 1 urinary tract infection [10]. In non-athletes with spinal cord injury, an incidence of 2 urinary tract infections per year has been reported [17]. In non-disabled individuals, both athletes and non-athletes, urinary tract infections are more common in females than in males [1, 18, 19]. Interestingly, sex was

Table 2:
Characteristics of urinary tract infections during the previous 12 months, in all athletes. Data are presented as count (percentage).

	Overall	Spinal cord injury?			Using a catheter?		
		Yes (n = 67)	No (n = 14)	p-value	Yes (n = 56)	No (n = 25)	p-value
Is using urinary tract infection prophylaxis	38 (47%)	36 (95%)	2 (5%)	0.007	33 (87%)	5 (13%)	0.001
Has had at least one urinary tract infection	36 (44%)	34 (94%)	2 (6%)	0.013	32 (89%)	4 (11%)	0.001

Figure 1: Prophylaxis for urinary tract infections (UTIs) used by athletes. This was a multiple-answer question.

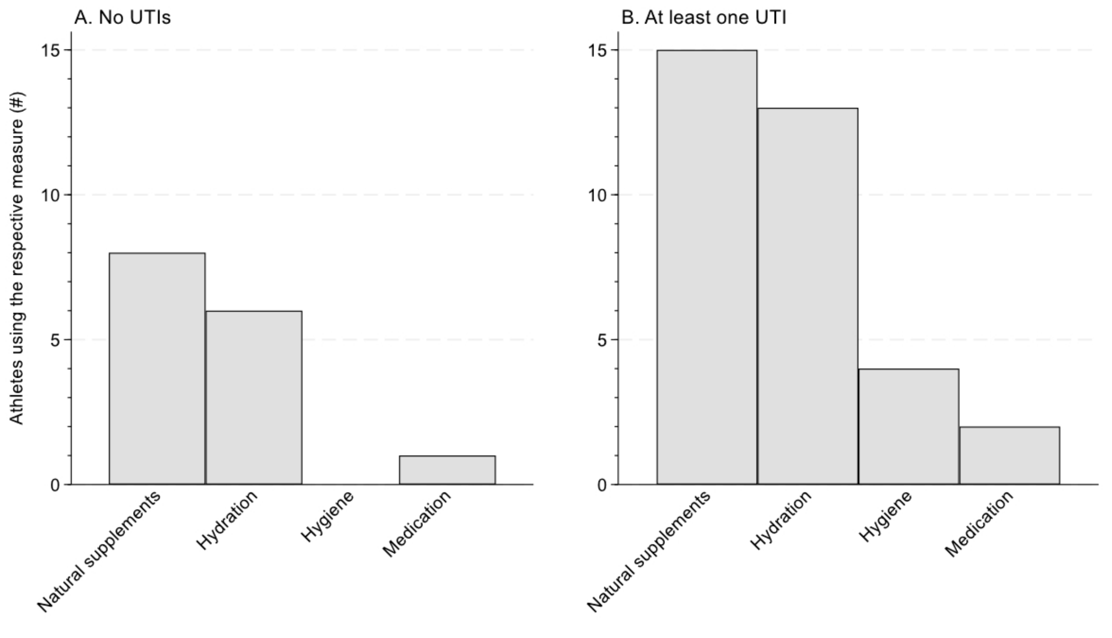

Table 3:
Characteristics of urinary tract infections over the previous 12 months, in athletes with at least one episode. Data are presented as mean (standard deviation).

	Overall	Spinal cord injury?			Using a catheter?		
		Yes (n = 34)	No (n = 2)	p-value	Yes (n = 32)	No (n = 4)	p-value
Number of urinary tract infections (mean ± SD)	3 ± 3	3 ± 3	9 ± 4	0.002	3 ± 3	5 ± 5	0.31
Duration of urinary tract infection (days, mean ± SD)	7 ± 5	7 ± 5	4 ± 4	0.27	7 ± 5	6 ± 4	0.68
Missed training due to urinary tract infection (days, mean ± SD)	4 ± 6	4 ± 6	4 ± 5	0.94	4 ± 6	4 ± 7	0.91

not a significant predictor for urinary tract infections in our study. However, this finding is consistent with other studies in individuals with spinal cord injury in which no difference was observed in the occurrence of urinary tract infections between sexes [8, 20, 21]. Corroborating previous findings [5, 11], we found that athletes with spinal cord injury or using a catheter were more likely to have had at least one urinary tract infection. Individuals with spinal cord injury are at increased risk of urinary tract infections due to a neurogenic bladder and the need to use catheterisation as a method of voiding the bladder [6, 9]. The cellular and humoral immune response may also be affected in spinal cord injury [22]. This results in a 2- to 3-fold higher level of circulating inflammatory markers compared to non-disabled individuals, which further increases the risk of urinary tract infections [22]. Further demographic or le-

Figure 2: Impact of urinary tract infections (UTIs) on (A) training volume and (B) performance among athletes with at least one urinary tract infection. These were multiple-choice questions.

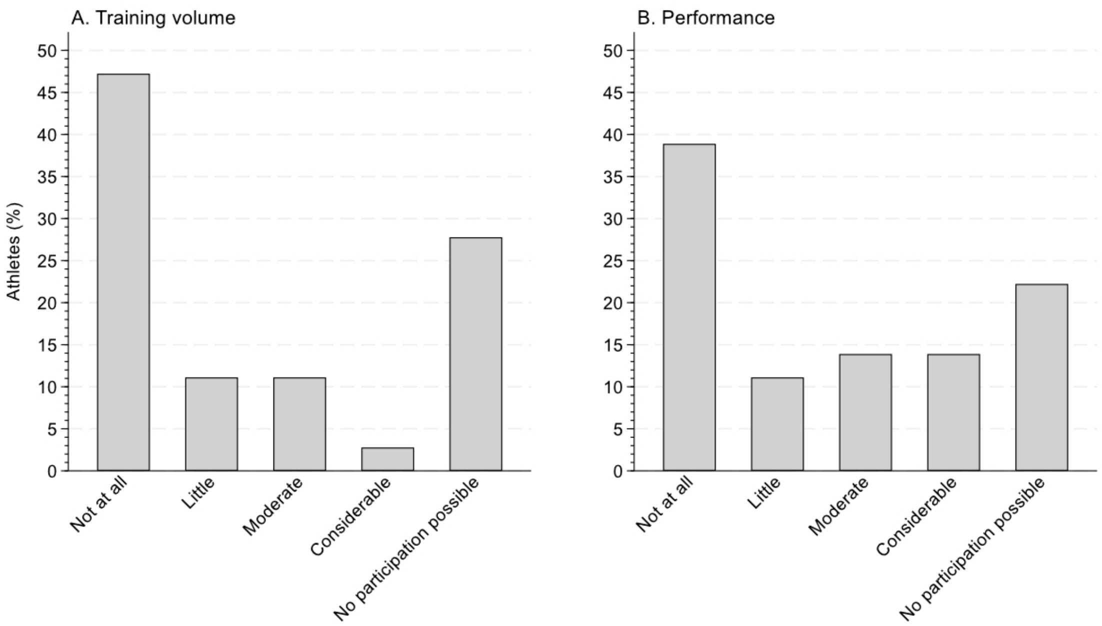

Table 4:
Binary logistic regression for having at least one urinary tract infection over the previous 12 months, including all athletes. $\chi^2(6) = 21.31$, p = 0.002, Hosmer-Lemeshow p = 0.77.

		Odds ratio	95% confidence interval		p-value
			Lower	Upper	
Age (years)		1.02	0.98	1.07	0.33
Sex	Female	*Reference*			
	Male	0.84	0.24	3.00	0.79
Spinal cord injury	No	*Reference*			
	Yes	1.41	0.16	12.53	0.76
Using a catheter?	No	*Reference*			
	Yes	4.43	0.93	20.98	0.06
Training (sessions/week)		1.00	0.90	1.12	0.95
Urinary tract infection prophylaxis?	No	*Reference*			
	Yes	3.49	1.22	10.02	0.02

Table 5:
Binary logistic regression for having at least one urinary tract infection over the previous 12 months, including only athletes with spinal cord injury. $\chi^2(7) = 15.28$, p = 0.02, Hosmer-Lemeshow p = 0.37.

		Odds ratio	95% confidence interval		p-value
			Lower	Upper	
Age (years)		1.03	0.98	1.09	0.25
Sex	Female	*Reference*			
	Male	1.22	0.30	4.94	0.78
Spinal cord injury duration (years)		1.01	0.95	1.07	0.85
Using a catheter?	No	*Reference*			
	Yes	2.94	0.61	14.19	0.18
Training (sessions/week)		1.01	0.89	1.34	0.42
Urinary tract infection prophylaxis?	No	*Reference*			
	Yes	4.42	1.42	13.76	0.01

sion characteristics did not predict the occurrence of a urinary tract infection, which was also found in a study in international athletes with spinal cord injury [11].

Most athletes with spinal cord injury (95%) reported using prophylactic measures. In another study in athletes with spinal cord injury having neurogenic lower urinary tract dysfunction, 52% used antibiotics as prophylaxis [10]. None of our athletes used antibiotics as prophylaxis, but 64% received antibiotic treatment for their urinary tract infection. The presence of bacteria or leukocytes in the urine without symptoms, also known as asymptomatic bacteriuria and pyuria, is prevalent in 50–100% of individuals with spinal cord injury using a catheter [5]. Instead of medical treatment, this should be addressed by improving hydration status and hygiene during voiding routines [5, 23]. Though urine laboratory testing is recommended when athletes have urinary tract infection symptoms, dipstick testing or measuring urine specific gravity with a handheld refractometer provides an indication of hydration status that is practical and straightforward to implement in an athletic environment [5, 24].

Natural supplements and hygiene measures were the most commonly reported measures for preventing urinary tract infections. The prophylactic measures did not appear to be very successful in reducing the occurrence of urinary tract infections as 69% of athletes experienced at least one urinary tract infection despite implementing prophylactic measures. The use of urinary tract infection prophylaxis was also a significant predictor for the occurrence of urinary tract infections, which corresponds to findings in individuals with chronic neurogenic lower urinary tract dysfunction [8]. Nevertheless, the cross-sectional study design does not allow for causal conclusions to be drawn. We hypothesise that a previous history of recurrent urinary tract infections was the reason for taking prophylactic measures and not vice versa. Evidence regarding the effectiveness of urinary tract infection prophylaxis, including cranberries, D-mannose, vitamin C, methenamine or probiotics, in individuals with spinal cord injury remains inconclusive [5, 23, 25–30]. Optimising bladder management, hand hygiene and fluid intake appear to be the most important measures for preventing urinary tract infections in athletes with neurogenic bladder [5, 7]. Our findings provide valuable insights into potentially unsuccessful urinary tract infection prophylaxis practices used by elite wheelchair athletes, highlighting the need for further evaluation of the effectiveness of current prophylactic measures and the potential exploration of other strategies tailored to this specific population.

Causes of urinary tract infections may be different in athletes compared to non-athletes. Stress was mentioned most often as a potential cause of urinary tract infections by our athletes, followed by air travel, training intensity and competition. These self-reported potential causes provide valuable insights that, while warranting further research, can already inform practices that can be incorporated into training. In non-disabled athletes, changes in training load, increased exposure to non-exercise stressors, competing at major competitions and international travel are associated with a higher risk of illness [2, 31]. The impact of a spinal cord injury on daily life can also indirectly increase the risk of urinary tract infections, especially in athletes. Often more time is needed for activities of daily living, including nutrition and personal hygiene, compared with non-disabled athletes. This leaves less time for rest and recovery, which, combined with a high training load, can lead to immunosuppression and an increased risk of infection [22]. Interestingly, in elite non-disabled athletes, higher training loads are, up to a certain point, associated with a lower risk of infection [1, 31].

Even the occurrence of a single urinary tract infection is relevant for elite athletes. A seemingly minor decrease in training volume or performance can have huge consequences in elite sports, where the difference between winning and losing competitions can be very small [32]. In non-disabled endurance athletes, a short-term (0–4 weeks) reduction or complete cessation of training leads to decreased cardiorespiratory, muscular, metabolic and hormonal functioning [33]. In elite track and field athletes, every training week that had to be modified due to illness or injury led to a significant decrease in the achievement of performance goals during international competitions [34]. The majority of our athletes who had experienced a urinary tract infection reported a negative impact on training volume and performance. Furthermore, an average loss of four training days was reported. The high number of urinary tract infections, together with the impact on training and performance, highlights the relevance of this problem and the need for effective strategies to reduce the occurrence of urinary tract infections in this population.

Strengths and limitations

This is the first study investigating the occurrence of self-reported urinary tract infections in a large cohort of elite wheelchair athletes. The cross-sectional design of our study prohibited any causal interpretation. Reuse of disposable catheters is a risk factor for developing urinary tract infections in elite wheelchair athletes [11], but this parameter was not collected in the current study and needs to be considered in future studies. The collected information was based on self-reported data which may be affected by recall and social desirability bias. The mediocre accuracy (66%) of self-prediction of a urinary tract infection further contributes to the uncertainty about the true number of urinary tract infections [35]. Nevertheless, as subjective measures may indeed surpass objective measures in athlete monitoring [36], we consider our collected data sufficiently reliable and clinically relevant. Future studies may investigate the incidence of urinary tract infections in wheelchair athletes longitudinally based on clinical symptoms and laboratory parameters, including leukocytes in the urine and bacterial culture.

Conclusion and clinical perspective

Although many athletes used prophylaxis, urinary tract infections were common in elite wheelchair athletes and had a negative impact on training and performance. More education seems to be needed regarding prophylactic measures, both for athletes as well as their support teams. We recommend that basic prophylactic measures, such as proper catheter hygiene and adequate hydration, be implemented in the daily routine of every athlete. Urine specific gravity testing provides a straightforward indication of the current hydration status and can be easily implemented during training or while traveling. The effectiveness of existing prophylactic measures needs to be evaluated and new prophylactic measures may need to be developed.

Availability of data

The dataset generated and analysed during the current study is available from the corresponding author upon reasonable request.

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Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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