Interrelation between Cycling and Renal and Urological Health: A Bibliometric and Systematic Review

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Keywords:	physical exercise, renal diseases, public health, risk factors, sport
Abstract:	This systematic and bibliometric review synthesizes current knowledge of the relationship between cycling, renal and urological health. A comprehensive search of databases from 2000 to 2023 yielded 38 relevant studies. Bibliometric analysis revealed research trends, key institutions, authors, and countries that contributed to this field. This review discusses the benefits and risks associated with cycling. Benefits

	included improved cardiovascular health and metabolic function. However, cycling was also associated with urological symptoms, particularly in women, and with risks of erectile dysfunction and genital numbness in both genders. Mountain biking demonstrated higher rates of scrotal pathologies. Saddle design, riding position, and cycling intensity significantly influenced perineal pressure and potential urological issues. Renal biomarkers indicated dehydration, muscle damage, and potential renal insufficiencies in cyclists, especially after prolonged and intense activity. Elevated inflammatory markers and reduced glomerular filtration rates were observed post-cycling. Sodium intake and L-tryptophan supplementation demonstrated positive effects on fatigue reduction and recovery. The review identified research gaps, including limited long-term studies and inconsistent methodologies. Future research should focus on the relationship between high-volume cycling and prostate cancer risk, optimizing bicycle design to reduce urological issues, and developing reliable methods to measure saddle pressure effects on renal health. This review provided valuable insights for cyclists, health professionals, and researchers, emphasizing the need for awareness of potential health impacts and the importance of proper equipment and techniques to minimize risks while maximizing cycling benefits.

Title: **Interrelation between Cycling and Renal and Urological Health: A Bibliometric and Systematic Review**

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Abstract

This systematic and bibliometric review synthesizes current knowledge of the relationship between cycling, renal and urological health. A comprehensive search of databases from 2000 to 2023 yielded 38 relevant studies. Bibliometric analysis revealed research trends, key institutions, authors, and countries that contributed to this field. This review discusses the benefits and risks associated with cycling. Benefits included improved cardiovascular health and metabolic function. However, cycling was also associated with urological symptoms, particularly in women, and with risks of erectile dysfunction and genital numbness in both genders. Mountain biking demonstrated higher rates of scrotal pathologies. Saddle design, riding position, and cycling intensity significantly influenced perineal pressure and potential urological issues. Renal biomarkers indicated dehydration, muscle damage, and potential renal insufficiencies in cyclists, especially after prolonged and intense activity. Elevated inflammatory markers and reduced glomerular filtration rates were observed post-cycling. Sodium intake and L-tryptophan supplementation demonstrated positive effects on fatigue reduction and recovery. The review identified research gaps, including limited long-term studies and inconsistent methodologies. Future research should focus on the relationship between high-volume cycling and prostate cancer risk, optimizing bicycle design to reduce urological issues, and developing reliable methods to measure saddle pressure effects on renal health. This review provided valuable insights for cyclists, health professionals, and researchers, emphasizing the need for awareness of potential health impacts and the importance of proper equipment and techniques to minimize risks while maximizing cycling benefits.

Keywords: Physical Exercise, Renal Diseases, Public Health, Risk Factors.

Highlights

- Cycling has both benefits and risks for renal and urological health. Benefits include improved cardiovascular health, while risks include urological symptoms and potential erectile dysfunction.
- Factors like saddle design, riding position, and cycling intensity significantly impact perineal pressure and urological issues. Mountain biking was associated with higher rates of genital numbness and scrotal problems compared to road cycling.
- More research is needed on the long-term effects of high-volume cycling on prostate cancer risk, optimizing bicycle design to reduce urological issues, and developing reliable methods to measure how saddle pressure affects renal health.

INTRODUCTION

Physical activity is widely recognized as an essential component of a healthy lifestyle, offering numerous benefits for both physical and mental health across different age groups: children (Biddle & Asare, 2011), adolescents (Hallal et al., 2006), adults (Peluso & Guerra de Andrade, 2005), and older adults (Leyland et al., 2019). Cycling is a popular and accessible form of physical activity that provides various physiological advantages, such as improvements in insulin sensitivity, body composition, inflammatory processes, and cardiovascular function, among others (Peruzzi et al., 2020). Cycling can be performed at varying intensities, durations, and frequencies, which makes it suitable for individuals of all ages and fitness levels. Moreover, cycling can be incorporated into daily routines, such as commuting or running errands, making it a convenient and sustainable mode of transportation (Anderson et al., 2022; Peruzzi et al., 2020).

The interaction between cycling and health is complex and multifaceted, and is influenced by numerous factors. On the one hand, cycling has been shown to provide numerous health benefits, including improvements in cardiovascular health, metabolic function, and mental well-being (Oja et al., 2011). On the other hand, cycling also poses health risks, particularly in terms of injury risk, accidents, and exposure to air pollution and traffic-related noise (Cherington, 2000; Dill, 2009; Edwards & Mason, 2014). Studies have indicated that the benefits of cycling, both as a sport and as a mode of transportation, far outweigh the risks (Rojas-Rueda et al., 2011).

Understanding the interaction between cycling and health requires a multidisciplinary approach that considers a variety of factors, including individual characteristics, environmental factors (Fraser & Lock, 2011), social and cultural factors, policies (Friss, 2022), and infrastructure (Dill, 2009). The physiological and mental benefits of cycling are thought to be mediated by a variety of mechanisms. For example, cycling increases blood flow to the brain (Linder et al., 2024), which can enhance cognitive function and reduce symptoms of depression and anxiety (Leyland et al., 2019). Cycling also stimulates the release of endorphins, which are natural painkillers that can improve mood and reduce stress (Bueno-Antequera et al., 2020). Additionally, cycling is a weight-bearing exercise that can increase bone density (Faria et al., 2005). The repetitive nature of cycling also improves neuromuscular coordination, which can enhance balance (Roberts et al., 2003).

While cycling's cardiovascular and metabolic benefits have been well-established, its specific effects on renal and urological systems warrant systematic investigation (Graham-Brown et al., 2021). Furthermore, the benefits of cycling extend to improving renal function in healthy individuals and even in patients with cardiovascular diseases (e.g., myocardial fibrosis, aortic stenosis) (Graham-Brown et al., 2021). As an aerobic exercise, cycling improves blood circulation, tissue oxygenation, and blood pressure control, which are essential for maintaining proper renal function. Additionally, cycling is a low-impact physical activity that helps manage conditions like overweight and obesity, which are risk factors for chronic renal diseases by aiding in calorie oxidation and weight control. However, prolonged cycling can also negatively impact these systems through dehydration and mechanical stress (Colombini et al., 2012; McDermott et al., 2018). Despite these multiple benefits, prolonged cycling (e.g., ultramarathons, multi-stage events) and overexposure to high temperatures can affect renal perfusion, fluid and electrolyte regulation, and dehydration indices, reducing renal function during and even after exercise (Colombini et al., 2012; Junglee et al., 2013; McDermott et al., 2018; Rojas-Valverde et al., 2020).

Under certain conditions, such as high physical load, heat exposure, and dehydration, there can be an exacerbated decline in renal function during cycling. Cycling also presents unique urological challenges due to its biomechanical demands (Dettori et al., 2004). Urological health can also face complications, such as nerve and blood vessel compression in the genital area, urinary infections, decreased glomerular filtration rate, proteinuria, hematuria, rhabdomyolysis, and other conditions (McDermott et al., 2018; Rojas-Valverde et al., 2020). Prolonged use of the saddle and constant pressure on the perineal area can lead to numbness, tingling, and, in more extreme cases, potential associations with erectile dysfunction, infertility, and prostate cancer, though direct evidence is still lacking (Dettori et al., 2004; Hollingworth et al., 2014).

Given the complex relationship between cycling's benefits and potential risks to renal and urological health, systematic evaluation is essential (Rojas-Rueda et al., 2011). In conclusion, and considering the evidence presented, a systematic and bibliometric review of the literature can provide a comprehensive overview of the existing research on this topic and identify key trends and knowledge gaps (Donthu et al., 2021a). The purpose of this review was to synthesize the current state of knowledge on the interaction between cycling and health, with a particular focus on the health benefits and risks associated with cycling. By employing a systematic and bibliometric approach, this review identified the most significant studies and their methods, as well as gaps in the existing literature and areas for future research.

METHODS

Study design

Systematic review

This research was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2015). The search included articles those published between January 2000 and January 2024. The keywords used for the search were "kidney (renal)" and "cyclis*", "urolog*" and "cyclis*". To better identify the keywords, reducing irrelevant resources or those with little information of interest, a bibliometric review was conducted before the main search to organize the information, identify key aspects, and discover people or organizations interested in the topic. All bibliographic references were collected using an open-source research tool called Zotero (Fairfax, Virginia, USA), then organized into a spreadsheet (Excel, Microsoft, California, USA). To select the most relevant studies, the inclusion and exclusion criteria were defined by the authors through consensus after reviewing potential articles for the research (Table 1).

[Table 1 near here]

Bibliometric review

Bibliometric analysis is a method of assisted scientific review that conducts evaluation and identification of key research or authors and their relationships. It compiles all publications related to the search topic in specific areas and those currently under development in the field of study (Han et al., 2020). Bibliometric analysis can provide more information and insight into the state of research on cycling related to renal and urological health (Churruca et al., 2019). Researchers use this type of analysis to stay updated on trending publications, articles and journal performance, collaboration elements, and research patterns in emerging literature (Verma & Gustafsson, 2020). This phase of the review was conducted following previously published procedures (Donthu et al., 2021a). A set of tools for bibliometric analysis was used, considering performance analysis (Cobo et al., 2011; Donthu et al., 2021b) (e.g., citation and publication metrics), and scientific mapping (Baker et al., 2021) (e.g., co-citation, co-word, co-authorship).

Consequently, the bibliometric analysis considered information such as authorship and co-authorship networks, year of publication, journals, affiliation, country, citations, and keywords. This study employed a homogeneous group of articles as a citation base, including the main Web of Science (WoS) database, based on a search vector exploring the interrelation between cycling and renal and urological health. The set of articles obtained was analyzed using bibliometrics, a method previously used in the field of exercise and health sciences to evaluate general bibliometric indicators, analyze scientific production, map scientific knowledge, and identify trends in terms of exponential growth. This approach ensured a sufficient volume of documented scientific production of interest to the international scientific community and allowed for meaningful analysis (Araya-Castillo et al., 2021; Marín-Suelves & Más, 2021).

Search and extraction process

The search and extraction of articles were conducted independently by one researcher (first author), while the selection of articles to be used was carried out jointly by all authors (advisory group and student). Studies with scientific evidence classified as second-level for the fields of exercise and health sciences were included. Literature related to book chapters, abstracts, and articles with significant information gaps was excluded. Duplicates between databases were identified and removed, and essential data from the selected studies were collected. To assess the relevance of each article, the full text was reviewed to verify compliance with the proposed eligibility criteria. The PRISMA flow diagram of the process can be seen in Figure 1-6. The information was presented in a matrix containing the following details for each of the finally selected articles: authors, participant characteristics, study design, health indicators assessed, and results.

[Figure 1 near here]

Statistical analysis

For the statistical analysis, Bradford's Law of Scattering was applied to the academic publications, dividing the articles into thirds to avoid the exponential decrease in yield when expanding the search to peripheral scientific journals related to the research topic (Borgohain et al., 2021). After identifying the most prolific group of authors and research subjects, Lotka's Law was applied to isolate authors with fewer publications based on the irregular distribution of scientific production among authors (Lotka, 1926). The h-index was applied to the works based on the most cited articles by the scientific community and the citations they received in other publications from the studied databases, defined as "n" documents cited "n" times or more (Crespo & Simoes, 2019). Zipf's Law was applied to discover the most frequently used words in the collection of evaluated articles through empirical observation (author keywords, keywords plus, or key terms in titles or abstracts). To visualize the spatiality and processing of information, co-authorship, and co-occurrence, VOSviewer software was used to perform fragmentation analysis with visualized results of topic and time (Bondanini et al., 2020; Uribe-Toril et al., 2019).

RESULTS

Search Extraction Results

In the first phase of "identification" using predetermined databases (Web of Science, Scopus, PubMed) and keyword searches, a total of 272 results were identified. The documents had to be published between 2000 and 2023. After applying the inclusion criteria by year, 234 documents were retained. The second phase, "eligibility," involved analyzing the documents based on their titles and abstracts. They had to meet at least one criterion: use of established keywords, specific population "cyclists," renal health evaluations (biomarkers), and exclusion of all scientific literature lacking the descriptors. This phase concluded with 114 results. The third phase, "selection," was facilitated using an Excel spreadsheet to exclude duplicate documents, identifying 48 duplicates and leaving 66 documents. For the fourth phase, "inclusion," the inclusion criteria were used to identify the scientific articles for the systematic review. The full texts were evaluated, excluding documents that mentioned clinical cases, literature reviews, commentaries, non-English texts, unavailable texts, motorcyclists, and other topics not specified in the criteria. The final result was 38 full original scientific articles in English (Figure 1).

Bibliometric Review

Research evolution

Over the last 23 years, scientific publications focused on renal health in cycling have been sparse. Based on the selected articles from 2000 to 2023, we observed that the years 2000, 2006, 2007, 2010, 2013, 2015, 2017, 2020, 2022, and 2023 recorded 0% productivity over a cumulative 10-year period. During the years 2004, 2005, 2012, 2016, and 2018, the annual productivity was 10.52%, averaging with two articles per period. In other years, at least one article was published annually, representing 5.26%, indicating generally low annual figures for renal health in cycling during the study period.

Publications focused on urological health in cycling have declined in recent years. From 2000 to 2023, the years 2009 and 2018 stood out with three publications each, representing 15.78% of the literature in each period. The years 2001, 2004, and 2019 had 10.52% productivity, equivalent to two publications each year. During 2005, 2008, 2014, 2016, 2020, 2021, and 2022, the publication percentage was 5.26%, with one article per year. In the years 2000, 2002, 2003, 2006, 2007, 2010, 2011, 2012, 2013, 2015, 2017, and 2023, productivity was 0%, indicating a significant gap in scientific development on "cycling and urological health."

[Figure 2 near here]

Institutions

The University of Milan contributed 26.31% of the research and scientific publications on renal health in cycling from 2000 to 2023, making it the most productive institution. It was followed by the IRCCS Galeazzi Orthopedic Institute and Innsbruck Medical University, each contributing 15.78%. Institutions such as Cedal Laboratory, Midwest State University, University of Innsbruck, and University of Padua each contributed 10.52% to the scientific literature, while the remaining institutions collectively contributed 5.26%.

The University of California, San Francisco, and the University of California system showed a 31.57% productivity in "cycling and urological health" from 2000 to 2023. Stanford University contributed 26.31%, and King Abdulaziz University contributed 21.05%. Other notable institutions include the Federal University of Santa Maria (UFSM), Federal University of Rio Grande do Sul, University of Cologne, University of Texas Austin, University of Texas System, and Washington University in St. Louis (WUSTL), each contributing 10.52%, with the remaining institutions collectively contributing 5.26%.

[Figure 3 near here]

Authors

The most prominent author was Banfi, with 5 scientific publications, representing 26.31% of the total productivity over the last 23 years in renal health and cycling. Corsetti and Lombardi each had a 21.05% contribution. Colombini, Graziani, and Lanteri contribute 15.78%. Authors Cappellin, De Palo, Gatti, Hoertnagl, Joannidis, Mittterbauer, Neumayr, Pfister, and Spinella each had a 10.52% contribution with 2 publications each, while the remaining authors contributed 1 publication each, making up 5.26% of the available scientific literature.

Breyer was the leading author with a 31.57% contribution to the scientific publications. Eisenberg had a 26.31% contribution, followed by Sanford with 21.05%. Awad, Gaither, Murphy, and Osterberg each contributed 15.78% to the research. Carpes, Carrol, Dagnese, Engelmann, Kleinpaul, Klotz, Martins, Metzler, Mota, Schwarzer, Sommer, and Sutcliffe each individually contributed 10.52%, with the remaining authors collectively contributing 5.26%.

[Figure 4 near here]

Countries

Italy stood out as the country with the highest number of academic publications in cycling and renal health, contributing 42.10% globally. Austria and the United States each represented 21.05% of the scientific productivity. Brazil and Spain contributed 10.52%, while Canada, Denmark, Germany, and South Africa each contributed 5.26%.

The United States led with 42.10% of global scientific research on "cycling and urological health." Saudi Arabia contributed 21.05%. Brazil, England, and Germany each contributed 10.52%. Austria, Italy, the Netherlands, Portugal, and Turkey each had a productivity of 5.26%.

[Figure 5 near here]

Research Areas

Of the scientific publications collected from 2000 to 2023, 57.89% were primarily focused on "Sports Sciences," representing the most developed research area.

"Medical Laboratory Technology" accounts for 15.79%, while "Nutrition Dietetics" and "Physiology" each contributed 10.52%. The remaining research areas accounted for 5.26%, highlighting the need for multidisciplinary approaches to expand the scientific reach and generate future research lines.

The research areas for urological health were predominantly concentrated in "Urology Nephrology," representing 84.21% of the collected information, with 16 scientific articles. "General Internal Medicine" and "Sports Sciences" each contributed 10.52%. "Physiology" and "Public Environmental Occupational Health" each contributed 5.26%.

[Figure 6 near here]

Participants and characteristics

The studies included in this review reported different sample sizes. In total, 44,131 participants were recorded, comprising 23,085 men, 4,461 women, and 3 participants who identified as non-binary (reported in one study). Another study reported a sample of 16,585 participants, including both men and women, but did not adequately specify the gender distribution. The selected studies encompassed a broad range of participants by practice level (e.g., amateur, recreational, elite, professional, competitive), category (e.g., non-cyclists, experienced, high and low intensity), modality (e.g., ultramarathon, endurance), teams (e.g., sports clubs, professional teams), discipline (e.g., MTB, track), sports (e.g., kayaking, athletics, football), physical condition (e.g., healthy, sedentary, athletic, and physically active), and health condition (e.g., trauma patients, transplant recipients).

Study design

The designs and types of interventions varied among the included studies, with a higher incidence of observational designs (n=9), experimental (n=7), and cross-sectional (n=7). The distribution of study types was as follows: online questionnaires (n=12), recruitment by selection (n=11), voluntary participation (n=10), and data analysis (n=5).

Main Results

Table 2 presents the main results of the urological health variables. Regarding cycling and health outcomes, a mild association was found between cycling duration and prostate cancer (CaP), particularly in subjects cycling more than 8.5 hours per week (Hollingworth et al., 2014). However, another study did not establish a correlation between cycling and CaP, erectile dysfunction (ED), chronic pelvic pain syndrome (CPPS), or lower urinary tract symptoms (LUTS) in men (Koupparis et al., 2020). Despite this, ED was not linked with genital numbness, irrespective of cycling frequency and intensity (Baradaran et al., 2019). Nonetheless, reports from male cyclists highlighted associations between age, comorbidities, and ED (Brito et al., 2022), and mountain biking was associated with higher rates of ED and scrotal pathologies (Dettori et al., 2004; Mitterberger et al., 2008).

Symptoms resembling edema were reported in both genders during and after prolonged rides, with a more pronounced impact observed in women (Gauckler et al., 2021). Female cyclists engaging in high-intensity cycling exhibited a higher likelihood of urinary tract infections (UTIs) (Gaither et al., 2018). High prevalences of urological symptoms and injuries, including sexual dysfunction, vulvar edema, and genital pain and numbness, were reported (Greenberg et al., 2019; Hermans et al., 2016; Lui et al., 2021). Additionally, a negative correlation was found between cycling intensity and LUTS (Awad et al., 2018).

Studies exploring perineal pressure revealed that trunk position, saddle design, and pedaling conditions significantly influenced perineal pressure (Carpes et al., 2009a, 2009b; Sanford et al., 2018). The SMP saddle design was noted for reducing vascular compression and perineal injuries in long-distance cyclists (Breda et al., 2005). Different seating postures affected penile transcutaneous oxygen pressure (tpO2), with decreases observed in sitting and upright positions compared to reclining positions (Sommer et al., 2001a, 2001b).

Increases and improvements in maximum oxygen consumption (VO2max) and power output (POT) were observed following physical training. However, mineral supplementation with calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and copper (Cu) did not enhance cyclist performance (Dressendorfer et al., 2002).

Renal and genital injuries were frequent among cyclists, primarily in males, involving the kidney, bladder, urethra, penis, and scrotum (Baradaran et al., 2019; Bjurlin et al., 2011). Significant changes in renal biomarkers included elevated levels of creatinine (CR), urea, uric acid, blood urea nitrogen (BUN), creatine kinase (CK), serum creatinine (sCr), lactate dehydrogenase (LDH), and aspartate aminotransferase (AST) (Neumayr et al., 2003, 2005; Venta et al., 2009; Colombini et al., 2012b; Corsetti et al., 2016), alongside reductions in glomerular filtration rate (GFR) (Colombini et al., 2012a; Lippi et al., 2008; Touchberry et al., 2004). Inflammatory biomarkers IL-6, TNF-α, and IFN-γ were elevated post-cycling (Cappuccilli et al., 2016), as were urinary levels of proANP31 67 and proANP1–30 (Cappellin et al., 2004).

Supplementation with L-tryptophan was found to be effective in reducing fatigue and improving efficiency and recovery among cyclists (De Yzaguirre et al., 2019). Sodium (Na+) intake mitigated dehydration during prolonged and intense physical activities (Sanders et al., 2001). Increases were recorded in plasma concentrations of homocysteine (Hcy), homocysteine cysteine (Cys), pyridoxal-5'-phosphate (PLP), and vitamin B12 (Venta et al., 2009). Progressive increases during continuous endurance exercise were observed in fibroblast growth factor 23 (FGF23) and plasma volume (PV) (Lombardi et al., 2014). Prostate-specific antigen (PSA), follicle-stimulating hormone (FSH), luteinizing hormone (LH), and uroflowmetry did not differ significantly between cyclists and non-cyclists (Saka et al., 2009). High levels of urinary neutrophil gelatinase-associated lipocalin (uNGAL) were found in endurance cyclists (Machado et al., 2018; McDermott et al., 2018). Increases in insulin-like growth factor I (IGF-I), total urinary proteins (uPr), and urinary creatinine (uCr) were observed following prolonged strenuous exercise (De Palo et al., 2005).

[Table 2 near here]

DISCUSSION

This systematic and bibliometric review integrates current information about cycling and renal/urological health. Through a comprehensive search between 2000 and 2023, 38 relevant studies were identified for inclusion in this analysis. By bibliometric analysis, significant gaps in research were identified, as themes concerned with renal and urological health had 10- and 12-year productivity rates of 0% during the period 2000-2023, which indicates an unbalanced emphasis in this specialty. Studies were highly concentrated in Europe, especially in Italy, and in North America, namely in the USA, in which 48 institutions were active through individual and collaborative work. These findings indicate the need for greater global collaboration in order to heighten awareness and build greater attention in this specialized area through its empirical basis.

Urological effects

The extensive research revealed complex urological effects linked with cycling exercises. Female riders show significantly greater prevalence in urological symptoms, with 44% of the respondents reporting episodes of genital numbness, as reported in previous literature (Greenberg et al., 2019; Hermans et al., 2016; Lui et al., 2021). Additionally, individuals participating in vigorous cycling show increased vulnerability towards urinary tract infections in comparison with non-cycling individuals (Gaither et al., 2018). Male and female respondents face prospective danger in genital numbness and sexual impairment; however, the correlation remains specific to the cycling exercises exercised (Taylor et al., 2004).

Mountain biking has been linked with increased urological hazards in comparison with road cycling, displaying enhanced frequencies in erectile dysfunction and scrotal disease (Dettori et al., 2004; Mitterberger et al., 2008). Interestingly, 94% of the mountain bikers had at least one pathological finding in scrotal ultrasound, in contrast with 48% in road cyclists. This increased vulnerability has been linked with the serial trauma delivered by uneven surfaces and variegated terrains.

Basic biomechanical factors contribute significantly towards the urological outcomes in the form of saddle geometry, trunk angle, cycling surroundings, and pedaling force, which all contribute towards the distribution of pressure in the perineum (Carpes et al., 2009a; Carpes et al., 2009b; Sanford et al., 2018). Studies concerned with perineal pressure have confirmed that trunk angle and saddle geometry have important influences towards pressure distribution and long-term urological system health.

Renal Function Changes

Intensive cycling exercises, especially ultra-endurance events, bring about extensive changes in renal biomarkers. Noticeable increases have been reported in the levels of creatinine (CR), urea, uric acid, blood urea nitrogen (BUN), creatine kinase (CK), serum creatinine (sCr), lactate dehydrogenase (LDH), and aspartate aminotransferase (AST) (Colombini et al., 2012a; Corsetti et al., 2016; Neumayr et al., 2005; Venta et al., 2009). Increased levels indicate a transient physiological stress response, which can include dehydration, muscle damage, and possible renal compromise.

Numerous studies have all provided findings of lowered glomerular filtration rate (GFR) after cycling, which suggest altered renal function and the possible accretion of muscle activity-derived metabolites (Colombini et al., 2012b; Lippi et al., 2008; Touchberry et al., 2004). Increased levels of proANP31 67 and proANP1–30 were found after sustained physical exercise, suggesting the onset of cardiac stress responses (Cappellin et al., 2004).

Increased levels of inflammatory cytokines, including IL-6, TNF-α, and IFN-γ, were found after cycling exercise, and systemic inflammatory processes could potentially affect long-term renal function (Cappuccilli et al., 2016). Long-distance cyclists also had increased levels of urine neutrophil gelatinase-associated lipocalin (uNGAL), which indicates inflammatory processes related to renal stress or potential temporary renal dysfunction (Machado et al., 2018; McDermott et al., 2018).

Transcutaneous penile oxygen pressure (tpO2) had fluctuations that were correlated with various sitting and upright cycling postures, and decreases in sitting and upright postures when compared with reclining postures (Sommer et al., 2001a; Sommer et al., 2001b). Participants in the cycling study were mainly males and often had histories that incorporated renal and genital trauma, which included the kidney, bladder, urethra, penis, and scrotum (Baradaran et al., 2019; Bjurlin et al., 2011).

Protective Strategies and Positive Adaptations

Several interventions have had favorable effects in cyclists. Sodium (Na+) supplementation has been found efficacious in countering dehydration during long and intense physical exercise and thus ensuring plasma volume maintenance and fluid losses reduction (Sanders et al., 2001). Furthermore, L-tryptophan administration at 10 mg/kg has been reported significantly to diminish fatigue subjective perception as well as performance and recovery in elite cyclists when taken during dinner, breakfast, and 30 minutes before exercise (De Yzaguirre et al., 2019).

Equipment modifications have proved significant protective effects. Saddle designs that include SMP technology have significantly lowered the number of long-distance cyclists using conventional saddle styles suffering from perineal injury and vascular constriction (Breda et al., 2005). Specialized saddles attempt to mitigate urological symptoms and examine possible links between prostate cancer risk and symptoms; some research has reported an unclear association between extended cycling times in excess of 8.5 hours per week and prostate cancer in men (Hollingworth et al., 2014).

Some biomarkers have been identified as indicators of favorable physiological adaptions related to cycling. Significantly, the major increase in plasma volume (PV) and fibroblast growth factor 23 (FGF23) during intense endurance training indicates adaptive processes that increase thermoregulation, tissue perfusion, and mineral homoeostasis (Lombardi et al., 2014). Furthermore, prostate-specific antigen (PSA), follicle-stimulating hormone (FSH), luteinizing hormone (LH), and uroflowmetric parameters did not differ between non-cyclists and cyclists and thus indicate that regular cycling has no detrimental effects on male reproductive fitness and doesn't increase prostate cancer risks (Saka et al., 2009).

However, increases in plasma homocysteine (Hcy), homocysteine cysteine (Cys), pyridoxal-5'-phosphate (PLP), and vitamin B12 during intense exercise may have detrimental effects on renal and cardiovascular fitness and represent potential nutritional deficiencies (Venta et al., 2009). Additionally, other physiological changes were noted, which included increased levels of insulin-like growth factor I (IGF-I), consistent with indicators of anabolic activity related to muscle strengthening and repair during long exercise intervals. Increased total urinary proteins (uPr) and urinary creatinine (uCr) after intense exercise were consistent with renal stress, which if long-term, would require counteraction through traditional medical interventions in order to forestall extensive renal compromise (De Palo et al., 2005). These findings support previous reports in several ultra-endurance events and support the initiation of preventive measures as a means of protecting against future disease states (Scheer et al., 2021).

Research Limitations and Future Directions

Recent studies unveil common shortcomings in methodology typical for the field of sports medicine. Heterogeneity in samples remains a problem, as seen in uneven gender allocation, which makes it difficult to interpret findings. Furthermore, there remains inadequate control for important factors like bike make, rider posturing, saddle characteristics, environmental factors, and standardization in laboratory analyses. Variability in sample size, ranging from small groups to larger populations (maximum 44,131 participants), affects the limitation in analysis specificity and may bring in confounders. Overall dependence in 12 out of 38 studies using online surveys as methodology diminishes face-to-face contacts between investigators and respondents and may compromise the quality and richness in obtained data. Although efficient and convenient, this technique has limited potential for validation and assessment in the clinical environment and objective measures. Additionally, lack of longitudinal follow-up studies further limits understanding about chronic health effects related to long-term cycling exposure.

Future research projects should fill several important gaps in current literature identified through this review. They should include prospective cohort studies examining the long-term association between cycling for periods longer than 8.5 hours per week and prostate cancer risk, establishing if relief of genital pain and numbness can facilitate recovery in females with sexual dysfunction, establishing sound methodologies for assessing the effect of saddle pressure across renal function, and calibrating cycling geometry so that urological complications are restricted and benefits for cardiovascular disease are maintained. Secondary research goals should include assessing the value of ultrasound anomalies in road and mountain bikers as objects of clinical attention, examining the cardioprotective effect of adiponectin in ultra-distance recovery, tracking ultra-distance exercise effects across calcium levels and urine biomarker concentrations, examining the effectiveness of preventive measures across long-distance cycling complications, examining analgesic and fluid replacement protocols during ultra-distance events, comparative studies aiming at endurance events with primary renal function emphasis, and establishing validated questionnaires for assessing sexual health in females across cycling.

CONCLUSIONS AND PRACTICAL APPLICATIONS

This systematic review clarifies that cycling has a complex health profile, which includes significant benefits along with specific urological and renal considerations. Cycling and health outcome association displays significant heterogeneity, which gets affected by factors like cycling modality, equipment design used, time of practice, and divergent levels of intensiveness. Although fears about urological disease and signs of temporary renal stress exist, there exists ample evidence in support of cycling as a good exercise modality, provided there is specific preventive attention. A best possible balance between benefits and limitations can be reached through application of evidence-based equipment selection, correct positioning, and cognizance about potential complications; however, extensive gaps in research remain regarding long-term results and inherent mechanisms.

Healthcare providers should provide evidence-informed advice prioritizing the best use of equipment, in particular, specialized saddle types like SMP models, appropriate bike alignment, and implementing symptom monitoring guidelines for urological or renal symptoms during and after cycling activity. Key recommendations include provision for adequate nutrition and hydration, with specific regard for sodium and L-tryptophan supplementation in endurance rides in excess of 90 minutes, seeking medical evaluation for symptoms that do not cease, and acknowledgement that mountain biking presents increased incidences of urological complication when set alongside road cycling. This paper identifies the need for evidence-based guidelines in optimizing the benefits of cycling and minimizing harm potential through continued cycling participation with appropriate safety measures rather than promoting activity discontinuation.

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TITLES OF TABLES

Table 1. Inclusion and exclusion criteria for the study selection.

Table 2. Studies included in the systematic review.

TITLES OF FIGURES

Figure 1. Systematic review process flowchart.

Figure 2. Publication trends of articles related to (A) renal and (B) urological health in cycling.

Figure 3. Productivity of institutions of articles related to (A) renal and (B) urological health in cycling

Figure 4. Productivity of authors of articles related to (A) renal and (B) urological health in cycling.

Figure 5. Research distribution based on countries of articles related to (A) renal and (B) urological health in cycling.

Figure 6. Research areas of articles related to (A) renal and (B) urological health in cycling.

Table 1. Inclusion and exclusion criteria for the study selection

Inclusion criteria
Original scientific studies
About the study topic cycling and renal and urology
English and Spanish manuscripts
Full-text research available
Publication date between 2000 and 2023
Studies about assessments of renal health (e.g. biomarkers, signs, symptoms).
Search terms needs to be included in title, abstract or keywords
Participants were included independently of level (e.g. competitive, trained, recreative, etc.).
Exclusion criteria
Incomplete documents
No published studies (preprints)
Not referenced studies
Not academic manuscripts (e.g. editorials, newspapers, web pages, opinions, congress communications or others).
Studies that participants are not humans
Studies in motorcycling

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
1	(Hollingworth et al., 2014)	Observational Cross-sectional	Investigate the association between cycling volume and erectile dysfunction, infertility, and PCa	n= 5282 ♂ cyclists' Hours/week: <3.75 = 1269 3.75 – 5.75 = 1223 5.76 – 8.5 =1492	Online survey	Erectile Dysfunction (ED), infertility and prostate cancer.	ND	There is a relationship between cycling time (3.75 - 8.5 hours per week) and prostate cancer (PCa).	Deeper study into the relationship between high volumes of cycling and prostate cancer
2	(Lui et al., 2021).	Cross-sectional International	Explore the associations between cycling characteristics, female genital numbness, and FSD.	n= 875♀ cyclists from sports clubs Groups: Without numbness = 494♀ With numbness = 381♀	Online survey	BMI, hypertension, diabetes mellitus, ischemic heart disease, urinary tract infection, smoking, alcoholism and FSFI	ND	There is a relationship between cycling practice and genital numbness in 44% of subjects.	Identify the anatomical and physiological factors that contribute to genital numbness in female cyclists
3	(Taylor et al., 2004).	Cross-sectional	Investigate whether there is a correlation between cycling practice and ED	n= 688♂ cyclists from cycling clubs Groups: Recreational: n= 252♂ Competitive: n= 401♂ Professional: n= 35♂	Online survey	Hypertension, coronary artery disease, age, diabetes mellitus, smoking and IIEF questionnaire.	ND	Duration of 1-59min in female sexual dysfunction post exercise.	Larger case-control studies are needed to define the relationship between cycling and ED
4	(Carpes et al., 2009a).	Observational	Investigate the effect of trunk position and saddle design on saddle pressure during cycling for men and women	n= 22 (11♂ and 11♀) recreational cyclists Age: 22 ± 3 years	Recruited by selection	Age, height, body mass, BMI, body position (trunk, legs, head and neck). Length of hospital stay, intensive care, ventilatory support, mortality and ISS.	ND	In ♂, saddle pressure is affected by trunk position at 60° and saddles with holes. In ♀, saddle pressure is not influenced by trunk position or saddle design.	Develop more reliable and valid methodologies to measure saddle pressure and its effects on kidney health.
5	(Bjurlin et al., 2011).	Retrospective cohorts	Evaluate cycling-related GU injuries.	n= 16,585♂♀ cyclists with trauma	Data analysis	Weight, height and BMI, Hb, Hct, PO/m and NEE Age, body weight, height and BMI	AIS and AAST organ injury scale.	GU organ injuries; most frequent; kidney (75%), bladder and urethra (15%), penis and scrotum (10%). 368 GU injuries were identified in 358 subjects, 86% ♂	ND
6	(Corsetti et al., 2016).	Observational	Identify the relationship between metabolic effort, muscle activity/damage indices and urinary amino acid profile in endurance activity	n= 9♂ professional cyclists Age: 24.6 – 34.5 years	Data analysis	Age, height, body mass, BMI, body position (trunk, legs, head and neck). Length of hospital stay, intensive care, ventilatory support, mortality and ISS.	GFR, eGFR, MDRD, BUN, sCr, CK, LDH and AST.	↑ levels of BUN, CK and sCr. ↑ PO/m and NEE during the first half of the race. Renal function in GFR remained stable.	The identified fatigue markers may be useful for monitoring and evaluating athlete performance in similar competitions.

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
7	(Lippi et al., 2008).	Comparative Cross-sectional	Evaluate differences in eGFR by different equations in professional cyclists at rest and sedentary healthy controls.	n= 120♂ Groups: n= 60♂ professional cyclists n= 60♂ healthy sedentary	Data analysis	Weight, height and BMI, Hb, Hct, PO/m and NEE Age, body weight, height and BMI	sCr, GFR, MDRD, MCQE and C-G equation	↓ sCr concentrations in cyclists. ↑ eGRF by MDRD in cyclists. MCQE and C-G did not differ compared to the control group.	ND
8	(Gaither et al., 2018).	Cross-sectional International	Explore the relationship between cycling and sexual and urinary dysfunction in women..	n= 3118♀ Groups: n= 1053♀ non-cyclists n= 1656♀ low-intensity cyclists n= 409♀ high-intensity cyclists	Online survey	Age, BM, hypertension, diabetes mellitus, ischemic heart disease, tobacco use, race, urinary symptoms, sexual activity, FSFI, AUA-SI, UTIs and LUTs	ND	↓ sexual dysfunction in high-intensity ♀ cyclists. ↑ probability of UTIs in high-intensity ♀ cyclists vs ♀ non-cyclists.	Analysis of UTIs and prevention measures for saddle sores.
9	(Koupparis et al., 2020).	Cross-sectional	Examine the association between cycling and men's health issues in PCa, ED, CPPS and LUTs.	n= 8074♂ cyclists	Online survey	Hypertension, high cholesterol, family history of PCa, ED, CPPS, LUTS, heart attack or angina, active smoker, BMI, SHIM, NIH-CPSI and ICIQ-MLUTS	ND	No correlation between cycling and health problems; PCa (0.57%), ED (145%), CPPS (8.82%) and LUTs (12.5%).	ND
10	(Awad et al., 2018).	Cross-sectional International	Explore the relationship of cycling with urinary and sexual function in a large multinational sample of men.	n= 3932♂ Groups: n= 1158♂ non-cyclists n= 1858♂ low-intensity cyclists n= 916♂ high-intensity cyclists	Online survey	BMI, diabetes mellitus, hypertension, ischemic heart disease, benign prostatic hyperplasia, smoking, SHIM, I-PSS, NIH-CPSI, UTIs and LUTs.	ND	Negative relationship of LUTS in low or high intensity and recreational cyclists. No relative differences in I-PSS and NIH-CPSI results. ↓ SHIM score in non-cyclists.	ND
11	(Breda et al., 2005).	Experimental	Identify a bicycle saddle model for long-distance cyclists to minimally reduce compression on pelvic floor structures.	n= 29♂ healthy cyclists Age: 25.14 years	Voluntary participation	Weight, height, heart rate, oxygen saturation, blood pressure, IIEF and PtcO2	ND	SMP design is superior to traditional saddle design. ↓ vascular compression of perineal and pelvic floor structures in long-distance cycling.	ND
12	(Mitterberger et al., 2008).	Cross-sectional	Ultrasonographically investigate whether mountain bikers have a higher prevalence of scrotal abnormalities compared to road cyclists.	n= 135♂ cyclists Groups: n= 85♂ mountain bikers n= 50♂ road cyclists	Data analysis	Scrotoliths, testicular/epididymal calcifications, spermatoceles, hydroceles, varicoceles and testicular microlithiasis	ND	94% of mountain bikers had at least one pathological finding on scrotal ultrasound compared to 48% of road cyclists.	Determine the clinical significance of the ultrasound abnormalities observed in the study.

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
13	(Gauckler et al., 2021).	Cross-sectional	Investigate the prevalence and factors associated with edema-like symptoms in ultra-endurance cyclists	n= 919 ultra-endurance cyclists n= 814♂ n= 102♀ n= 3⚥	Online survey	Blood pressure, heart rate, BMI, consumption and intake of electrolytes, fluids and analgesics.	ND	65.6% reported presence of body swelling symptoms, changes in diuresis and urine. 54.2% experienced at least one swelling symptom, with higher prevalence in ♀.	Analysis of analgesic and fluid intake in ultra-distance cyclists.
14	(Sanford et al., 2018).	Experimental	Evaluate the relationship between oscillation forces and perineal pressures among cyclists in a simulated laboratory setting.	n= 39 (29♂ and 10♀) healthy cyclists	Online survey	Height, age, weight, and BMI	ND	↑ of 19.4% in stationary condition and 26.9% in pedaling condition in perineal pressure, ↓ of 53% in oscillation impact with saddle post shock absorber in stationary condition.	Evaluate whether perineal-specific shock absorption reduces perineal diseases
15	(Cappellin et al., 2004).	Observational	Investigate the effect of prolonged physical exercise on urinary proANP levels in a group of cyclists	n= 28♂ professional cyclists Age: 16.6 ± 0.1	Recruited by selection	Body mass, height, BMI health questionnaires.	proANP1–30 y proANP31–67, sCr, total protein	↑ urinary levels of proANP31–67 post exercise. proANP1–30 had no variability. ↓ creatinine and total protein in urine post exercise.	Functionality of monitoring urinary biomarkers to evaluate renal function in athletes.
16	(Carpes et al., 2009b).	Experimental	Evaluate the effects of two different pedaling workloads and two saddle designs on saddle pressure.	n= 22 (11♂ and 11♀) recreational cyclists Age: ♂22 ± 2 / ♀22 ± 3	Voluntary participation	Body mass, height, BMI, mean and maximum saddle pressure.	ND	↑ mean pressure in simple saddle in relation to workload in males. ↑ mean pressure in saddle with hole in relation to workload, regardless of sex.	ND
17	(Dettori et al., 2004).	Prospective cohorts	Examine the relationship between bicycle characteristics and ED.	n= 463♂ endurance cyclists	Online survey	Body weight, BMI, tobacco and alcohol consumption, history of diabetes and hypertension and perineal numbness.	ND	↑ risks of suffering ED in mountain bikes compared to road bikes and when using a handlebar height equal to or higher than the saddle. Little association between ED and saddle width, padding and inclination.	Analyze whether long-distance road cycling can reduce the risk of erectile dysfunction
18	(Sommer et al., 2001a).	Experimental	Investigate if there is any difference in penile oxygen tension when cycling in an upright versus reclined position	n= 46♂ healthy athletes Age: 32 ± 5.13	Data analysis	Weight, height, heart rate, blood pressure and tpO2.	ND	↓ of tpO2 in upright position to 17.9±3.9mmHg (initial 60.5±8.1mmHg. ↓ of tpO2 in reclined position 58.8±3.7mmHg (initial 61.1±6.9mmHg).	ND

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
19	(Brito et al., 2022).	Cross-sectional	Evaluate the effects of amateur cycling on erectile function using a comparative athlete group and a validated sexual questionnaire.	n= 242♂ Groups: n= 199♂ amateur cyclists n= 43♂ amateur soccer players	Recruited by selection	BMI, age, ED, tobacco consumption, alcohol, comorbidities and IIEF	ND	Age and comorbidities are associated with ED in cyclists. No relative differences in total IIEF score between both groups.	ND
20	(Colombini et al., 2012a).	Observational	Evaluate GFR using creatinine-based equations on renal function of professional cyclists during a 3-week stage race (T).	n= 9♂ professional cyclists Age: 27 ± 2.5 years	Recruited by selection	BMI, BSA, Hb and Hct.	sCr, cystatin C, eGFR, CG formula, MDRD and CKD-EPI.	Stable values of sCr, cystatin C and eGFR. ↓ of Hb and Hct in T12 and stabilization in T22. ↓ GFR with CG formula notably in T22 compared to T1.	More accurate methods to evaluate renal function in athletes
21	(De Yzaguirre et al., 2019).	Double-blind crossover	Determine under which test conditions, oral L-tryptophan supplementation favorably influences the perception of fatigue during exercise.	n= 10♂ elite cyclists Age: 21.3 ± 5.57 years	Voluntary participation	Weight, height, body fat, BMI, heart rate, blood pressure, Ht, lactic acid, glucose, total cholesterol, HDL cholesterol, triglycerides, uric acid and free fatty acids.	Urea and sCr.	85% elite ♂ cyclists experienced less fatigue when consuming L-tryptophan supplements (10 mg/kg). Dose ingested at dinner the day before, at breakfast on the day of the test and 30min pre-exercise.	ND
22	(Greenberg et al., 2019).	Cross-sectional survey	Investigate the association between genital pain and numbness experienced in female cyclists and FSD.	n= 178♀ cyclists Age: 48.1 ± 0.8 years	Online survey	Age, race/ethnicity, BMI, smoking and comorbidities, hypertension, diabetes and cardiovascular diseases, arthritis and FSFI.	ND	53.9% of female cyclists had FSD, 58.1% genital numbness and 69.1% genital pain, Cycling >10h weekly increases the risk of suffering genital pain.	Determine if relieving genital pain and numbness can improve FSD.
23	(Sommer et al., 2001b).	Crossover	Determine if perineal compression during cycling causes changes in blood supply to the penis.	n= 40♂ healthy athletes Age: 30 ± 5.3 years	Voluntary participation	Age, weight, height, tpO_2, heart rate, blood pressure and KEED.	ND	↓ of tpO_2 in 70% of ♂ in sitting position. Standing position showed no relative alteration in tpO_2 results. 61% of ♂ reported genital numbness and 19% erectile dysfunction.	Evaluate the impact level of proper positioning on the bicycle and different saddle designs.

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
24	(Cappuccilli et al., 2016).	Observational prospective	Investigate the effect of a 130 km cycling race on inflammatory cytokines and adiponectin levels in transplant recipients.	n= 86♂ Groups: n= 35 healthy cyclists n= 19 cyclists with transplant n= 32 sedentary transplant recipients	Recruited by selection	Age, BMI, heart rate, blood pressure, clinical history, fluid intake, (IL-6), TNF-a, IFN-y, adiponectin, SF-36 health questionnaire, anamnesis, immunosuppressive and antihypertensive therapy.	ND	↑ of IL-6 by 6 to 8 times in both groups of cyclists. ↑ progressively TNF-a and IFN-y, remained between 18-24h post-race in healthy cyclists.	Question the function of adiponectin as a molecule that protects the cardiovascular system.
25	(Dressendorfer et al., 2002).	Experimental	Analyze the effects of intense endurance training on basal plasma and urinary Ca, Mg, Fe, Zn and Cu levels.	n= 9♂ experienced cyclists	Voluntary participation	Age, height, weight, VO2max heart rate, basal plasma, POT, Ca, Mg, Fe, Zn and Cu.	ND	↑ of 9% in VO2max (4.72L) and 19% POT (307W). Stable mineral levels, did not improve performance pre and post workouts.	Effect of high-intensity training on Ca levels.
26	(Venta et al., 2009).	Experimental	Investigate the effect of different acute intense aerobic exercises on Hcy and Cys.	n= 19♂ Groups: n= 15♂ endurance cyclists n= 14♂ kayakers	Recruited by selection	Age, height, weight, BMI, fat percentage, SM4, RER, expired respiratory gases, VO2max, heart rate, Hb and Hct.	Folate, vitamins B12, aminothiols, sCr, amino acids, PLP, rHcy, tHcy, rCys and tCys.	↑ of plasma concentrations of tHcy and rHcy, in both groups. ↑ of PLP, vitamins B12 and creatinine post exercise. No changes in amino acids and folate.	ND
27	(Machado et al., 2018).	Observational	Quantify urinary NGAL in endurance cyclists and compare it with physically active subjects	n= 36♂♀ Groups: n= 13♂ and 6♀ endurance cyclists n= 12♂ and 5♀ physically active subjects	Voluntary participation	Height, weight, BMI, fat percentage, abdominal circumference, waist and hip, waist-hip ratio, Hb and Hct.	sCr, urea, uNGAL and GFR.	↑ levels of uNGAL in cyclists (387.7ng/mL) compared to physically active subjects. No correlations between uNGAL levels and sCr, urea or GFR between both groups.	Evaluation of the 48-hour post-exercise recovery period, even immediately.
28	(Lombardi et al., 2014).	Observational	Explore the effects of long-term continuous endurance exercise on the hormonal axis regulating calcium/phosphorus metabolism.	n= 9♂ professional cyclists Age: 26.7 ± 2.50	Recruited by selection	Height, weight and BMI, fat percentage, net energy expenditure and power.	PTH, 25(OH)D, Ca, P, PV and FGF23.	↑ progressively in PV 10.9% and FGF 23. No relevant changes in PTH and 25(OH)D. Ca and P remained stable.	ND
29	(Neumayr et al., 2005).	Cross-sectional	Evaluate the renal and hematological effects of ultra-endurance cycling in the world's top ultra-marathon cyclists.	n= 16♂ professional ultra-marathon cyclists	Voluntary participation	Age, height, weight, BMI, Hb, Hct, RBC, Na+, K+, Cl-2 and Ca2+ concentrations	CR, CK, urea, FENa+, FEUA, CCR, TTKG and PV	↑ in urea (97%), CR (33%), uric acid (18%), PV (8-22%), ↓ of CCR (25%), FEUA (7%) and FENa+ (0.5%)	ND

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
30	(McDermott et al., 2018).	Observational	Observe the effects of endurance cycling in heat conditions on renal function and IBU intake on renal stress.	n= 40 (34♂ and 6♀) endurance cyclists	Voluntary participation	Age, height, weight, body mass and fat,	sCr, NGAL, FENa+, USG.	↑ of NGAL (139.12 ng/mL), sCr (62%) ↓ FENa+ decreased (0.27%). No differences in renal stress biomarkers between subjects who ingested IBU or placebo.	Identify the specific causes of renal stress that contribute to possible acute kidney injury (AKI), or elevation of biomarkers.
31	(Saka et al., 2009).	Observational Cross-sectional	Determine the effect of cycling on various PSA isoforms, gonadotropins and uroflowmetric parameters	n= 58♂ Groups: n= 34♂ healthy cyclists n= 24♂ healthy	Voluntary participation	Age, BMI, tPSA, fPSA, LH, testosterone uroflowmetry, PVR and FSH.	ND	No relative differences between cyclists vs students, in tPSA, fPSA, FSH, LH and uroflowmetry values. ↓ of testosterone post activity in both groups.	ND
32	(Colombini et al., 2012b).	Prospective, no comparative, intervention	Investigate the relationship between CK activity and renal function indices in a 3-week stage race.	n= 9♂ profesional cyclists Age: 26.7 ± 2.50	Recruited by selection	ND	eGFR, CK, cystatin C, CR, LDH, AST.	No differences between eGFR, CK and cystatin C. Negative correlation between CK and GFR on day 12. ↑ progressive of LDH. ↑ of CK and AST during the second phase of the race.	ND
33	(Sanders et al., 2001).	Crossover	Examine the effects of Na+ replacement and water loss on changes in body fluid volume during exercise.	n= 6♂ endurance cyclists Frequency: <90min/day, 4-6 times per week	Recruited by selection	Age, weight, height, plasma osmolality, Hb, Hct, Na+, PV, ECF, ICF and VO2max.	ND	Na+ intakes maintained PV and reduced dehydration, ICF water losses and ECF contraction are related to Na+ replacement.	ND
34	(Baradaran et al., 2019).	Cross-sectional International	Evaluate the association of genital numbness and ED in male cyclists.	n= 2,774♂ cyclists Groups: With numbness: n= 1217 Without numbness: n= 1,557	Online survey	Height, weight, ED, SHIM, diabetes, hypertension, myocardial infarction smoking and alcoholism.	ND	ED is not associated with genital numbness, regardless of frequency and intensity. SHIM results without differences between groups. Genital affectations of 44% (penis) and 31% (scrotum).	ND
35	(Neumayr et al., 2003).	Observational	Investigate renal function in strenuous marathon cycling	n= 38♂ ultra-endurance cyclists Race: 230km	Voluntary participation	Age, height, weight, BMI, Hct, Hb and RBC	sCr, CK, urea, uric acid, CRP and Alb.	↑ levels of urea (54%), uric acid (42%) and serum creatinine (20%). And remained elevated 24h rest post activity in 89% of cyclists.	ND

Table 2. Studies included in the systematic review.

#	Author and year	Study design	Study aims	Participants	Data collection	Health markers	Renal health markers	Main results	Future research directions
36	(Touchberry et al., 2004).	Experimental	Explore the effects of a long-term training program on chronic homeostatic renal function in an athletic population.	n= 8♂ competitive cyclists Age: 22.2 ± 3.8	Voluntary participation	Age, height, weight, body fat VO2max and Wingate tests (anaerobic power)	GFR, sCr, SUN and Alb.	↓ of GFR in week 7. ↓ in week 11 fell below normal physiological ranges. Changes in renal serum chemical markers during training.	Studies in sports with greater emphasis on catabolism and renal function
37	(De Palo et al., 2005).	Observational	Effect of strenuous and prolonged physical exercise, during competition, on plasma and urinary IGF-I concentrations.	n= 20♂ professional cyclists Age: 17-18 years	Recruited by selection	Age, weight, height	pIGF uIGF, uPr and uCr.	↑ in the concentration of uIGF-I (76.2 to 256.9ng/l), uPr (29.4 to 325.9mg/l) and uCr (6.3 to 10 mmol/l) post competition. pIGF had no relevant alterations in results.	More tests in different disciplines and athletes, at rest and with exercise, to detect doping, with endogenous substances such as IGF-I.
38	(Hermans et al., 2016).	Cross-sectional	Determine the prevalence and duration of urogenital overuse injuries and sexual dysfunctions in female cyclists.	n= 147♀ Groups: n= 114 cyclists n= 33 runners	Online survey	BMI, FSD, dysuria strangury, dyspareunia, vulvar edema, hematuria, genital numbness and perineal furunculosis	ND	50.9% of ♀ cyclists present urogenital injuries. 30-40% ♀ cyclists presented symptoms of genital numbness, vulvar edema or dyspareunia.	Use of validated questionnaires, such as the Female Sexual Distress Scale and the Female Sexual Function Index

Note: ED = erectile dysfunction, PCa = prostate cancer, BMI = body mass index, FSFI = female sexual function index, FSD = female sexual dysfunction, IIEF = international index of erectile function, GU = genitourinary, ISS = injury severity score, AIS = abbreviated injury scale, AAST = American Association for the Surgery of Trauma, PO/m = power output, NEE = energy expenditure, GFR = glomerular filtration rate, eGFR = estimated glomerular filtration rate, MDRD = modification of diet in renal disease, BUN = blood urea nitrogen, sCr = serum creatinine, CR = creatinine, CK = creatine kinase, Hb = hemoglobin, Hct = hematocrit, LDH = lactate dehydrogenase, AST = aspartate aminotransferase, MCQE = Mayo Clinic quadratic equation, CG = Cockcroft-Gault, AUA-SI = American Urological Association symptom index, UTIs = urinary tract infections, LUTs = lower urinary tract symptoms, CPPS = chronic pelvic pain syndrome, SHIM = sexual health inventory for men, NIH-CPSI = National Institutes of Health chronic prostatitis symptom index, ICIQ-MLUTS = International Consultation on Incontinence Questionnaire Male Lower Urinary Tract Symptoms, I-PSS = International Prostate Symptom Score, tpO2 = transcutaneous penile oxygen pressure, proANP = pro-atrial natriuretic peptide, BSA = body surface area, KEED = Cologne Erectile Dysfunction Questionnaire, IL-6 = circulating interleukin, TNF-a = tumor necrosis factor, IFN-y = interferon, VO2max = maximum oxygen consumption, POT = power output, Ca = calcium, Mg = magnesium, Fe = iron, Zn = zinc, Cu = copper, SM4 = sum of four skinfolds, RER = respiratory exchange ratio, PLP = pyridoxal-5'-phosphate, Hcy = plasma homocysteine, rHcy = reduced plasma homocysteine, tHcy = total plasma homocysteine, Cys = homocysteine cysteine, rCys = reduced homocysteine cysteine, tCys = total homocysteine cysteine, NGAL = neutrophil gelatinase-associated lipocalin, uNGAL = urinary neutrophil gelatinase-associated lipocalin, PTH = parathyroid hormone, 25(OH)D = 25-hydroxyvitamin D, Ca = calcium, P = phosphorus, PV = plasma volume, FGF23 = fibroblast growth factor 23, RBC = red blood cells, FENa+ = fractional excretion of sodium, FEUA = fractional excretion of uric acid, CCR = creatinine clearance, TTKG = transtubular potassium gradient, Na+ = plasma sodium, K+ = potassium, Cl-2 = chloride, Ca2+ = calcium, USG = urine specific gravity, IBU = Ibuprofen, PSA = prostate-specific antigen, tPSA = total prostate-specific antigen, fPSA = free prostate-specific antigen, FSH = follicle-stimulating hormone, LH = luteinizing hormone, ECF = extracellular fluid, ICF = intracellular fluid, CRP = C-reactive protein, Alb = serum albumin, SUN = serum urea nitrogen, IGF-I = insulin-like growth factor, pIGF = plasma insulin-like growth factor, uIGF = urinary insulin-like growth factor, uPr = total urinary proteins, uCr = urinary creatinine, ND = No data.

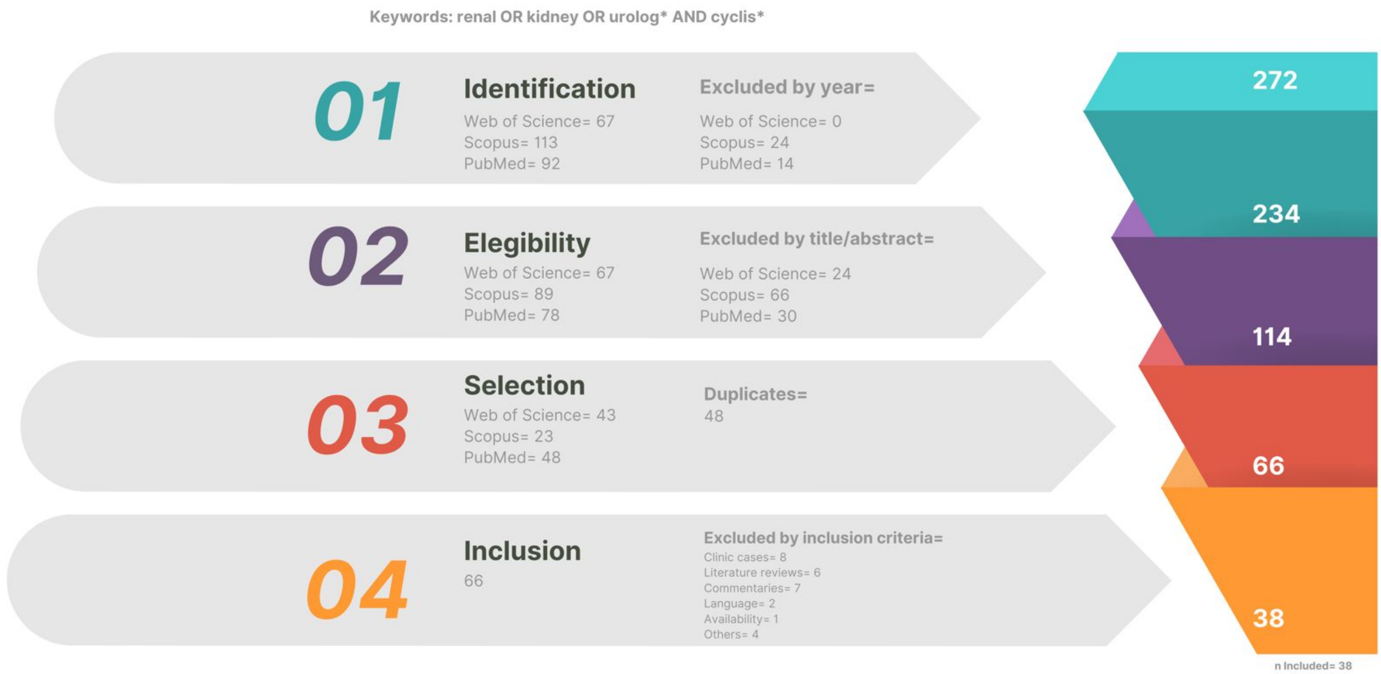


Figure 1. Systematic review process flowchart. ***Note:*** *Four-phase PRISMA flowchart displaying rectangular boxes for each selection stage (Identification, Eligibility, Selection, Inclusion) with arrows indicating flow direction. Numbers in colored boxes show studies retained/excluded at each phase, with final count of 38 studies highlighted in orange.*

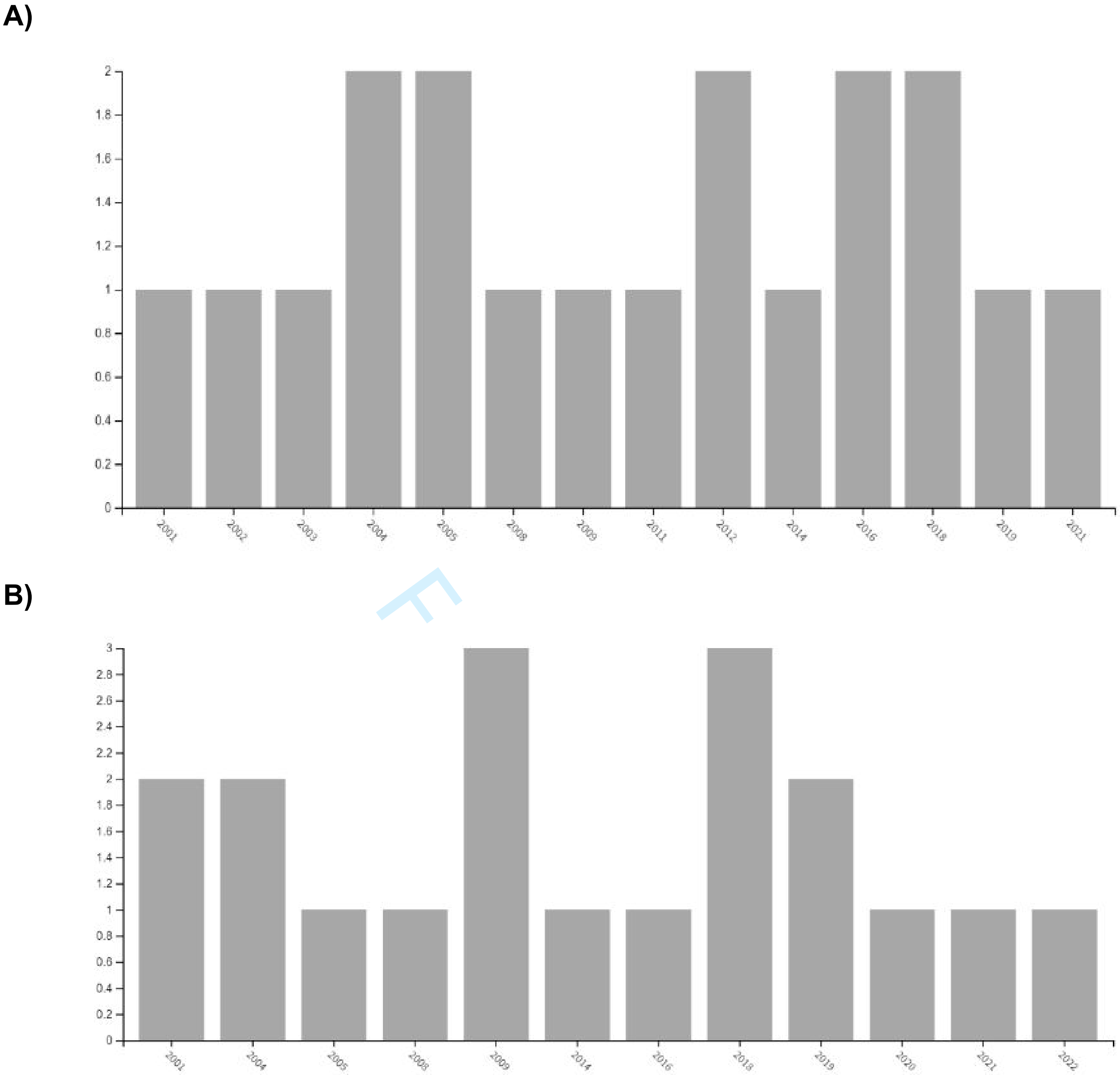


Figure 2. Publication trends of articles related to (A) renal and (B) urological health in cycling. ***Note:*** *Bar charts showing annual publication counts from 2000-2023. Panel A displays gray bars with heights corresponding to yearly publication numbers for renal studies. Panel B shows similar format for urological studies with peaks clearly visible in 2009 and 2018.*

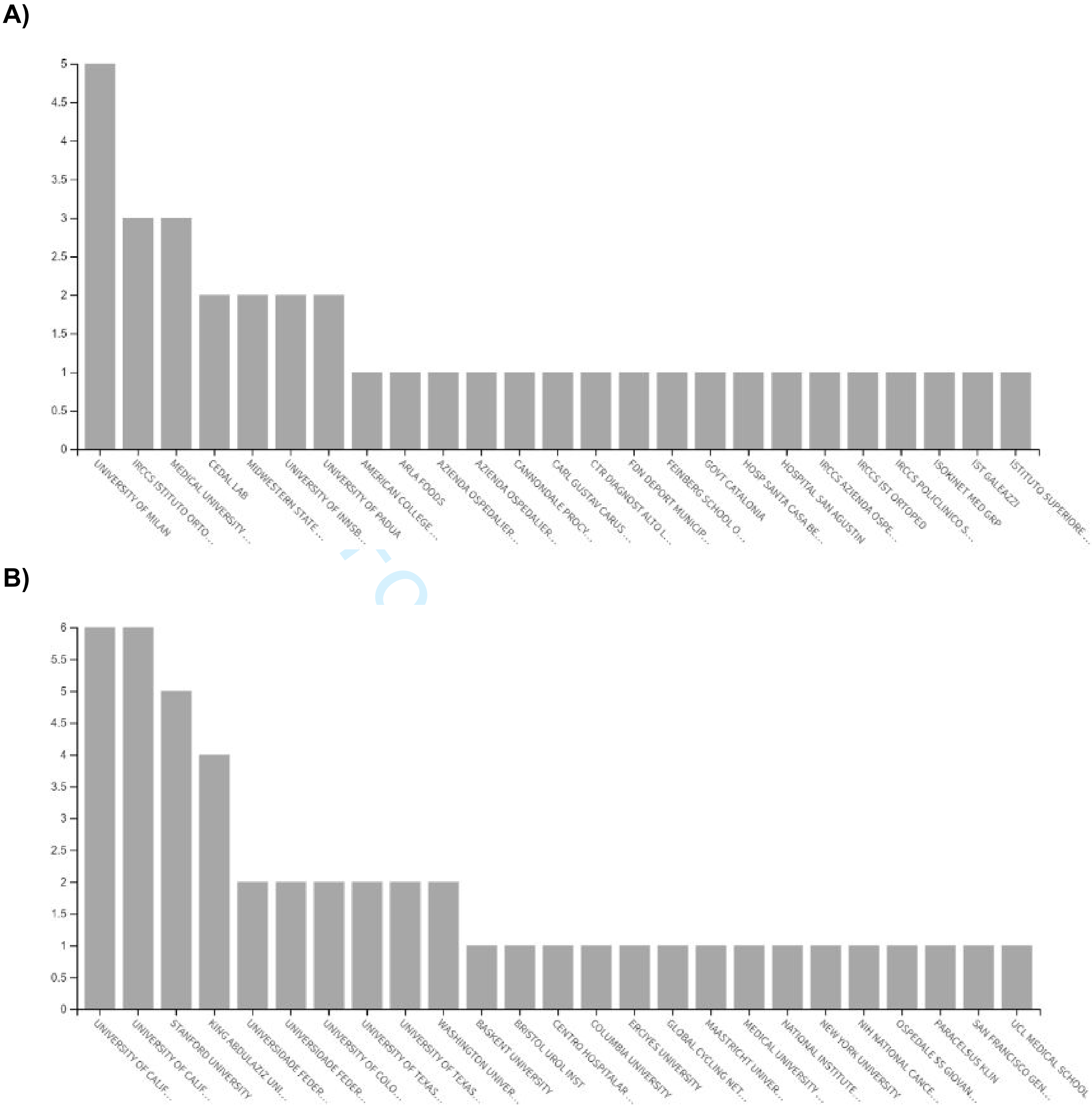


Figure 3. Productivity of institutions of articles related to (A) renal and (B) urological health in cycling. ***Note:*** *Horizontal bar charts ranking institutions by publication count. Panel A shows University of Milan with longest bar (5 publications), followed by other institutions in descending order. Panel B displays similar format with University of California system leading.*

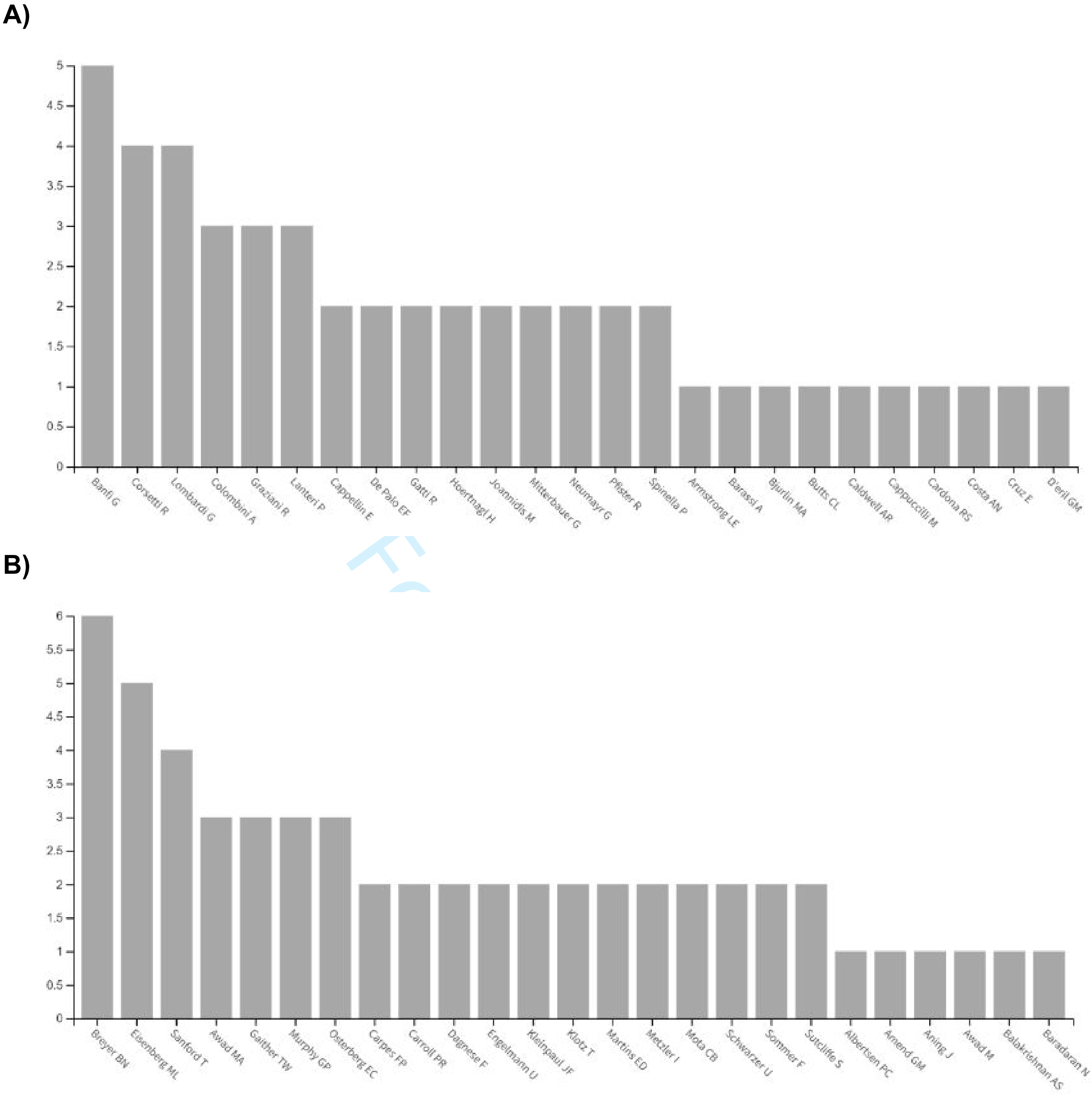
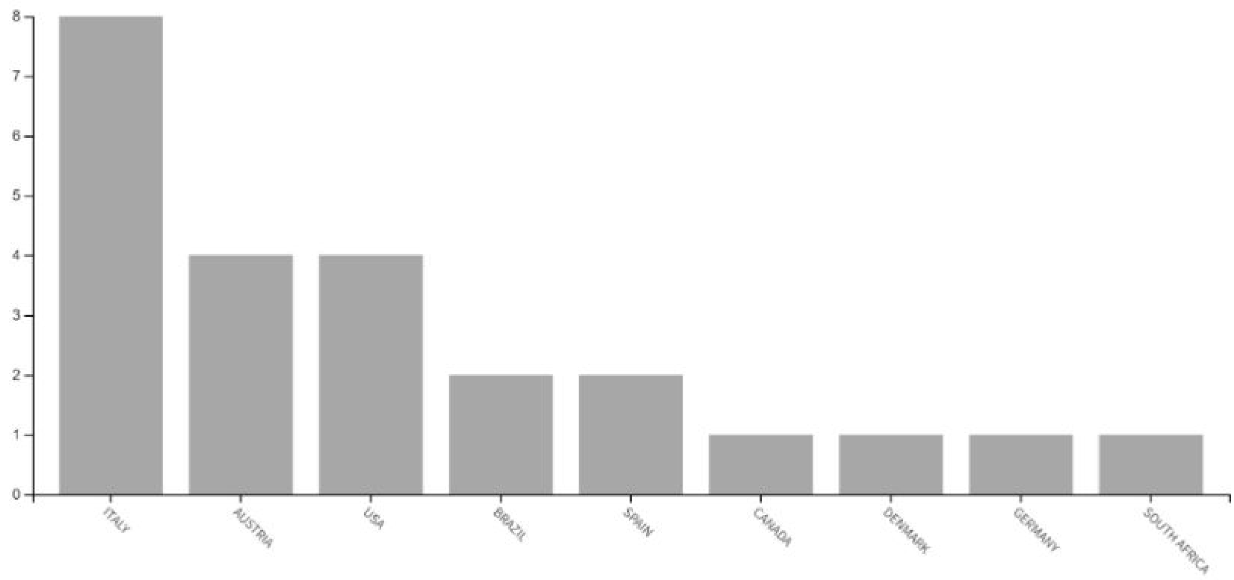


Figure 4. Productivity of authors of articles related to (A) renal and (B) urological health in cycling.
Note: *Horizontal bar charts displaying author names on y-axis and publication counts on x-axis. Panel A shows Banfi with highest bar (5 publications), other authors arranged in descending order. Panel B follows same format with Breyer leading.*

A)



B)

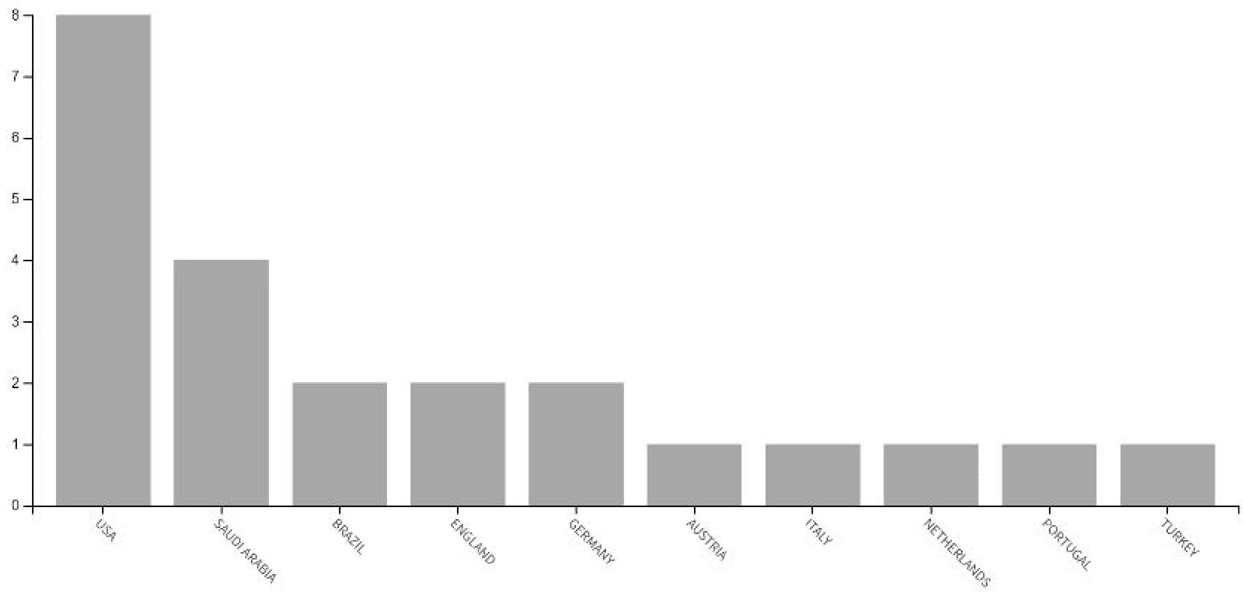


Figure 5. Research distribution based on countries of articles related to (A) renal and (B) urological health in cycling. ***Note:*** *Bar charts with country names on x-axis and publication percentages on y-axis. Panel A shows Italy with tallest bar (42.10%), other countries in descending height order. Panel B displays USA prominence with similar visual format.*

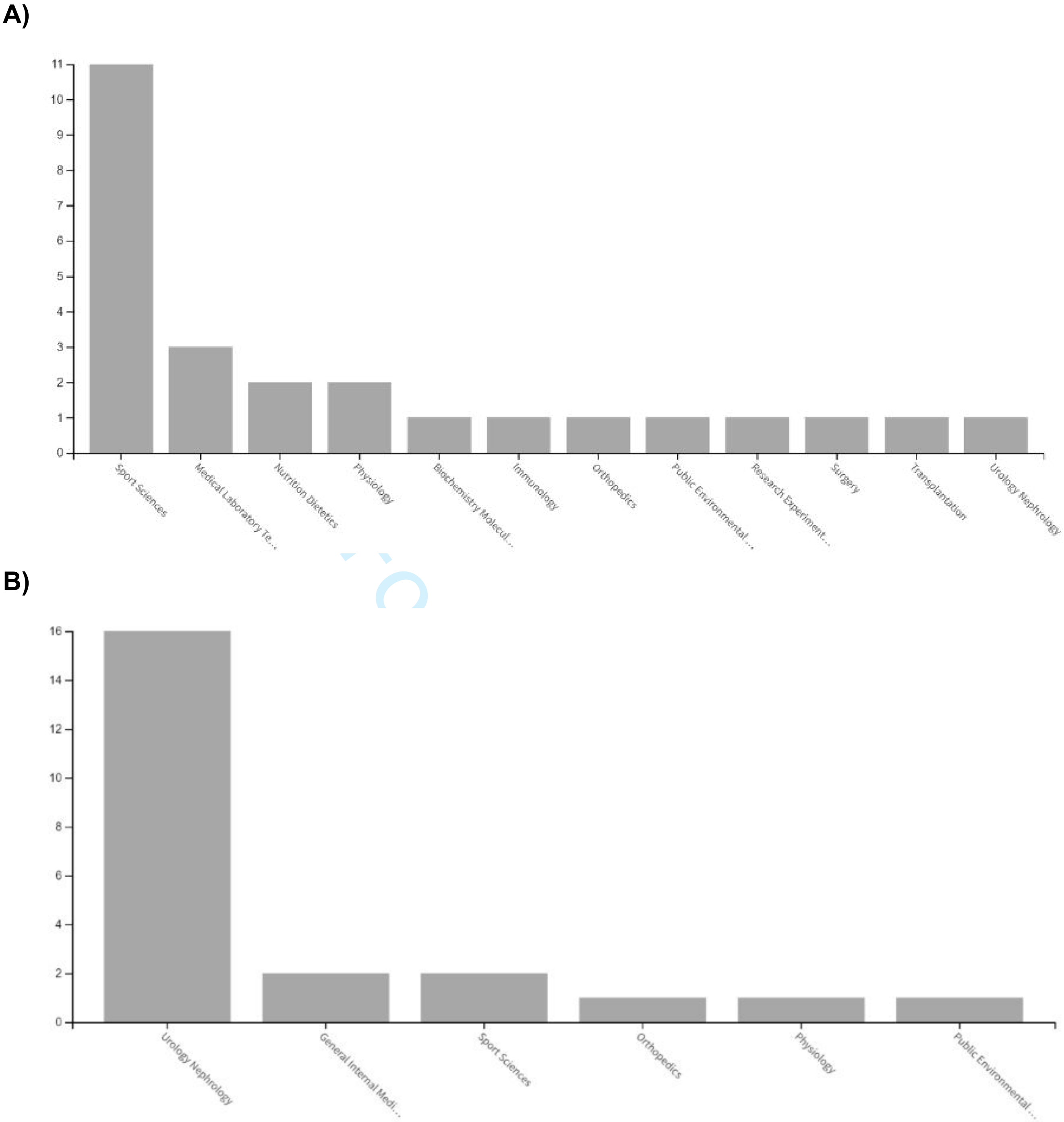


Figure 6. Research areas of articles related to (A) renal and (B) urological health in cycling. ***Note:*** *Bar charts showing research disciplines on x-axis and publication counts on y-axis. Panel A displays Sports Sciences with highest bar (11 articles), other areas progressively shorter. Panel B shows Urology Nephrology dominance with 16 articles.*