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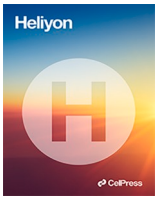

Research article

Global research trends on the links between prostate cancer and erectile dysfunction between 2003 and 2023: A bibliometrics and visualized study

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ABSTRACT

Background: The incidence of prostate cancer (PC) has increased in recent years. Erectile dysfunction (ED) after prostate cancer treatment has aroused extensive attention. Bibliometric analysis was designed to investigate a systematic understanding of developments between PC and ED during the past 20 years.

Methods: Literatures on PC and ED were retrieved from the Web of Science Core Collection database (WoSCC). By using the VOS viewer and CiteSpace software to analysis the metrics of bibliometric literature, such as number of articles, journals, countries, institutions, authors, keywords and associated information. The number of publications per year was statistically analysed and plotted thorough Microsoft Office. In addition, Pajek software was used to adjust the visual map.

Results: A total of 2332 screened articles were included in the analysis. The Journal of Sexual Medicine, ranking first among the analysed journals, published 235 articles. The United States and Canada were leaders in PC and ED research. There is a need to strengthen inter-agency cooperation in this area of research on a global scale. Mulhall JP, as the most prolific author in this area of research, published 80 articles. And Rosen RC was the author with the most co-citated (693 co-citated). The main research focus on the prevention, treatment and management of ED after PC treatment in this field through the keyword analysis.

Conclusions: Research on PC and ED is expected to expand further worldwide. We found ED, as new sustainable treatment modalities, scientific postoperative management and psychological interventions for patients, may become the research hotspots and should be closely concerned in this study.

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1. Introduction

Prostate cancer (PC), the most prevalent solid malignancy in males, is responsible for an average of 190,000 new cases annually. It is estimated that approximately 80,000 people worldwide succumb to PC each year [1]. Erectile dysfunction (ED) is a common consequence of PC treatment and significantly impacts the quality of life and psychological well-being of male patients. As a result, it has garnered considerable attention from researchers. Radical prostatectomy (RP) is acknowledged as the preferred method and standard treatment for localized PC. ED following RP is primarily influenced by neurovascular mechanisms, such as surgical removal of the seminal vesicles and prostate, which can damage the pelvic nerve plexus and consequently affect erectile function (EF) [2]. Therefore, current research efforts are focused on preserving more anterior nerve fibers originating from the pelvic plexus through advancements in RP surgical techniques. Menon et al. reported significant postoperative EF recovery in patients undergoing robotic-assisted RP with the anterior release technique, known as the "veil of Aphrodite" technique (70 % at 12 months, 100 % at 24 months) [3]. Radiation therapy (RT) is also a common treatment for PC. Studies have indicated that incidence of ED after RT ranges from about 20 % to 80 % [4]. Researchers have confirmed radiation-induced nerve damage using rat models where nitric oxide synthase-containing nerves in the penile shaft are reduced after radiation exposure [5]. Minimizing radiation exposure to the proximal penis during brachytherapy (BT) may improve postoperative recovery and prognosis for erectile function since radiation dose to this area correlates with erectile dysfunction (ED). With early detection of PC through PSA screening leading to decreased average age among PC patients and increased life expectancy in recent decades, we believe that post-operative restoration of EF holds greater significance due to its impact on patient and partner quality of life [6]. Despite extensive literature on PC and ED thus far, its sheer volume coupled with complex content makes it challenging for researchers to gain comprehensive understanding within this field. Henceforth, the authors conducted a focusing on literature related to PC and ED.

Bibliometric analysis involves the quantitative examination and analysis utilizing relevant software tools along with statistical methods applied across all literature within a specific area of interest. This scientific approach aids readers in comprehending current research status while identifying collaboration patterns alongside emerging trends within a particular field, thereby providing valuable insights guiding further research endeavors while serving as basis for clinical guideline development [7]. The objective here is predicting trends and offering reference to facilitate the research endeavors, by summarizing literature characteristics between PC and ED, reviewing existed research findings [8].

2. Materials and methods

2.1. Data collection

Web of Science (WoS) serves as a crucial platform for researchers to access global academic information, establishing itself as an authoritative source for obtaining literature in this field. In this study, we gathered literature and data from the Science Citation Index Expanded WoSCC database and conducted subsequent relevant analyses. All retrieval and data download processes for this study were completed within a single day on February 10, 2024, effectively eliminating potential data loss due to database updates. Fig. 1 illustrates all pertinent retrieval strategies and entire research process. The screened articles were published between January 1, 2003 and December 31, 2023. This study includes only original and review articles published in English.

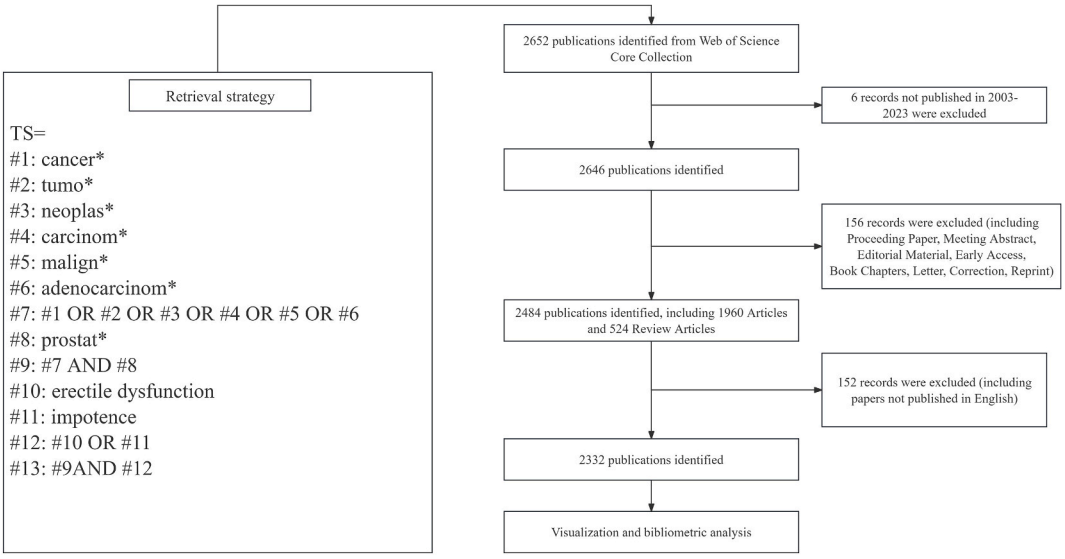

Fig. 1. Data Screening Flowchart. TS, topic search; *, truncation operator; #, connection character.

2.2. Data analysis

VOSviewer was utilized for conducting co-occurrence analysis of institutions, authors, countries, and keywords. The software comprises three modules: network visualization, overlay visualization, and density visualization. The resulting visual atlas offers a multidimensional mapping of the relationship between scientific literature and research hotspots. CiteSpace was employed to cluster keywords and analysed burst words within the time frame from January 2003 to July 2023 with a time slice of one. The node type was 'keywords', and default values were used for other parameter options. Data was tallied Using Microsoft Excel, and line graphs were generated to illustrate the annual volume of dispatches. Additionally, Pajek software was applied to adjust the visual map.

3. Results

3.1. Annual volume of publications

A bibliometric analysis was conducted in this study using a total of 2332 articles. A line graph was plotted to illustrate the annual publication trends based on the number of articles published each year in the WoS, as depicted Fig. 2. The annual publication counts for PC and ED research exhibited fluctuating upward trends, with six peaks observed in the years 2005, 2009, 2013, 2016, 2018, and 2021. The shortened intervals between these peaks indicate heightened research intensity in recent years, suggesting ongoing breakthroughs in the field. The number of articles published annually has remained consistently high over the past four years, indicating sustained attention to PC and ED as prominent topics in current research.

3.2. Bibliometric analysis of publishing journals

This study examined 462 academic journals published between 2003 and 2023. Table 1 presents the top ten journals ranked by the number of articles published. The Journal of Sexual Medicine ranked first with 235 articles, followed by the Journal of Urology (152), Bju International (136), and European Urology (80). Furthermore, the Journal of Urology was cited most frequently among the top 10 journals (9152 times), followed by European Urology (8122 times), the Journal of Sexual Medicine (7427 times), and Bju International (5157 times), indicating their significant influence in the field of PC and ED.

3.3. Bibliometric analysis of issuing countries/regions, institutions

The collaborative network of countries and regions involved in research on PC and ED is depicted in Fig. 3, as conducted in our study. The figure illustrates the participation of 51 countries or regions in PC and ED research, with the size of each circle below the country label representing the number of published articles. Different colours indicate different time intervals, while the thickness of the lines connecting nodes represents the strength of collaboration between different countries and regions. Among the 51 countries and regions involved in the research, the United States has produced the highest publication output with 1070 articles, followed by Canada with 234 articles, Italy with 230 articles, the United Kingdom with 201 articles, Germany with 189 articles, and China with 138 articles (Table 2). This indicates that research on PC and ED has been conducted globally across various regions. The top five countries for the intensity of associations are identified as: the United States, Italy, Canada, Germany, and the United Kingdom, suggesting increasingly closer collaborations among different countries/regions. Table 3 displays that Memorial Sloan Kettering Cancer Center (n = 123), University of California San Francisco (n = 66), and University Vita-Salute San Raffaele (n = 59) are the top three institutions

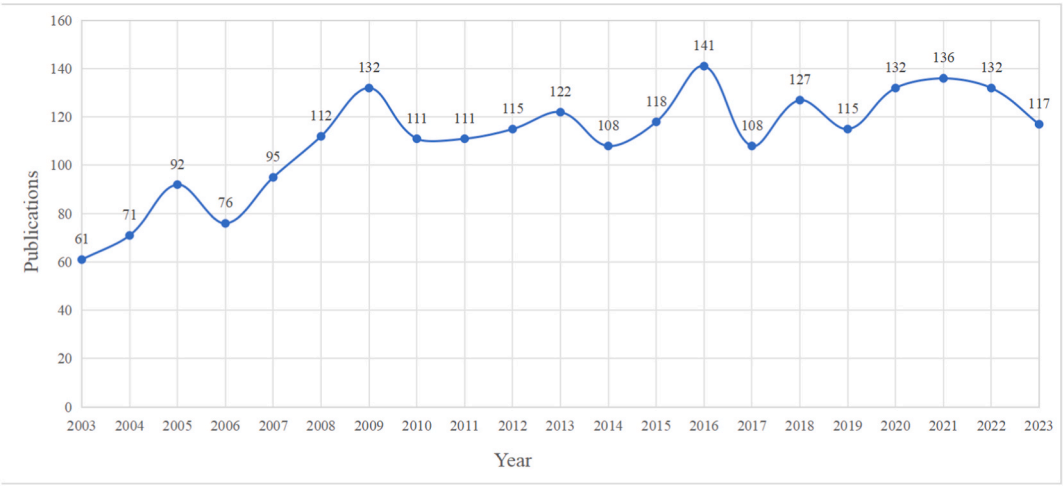

Fig. 2. Annual publication volume trend between 2003 and 2023.

Table 1
Top 10 journals in terms of publications.

Ranking	Journal	Record Count	% of 2332	Total Times Cited	IF(2022)
1	Journal of Sexual Medicine	235	10.077	7427	3.5
2	Journal of Urology	152	6.518	9152	6.6
3	Bju International	136	5.832	5157	4.5
4	European Urology	80	3.431	8122	23.4
5	Urology	79	3.388	2472	2.1
6	International Journal of Impotence Research	73	3.13	1837	2.6
7	International Journal of Radiation Oncology Biology Physics	64	2.744	2912	7
8	World Journal of Urology	36	1.544	846	3.4
9	Urologic Oncology Seminars and Original Investigations	33	1.415	516	2.7
10	Asian Journal of Andrology	32	1.372	450	2.9

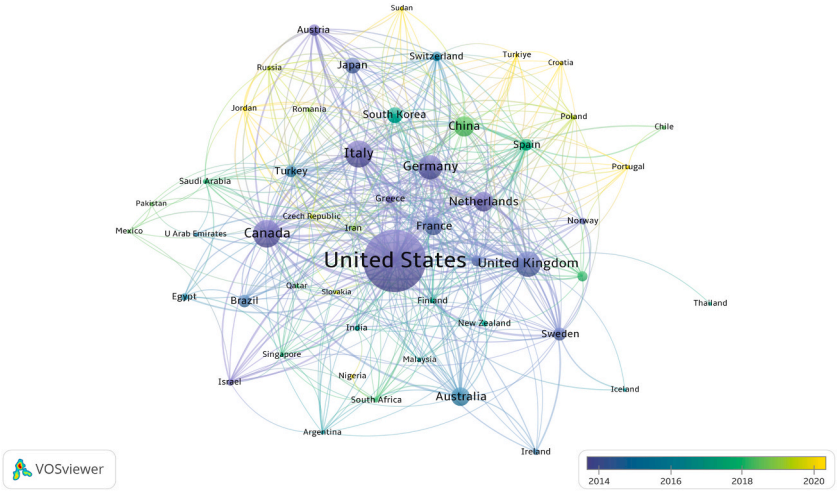

Fig. 3. The network map of countries and regions.

Table 2
Top 10 countries in terms of number of articles published.

Ranking	Countries	Publications	Total link strength
1	United States	1070	590
2	Canada	234	341
3	Italy	230	350
4	United Kingdom	201	327
5	Germany	189	336
6	China	138	67
7	Netherlands	127	229
8	Australia	117	118
9	France	114	186
10	Japan	88	51

contributing to research on PC and ED. Fig. 4 illustrates an institutional network collaboration map indicating that cross-institutional collaboration on PC and ED research worldwide needs to be further strengthened.

3.4. Bibliometric analysis of authors and co-cited authors

Fig. 5 shows the co-authorship network, with nodes of varying colours representing distinct clusters and lines indicating the strength of collaboration between authors. The analysis has identified five primary co-authorship groups, showcasing extensive and intricate collaboration among authors. Table 4 presents the top five authors with the highest number of published documents: Mulhall JP (80 articles), Montorsi F (59 articles), Salonia A (38 articles), Briganti A (34 articles), and Burnett AL (31 articles). The most co-cited authors are Rosen RC (693 co-citations), Walsh PC (683 co-citations), Mulhall JP (679 co-citations), Montorsi F (597 co-citations), and Litwin MS (501 co-citations). All these authors wield significant academic influence in the field of PC and ED.

Table 3
Top 10 academic institutions in terms of publications.

Ranking	Institutions	Publications	Total link strength
1	Memorial Sloan Kettering Cancer Center	123	113
2	University of California San Francisco	66	69
3	Università Vita-Salute San Raffaele	59	58
4	University of Michigan	58	64
5	Duke University	54	53
6	Mayo Clinic	44	44
7	University of Toronto	41	26
8	Harvard University	40	46
9	University College London	40	17
10	New York University	37	38

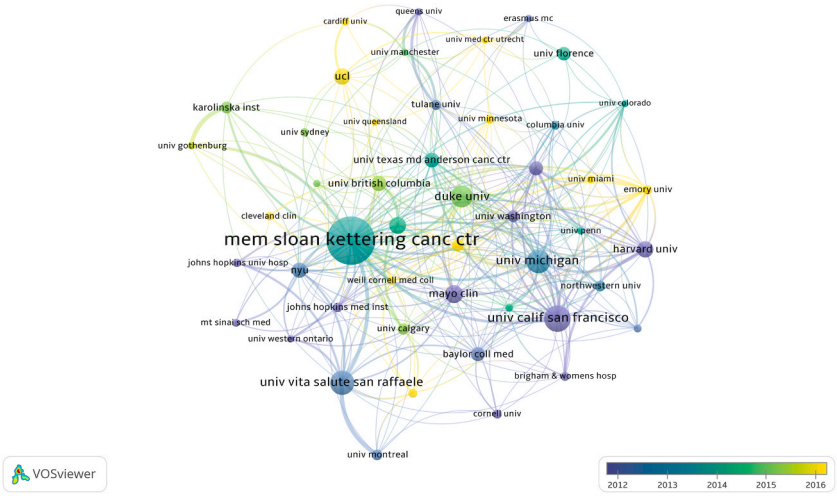

Fig. 4. The network map of institutions.

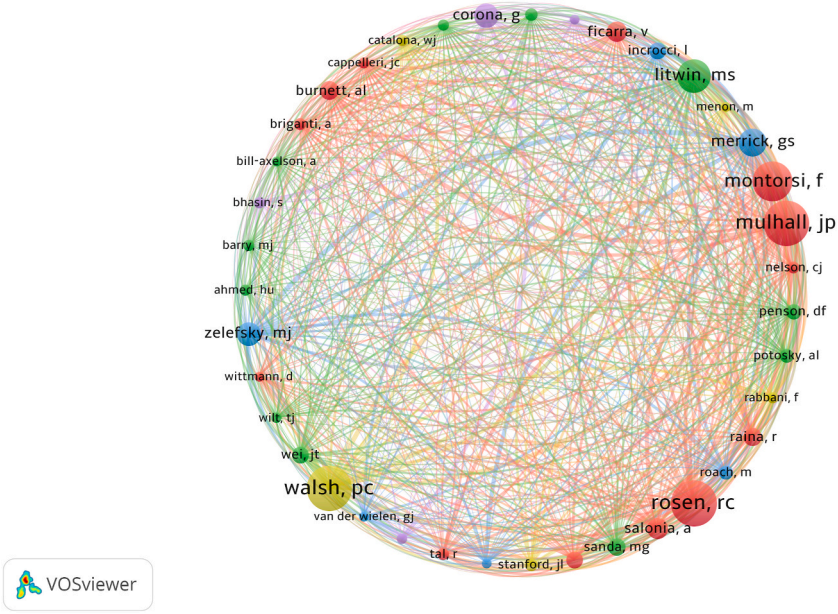

Fig. 5. Cooperation map of authors.

Table 4
Top 10 authors of publications and top 10 co-cited authors.

Ranking	Authors	Documents	Co-cited authors	Count
1	Mulhall JP	80	Rosen, RC	693
2	Montorsi F	59	Walsh, PC	683
3	Salonia A	38	Mulhall, JP	679
4	Briganti A	34	Montorsi, F	597
5	Burnett AL	31	Litwin, MS	501
6	Nelson CJ	29	Merrick, GS	419
7	Graefen M	25	Corona, G	368
8	Eastham JA	23	Zelefsky, MJ	356
9	Scardino PT	23	Salonia, A	316
10	Incrocci L	22	Ficarra, V	311

3.5. Bibliometric analysis of keywords and burst words

Keyword analysis is commonly utilized in bibliometric research. By extracting high-frequency keywords from literature, researchers can effectively summarize and refine the research content within a specific field, thereby facilitating the comprehension of research trends and prediction of future directions [9]. Table 5 shows the top 10 keywords in terms of frequency. Apart from erectile dysfunction and prostate cancer, the five most frequently occurring keywords were quality of life (748 occurrences), radical prostatectomy (676 occurrences), men (574 occurrences), radiation therapy (417 occurrences), and penile rehabilitation (389 occurrences). The research areas in this field encompass various domains such as Basic Medicine, Nursing, Clinical Medicine, and Pathophysiology (Fig. 6A and B). The clustering diagram is shown in Fig. 7. Keywords were clustered based on their frequency changes over time and presented in a timeline format (Fig. 8). This study identified five clusters: radiotherapy, quality of life, prostatectomy, penile rehabilitation, and testosterone replacement therapy. The cluster #3(penile rehabilitation) is still ongoing, which provides researchers with a reference for research hotspots. The term 'burst word' refers to a keyword that experiences a sudden increase in frequency in articles during a particular period. Burst word analysis is widely used in bibliometrics to reflect research hotspots within a specific short-term period. Researchers can also roughly grasp research trends and future directions by observing the appearance and disappearance time of burst keywords [10]. The 25 burst words identified in different time periods in this study reflect a shift from focusing solely on understanding the disease to exploring the mechanisms, management, treatment, and post-treatment care of ED after PC treatment, as shown in Fig. 9.

4. Discussion

4.1. General information

Prostate cancer (PC) is a prevalent global cancer and accounts for a significant number of cancer-related fatalities [11,12]. Annually, 1.6 million men are diagnosed with PC, and 366,000 men succumb to this disease [1]. Based on widespread screening for prostate specific antigen, over 90 % of patients are diagnosed with localised or regional prostate cancer [13]. Radical prostatectomy (RP) and radiation therapy (RT) are conventional treatment modalities for localized PC, yielding positive treatment outcomes. It should be noted that erectile dysfunction (ED) is a common side effect of PC treatment among survivors and requires attention [14]. Given that various conventional treatment methods result in effective outcomes and high survival rates among patients with PC, factors such as post-treatment quality of life are significant in patients' decision-making. Due to the increasing incidence of sexual dysfunction following PC treatment, there is a growing demand for early diagnosis, treatment, postoperative management, and psychological interventions for PC. The annual number and trend of literatures can reflect the development speed and research progress of this study, and can also indicate the concentration of research in this field. In recent years, the number of research articles on PC and ED has continued to increase, with over 100 articles published annually.

Bibliometric studies are secondary research that enables a comprehensive bibliometric analysis of the academic output on a specific

Table 5
Top 10 keywords in frequency.

Rank	Keywords	Counts
1	prostate cancer	1459
2	erectile dysfunction	1406
3	quality of life	748
4	radical prostatectomy	676
5	men	574
6	radiation therapy	417
7	penile rehabilitation	389
8	sexual function	381
9	outcome	324
10	erectile function	198

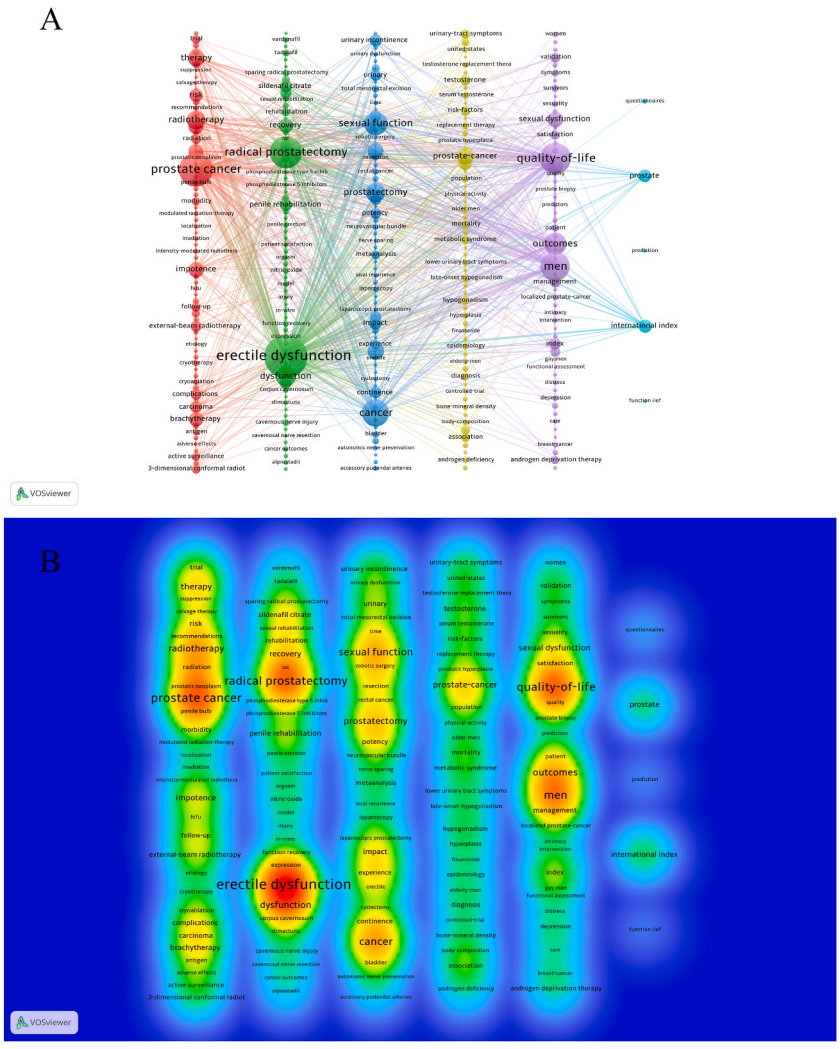

Fig. 6. Analysis of keywords. (A) co-occurring map of keywords. Note: Each node represents a keyword, and its size represents the frequency of occurrence of that keyword; the thickness of the lines between the nodes indicates the strength of association between each keyword. (B) keyword density map. Note: The brightness level of the ring around each keyword indicates the magnitude of the frequency with which the keyword appears.

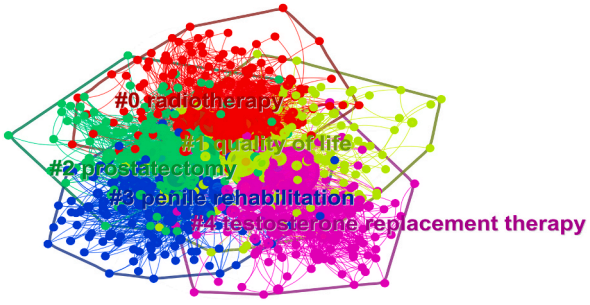

Fig. 7. Keyword clustering diagram.

topic [15]. While there has been no previous bibliometric study associating PC with ED. Xie et al. conducted a global analysis using the WoS database on radiotherapy for prostate cancer. They found that the toxicity of genitourinary (GU) in PC therapy cannot be overlooked and is a potential area of research hotspot [16].

The United States is a leading country in research of PC and ED. European countries are also actively engaged in researching PC and

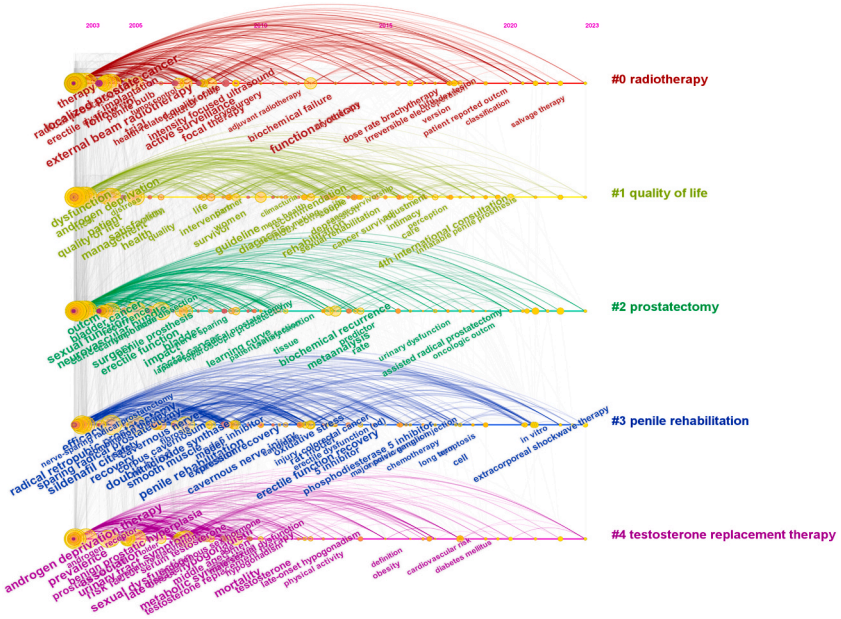

Fig. 8. Keyword timeline chart and keyword clusters.

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2003 - 2023
carcinoma	2003	17.84	**2003**	2009	
impotence	2003	16.42	**2003**	2006	
sildenafil citrate	2003	6.93	**2003**	2006	
neurovascular bundle	2004	6.41	**2004**	2010	
cancer outcm	2005	6.98	**2005**	2010	
retropubic prostatectomy	2003	6.63	**2005**	2006	
smooth muscle	2006	6.74	**2006**	2015	
bone mineral density	2003	5.89	**2006**	2010	
hormone binding globulin	2007	8.08	**2007**	2010	
androgen deficiency	2007	7.74	**2007**	2012	
hyperplasia	2007	6.24	**2007**	2010	
body mass index	2008	7.39	**2008**	2010	
radical retropubic prostatectomy	2003	7.1	**2008**	2014	
testosterone replacement therapy	2008	6.39	**2008**	2014	
middle aged men	2008	6.12	**2008**	2015	
endogenous sex hormone	2008	5.91	**2008**	2009	
metaanalysis	2013	11.14	**2014**	2020	
survivor	2008	6.18	**2014**	2018	
focal therapy	2008	8.85	**2015**	2023	
total mesorectal excision	2004	5.9	**2015**	2018	
biochemical recurrence	2013	6.49	**2016**	2020	
active surveillance	2007	7.65	**2017**	2023	
4th international consultation	2017	6.05	**2017**	2023	
sexual health	2020	6.36	**2020**	2023	
testosterone	2010	5.84	**2020**	2023	

Fig. 9. Top 25 keywords with the strongest citation bursts.

ED, as evidenced by the fact that three of the top five countries in terms of publication volume are from Europe. This trend is not only related to the advanced level of medical care in Europe and the United States, but also the epidemiology of PC, which is an influencing factor. Studies have shown that the age-standardized incidence rates of PC are very high in Northern and Western Europe, Australia, New Zealand, and North and South America [11]. The increasing prevalence of PC and its treatment-related adverse effects highlight the urgent need to improve general health and well-being of populations. Consequently, there has been a corresponding increase in research funding and talent resources across various countries. It is anticipated that collaboration among countries and regions will further strengthen, leading to qualitative breakthroughs in PC and ED research. Researchers worldwide should strengthen their cooperation and conduct more high-quality and innovative basic or clinical trials.

By analysing the co-authorship network, we found that Mulhall JP is the most prolific author in this research area, and Montorsi F

forms a cohesive research team by frequently collaborating with authors. Their collective research efforts primarily focus on exploring the mechanisms, treatment, and evaluation of ED following radical prostatectomy (RP). In 2016, Mulhall JP and Montorsi F et al. published an article in the journal European Urology which found that exploratory decision-tree analyses identified high pre-surgery sexual desire, confidence, and intercourse satisfaction as key predictors for the recovery of erectile function (EF) after nerve-sparing radical prostatectomy (nsRP) [17]. Male patients with PC who meet these criteria are more likely to benefit from conservative surgery and early post-surgery erectile function rehabilitation, which can lead to a satisfactory quality of life [17]. Mulhall JP and Montorsi F are also among the top five co-cited authors in the literature. This demonstrates that the research hotspots of PC and ED focus on the mechanism of occurrence, treatment, and management, are continuing to deepen. The United States which stands out among countries contributing to this field ranked first in publications on radiotherapy for prostate cancer worldwide during 2010–2022 [16]. Memorial Sloan Kettering Cancer Center is not only the most prolific institution, but also holds significant influence globally within this field. Their most cited publication on this topic is a systematic review and cumulative analysis of comparative studies of retropubic, laparoscopic, and robot-assisted radical prostatectomy [18]. The Journal of Sexual Medicine, Urology, and BJU International are the three prolific journals containing high-quality scientific results with an average of 41.58 citations per article and an H-Index of 74. This indicates the significant influence within PC and ED fields. The Journal Of Sexual Medicine has been noted for its relevance and citation impact within both topics [19], including recent publications summarizing advances in erectile function-preserving radiotherapy for prostate cancer [20]. Important outputs in these fields may be later published on these journals and make them become an important source for theoretical references and ideal choices for future publication.

4.2. Hotspots and frontiers

In the process of scientific research, it is crucial to effectively grasp the development trend within the research field. This paper presents a summary of research hotspots and development directions in the fields of PC and ED by utilizing keyword occurrence frequency, timeline mapping and burst word mapping. The timeline map of keyword clustering analysis reveals that current research primarily focuses on three aspects: mechanisms of ED after PC treatment (#0 radiotherapy and #2 prostatectomy), treatment (#3penile rehabilitation and #4 testosterone replacement therapy) and management (#1 quality of life) of related patients.

4.2.1. Mechanisms of ED after PC treatment

The standard treatment for patients with organ-confined PC is RP. Clinical date indicate the patients who undergo RP and receive appropriate treatment for RP-related side effects have a expectant over 10 years life [21]. It has been reported that the incidence of ED after RP treatment is relatively high [22]. The occurrence of ED is associated with RP, in which surgical experiences and techniques play a crucial role [23]. The incidence of postoperative ED after RP or other major pelvic surgeries for localized PC treatment is high due to nerve damage [24]. This involves local trauma-induced inflammation and ischemia resulting from intraoperative procedures such as cutting, coagulation, and traction, affecting the cavernous nerves, which can induce the decreased local oxygenation, pro-apoptotic and pro-fibrotic alterations in the corpora cavernosa [25,26]. Assessing the baseline erectile function of each PC patient using internationally recognized psychometric tools such as the International Index of Erectile Function (IIEF) prior to RP is critical in predicting ED recovery after RP [25]. Studies have shown that preoperative assessment using the IIEF to score baseline erectile function is associated with a higher likelihood of early EF recovery after RP in patients with higher baseline scores compared to those already experiencing ED preoperatively [27]. With the development of minimally invasive surgery, the visualization of prostate and surrounding structures make more precise dissection and less intra-operative bleeding. As a result, the incidence of post-operative ED after robot-assisted radical prostatectomy (RARP) is significantly lower than after traditional open surgery [28]. ED is also one of the most common sequelae of radiotherapy for prostate cancer, affecting 36–59 % of patients after external beam radiotherapy (EBRT) [29–31] and 24–50 % after brachytherapy (BT) [32,33] according to prospective studies. Any form of penile rehabilitation has been shown to be superior to doing nothing [25]. In conclusion, penile rehabilitation should be initiated promptly following treatment to prevent fibrosis and to irreversible structural changes.

4.2.2. Mining for continuous innovative treatment

There are various established options for managing ED after PC treatment. The first-line treatment for ED is using phosphodiesterase-5 inhibitors (PDE5Is), such as sildenafil, tadalafil and vardenafil [22]. PDE5i works by enhancing erectile function through the inhibition of cGMP breakdown, leading to increased intracellular calcium ion efflux, smooth muscle relaxation, and erection. Nitric oxide further reinforces this pathway through corporal nerve stimulation [34–36]. Jo et al. conducted a randomized clinical trial (RCT) to evaluate the clinical effectiveness of PDE5 inhibitors in patients with baseline IIEF-5 scores $\geq$17 who underwent nerve-sparing robot-assisted radical prostatectomy (NS-RARP), revealing that those who received prompt treatment with sildenafil x 100 mg twice weekly immediately after catheter removal achieved a higher proportion of complete EF recovery within one year compared to those in the delayed treatment group [37]. A systematic review and network meta-analysis demonstrated that early intervention with daily sildenafil 100 mg was significantly associated with a higher likelihood of baseline erectile function recovery among 16 different adjunctive penile rehabilitation strategies (OR: 4.00, 95 % credible interval (CrI): 1.40–13.4) [38]. Another systematic review found that daily tadalafil was linked to improve sexual intercourse quality and activity in postoperative rehabilitation patients [39]. Incorporating PDE5 inhibitors into post-RP penile rehabilitation plans is supported by existing literature and clinical research outcomes, offering better results than neglecting postoperative penile rehabilitation [40].

Analysis of the keyword timeline graph reveals ongoing research on testosterone replacement therapy, which has shown efficacy in treating postoperative ED in patients with acute hypogonadism resulting from cavernous nerve injury during RP [41]. Previous studies

have indicated that testosterone may enhance the response of hypogonadal patients to PDE5Is [42], suggesting a potential strategy for penile rehabilitation. However, further clinical trials are needed to determine the efficacy of testosterone in aiding EF recovery [43]. Alternative compounds such as triiodothyronine, rho kinase inhibitors, and stem cell therapy have been proposed as potential new treatments for ED following RP [44–46].

The bi-bliometric analysis revealed that intracavernosal injections (ICIs) have become a fundamental component of many penile rehabilitation programs. Montorsi et al. initially explored ICIs by administering alprostadil into the penile corpora cavernosa of patients undergoing NSRP early postoperatively (three times a week for 12 weeks). The study demonstrated an increase in the rate of spontaneous erection in treated patients, with sufficient rigidity for satisfactory intercourse (80 % vs 20 %, $P < 0.01$) [47]. In several studies, Mulhall et al. found that patients undergoing early penile rehabilitation after prostatectomy with a combination of sildenafil and ICIs had a higher degree of spontaneous EF recovery, suggesting that ICIs are a viable option for EF recovery [48]. Alprostadil ICI can lead to clinical discontinuation due to penile pain, while TriMix ICI (papaverine, phentolamine and PGE1) is clinically associated with less treatment-related pain and is better tolerated by patients. The combination of these three molecules (papaverine, phentolamine and PGE1) acts as a vasodilator, increasing blood flow to the corpora cavernosa of the penis, thereby improving erectile function [49].

Vacuum erection devices (VEDs) have also been utilized in penile rehabilitation programs for erection support [25]. VED has been demonstrated as a method capable of preserving penile length in patients after RP, enabling erections and sexual intercourse without reliance on functional nerves or intact vascular supply [50,51]. In a prospective clinical trial of early VED use after RP, researchers confirmed that 80 % of patients using VEDs had erections sufficient for intercourse after 9 months, with minimal likelihood of penile shrinkage [34,35]. Compared to the use of PDE5i alone for penile rehabilitation therapy, the combination of VED and PDE5i may yield superior results for ED patients after RP. When penile function fails to recover at 24 months post-treatment despite ineffective strategies such as ICIs or VEDs, penile prosthesis implantation (PPI) is emerging as an effective third-line treatment option [43]. Megas et al. demonstrated high satisfaction rates among patients treated with PPIs in their study. They scientifically evaluated outcomes post-RP ED patients who underwent PPI compared to those treated with tadalafil, and reported significantly better IIEF scores across various aspects in the PPI group [52]. Numerous studies have shown the efficacy of PPI as a penile rehabilitation strategy and postoperative satisfaction. when treating post-RP ED clinically, considering parameters such as penile firmness, penetration ability, frequency of intercourse, patient confidence and postoperative satisfaction, penile prosthesis implantation is preferred over PDE5i therapy.

In order to address the diverse needs of patients, there is a growing focus on exploring novel treatment modalities building upon existing options, such as Hyperbaric oxygen therapy (HBOT), low-intensity extracorporeal shockwave therapy (LI-ESWT), Stem cell therapy, Nerve-grafting techniques.

Hyperbaric oxygen therapy (HBOT): HBOTinvolves highly saturated circulating plasma and dissolved oxygen, aiming to enhance the diffusion gradient between blood flow and tissues. This process is intended to promote stem cell differentiation and subsequent neovascularization, showing potential for clinical therapy [53,54]. Muller et al. observed positive responses in EF in animal models following HBOT after cavernosal nerve (CN) injury [55]. However, it is important to interpret the results cautiously due to the lack of a sham condition and the exclusion of patients with poor baseline function.

Low-intensity extracorporeal shockwave therapy (LI-ESWT): LI-ESWT has shown promising preclinical evidence in contributing to nerve regeneration, angiogenesis and tissue healing processes [56]. A randomized controlled trial (RCT) was conducted to evaluate EF in patients who underwent nerve-sparing radical cysto-prostatectomy The study compared the effects of LI-ESWT with PDE5i and placebo, revealing improved better International Index of Erectile Function-EF (IIEF-EF) scores after LI-ESWT, although the difference was not statistically significant [57]. Clinical trials with varied protocols are necessary to determine the true effectiveness of this therapy. It is still considered to have research potential according to the published AUA ED guidelines.

Stem cell therapy: Research has shown that stem cell transplants enhance the autophagic activity of spiny cells, leading to differentiation into endothelial cells and smooth muscle cells for repairing cellular damage and subsequently restore EF in PC patients [58]. Adipose-derived stem cells are commonly utilized in stem cell therapy due to their accessibility and unaffected effectiveness by blood glucose levels [59].

Nerve-grafting techniques: The nerve-grafting techniques have been the subject of several studies, with Souza Trindade et al. [60] and Reece et al. [61] demonstrating experimentally that sural nerve grafts can be utilized for end-to-side neurohemorrhage between the femoral nerve and the corpora cavernosa, resulting in successful recovery of erectile function in non-responsive patients. Additionally, Souza Trinedade et al. proposed the plausibility of central plasticity. Furthermore, there is potential for neurotransmitter release within the corpora cavernosa, plasticity at the neuromuscular junctions of the corpora cavernosa, or retrograde activation of corporal fibers, all of which hold promise for facilitating nerve regeneration within the pelvic floor [62]. Further detailed research is necessary to investigate nerve graft procedures.

4.2.3. Comprehensive management

Although there are numerous multidimensional treatments available for ED, many people may have psychological barriers to seeking medical help and avoid it altogether. Among PC patients, only about 50 % are interested in seeking ED treatment and taking relevant measures [63]. Additionally, male PC patients seeking treatment for ED often exhibit poor adherence to treatment strategies throughout the course of their treatment. Given the importance of penile rehabilitation for male patients after ED treatment, difficulty initiating may negatively impact the recovery of EF in men. The emotional distress associated with ED is probably the most common reason for non-adherence to ED treatment [64]. Male patients with a high sexual self-schema tend to be more distressed by the prospect of sexual dysfunction before undergoing PC treatment, and show more depressive symptoms when experiencing ED [65]. Effective

communication between partners is crucial in managing both PC and ED, as the most rational approach would be to seek evidence-based clinical support and promote healthy dialogue [66,67]. Some psychosocial interventions adopt a biopsychosocial approach to assist men in psychologically recovering sexual function after PC treatment.

5. Conclusion

There has been a significant increase in research on PC and ED during the past two decades. Publications in high-impact, peer-reviewed journals receive more attention than those in general journals. Strengthening academic collaborations between countries, institutions and authors can further promote comprehensive research in this field. PC and ED represent a promising area for research, and advancing scientific treatment and management is critical to improving patients' quality of life. We speculate that with the continuous growth of global research on PC and ED and further exploration of its mechanism, finding new ways of ED treatment and reducing the vice effects caused by PC treatment will be the hotspot of future research.

Limitations

The aim of this study is to conduct a bibliometric analysis of current PC and ED research, offering valuable insights for relevant researchers regarding authors, journals, research institutions, hot topics and frontiers. There may be some limitation due to the reason of only literature from the WoSCC database is included. The lack of conferences, books and other types of articles is one of the reasons for the limited number of articles collected in this research paper.

CRediT authorship contribution statement

Songnian He: Writing – original draft. **Siming Zhang:** Funding acquisition, Date curation, Formal analysis. **Xinyang Sun:** Methodology. **Ruizi Liu:** Date analysisi and interpretation. **Tianyi Yuan:** Formal analysis. **Xu Chen:** Conceptualization and design. **Xu Zhang:** Funding acquisition, Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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