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ORIGINAL RESEARCH

Comprehensive Analysis of the Biomechanical Research of Pelvic Organ Prolapse: A Scientometric Approach

Haolan Du[1,*], Miyang Yang[2,3,*], Xuge Qi[3,*], Lanlan Yang[3,*], Zhaochu Wang[3], Tao Yang[3], Shangwen Xu[2], Liyuan Fu[2]

[1]Department of Radiology, The Affiliated People's Hospital of Fujian University of Traditional Chinese Medicine, Fuzhou, People's Republic of China; [2]Department of Radiology, 900th Hospital of Joint Logistics Support Force, Fuzhou, People's Republic of China; [3]The First Clinical Medical College, Fuzong Teaching Hospital, Fujian University of Traditional Chinese Medicine, Fuzhou, People's Republic of China

*These authors contributed equally to this work

Correspondence: Liyuan Fu; Shangwen Xu, Department of radiology, 900th Hospital of Joint Logistics Support Force, Fuzhou, People's Republic of China, Tel +86 13635275400; +86 13696881369, Email 313870625@qq.com; xu_swen@163.com

Background: Pelvic organ prolapse (POP) has become a significant public health issue, with its prevalence increasing proportionally with age. Despite the considerable number of biomechanical studies reported on POP, there remains a lack of a systematic approach to summarize and synthesize all existing research.

Methods: The Web of Science Core Collection (WoSCC) database was used as the data source to select literature published from 2003 to 2023 related to biomechanical research of POP. We employed various visualization software to generate scientific knowledge maps, facilitating data analysis and visual representation.

Results: This study included 292 publications, comprising 252 research articles (86.3%) and 40 review articles (13.7%). The United States has emerged as a leading nation in terms of productivity, with the University of Porto making significant contributions. Robust partnerships are maintained by all countries and institutions involved. Moali PA stands out as the most prolific author, while Deprest J exhibits exemplary levels of collaboration. Notably, the journal *Int Urogynecol J* has the highest publication rate and citation frequency, making a significant contribution and demonstrating considerable academic influence in the field. Keyword and cluster analysis reveal that key research areas include validating finite element (FE) models of pelvic floor structures, studying interactions among pelvic support systems, evaluating the impact of vaginal delivery, assessing the effects of various mesh or 3D-printed materials on POP repair, remodeling vaginal connective tissue in POP patients, and biomechanical performance evaluations of pelvic floor tissues. Future research will likely focus on the development of personalized and regenerative treatment strategies. Moreover, advancements in machine learning, various regenerative medicine approaches, and multimodal large-scale FE modeling offer promising insights for development.

Conclusion: This study presents a comprehensive analysis of the knowledge system and research directions of the biomechanics of POP, providing valuable guidance for future research endeavors.

Keywords: pelvic organ prolapse, biomechanics, bibliometric, visualization analysis

Introduction

The pelvic floor consists of complex and supportive connective tissue and muscles which are intended to counteract gravity and intra-abdominal pressure while providing support for the pelvic organs. When this system is damaged, it is possible to develop pelvic floor dysfunction (PFD), including pelvic organ prolapse (POP).[1,2] The International Urogynecological Association (IUGA) and the International Continence Society (ICS) define POP as the descent or displacement of one or more of the anterior vaginal wall, posterior vaginal wall, or apex of the vagina (uterus/cervix or vaginal cuff scar after hysterectomy).[3] The incidence of POP is on an upward trend year by year, with approximately 50% of mothers presenting with POP-related symptoms and 30–50% of adult women being affected by POP.[4,5] About 13% of women have undergone prolapse surgery in their lifetime.[6] Due

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to the complexity and variability of the female pelvic floor anatomy, the pathophysiological mechanisms of POP are very complex. Although numerous studies have shown that the occurrence of POP is closely related to the damage of paravaginal support structures and the morphological changes of the uterus and vagina.[7] However, due to the complex and variable anatomy of the female pelvic floor structure, we are not very specific on the mechanisms responsible for the occurrence of POP. With the wide application of finite element (FE) analysis, researchers have also started to perform mechanical analysis of pelvic floor organs and soft tissues by computer. Although the application of FE analysis to soft tissues is still in its early stages, with the development of computers, medical radiology imaging and image processing software, and the intersection of various disciplines, this field has now emerged as a popular research area.

FE analysis is a modern computer simulation method that divides complex objects into a limited number of small units and replaces the original complex objects by setting different material properties for each small unit. The mechanical analysis of the FE model can be used to observe the displacement, stress, and strain of its internal and external structure under the action of external forces.[8,9] Due to the deep anatomy of the pelvic organs, the interaction of the supporting structures is still highly controversial. Radiology examinations (such as ultrasound, CT, MRI etc) combined with 3D reconstruction technology to establish FE analysis can well simulate the motion deformation and stress of pelvic tissues and organs, which can accurately reflect both regional information and overall characteristics. This method is helpful in guiding the preoperative design and postoperative outcome assessment.[10–12] However, the current problem of pelvic floor FE analysis is that the soft tissues of the pelvic floor are not visible in various radiology examinations, which results in manual modeling errors and reduces the accuracy of the finite element model simulation. Meanwhile, incomplete knowledge of the structural relationships and material parameters of tissues and organs limits the accuracy of the model.[13,14] The application of the FE analysis to pelvic floor studies can establish a close relationship between engineering and medical disciplines to better understand the mechanics of the supporting structures of the female pelvic system and the POP mechanism.

The field of bibliometrics serves as a research methodology capable of quantitatively analyzing and visually representing extensive literature data, thereby unveiling the developmental trends and evolutionary patterns within specific research domains.[15–17] By employing bibliometric visualization techniques, researchers can efficiently identify key investigators, research institutions, countries, and journals within the field of POP biomechanics. This approach not only elucidates the interrelationships among researchers, institutions, and countries but also provides a comprehensive overview of developments, emerging research frontiers, and future trends within the field. It enables a deeper understanding of the historical evolution, current landscape, and future directions in this domain, highlighting areas that warrant further investigation and offering valuable insights to guide upcoming research endeavors.

Despite the abundance of studies conducted in the field of POP biomechanics, a comprehensive and systematic approach to reviewing all existing research in this area is still lacking. Although Yu et al conducted a bibliometric analysis of the mechanism of POP, they did not analyze the biomechanical mechanisms that have recently garnered attention in this field.[18] Meanwhile, given the extensive and rapid advancements in research within this domain, this paper presented a comprehensive bibliometric analysis of the biomechanics of POP with the aim of providing a holistic overview of the subject by investigating dynamic trends in research focus within this field. Based on this premise, we conducted a literature review to investigate the previous advancements and current research focal points in this domain, while also proposing future research trends and directions. The objective of this study was to utilize the biomechanical research literature on POP published in the Web of Science Core Collection (WoSCC) database over the past two decades as the primary focus of investigation, aiming to delineate the research force network within the realm of knowledge and ascertain focal areas of research and evolutionary trajectories in the domain of POP biomechanics. We believe that our findings may offer valuable references and novel perspectives for future research.

Materials and Methods

Data Source and Search Strategy

This study utilized the WoSCC database, which comprises sub-databases such as SCIE and CCR-EXPANDED. These databases serve as the primary sources of data for this research and encompass scholarly articles from reputable journals.[19] By ensuring the quality of literature while conducting a comprehensive search for core publications in this field, we aimed to

ensure the precision and consistency of the data. To achieve this, all literature searches and data extraction were performed simultaneously on the same day by three authors. The search strategy integrated MeSH terms with free words to establish a comprehensive retrieval approach. The specific search formula was as follows: ((((TS = (Pelvic organ prolapse OR pelvic organ prolapse OR pelvic organ prolapses)) AND TS = (biomechanical OR biomechanics OR biomechanic OR finite element)) AND DT = (Article OR Review)) AND LA = (English)) AND DOP = (2003–01-01/2022-12-31).

Bibliometric Analysis

Export the literature that fulfills the selection criteria in a plain text format, ensuring a complete record and citation of references. Import the file into VosViewer 1.6.18, CiteSpace 6.2, and Scimago Graphica software for further scientific knowledge map visualization. The normalization method in VosViewer is set to correlation strength, with minimum thresholds of 5 for countries, institutions, and authors' publications. For authors, journals, and keywords the minimum thresholds are adjusted to 100, 200, and 15 respectively. In CiteSpace, the time range is set from January 2003 to December 2022, with each slice representing a year. The selected node types include keywords and citations, based on the criterion of the top 50 for each slice. To ensure precision while maintaining default settings, pruning techniques such as Pathfinder, slicing networks, and merging networks are employed. In the analysis of Countries/Regions, Institutions, Authors, Journals, and References, the H-index serves as a quantitative metric for evaluating both the quantity and quality of academic output. Generally, a higher H-index indicates greater academic influence. Similarly, TLS reflects the degree of interconnectedness between a node and other nodes, with higher TLS values suggesting more extensive collaborative relationships for that specific node.[20–22]

Results

Analysis of Annual Publications

This study encompassed a total of 292 pertinent literature pieces in the realm of biomechanics in POP, comprising 252 research articles (constituting 86.3% of all articles) and 40 review articles (constituting 13.7% of all articles). As depicted in Figure 1, a consistent upward trend can be observed in the number of annual publications over the past two decades. After analyzing the

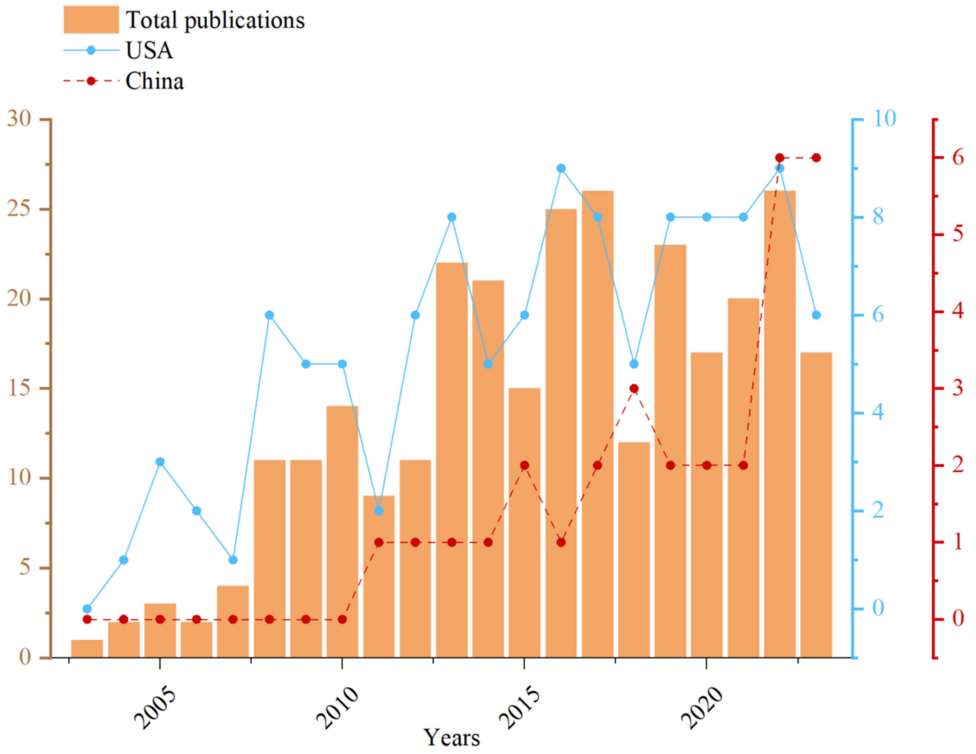

Figure 1 Annual publications chart of biomechanical research on POP.

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overall development of this field, we observe a consistent upward trend in its progress. The number of articles has significantly increased from 1 in 2003 to 17 in 2023, representing a seventeen-fold rise. Although this field has developed over the past 20 years, the total number of publications remains below one thousand. This indicates that further research by more scholars is needed to enhance its academic impact. Among them, the United States and China are the two countries with the highest number of publications in this field. As depicted in this figure, both nations have exhibited a consistent upward trend in their publication numbers. The cumulative count of publications from the United States (111 articles, 38%) surpasses that of China (30 articles, 10%), and it also commenced at a higher baseline within this domain. Nevertheless, China's publication volume has steadily increased over time and is now comparable to that of the United States. The present findings suggest that despite the growing research interest and awareness in this field, the overall publication volume remains relatively limited, indicating its status as an emerging field that requires further exploration by a broader range of scholars.

Analysis of Countries/Regions

Figure 2 depicts a knowledge graph showcasing the cooperative networks established among various countries/regions. Each colored block represents a country/region, with its size proportionate to the quantity of publications. The lines depict collaborative relationships between countries/regions, and the thickness and darkness of the lines signify the frequency of cooperation.[23–25] As depicted in the graph, the United States exhibits the highest number of publications in this particular field and maintains robust collaborations with multiple countries. However, Belgium emerges as the country engaging in the most extensive collaboration, fostering close connections with the Czech Republic, Switzerland,

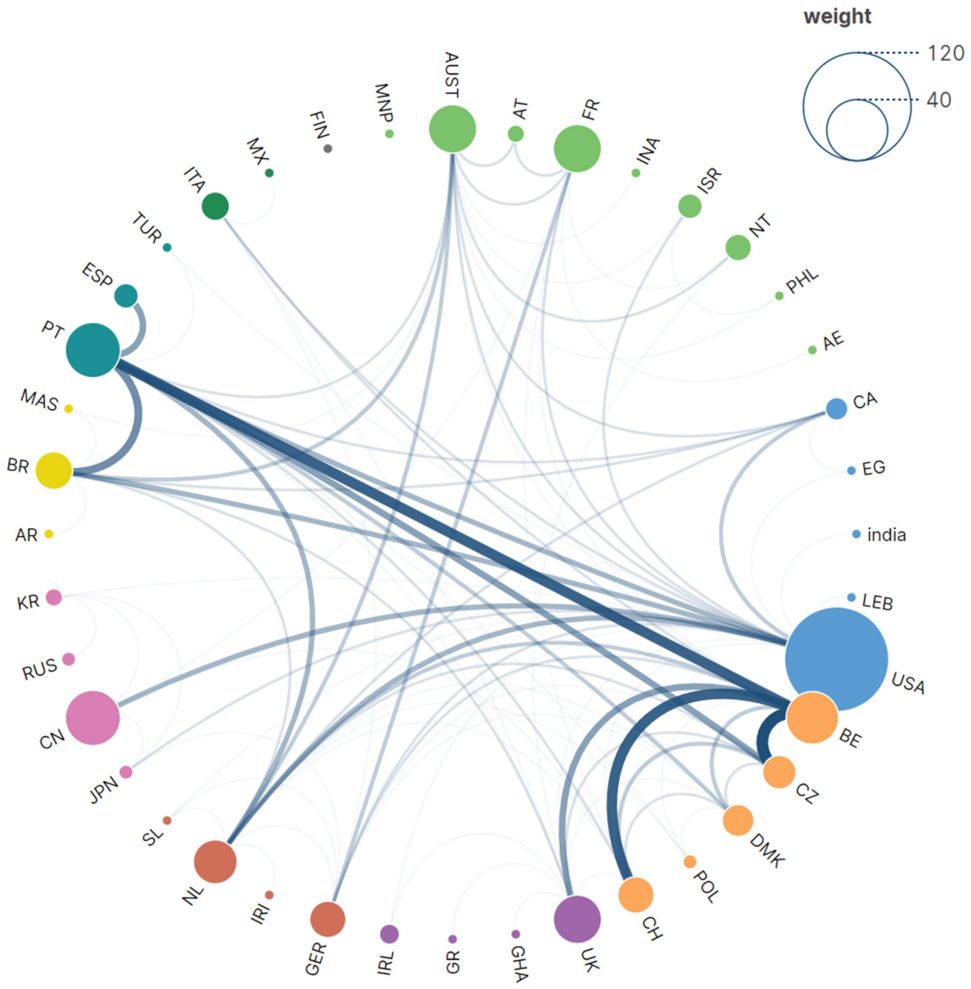

Figure 2 National/regional cooperative network knowledge graph.

Table 1 Top 10 Countries/Regions Ranked by Number of Publications

Rank	Countries/Regions	Counts (%)	TC	ACPP	H-index	TLS
1	United States	111(38%)	2931	26.41	29	41
2	China	30(10%)	394	13.13	11	8
3	Portugal	30(10%)	611	20.37	11	44
4	Belgium	27(9%)	587	21.74	16	44
5	Australia	25(9%)	697	27.88	16	23
6	England	23(8%)	567	24.65	15	18
7	France	23(8%)	608	26.43	12	14
8	Netherlands	19(7%)	280	14.74	9	26
9	Brazil	14(5%)	218	15.57	9	21
10	Switzerland	13(4%)	381	29.31	11	20

Abbreviations: TC, total citations; ACPP, average citation per publication; TLS, total link strength.

and Portugal. Furthermore, Table 1 presents pertinent information regarding the top 10 countries/regions in terms of publication volume. Among them, the United States (111 articles, 38%), China (30 articles, 10%), and Portugal (30 articles, 10%) collectively contribute to a significant proportion of the overall publication volume, accounting for approximately 58%, thus establishing themselves as prominent contributors within this domain. The United States leads significantly in terms of total citations (TC=2931) and H-index (29), while Switzerland, despite ranking tenth in total publications, exhibits the highest average citation per publication (ACPP=29.31). Portugal and Belgium share the top spot for total link strength (TLS=44).

Analysis of Institutions

Figure 3 depicts the collaborative efforts among institutions with a publication count exceeding 5 in this particular field, along with their average publication year. Based on this figure, it is evident that the University of Michigan, University of Auckland, University of Sydney, University of Zaragoza, and University of Texas Southwestern Medical Center at Dallas have demonstrated early contributions in this field. Conversely, there has been a recent increase in research activity from the University of Amsterdam, Radboud University Nijmegen, Cleveland Clinic, Louis Stokes Cleveland VA Medical Center, Cleveland Clinic, Tulane University, and Virginia Polytechnic Institute and State University. The top ten institutions in terms of the number of published articles in this field are presented in Table 2. The University of Porto exhibits the highest

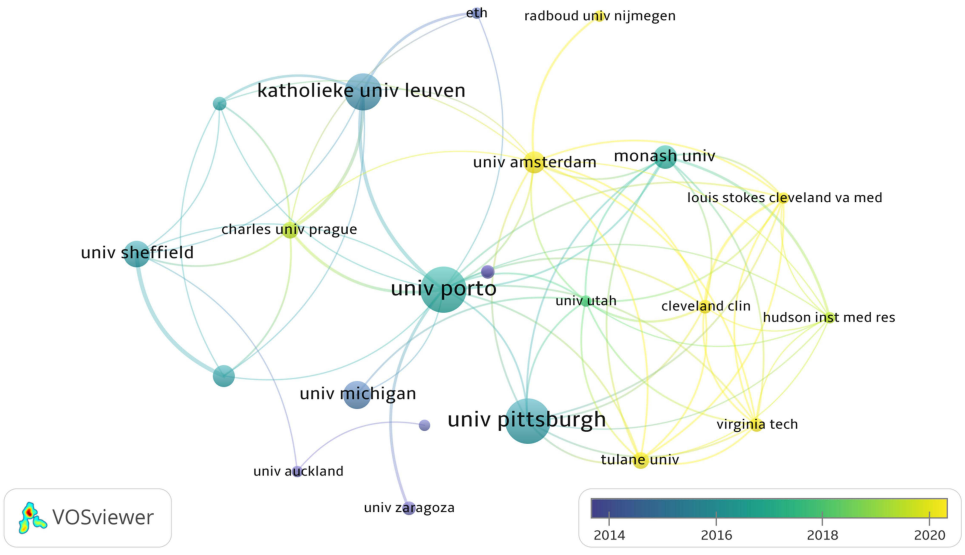

Figure 3 Institutions cooperative network knowledge graph.

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Table 2 Top 10 Institutions Ranked by Number of Publications

Rank	Institutions	Counts (%)	TC	ACPP	H-index	TLS	Country
1	University of Porto	27(9%)	553	20.48	11	40	Portugal
2	Magee Woman Research Institution	22(8%)	789	35.86	14	4	USA
3	University of Pittsburgh	20(7%)	788	39.4	14	17	USA
4	University of Michigan	16(5%)	806	50.38	11	3	USA
5	University of Sheffield	14(5%)	409	29.21	11	17	England
6	University of Lille	13(4%)	440	33.85	7	0	France
7	University of Monash	12(4%)	348	29	9	20	Australia
8	University of Texas System	12(4%)	274	22.83	8	0	USA
9	Katholieke Universiteit Leuven	11(4%)	219	19.91	7	25	Belgium
10	University of Amsterdam	11(4%)	165	15	6	23	Netherlands

Abbreviations: TC, total citations; ACPP, average citation per publication; TLS, total link strength.

publication count (27 articles, 9%), followed by Magee Woman Research Institution (22 articles, 8%) and the University of Pittsburgh (20 articles, 7%). The University of Michigan is at the forefront in terms of TC (TC=806), while Magee Woman Research Institution and the University of Pittsburgh have achieved the highest H-index, both being 14. Conversely, the University of Porto holds a significant lead in TLS (TLS=40). Among the top ten institutions ranked by publication volume, the majority are located in the United States, consistent with the results of the country analysis. While China and Portugal rank second in publication volume within this field, no institutions from China are included in the top ten.

Analysis of Authors

The collaboration network and average publication time of authors who have published no fewer than five articles in this field are illustrated in Figure 4. Notably, in the early stages of research in this field, prominent scholars such as Feola A, Abramowitch S, and Mascarenhas T played a pivotal role. However, recent studies have witnessed the emergence of scholars like Guler Z and De Vita R who have made significant contributions. The specific details of the top ten authors with the highest publication volume in this field are presented in Table 3. As shown in this table, Moali PA is the most prolific author, with a publication record of 27 publications (9%). He demonstrates strong performance in terms of TC (TC = 1098), ACPP (ACPP = 40.67), and H-index (18). In contrast, Deprest J holds a prominent position in TLS (TLS=53).

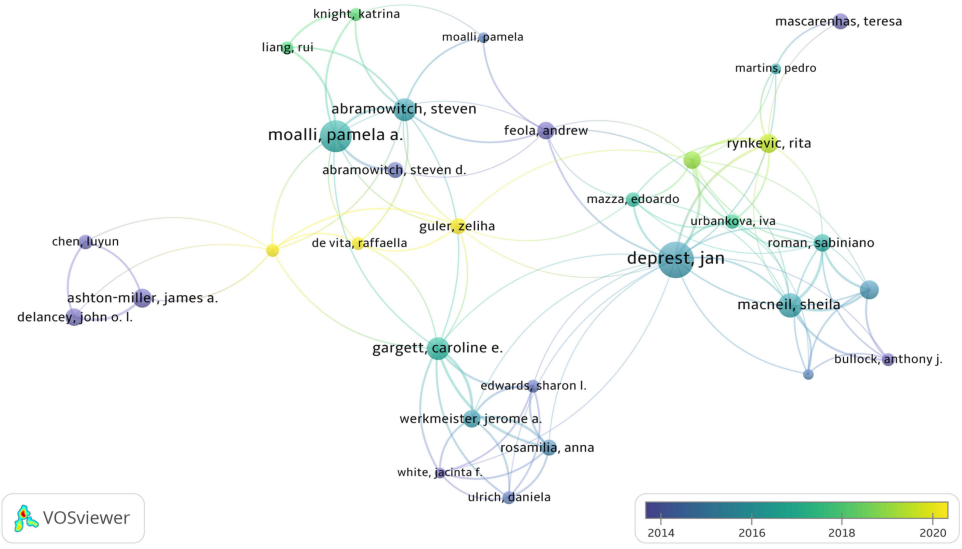

Figure 4 Authors cooperative network knowledge graph.

Table 3 Top 10 Authors Ranked by Number of Publications

Rank	Author	Counts (%)	TC	ACPP	H-index	TLS
1	Moali PA	27(9%)	1098	40.67	18	35
2	Deprest J	25(9%)	561	22.44	16	53
3	Jorge RN	20(7%)	485	24.25	10	8
4	Mascarenhas T	17(6%)	478	28.12	10	12
5	Feola A	16(5%)	773	48.31	13	18
6	Parente M	14(5%)	250	17.86	7	8
7	Abramowitch S	14(5%)	469	33.5	11	32
8	Macneil S	13(4%)	404	31.08	11	40
9	Chapple CR	12(4%)	397	33.08	11	31
10	Brieu M	12(4%)	439	36.58	7	20

Abbreviations: TC, total citations; ACPP, average citation per publication; TLS, total link strength.

Analysis of Journals

The top ten journals in this field, ranked by publication volume and sorted based on the number of publications, are presented in Table 4. The *Int Urogynecol J* holds the first position with a significantly higher publication volume (51 articles, 17%) compared to other journals. Moreover, it exhibits TC value (TC=1219) and H-index (20). However, the *Am J Obstet Gynecol* boasts the highest impact factor among its peers, with an impressive ACPP score of 37.81 and an IF rating of 9.8, placing it in the top quartile (Q1) for scholarly publications among these top ten journals. The co-citation relationships among these journals are depicted in Figure 5 and Table 5, where *Int Urogynecol J, Am J Obstet Gynecol*, and *Obstet Gynecol* exhibit significantly higher citation frequency and TLS compared to other journals.

Analysis of References

The co-citation relationships among 28 publications, which have received a minimum of 50 citations, are illustrated in Figure 6. Additionally, Table 6 provides comprehensive details on the top 10 most frequently cited publications. According to the study conducted by Summer et al published in 2006 in the *American Journal of Obstetrics and Gynecology*, their work has received the highest number of citations within the field. Conversely, Lei et al's publication in 2006 in the *International Urogynecology Journal* holds the record for having achieved the highest TLS (TLS=61). By defining the minimum duration of an outbreak as 3 years, a total of 30 reference articles reporting high-intensity outbreaks were identified, as depicted in Figure 7. The term "citation burst" refers to papers that experience a high frequency of citations within a specific time frame.[26,27] The time interval is represented by the blue line in this figure, while the duration of the outbreak is indicated by the red line. "Strength" refers to the magnitude of the eruption, and "Begin" and "End" respectively

Table 4 Top 10 Journals Ranked by Number of Publications

Rank	Journal	Counts (%)	TC	ACPP	H-index	IF (2022)	JCR Quartile	Country
1	*Int Urogynecol J*	51(17%)	1219	23.9	20	1.8	Q4	England
2	*Am J Obstet Gynecol*	21(7%)	794	37.81	16	9.8	Q1	USA
3	*J Mech Behav Biomed*	14(5%)	302	21.57	8	3.9	Q2	Netherlands
4	*J Biomech*	13(4%)	368	28.31	9	2.4	Q3	England
5	*Neurourol Urodynam*	12(4%)	244	20.33	8	2	Q3	USA
6	*J Biomech Eng-T ASME*	10(3%)	148	14.8	8	1.7	Q4	USA
7	*Sci Rep-UK*	9(3%)	88	9.78	6	4.6	Q2	England
8	*Eur J Obstet Gyn R B*	8(3%)	252	31.5	5	2.6	Q3	Netherlands
9	*Arch Gynecol Obstet*	7(3%)	54	7.71	4	2.6	Q3	Germany
10	*PLOS ONE*	7(3%)	153	21.86	7	3.7	Q2	USA

Abbreviations: TC, total citations; ACPP, average citation per publication; IF (2022), impact factor.

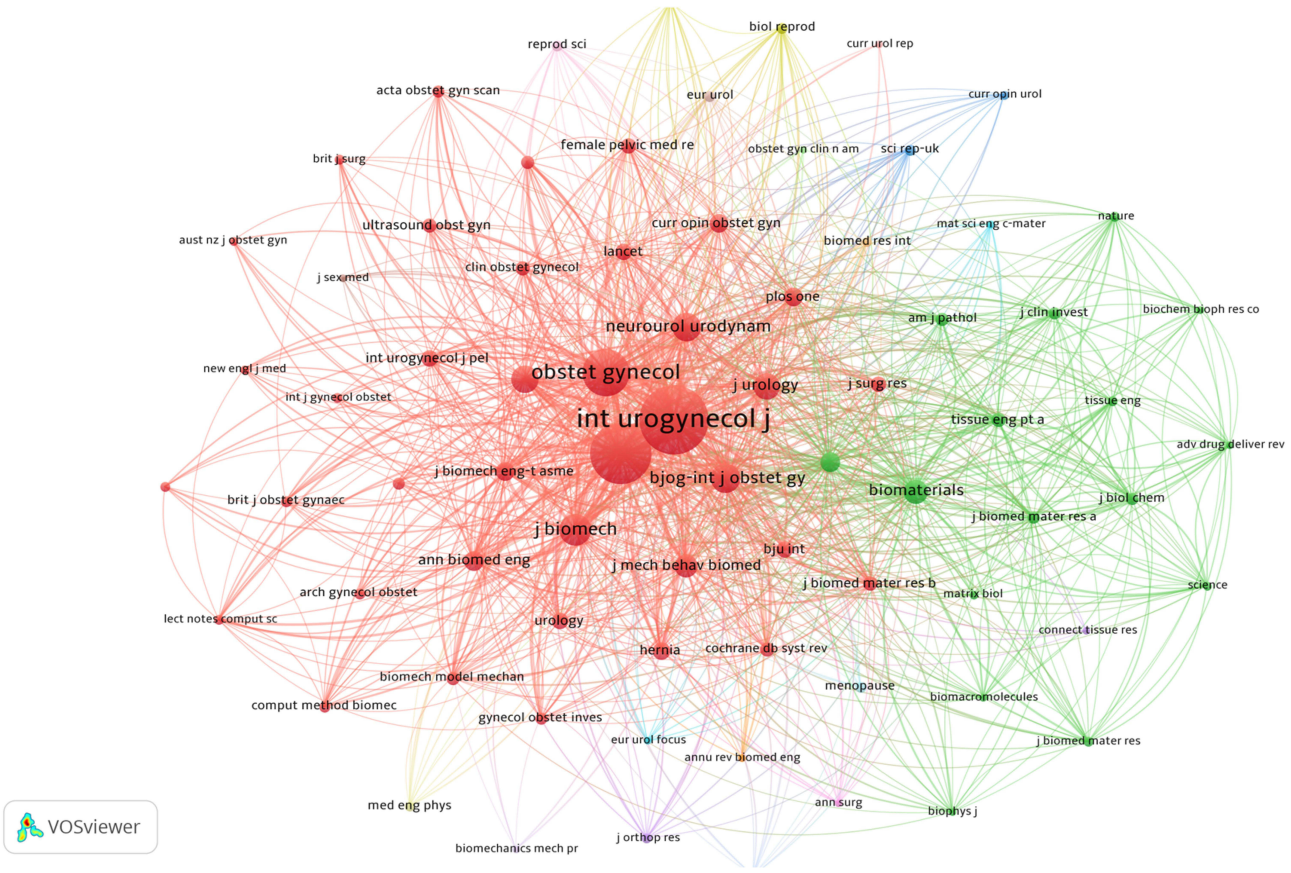

Figure 5 Journal co-citation network knowledge graph.

denote the initiation and termination time of the eruption.[25,28] We can discern that the developmental emphasis in this domain fluctuates over different epochs. The literature that has garnered attention focuses on electron microscopy examination of biopsy specimens from various supportive structures of the pelvic floor to elucidate their composition or biomechanical measurements for determining their material parameters.[29–32] In the mid-term of this field, scholars have increasingly turned their attention to conducting FE analysis on various supporting structures of the pelvic floor in order to enhance our understanding of the biomechanical mechanisms underlying POP.[33–35] In recent years, the literature in this field has increasingly focused on developing diverse mesh-based FE models to investigate the repair outcomes of POP and examine the comparative effects of different materials on these repairs.[35–37]

Table 5 Top 10 Co-Cited Journals Ranked by Citation Frequency

Rank	Co-Cited Journal	Citations	TLS	H-index	IF (2022)	JCR Quartile
1	*Int Urogynecol J*	1411	40,758	20	1.8	Q4
2	*Am J Obstet Gynecol*	1137	31,512	16	9.8	Q1
3	*Obstet Gynecol*	679	21,309	7	7.2	Q1
4	*J Biomech*	315	13,830	9	2.4	Q3
5	*Bjog-Int J Obstet Gy*	283	9571	5	5.8	Q1
6	*Neurourol Urodynam*	247	8768	8	2	Q3
7	*Eur J Obstet Gyn R B*	230	7926	5	2.6	Q3
8	*J Urology*	218	8347	5	6.6	Q1
9	*Biomaterials*	183	11,190	2	14	Q1
10	*J Mech Behav Biomed*	165	8390	8	3.9	Q2

Abbreviations: TLS, total link strength; IF (2022), impact factor.

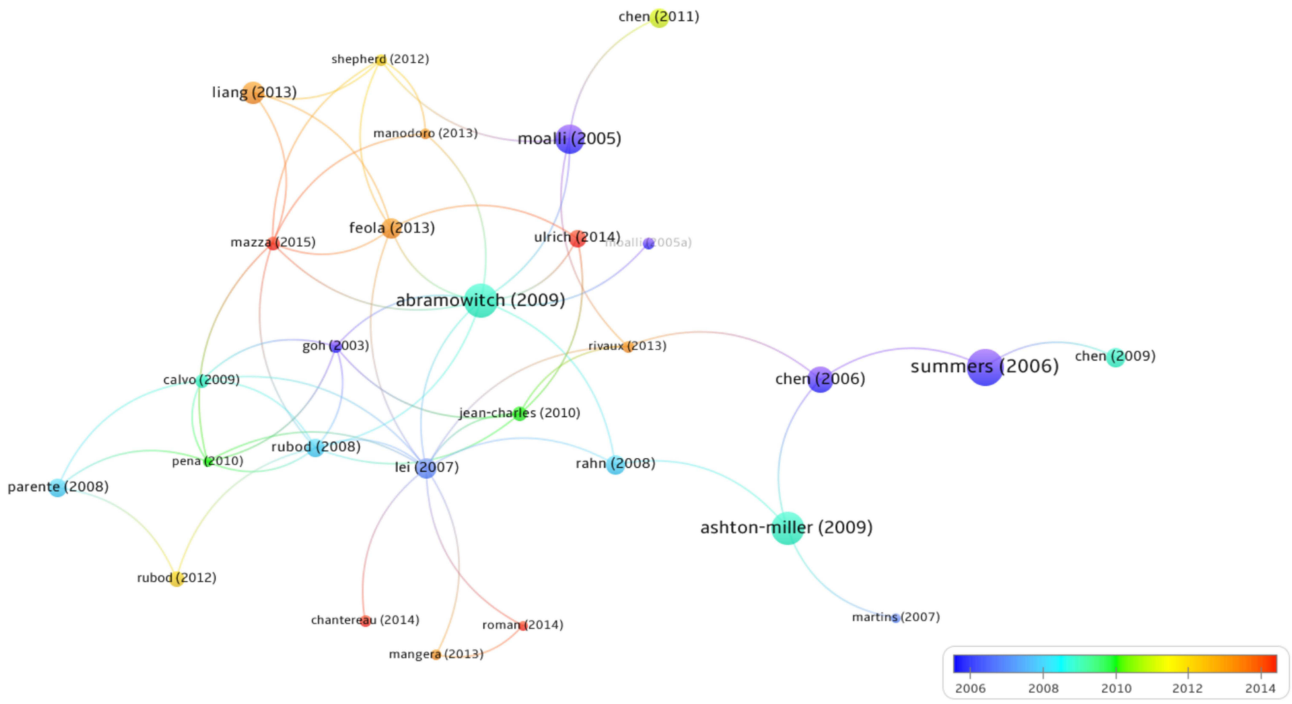

Figure 6 References co-citation network knowledge graph.

Analysis of Keywords

Summarizing the entire research content in this field through keywords analysis can provide valuable insights into the primary research topics and current issues, facilitating an exploration of the developmental status and emerging trends within this domain.[38–40] Figure 8 depicts the collaborative relationships, occurrence frequency, and average appearance time of keywords that have a minimum frequency of 15 occurrences. In this figure, larger nodes represent keywords with higher frequencies of occurrence, while the connections between nodes indicate their collaborative relationships.

Table 6 Top 10 Co-Cited References Ranked by Citation Frequency

Rank	Co-Cited Reference	Author and Publication Year	Citations	TLS	Journal	JCR Quartile
1	The relationship between anterior and apical compartment support	Summer A (2006)	192	13	*Am J Obstet Gynecol*	Q1
2	Tissue mechanics, animal models, and pelvic organ prolapse: A review	Abramowitch SD (2009)	178	60	*Eur J Obstet Gyn R B*	Q3
3	On the Biomechanics of Vaginal Birth and Common Sequelae	Ashton-Miller JA (2006)	168	22	*Annu Rev Biomed Eng*	Q1
4	Remodeling of vaginal connective tissue in patients with prolapse	Moalli PA (2005)	152	37	*Obstet Gynecol*	Q1
5	Interaction among apical support, levator ani impairment, and anterior vaginal wall prolapse	Chen LY (2006)	138	22	*Obstet Gynecol*	Q1
6	Vaginal degeneration following implantation of synthetic mesh with increased stiffness	Liang R (2013)	116	51	*Bjog-Int J Obstet Gy*	Q1
7	Deterioration in biomechanical properties of the vagina following implantation of a high-stiffness prolapse mesh	Feola A (2013)	108	58	*Bjog-Int J Obstet Gy*	Q1
8	Biomechanical properties of prolapsed vaginal tissue in pre- and postmenopausal women	Lei LL (2007)	104	61	Int Urogynecol J	NA
9	Biomechanical properties of the vaginal wall: effect of pregnancy, elastic fiber deficiency, and pelvic organ prolapse	Rahn DD (2008)	103	29	*Am J Obstet Gynecol*	Q1
10	Alterations in Connective Tissue Metabolism in Stress Incontinence and Prolapse	Chen B (2011)	102	7	*J Urology*	Q1

Abbreviation: TLS, total link strength.

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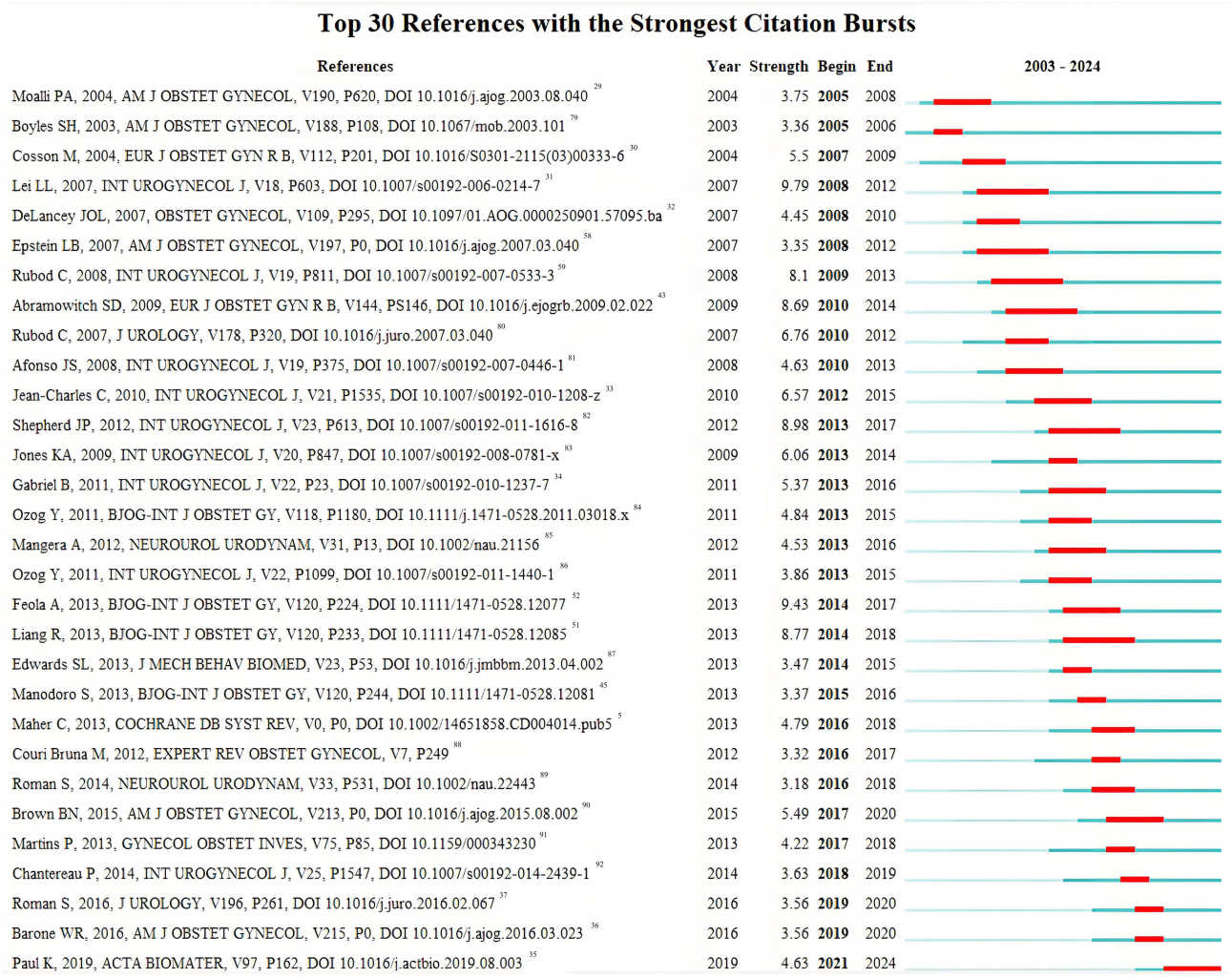

Figure 7 Top 30 co-cited references ranked by citation frequency.

Generally, thicker connections imply stronger collaboration among the keywords. To enhance the precision of this study, we manually processed all instances of "Stress urinary-incontinence" and "Mechanical-properties" keywords, as these terms possess similar connotations across various literature but are expressed differently. Consequently, we revised them to "Stress urinary incontinence" and "biomechanical properties". From this graph, it is evident that keywords such as "prolapse", "stress urinary incontinence" and "vaginal tissue" have emerged prominently in this domain. Conversely, keywords like "biomechanical properties", "implantation" and "impact" have gained significant attention in recent years. Furthermore, Table 7 presents the top 20 high-frequency keywords along with their TLS, which partially reflects the predominant research themes and emerging trends in this particular domain. This study also employs keywords clustering to derive 5 cluster labels, which are then visualized in the form of a keyword timeline graph (Figure 9). This visualization enables a comprehensive examination of the temporal evolution characteristics exhibited by each clustered field. The term "emerging keywords" refers to key terms that frequently occur within a specific time frame, and analyzing them can unveil research hotspots and development trends in a particular field.[22] By setting the minimum duration of an outbreak at 3 years, we detected the top 20 keywords with the highest outbreak intensity. Among them, tissue engineering and extracellular matrix will continue to be prominent until 2023 or later (Figure 10), thus reflecting recent research focuses to some extent.

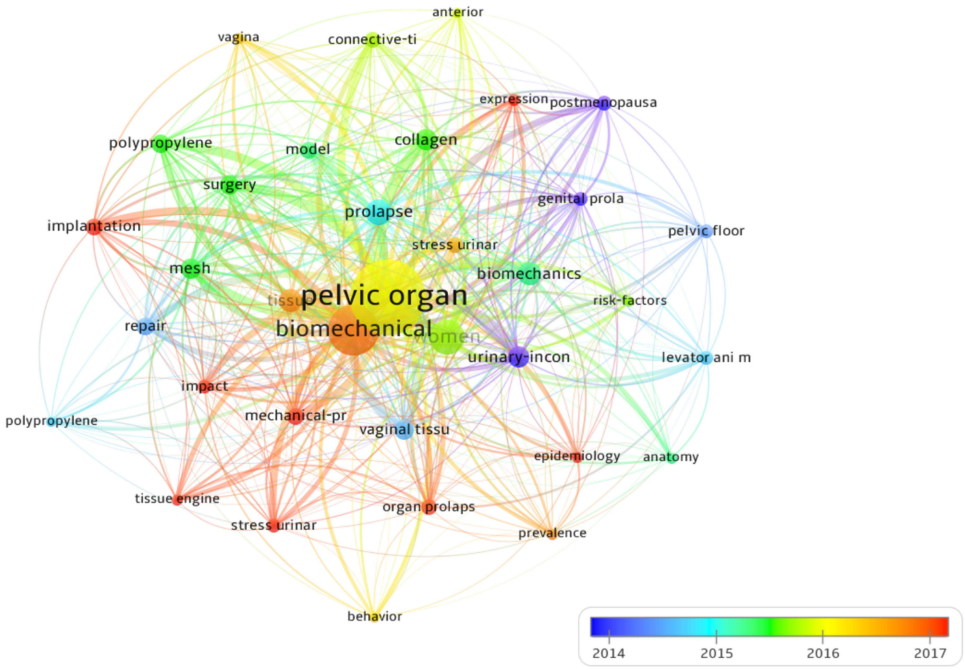

Figure 8 Keywords co-citation network knowledge graph.

Discussion

In the past two decades, researchers have dedicated significant efforts to the field of biomechanics in POP and achieved remarkable progress, thereby making substantial contributions to this domain. This present study employs a bibliometric analysis of biomechanical research pertaining to the WoSCC database and POP over the past two decades, effectively illustrating the current state of research in this field through a comprehensive graphical representation.

With the advancement of solid biomechanics, biofluid mechanics, and movement biomechanics, along with continuous progress in radiographic imaging and computer technology, this field has demonstrated a steady upward trajectory in overall development. However, the current publication volume in this field remains relatively low, indicating its nascent stage but with significant potential. In the future, we anticipate a substantial increase in high-quality research publications. In recent years, compared to the initial research achievements in 2003, there has been a twenty-fold increase. The United States leads the world in terms of published research, making a substantial contribution to this field and accounting for 38% of total publications. It holds the top position in TC, h-index, and TLS, highlighting its substantial academic influence and prominent status in this research domain, while maintaining strong collaborations

Table 7 Top 20 Keywords Ranked by Number of Publications

Rank	Keyword	Counts	TLS	Rank	Keyword	Counts	TLS
1	Pelvic organ prolapse	214	1342	11	Vaginal tissue	33	216
2	Biomechanical properties	152	1042	12	Polypropylene mesh	31	182
3	women	77	560	13	Repair	29	204
4	Stress urinary incontinence	58	391	14	Implantation	28	202
5	prolapse	51	317	15	Model	27	175
6	Tissue	43	306	16	Connective-tissue	26	190
7	Biomechanics	42	281	17	Organ prolapse	25	170
8	Collagen	38	268	18	Levator ani muscle	22	152
9	Mesh	36	249	19	Genital prolapse	21	168
10	surgery	33	222	20	Impact	21	163

Abbreviation: TLS, total link strength.

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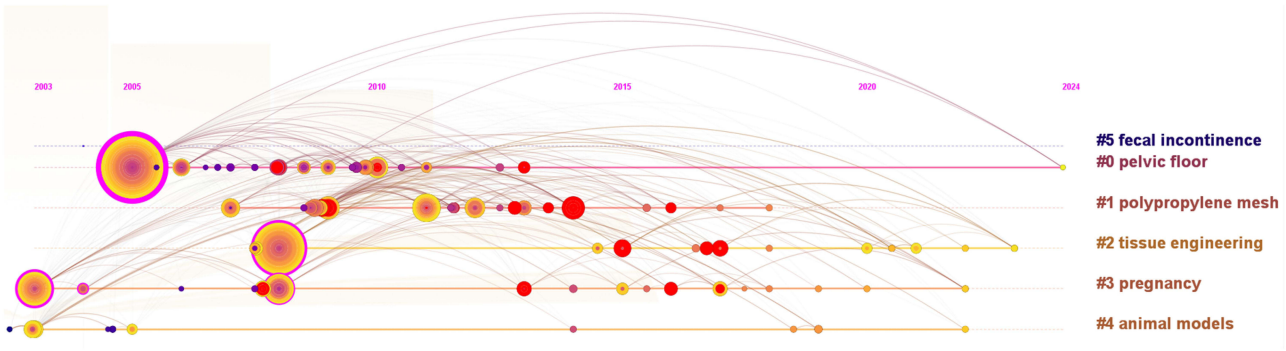

Figure 9 Keywords timeline graph.

Top 20 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2003 - 2024
genital prolapse	2008	4.93	**2008**	2010	
postmenopausal women	2008	4.69	**2008**	2012	
biomechanical properties	2010	3.64	**2010**	2013	
vaginal tissue	2010	3.13	**2010**	2012	
repair	2009	3.69	**2011**	2017	
tissue	2011	2.53	**2011**	2012	
polypropylene mesh	2009	3.42	**2012**	2016	
graft materials	2012	2.54	**2012**	2014	
wall	2013	2.87	**2013**	2016	
finite element model	2014	2.93	**2014**	2015	
implantation	2014	2.52	**2014**	2022	
behavior	2016	3.34	**2016**	2018	
anterior	2013	2.74	**2016**	2017	
complications	2016	2.58	**2016**	2017	
smooth muscle	2017	3.38	**2017**	2019	
impact	2017	3.03	**2017**	2018	
organ prolapse	2008	3.89	**2018**	2020	
expression	2013	3.4	**2019**	2022	
tissue engineering	2015	3.58	**2020**	2024	
extracellular matrix	2017	4.34	**2022**	2024	

Figure 10 Top 20 keywords ranked by burst strength.

with other countries and regions. Amidst the wave of enhanced collaboration, Portugal, Belgium, the Czech Republic, and Switzerland have established robust connections in this domain, emerging as pivotal contributors alongside the United States and China - the leading nations in terms of publication output. Meanwhile, Switzerland's lower publication output is counterbalanced by its highest ACPP, indicating widespread recognition and citation of its research achievements among peers. It is noteworthy that 70% of the top ten high-productivity countries/regions are predominantly concentrated in North America and Europe, underscoring their prominent status as primary research hubs in this field.

The University of Porto, situated in Portugal, stands out as the institution with the highest number of published papers and TLS. This indicates its exceptional productivity in this field and its robust collaborative network with other institutions. The publication with the highest citation rate in this institution employed the FE method to simulate the complete process of vaginal delivery in early-stage research, investigating the impact of the fetal head on pelvic floor muscles during vaginal delivery. The findings of this study suggest that the levator ani muscle and the pubococcygeus muscle undergo significant stretching and strain during vaginal delivery, with a potential risk for pelvic floor muscle injury in the second stage of labor.[41] The University of Michigan, situated in the United States, is widely regarded as the foremost institution in the field concerning TC and ACPP. Meanwhile, both the University of Pittsburgh and Magee Woman Research Institution, also based in the United States, are acknowledged for their exceptional H-index among institutions within this domain. These accomplishments reflect America's robust research capabilities within this discipline and have garnered significant attention from scholars in this field. The University of Michigan's highly influential publication provides a biomechanical perspective on the correlation between the anterior compartment (bladder) and the apical compartment (cervix). The findings suggest that approximately 50% of the observed variability in anterior compartment support can be attributed to apical support, thus establishing a theoretical framework for comprehending the underlying mechanism of POP.[42] The University of Pittsburgh's most influential publication is a comprehensive review article that critically examines the extensive research conducted in 2009, providing an insightful synthesis of diverse animal models, anatomical manifestations, and biochemical constituents pertaining to POP. Furthermore, it delves into the intricate structure and biomechanical properties of vaginal supportive connective tissues.[43] The most influential publications from Magee Women's Research Institution primarily focus on organizational remodeling and biochemical evidence pertaining to advancements in POP. This research suggests that vaginal collagen fibers exhibit a whorled pattern, predominantly composed of type III collagen. In comparison to women without prolapse, those with prolapse demonstrate elevated levels of total collagen protein and increased activity of MMP-9 within the vagina.[44] The University of Porto maintains strong collaborations with prominent institutions such as the University of Pittsburgh, Katholieke Universiteit Leuven, and Monash University, among others. It is noteworthy that Royal Hallamshire Hospital exhibits the most extensive collaboration with the University of Sheffield among all institutions in this field. In their collaborative research, the most influential articles focused on assessing the in vivo response of alternative materials (polypropylene (PPL), polyvinylidene fluoride (PVDF), poly-lactic acid (PLA), and polyurethane (PU) mesh implants)) for the management of stress urinary incontinence and POP in rabbits over a three-month duration. This study revealed that PLA and PU mesh implants demonstrate superior host tissue integration, whereas commercial PPL and PVDF mesh implants exhibit a heightened level of sustained inflammation in comparison to the former.[37] It is evident that the majority of highly productive and influential institutions are concentrated in Europe and the United States, indicating a predominant research presence in Western countries, consistent with our country/region analysis.

Moali PA, affiliated with Magee Women's Research Institution, emerges as the most prolific author in this field, surpassing other researchers in terms of his TC, ACPP, and H-index. This not only highlights his exceptional academic accomplishments and influence but also underscores his extensive collaborations with scholars such as Abramowitch S, Feola A, Jallah Z, and Shand SH. This scholar's research, aligned with the work conducted by their affiliated institution, highlights their significant contributions and respected status within both the academic field and their organization. Deprest J from Katholieke Universiteit Leuven emerges as a leading scholar in this field, boasting the highest TLS. He demonstrates an impressive publication record, along with high TC, ACPP, and H-index rankings. These accolades attest to his respected standing within the academic community and exemplary collaboration with fellow scholars, rendering him an indispensable pillar for advancing the progress of this discipline. His highly cited article primarily focuses on the biomechanical performance and incidence of associated complications in comparing vaginal and abdominal mesh

implantation. This study revealed a significant correlation between the size of vaginal mesh pores and transplant-related complications, based on research involving 20 sheep. Furthermore, it demonstrated that the biomechanical performance of extraperitoneal implants is comparable to that of abdominal implants.[45]

Int Urogynecol J, Am J Obstet Gynecol, and *J Mech Behav Biomed* are highly productive and influential journals with a strong co-citation network in this field. Therefore, when disseminating research findings or conducting literature searches, these five journals should be prioritized. It is noteworthy that among the top ten high-productivity journals, only those originating from Europe and the United States are included, with 70% of them being affiliated with institutions in the United States and the United Kingdom. This indicates that the journals of these countries have made significant contributions to this field, garnering extensive attention and recognition from researchers worldwide. Consequently, they are regarded as valuable platforms for disseminating and accessing high-level research accomplishments.

Highly cited publications serve as a reflection of the research status and focal points within a specific field, enabling an analysis that aids in summarizing significant research accomplishments. This analysis provides valuable theoretical guidance for conducting future in-depth investigations.[46–48] One of the most frequently cited studies is a 2006 publication by Summer A et al in the journal *Am J Obstet Gynecol*, widely regarded as a highly influential piece of research originating from the University of Michigan. Similarly, the paper published by Abramowitch SD et al in 2009 holds the second highest citation count and is widely acknowledged as a highly influential publication at The University of Pittsburgh. These findings suggest that both universities played a pioneering role in the nascent stages of this field and made substantial contributions to its advancement, aligning with institutional analysis. Additionally, Ashton-Miller et al conducted a pioneering research, utilizing MRI to model the pelvic floor region and investigate the specific biomechanical mechanisms underlying pelvic floor injury resulting from vaginal childbirth, thereby providing an unprecedented understanding of the functional anatomy and daily load on the female pelvic floor in everyday life.[49] This study suggests that muscle damage occurs in the region experiencing the greatest stretch during the second stage of labor, and there is a significant correlation between forceps usage and levator ani muscle injury. The urogenital hiatus undergoes forced dilation due to increased intraabdominal pressure, resulting in distal vaginal exposure to a pressure differential, apical descent, and cystocele formation. Amongst the major pelvic floor nerves, the anal sphincter nerve experiences the highest level of pressure during the second stage of labor. However, further investigation is warranted to explore the impact of pregnancy on the constitutive behavior and failure characteristics of pelvic floor tissues. Fourthly, the study conducted by Moalli et al in 2005 focused on the histological and biochemical evidence of vaginal connective tissue remodeling in patients with prolapse. This study is also one of the most influential research conducted by the Magee-Womens Research Institute. In contrast to the highly influential publications from the University of Michigan, Chen et al's 2006 study specifically examined the interaction between the anterior vaginal wall and its supporting system with respect to the levator ani muscle.[50] The research findings revealed that the degree of anterior vaginal wall prolapse is a result of combined damage to both pubovisceral muscle, uterosacral, and/or cardinal ligament ("apical supports") impairment under increased intra-abdominal pressure. Once a certain level of visceral damage to the pubovisceral is reached, it leads to genital hiatus opening and subsequent prolapse development. The severity of anterior wall prolapse increases with a greater extent of pubovisceral injury. By comparing this study with the research conducted by Summers et al, we can enhance our comprehensive understanding of the intricate interrelationships among diverse supporting structures within the pelvic floor.[42] The study conducted by Liang et al in 2013 aimed to investigate the impact of synthetic meshes with varying stiffness (The prototype prolapse mesh Gynemesh PS was compared to two new generation lower stiffness meshes, UltraPro and SmartMesh) on vaginal morphology and structural composition.[51] The findings suggest that the implantation of mesh has a detrimental impact on vaginal morphology and connective tissue remodeling. It is possible that the utilization of more rigid mesh results in an upregulation of collagenase activity, a decrease in collagen and elastin content, and an increase in GAG content, all of which have negative effects on the structural integrity of the vagina. It is noteworthy that Feola et al, in a study published in the same year, conducted a biomechanical analysis of Liang et al's research and arrived at an identical conclusion.[52] To comprehensively validate these findings, further research from multiple perspectives is warranted to investigate the impact of various synthetic mesh patches on vaginal functionality and elucidate the molecular and biomechanical mechanisms underlying these changes. The study conducted by Lei et al in 2006 involved pathological biopsies of vaginal tissues in 43 patients with varying degrees of menopausal status and prolapse after transvaginal hysterectomy.[31] This study revealed that pre- and postmenopausal patients with POP exhibit reduced vaginal connective tissue elasticity and

increased stiffness compared to the general population. Substantial variations in biomechanical properties were observed between mild and moderate types, as well as between mild type and severe type. However, no significant difference was found between moderate type and severe type. Rahn et al investigated the alterations in biomechanical properties of the vaginal wall induced by pregnancy and childbirth using Fibulin-5 knockout (*Fbln5*$^{-/-}$) mice model, both with and without POP.[53] From an animal model perspective, this study has shown that pregnancy can induce changes in the vaginal wall similar to those observed in POP, including increased distensibility, decreased stiffness, and reduced maximum pressure. These alterations may contribute to the poorer durability of many restorative surgical procedures for POP. The 2011 publication by Chen et al is a comprehensive review that extensively explores the impact of collagen/elastin and extracellular matrix metabolism on the urinary reproductive system, with a specific focus on stress urinary incontinence.[54] Furthermore, this study provides an overview of the influence of genetics and reproductive hormones on extracellular matrix metabolism, encompassing collagen, elastin, and transforming growth factor-β. The aforementioned highly cited articles serve as a fundamental research foundation with substantial academic influence and reference value in this field. By interpreting and exploring these articles, we can enhance our comprehension of the developmental trends within this field and identify potential directions for future research.

The term "Citation burst" typically denotes the literature that garnered significant attention during a specific timeframe. Analyzing these publications from various periods can facilitate comprehension of research trends prevalent in the field at that particular time and enable the identification of prospective avenues for future research.[55–57] To comprehensively capture the current research trends and anticipate future developments in this field, this study will primarily focus on the literature that continues to generate significant interest until 2024 or later. In the field of research, only one article garnered significant attention until 2024, which was authored by Paul et al from the Hudson Institute of Medical Research in 2019.[35] This study represents a pioneering application of 3D printing technology for the fabrication of endometrial mesenchymal stem/stromal cells (eMSCs) onto a mesh, aiming at targeted repair of POP in the vaginal wall. The study was conducted in three stages, including the fabrication of a melt electrospun (MES) mesh, bioprinting eMSCs into a Ca^{2+} free Aloe Vera-Alginate (AV-Alg) based hydrogel, and in vivo study. The result demonstrated that AV-ALG hydrogel has the potential to suppress the foreign body response, and the additional incorporation of eMSCs induced a significant influx of anti-inflammatory CD206+ M2 macrophages. This study represents a significant breakthrough in the field of tissue engineering and bioprinting for POP treatment, providing an alternative approach to overcome the challenges posed by non-degradable knitted meshes currently used. This method has important implications for future advancements in this field. By analyzing highly cited and "Citation burst" research, it can be inferred that the primary research areas in this field encompass the development and validation of three-dimensional FE models for pelvic floor structures, investigation into the interplay among diverse supporting systems within the pelvic floor, verification of the impact of vaginal delivery on various supportive structures, analysis of different mesh or 3D printing materials' effects on POP repair, remodeling of vaginal connective tissue in patients with prolapse conditions, and biomechanical performance assessment of pelvic floor tissues in individuals with prolapse disorders.

Through the analysis of keyword co-occurrence relationships, clustering, and bursts, we have identified that the predominant research topics in this field encompass POP, biomechanical properties, women, stress urinary incontinence (SUI), and prolapse. These topics exhibit a significantly high frequency of occurrence. The 5 clustering labels, encompassing #0 pelvic floor, #1 polypropylene mesh, #2 tissue engineering, #3 pregnancy, #4 animal models, and #5 fecal incontinence to some extent reflect the predominant research themes within this field. Among them, the research field of tissue engineering and extracellular matrix, which are emerging keywords with durations ending in 2022 or later, has gained prominence in recent years. It has attracted great attention from the scientific community and is expected to become the focus of future research in this field. A comprehensive analysis of all articles in this field reveals that the focus of research shifts across different stages of the field's development. Early biomechanical research on POP primarily centered on identifying and understanding the anatomical and mechanical properties of the pelvic floor and associated structures contributing to POP. Researchers recognized that biomechanical alterations in pelvic tissues, such as changes in tensile strength, elasticity, and extensibility, are crucial factors in the onset of prolapse.[58] An early discovery highlighted the role of vaginal tissue mechanics in POP. Studies by Rubod et al demonstrated that vaginal tissues in prolapse patients exhibit distinct biomechanical characteristics, such as hyperelasticity and increased deformation prior to rupture, compared to individuals without POP.[59] These insights laid the groundwork for subsequent research focused on

quantifying mechanical behavior and refining surgical interventions for POP. Early studies also identified collagen, particularly types I and III, as fundamental to maintaining the structural integrity of the pelvic floor, noting that prolapsed tissues exhibit an altered collagen composition.[60] Furthermore, the connective tissue properties of the uterosacral ligaments and other supporting structures became a focal point in studies investigating why some individuals are more prone to developing POP. Many research highlighted that a combination of genetic predisposition and external factors could weaken these support structures, thereby increasing susceptibility to POP.[49,61] In the early stages of research in this field, numerous studies were conducted to elucidate the mechanisms underlying the occurrence of POP. Most of these studies focused on mechanical testing of cadaveric and animal models, in vitro evaluations of organs, and assessments of various implant materials used in pelvic floor repair surgeries. Additional research included in vitro mechanical testing of tissues and organs from living human subjects and analyzing the mechanical properties of collagen fibers in different tissues. In the mid-stage of biomechanical research on POP, attention shifted to the development of biomechanical FE models to simulate pelvic floor mechanics. Biomechanical modeling emerged as a prominent tool in understanding POP pathophysiology during this period. Advanced techniques, including FE analysis and computational simulation, were employed to replicate the mechanical environment of the pelvic floor. For instance, Yang et al used FE analysis to assess how mechanical forces affect the pelvic floor musculature and connective tissues under various loading conditions.[10] This modeling enabled researchers to simulate and predict the progression of prolapse and evaluate the effectiveness of different surgical interventions in restoring pelvic support. Studies in this phase also revealed the importance of muscular support, particularly the role of the levator ani muscle complex. These muscles, particularly the pubovisceral component, were identified as essential in counteracting pelvic organ descent. The work of researchers like Jing highlighted how weakening or damage to these muscles during childbirth could predispose individuals to prolapse later in life, further emphasizing the need for protective interventions during childbirth.[62] The use of high-resolution imaging techniques, such as MRI and ultrasound, has allowed for more accurate assessments of pelvic floor anatomy and biomechanical properties. For example, Brandão utilized MRI to quantify parameters like the moment of inertia of pelvic structures, providing insights into the anatomical changes associated with POP.[63] These imaging techniques facilitate early diagnosis, allowing for preventive measures and tailored interventions.

The integration of these imaging modalities into FEA models allows clinicians to predict patient-specific outcomes more accurately and adjust surgical approaches based on individualized risk factors. However, during this stage, most FE analyses were based on models that included only one or a few pelvic tissues or organs, lacking a comprehensive model encompassing all pelvic floor tissues and organs. Such a complete model is needed to more accurately reflect the real development of POP and the mechanical performance of various materials used in POP repair. In recent years, biomechanical research on POP has adopted a more integrative approach, combining biomechanics, imaging, and genetic analysis to understand the complex interactions that contribute to prolapse. These trends reflect the progression toward personalized medicine and improved clinical interventions. Predictive FE modeling has become an area of great interest, as it allows for the identification of patients at high risk of developing POP. By inputting data on tissue and organ composition, mechanical properties, and load patterns, these models can simulate the long-term effects of repetitive mechanical stress on the pelvic floor. For example, studies by Gong et al have suggested that combining genetic information on collagen and ECM remodeling with FE analysis could enhance the predictive power of these models, providing a multi-faceted approach to risk assessment.[64] This predictive capability is instrumental in proactive management and may reduce the need for invasive interventions by targeting preventive measures in high-risk individuals. Additionally, this field has recently shifted attention toward using FE analysis to optimize mesh placement strategies for improved outcomes in POP repair. By simulating various attachment points and tension levels, researchers can predict which placements offer the best support while minimizing tissue strain. Alperin et al demonstrated that mesh anchored at specific pelvic ligaments could reduce tension and lower the likelihood of mesh failure or displacement.[65] This optimization has implications for reducing recurrence rates and improving patient outcomes post-surgery. In recent years, numerous comprehensive models of POP have emerged, with a growing body of research focusing on simulating pelvic floor muscles in puerperal women across various stages of labor, exploring interactions between pelvic organs and tissues in large-scale models, analyzing the stress-strain relationships of various implants under real-life conditions, and biomechanical alterations in organs treated with hormone therapy and mesenchymal stem cells.[66–69] This progress offers

a more precise and innovative framework for enhancing the understanding of POP mechanisms. Notably, Egorov et al developed a novel comprehensive scoring system for female pelvic floor biomechanics, known as the Biomechanical Index (BI) score.[70] This score was subdivided into five categories to characterize (1) tissue elasticity, (2) pelvic support, (3) pelvic muscle contraction, (4) involuntary muscle relaxation, and (5) pelvic muscle mobility. Although this scoring system has shown strong reliability in recent validation studies, further large-sample clinical research is needed to evaluate its accuracy, and additional, more detailed scoring methods will be essential for future developments.[71,72]

Based on the above analysis, future research is anticipated to concentrate on the development of personalized and regenerative therapeutic strategies. Advancing multi-scale, multi-modal, and personalized modeling for various populations with pelvic organ prolapse (POP) will likely become a trend to meet individualized clinical needs in this field. In the future, artificial intelligence (AI) and machine learning (ML) techniques may be integrated into finite element analysis (FEA) models, enabling early screening and predictive analysis of high-risk individuals by training models on extensive patient data. Simultaneously, further optimization of regenerative medicine and biomaterials, as well as FEA-based preventive treatments and risk assessments, are also expected to become significant directions for future development.

Strengths and Limitations

The present study represents the first comprehensive and systematic analysis of the existing literature on the biomechanics of POP using bibliometric and visualization techniques. Bibliometrics is an interdisciplinary field that integrates mathematics, statistics, and library science to leverage bibliometric features and research accomplishments in specific journals and disciplines. Its primary focus lies in quantifying comprehensive knowledge systems, particularly through the application of information visualization techniques and methodologies. This facilitates an intuitive presentation of the research development process, current status, emerging topics, and trends within a particular domain.[73–76] The present study, however, is subject to certain limitations. Firstly, although the WoSCC database is widely utilized in bibliometrics research, our study exclusively focused on SCI-Expanded within the WoSCC database, potentially excluding pertinent research findings. Secondly, our analysis may underestimate some recently published high-quality studies due to limited citation frequencies. Third, our study only considered the analysis of English-language publications, which may introduce a certain degree of bias to the findings. Lastly, as a result of continuous updates to the database, the dataset of 2024 remains incomplete and was therefore not included in this study. Despite certain limitations, this pioneering bibliometric study holds significant scholarly value as the first of its kind in this field. It offers valuable insights into the current state of development and serves as a guiding reference for future research endeavors.

Conclusion

Over the past two decades, there has been a substantial increase in the number of publications on biomechanics in POP, drawing growing scholarly attention to this field. The United States has emerged as the leading nation in terms of productivity, with the University of Porto making a significant contribution. All nations and institutions maintain robust collaborative partnerships. The current primary research areas in this field encompass the establishment and validation of three-dimensional FE models for pelvic floor analysis, investigation into the interplay between different support systems within the pelvic floor, assessment of the impact of vaginal delivery on various supporting structures, analysis of the effects of diverse meshes or 3D printing materials on POP repair, evaluation of connective tissue remodeling in patients with prolapse, and biomechanical performance assessment of pelvic floor tissues in individuals with obstructed defecation. Future research trends are anticipated to concentrate on the development of more intricate pelvic floor FE methodologies, integrating “tissue engineering” and “extracellular matrix” as key components for multidimensional biomechanical analysis of POP. In conclusion, advancing multi-scale, multi-modal, and personalized modeling for POP is expected to play a critical role in addressing individualized clinical needs within this field. The integration of artificial intelligence and machine learning into FE models, along with advancements in regenerative medicine, biomaterials, and the optimization of FE-based preventive treatments and risk assessment, represents a promising direction for future development. These emerging research trends are expected to introduce novel ideas and methodologies for the investigation and personalized clinical management of POP, thereby facilitating accelerated advancements in this domain.

Data Sharing Statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

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Disclosure

The authors report no conflicts of interest in this work.

References

1. Easley DC, Abramowitch SD, Moalli PA. Female pelvic floor biomechanics: bridging the gap. *Curr Opin Urol*. 2017;27(3):262–267. doi:10.1097/MOU.0000000000000380
2. Iglesia CB, Smithling KR. Pelvic organ prolapse. *Am Fam Physician*. 2017;96(3):179–185.
3. Haylen BT, Maher CF, Barber MD, et al. An international urogynecological association (IUGA) / international continence society (ICS) joint report on the terminology for female pelvic organ prolapse (POP). *Neurourol Urodyn*. 2016;35(2):137–168. doi:10.1002/nau.22922
4. Fialkow MF, Newton KM, Lentz GM, et al. Lifetime risk of surgical management for pelvic organ prolapse or urinary incontinence. *Int Urogynecol J Pelvic Floor Dysfunct*. 2008;19(3):437–440. doi:10.1007/s00192-007-0459-9
5. Maher C, Feiner B, Baessler K, et al. Surgical management of pelvic organ prolapse in women. *Cochrane Database Syst Rev*. 2013;4:CD004014.
6. Raju R, Linder BJ. Evaluation and management of pelvic organ prolapse. *Mayo Clin Proc*. 2021;96(12):3122–3129. doi:10.1016/j.mayocp.2021.09.005
7. Quaghebeur J, Petros P, Wyndaele JJ, et al. Pelvic-floor function, dysfunction, and treatment. *Eur J Obstet Gynecol Reprod Biol*. 2021;265:143–149. doi:10.1016/j.ejogrb.2021.08.026
8. Li S, Yao TQ, Wang HF, et al. Two-dimensional equivalent mechanical modeling and finite element analysis of normal female pelvic floor system. *Zhonghua Yi Xue Za Zhi*. 2022;102(28):2189–2195. doi:10.3760/cma.j.cn112137-20211108-02478
9. Welch-Phillips A, Gibbons D, Ahern DP, et al. What is finite element analysis? *Clin Spine Surg*. 2020;33(8):323–324. doi:10.1097/BSD.0000000000001050
10. Yang Z, Hayes J, Krishnamurty S, et al. 3D finite element modeling of pelvic organ prolapse. *Comput Methods Biomech Biomed Engin*. 2016;19(16):1772–1784. doi:10.1080/10255842.2016.1186662
11. Babayi M, Azghani MR, Hajebrahimi S, et al. Three-dimensional finite element analysis of the pelvic organ prolapse: a parametric biomechanical modeling. *Neurourol Urodyn*. 2019;38(2):591–598. doi:10.1002/nau.23885
12. Gordon MT, DeLancey JOL, Renfroe A, et al. Development of anatomically based customizable three-dimensional finite-element model of pelvic floor support system: POP-SIM1.0. *Interface Focus*. 2019;9(4):20190022. doi:10.1098/rsfs.2019.0022
13. Martins JA, Pato MP, Pires EB, et al. Finite element studies of the deformation of the pelvic floor. *Ann N Y Acad Sci*. 2007;1101:316–334. doi:10.1196/annals.1389.019
14. Yang M, Chen C, Wang Z, et al. Finite element analysis of female pelvic organ prolapse mechanism: current landscape and future opportunities. *Front Med*. 2024;11:1342645. doi:10.3389/fmed.2024.1342645
15. Xu Q, Zhou Y, Zhang H, et al. Bibliometric analysis of hotspots and frontiers of immunotherapy in pancreatic cancer. *Healthcare*. 2023;11(3):304. doi:10.3390/healthcare11030304
16. Wang H, Qu S, Zhou T, et al. Current perspectives and trend of acupuncture in breast cancer-related symptoms: a bibliometric study. *J Pain Res*. 2023;16:4165–4180. doi:10.2147/JPR.S442151
17. Ding Z, Tang N, Huang J, et al. Global hotspots and emerging trends in 3D bioprinting research. *Front Bioeng Biotechnol*. 2023;11:1169893. doi:10.3389/fbioe.2023.1169893
18. Guo K, Mao M, Zhang S, et al. Research trends and hot spots of allopregnanolone research in the last 20 years: a bibliometric analysis. *Drug Des Devel Ther*. 2023;17:3397–3408. doi:10.2147/DDDT.S434364
19. Liu Q, Gao J, Li G, et al. Bibliometric analysis on mercury emissions from coal-fired power plants: a systematic review and future prospect. *Environ Sci Pollut Res Int*. 2024;31(13):19148–19165. doi:10.1007/s11356-024-32369-z
20. Huang P, Feng Z, Shu X, et al. A bibliometric and visual analysis of publications on artificial intelligence in colorectal cancer (2002-2022). *Front Oncol*. 2023;13:1077539. doi:10.3389/fonc.2023.1077539
21. Zhang JY, Xiao CF, Wang C, et al. Bibliometric insights in fournier's gangrene: research landscapes, turning points, and global trends. *Front Surg*. 2023;10:1057486. doi:10.3389/fsurg.2023.1057486
22. Tang F, Jiang C, Chen J, et al. Global hotspots and trends in myofascial pain syndrome research from 1956 to 2022: a bibliometric analysis. *Medicine*. 2023;102(12):e33347. doi:10.1097/MD.0000000000033347
23. Lu H, Han T, Li F, et al. Global trends and hotspots in research of robotic surgery in oncology: a bibliometric and visual analysis from 2002 to 2021. *Front Oncol*. 2022;12:1055118. doi:10.3389/fonc.2022.1055118
24. Yang J, Wu J, Han T, et al. Global research hotspots and frontiers of myasthenia gravis from 2002 to 2021: a bibliometric study. *Medicine*. 2023;102(24):e34002. doi:10.1097/MD.0000000000034002
25. Hou Z, Wang W, Su S, et al. Bibliometric and visualization analysis of biomechanical research on lumbar intervertebral disc. *J Pain Res*. 2023;16:3441–3462. doi:10.2147/JPR.S428991

26. Liu ZJ, Wang MJ, Luo J, et al. A bibliometric analysis of hotpots and trends for the relationship between skin inflammation and regeneration. *Front Surg*. 2023;10:1180624. doi:10.3389/fsurg.2023.1180624
27. Wang Y, Zhang S, Zhi J, et al. A bibliometric analysis: current status and frontier trends of Schwann cells in neurosciences. *Front Mol Neurosci*. 2023;15:1087550. doi:10.3389/fnmol.2022.1087550
28. Zhang T, Zhang B, Tian W, et al. A bibliometric analysis of atrophic gastritis from 2011 to 2021. *Front Med*. 2022;9:843395. doi:10.3389/fmed.2022.843395
29. Moalli PA, Talarico LC, Sung VW, et al. Impact of menopause on collagen subtypes in the arcus tendineous fasciae pelvis. *Am J Obstet Gynecol*. 2004;190(3):620–627. doi:10.1016/j.ajog.2003.08.040
30. Cosson M, Lambaudie E, Boukerrou M, et al. A biomechanical study of the strength of vaginal tissues. Results on 16 post-menopausal patients presenting with genital prolapse. *Eur J Obstet Gynecol Reprod Biol*. 2004;112(2):201–205. doi:10.1016/S0301-2115(03)00333-6
31. Lei L, Song Y, Chen R. Biomechanical properties of prolapsed vaginal tissue in pre- and postmenopausal women. *Int Urogynecol J Pelvic Floor Dysfunct*. 2007;18(6):603–607. doi:10.1007/s00192-006-0214-7
32. DeLancey JO, Morgan DM, Fenner DE, et al. Comparison of levator ani muscle defects and function in women with and without pelvic organ prolapse. *Obstet Gynecol*. 2007;109(2 Pt 1):295–302. doi:10.1097/01.AOG.0000250901.57095.ba
33. Jean-Charles C, Rubod C, Brieu M, et al. Biomechanical properties of prolapsed or non-prolapsed vaginal tissue: impact on genital prolapse surgery. *Int Urogynecol J*. 2010;21(12):1535–1538. doi:10.1007/s00192-010-1208-z
34. Gabriel B, Rubod C, Brieu M, et al. Vagina, abdominal skin, and aponeurosis: do they have similar biomechanical properties? *Int Urogynecol J*. 2011;22(1):23–27. doi:10.1007/s00192-010-1237-7
35. Paul K, Darzi S, McPhee G, et al. 3D bioprinted endometrial stem cells on melt electrospun poly ε-caprolactone mesh for pelvic floor application promote anti-inflammatory responses in mice. *Acta Biomater*. 2019;97:162–176. doi:10.1016/j.actbio.2019.08.003
36. Barone WR, Moalli PA, Abramowitch SD. Textile properties of synthetic prolapse mesh in response to uniaxial loading. *Am J Obstet Gynecol*. 2016;215(3):326.e1–326.e3269. doi:10.1016/j.ajog.2016.03.023
37. Roman S, Urbánková I, Callewaert G, et al. Evaluating alternative materials for the treatment of stress urinary incontinence and pelvic organ prolapse: a comparison of the in vivo response to meshes implanted in rabbits. *J Urol*. 2016;196(1):261–269. doi:10.1016/j.juro.2016.02.067
38. Cooper ID. Bibliometrics basics. *J Med Libr Assoc*. 2015;103(4):217–218. doi:10.3163/1536-5050.103.4.013
39. Ninkov A, Frank JR, Maggio LA. Bibliometrics: methods for studying academic publishing. *Perspect Med Educ*. 2022;11(3):173–176. doi:10.1007/S40037-021-00695-4
40. Hani U, Mulvaney GG, O'Brien MD, et al. Review: patent bibliometrics in cranial neurosurgery: the first bibliometric analysis of neurosurgery's technological literature. *World Neurosurg*. 2023;171:115–123. doi:10.1016/j.wneu.2022.12.103
41. Parente MP, Jorge RM, Mascarenhas T, et al. Deformation of the pelvic floor muscles during a vaginal delivery. *Int Urogynecol J Pelvic Floor Dysfunct*. 2008;19(1):65–71. doi:10.1007/s00192-007-0388-7
42. Summers A, Winkel LA, Hussain HK, et al. The relationship between anterior and apical compartment support. *Am J Obstet Gynecol*. 2006;194(5):1438–1443. doi:10.1016/j.ajog.2006.01.057
43. Abramowitch SD, Feola A, Jallah Z, et al. Tissue mechanics, animal models, and pelvic organ prolapse: a review. *Eur J Obstet Gynecol Reprod Biol*. 2009;144 Suppl 1:S146–S158. doi:10.1016/j.ejogrb.2009.02.022
44. Moalli PA, Shand SH, Zyczynski HM, et al. Remodeling of vaginal connective tissue in patients with prolapse. *Obstet Gynecol*. 2005;106(5 Pt 1):953–963. doi:10.1097/01.AOG.0000182584.15087.dd
45. Manodoro S, Endo M, Uvin P, et al. Graft-related complications and biaxial tensiometry following experimental vaginal implantation of flat mesh of variable dimensions. *BJOG*. 2013;120(2):244–250. doi:10.1111/1471-0528.12081
46. Zhu X, Hu J, Deng S, et al. Comprehensive bibliometric analysis of the Kynurenine pathway in mood disorders: focus on gut microbiota research. *Front Pharmacol*. 2021;12:687757. doi:10.3389/fphar.2021.687757
47. Wu H, Zhou Y, Wang Y, et al. Current state and future directions of intranasal delivery route for central nervous system disorders: a scientometric and visualization analysis. *Front Pharmacol*. 2021;12:717192. doi:10.3389/fphar.2021.717192
48. Chen S, Sun D, Wang N, et al. Current status and trends in quantitative MRI study of intervertebral disc degeneration: a bibliometric and clinical study analysis. *Quant Imaging Med Surg*. 2023;13:2953–2974. doi:10.21037/qims-22-1219
49. Ashton-Miller JA, Delancey JO. On the biomechanics of vaginal birth and common sequelae. *Annu Rev Biomed Eng*. 2009;11:163–176. doi:10.1146/annurev-bioeng-061008-124823
50. Chen L, Ashton-Miller JA, Hsu Y, et al. Interaction among apical support, levator ani impairment, and anterior vaginal wall prolapse. *Obstet Gynecol*. 2006;108(2):324–332. doi:10.1097/01.AOG.0000227786.69257.a8
51. Liang R, Abramowitch S, Knight K, et al. Vaginal degeneration following implantation of synthetic mesh with increased stiffness. *BJOG*. 2013;120(2):233–243. doi:10.1111/1471-0528.12085
52. Feola A, Abramowitch S, Jallah Z, et al. Deterioration in biomechanical properties of the vagina following implantation of a high-stiffness prolapse mesh. *BJOG*. 2013;120(2):224–232. doi:10.1111/1471-0528.12077
53. Rahn DD, Ruff MD, Brown SA, et al. Biomechanical properties of the vaginal wall: effect of pregnancy, elastic fiber deficiency, and pelvic organ prolapse. *Am J Obstet Gynecol*. 2008;198(5):590.e1–590.e5906. doi:10.1016/j.ajog.2008.02.022
54. Chen B, Yeh J. Alterations in connective tissue metabolism in stress incontinence and prolapse. *J Urol*. 2011;186(5):1768–1772. doi:10.1016/j.juro.2011.06.054
55. Guo Y, Yang Y, Xu M, et al. Trends and developments in the detection of pathogens in central nervous system infections: a bibliometric study. *Front Cell Infect Microbiol*. 2022;12:856845. doi:10.3389/fcimb.2022.856845
56. Yang P, Wang T, He YJ, et al. Research trends of acupuncture therapy for chronic pain-related depression or anxiety from 2003 to 2023: a bibliometric analysis. *J Pain Res*. 2023;16:4301–4315. doi:10.2147/JPR.S436434
57. Cheng K, Guo Q, Yang W, et al. Mapping knowledge landscapes and emerging trends of the links between bone metabolism and diabetes mellitus: a bibliometric analysis from 2000 to 2021. *Front Public Health*. 2022;10:918483. doi:10.3389/fpubh.2022.918483
58. Epstein LB, Graham CA, Heit MH. Systemic and vaginal biomechanical properties of women with normal vaginal support and pelvic organ prolapse. *Am J Obstet Gynecol*. 2007;197(2):165.e1–165.e1656. doi:10.1016/j.ajog.2007.03.040

59. Rubod C, Boukerrou M, Brieu M, et al. Biomechanical properties of vaginal tissue: preliminary results. *Int Urogynecol J Pelvic Floor Dysfunct*. 2008;19(6):811–816. doi:10.1007/s00192-007-0533-3
60. Goh JT. Biomechanical and biochemical assessments for pelvic organ prolapse. *Curr Opin Obstet Gynecol*. 2003;15(5):391–394. doi:10.1097/00001703-200310000-00007
61. Kim EJ, Chung N, Park SH, et al. Involvement of oxidative stress and mitochondrial apoptosis in the pathogenesis of pelvic organ prolapse. *J Urol*. 2013;189(2):588–594. doi:10.1016/j.juro.2012.09.041
62. Jing D, Ashton-Miller JA, DeLancey JO. A subject-specific anisotropic visco-hyperelastic finite element model of female pelvic floor stress and strain during the second stage of labor. *J Biomech*. 2012;45(3):455–460. doi:10.1016/j.jbiomech.2011.12.002
63. Brandão S, Da Roza T, Mascarenhas T, et al. Moment of inertia as a means to evaluate the biomechanical impact of pelvic organ prolapse. *Int J Urol*. 2013;20(1):86–92. doi:10.1111/j.1442-2042.2012.03219.x
64. Gong R, Xia Z. Collagen changes in pelvic support tissues in women with pelvic organ prolapse. *Eur J Obstet Gynecol Reprod Biol*. 2019;234:185–189. doi:10.1016/j.ejogrb.2019.01.012
65. Alperin M, Abramowitch S, Alarab M, et al. Foundational science and mechanistic insights for a shared disease model: an expert consensus. *Female Pelvic Med Reconstr Surg*. 2022;28(6):347–350. doi:10.1097/SPV.0000000000001216
66. Diallo MN, Mayeur O, Lecomte-Grosbras P, et al. Simulation of the mobility of the pelvic system: influence of fascia between organs. *Comput Methods Biomech Biomed Engin*. 2022;25(10):1073–1087. doi:10.1080/10255842.2021.2001460
67. Stansfield E, Fischer B, Grunstra NDS, et al. The evolution of pelvic canal shape and rotational birth in humans. *BMC Biol*. 2021;19(1):224. doi:10.1186/s12915-021-01150-w
68. Xie J, Li S, Yao T, et al. A 2D equivalent mechanical model of the whole pelvic floor and impairment simulation. *Int J Numer Method Biomed Eng*. 2023;39(1):e3659. doi:10.1002/cnm.3659
69. Xu Z, Chen N, Wang B, et al. Creation of the biomechanical finite element model of female pelvic floor supporting structure based on thin-sectional high-resolution anatomical images. *J Biomech*. 2023;146:111399. doi:10.1016/j.jbiomech.2022.111399
70. Egorov V, van Raalte H, Takacs P, et al. Biomechanical integrity score of the female pelvic floor. *Int Urogynecol J*. 2022;33(6):1617–1631. doi:10.1007/s00192-022-05120-w
71. Koroknai E, Rátonyi D, Pákozdy K, et al. Correlation between the female pelvic floor biomechanical parameters and the severity of stress urinary incontinence. *BMC Urol*. 2023;23(1):198. doi:10.1186/s12894-023-01375-7
72. Takacs P, Pákozdy K, Koroknai E, et al. A randomized controlled pilot trial to assess the effectiveness of a specially formulated food supplement and pelvic floor muscle training in women with stress-predominant urinary incontinence. *BMC Womens Health*. 2023;23(1):321. doi:10.1186/s12905-023-02476-z
73. Sang D, Guo J, Meng H, et al. Global trends and hotspots of minimally invasive surgery in lumbar spinal stenosis: a bibliometric analysis. *J Pain Res*. 2024;17:117–132. doi:10.2147/JPR.S440723
74. Ge Y, Chao T, Sun J, et al. Frontiers and hotspots evolution in psycho-cardiology: a bibliometric analysis from 2004 to 2022. *Curr Probl Cardiol*. 2022;47(12):101361. doi:10.1016/j.cpcardiol.2022.101361
75. Tian Z, Jiang Y, Zhang N, et al. Analysis of the current state of COPD nursing based on a bibliometric approach from the web of science. *Int J Chron Obstruct Pulmon Dis*. 2024;19:255–268. doi:10.2147/COPD.S440715
76. Zeng Q, Liu X, Li L, et al. Bibliometric analysis of research on traditional Chinese exercise and osteoarthritis. *J Pain Res*. 2024;17:559–569. doi:10.2147/JPR.S436457
77. Shepherd JP, Feola AJ, Abramowitch SD, et al. Uniaxial biomechanical properties of seven different vaginally implanted meshes for pelvic organ prolapse. *Int Urogynecol J*. 2012;23(5):613–620. doi:10.1007/s00192-011-1616-8