

BIBLIOMETRICS

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Bibliometric Analysis of Wrestling Research Progress in the Past Century (1924–2024)

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Abstract

Background. Wrestling enjoys global renown, yet scholarly exploration of the sport still needs to be expanded. This study seeks to delineate the existing body of wrestling research, pinpoint pivotal issues, and trace their evolution to guide future academic endeavors. **Materials and methods.** Using the keywords “wrestling,” “professional wrestling,” and “combat sports,” a comprehensive search was conducted in the Web of Science Core Collection, Scopus, PubMed, and Google Scholar databases. The study systematically analyzed core literature in these databases published between January 1924 and March 2024. CiteSpace software was used for bibliometric analysis and data visualization. A total of 431 studies were reviewed and analyzed.

Results. Wrestling research literature has experienced significant growth, progressing from an early stage to a developmental phase and then undergoing rapid expansion. Substantial contributions from the United States and Queen Mary University of London have greatly influenced this advancement. Before 2015, research focused on fundamental topics such as adolescent development, health training, dermatology, weight management, dehydration, sports injuries, and physiological endurance. However, since 2015, there has been a noticeable shift towards more specialized and advanced areas of study, including technical and tactical analysis, epidemiology, martial arts, and sports performance studies. The key domains of wrestling research now encompass technical and tactical analysis, exercise physiology, sports medicine, psychology, and international cooperation. These developments indicate

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that the sport is continuously advancing and becoming increasingly sophisticated. Conclusions. Wrestling research has evolved significantly over the past century, progressing from fundamental health and safety topics to specialized areas of contemporary concern, such as technical and tactical analysis, sports medicine, exercise physiology, psychological research, and international collaboration. This shift underscores the increasingly intricate and interdisciplinary nature of the sport. The expanding realm of research offers a practical scientific foundation and methodology for coaches, athletes, and professionals while providing a clear roadmap for future research endeavors.

Introduction

Wrestling, a sport with ancient origins, has evolved significantly over the centuries and is now recognized as a prestigious Olympic event [Huggins 2001]. Since its inclusion in the ancient Olympic Games, it has symbolized individual prowess and national strength [Barney 2007]. More than just a measure of physical strength, wrestling comprehensively tests an athlete's intellect, technique, stamina, and decision-making skills [Weldon *et al.* 2022].

The enduring popularity of the sport is deeply rooted in its historical significance. From the earliest days of human civilization, individuals honed their fighting skills for self-protection and survival, which gradually evolved into more sophisticated martial arts [Kohler 1990]. In the Middle Ages, wrestling was an integral part of the self-defense training of knights, growing from a survival skill to a structured sport [Singer, Donald 2016]. Despite the prevailing asceticism of the Middle Ages, which often restricted sporting activities, wrestling became a spectator sport among the upper classes during the Italian Renaissance. In England and France, it served as military training for knights and as entertainment at public festivals, where contests of strength were staged [Chow, Laine 2014].

In modern times, wrestling has evolved into several styles, such as freestyle, Greco-Roman, and various folk traditions. The diversity of these styles enhances the sport's appeal and enjoyment and contributes to its global spread [Sterchele 2015]. Wrestling's association with nationalism led to its inclusion in military training and school physical education curricula, contributing significantly to its development [Demoyan 2014]. In addition, active promotion at the club level and the influence of the Olympics have further expanded wrestling's global appeal [Ridpath *et al.* 2008]. The efforts of the World Wrestling Federation (UWW) to promote and regulate the sport [Cho *et al.* 2024], coupled with the global appeal of the Olympic movement [Girginov 2017], have helped wrestling transcend national borders and connect with spectators and athletes around the world [Besnier *et al.* 2018]. These factors have been crucial in elevating wrestling's status as a global sport [Stone 2002].

Wrestling has attracted significant attention in the international sports science community, leading to extensive academic research that has explored its physiological, psychological, and technical aspects, as well as training methods, injury prevention, and rehabilitation strategies

[Eunbin 2024]. This research aims to improve athlete performance, ensure health, and improve wrestling fairness and rules [Artioli *et al.* 2010]. Additionally, bibliometric analysis and visualization tools have proven to be very effective in analyzing large amounts of literature. These tools help track the evolution of knowledge, estimate the coverage of scientific journals, identify lead authors and institutions, and facilitate the exploration of relationships between different disciplines and areas of knowledge [Pavilets *et al.* 2017; Menzhestok 2014]. When applied to wrestling research, these insights have significantly impacted wrestling education, training, and competitive practices [Juhanis *et al.* 2024]. This integrated approach deepens our understanding of the technical and strategic aspects of the sport but also fosters the development of effective training methods and policies to support athletes and coaches in the wrestling community. This approach is essential to advancing the practice and scientific study of wrestling, ensuring that the sport continues to evolve and adapt on a solid research foundation.

Material and methods

Data sources and retrieval strategies

We carefully designed data source selection and search strategies to ensure scientific rigor, relying mainly on Web of Science Core Collection, Scopus, PubMed, and Google Scholar as core data sources. Among them, the Web of Science (WoS) database, as the primary source, is known for its collection of a large number of peer-reviewed literature and broad influence in the international academic community and is recognized as an authoritative academic resource [Wang *et al.* 2015]. The database covers many forms of scholarly work, including academic journals, conference proceedings, and books, providing a solid foundation for our literature reviews.

The earliest academic articles on wrestling in the WoS database date back to 1924. We screened high-quality academic journals, screened literature strictly according to quality standards, and conducted a comprehensive bibliometric analysis to explore the development process and research trends of wrestling research. This process has dramatically improved our systematic understanding of the field.

To collect the data, we used the terms “wrestling,” “professional wrestling,” and “combat sports” for a subject search, targeting articles published between 1924 and 2024. All relevant data were retrieved on March

12, 2024. To maintain consistency and avoid potential bias from database updates, we excluded literature that did not fit the specific type of study. Through this rigorous method, we ended up with 431 relevant articles. Figure 1 details our research methodology and search strategy, providing a clear framework for subsequent research or review.

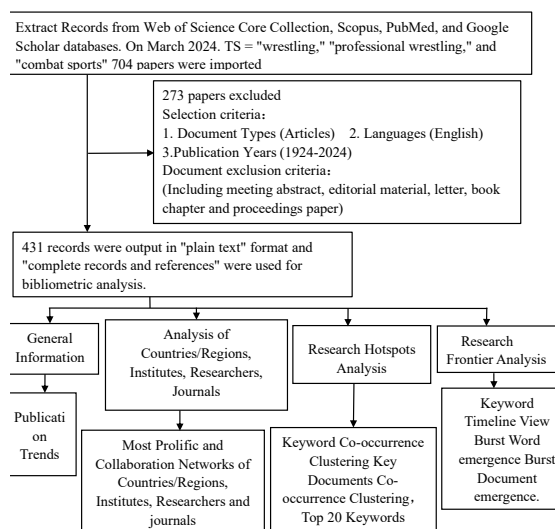


Figure 1. Workflow diagram

Data analysis

Bibliometrics integrates mathematical and statistical methods to quantitatively analyze the development characteristics of literature within a specific research area [Kokol *et al.* 2021]. Analysis tools such as Cite Space, Pajek, UCINET, and VOS Viewer are commonly employed. Cite Space, developed by Chaomei Chen in 2004, is favored for its functionality and user-friendliness. Cite Space enables the exploration of knowledge structures, evolutionary patterns, and emergent trends across various disciplines, with findings often published in high-impact journals [Chen *et al.* 2010].

Table 1. Cite Space Operating Parameters

Software Parameters	Set Values
Time Slicing	Time Interval: 1924-2024 Interval Unit: 1 year
Term Source	Keywords
Node Types	Authors Institution Country Keywords Term Category Cited Author Cited Journal
Links Strength	Cosine
Top N	fifty

This study used Web of Science Core Collection, Scopus, PubMed, and Google Scholar databases to conduct bibliometric analysis of academic research on wrestling. Employing tools such as Cite Space and Microsoft Excel 2016, we aim to delineate the current landscape and identify emerging topics and potential research frontiers in wrestling research. After importing 431 relevant

literature records into Cite Space, we set the time slice to '1 year' and adjusted node selection criteria to establish suitable thresholds. The development trajectory of wrestling research is represented through co-occurrence networks, time zone maps, and visual mapping analysis, supplemented by author and keyword knowledge maps. This analysis covers the period from January 1924 to December 2024, with each time slot containing data for one year. Other parameters follow the default settings of Cite Space. The detailed parameter settings are shown in Table 1.

Result

General analysis of publications

"Publication volume" is a crucial metric for assessing academic productivity within a specific research field, institution, country, or by individual researchers over time [Bornmann, Leydesdorff 2014]. We can gain insights into the activity levels and evolving trends within a research domain by quantifying the number of academic publications [Olive *et al.* 2022]. This information proves invaluable for research managers, policymakers, and academic peers. [Mamani *et al.* 2023]

In this study, we employed Web of Science Core Collection, Scopus, PubMed, and Google Scholar to carry out a literature search regarding wrestling and related subjects. The search terms utilized were "wrestling," "professional wrestling," and "combat sports." After eliminating duplicates, Cite Space software version 5.7R2 identified 431 publications related to wrestling from the WoS database. To illustrate the trends in the quantity of publications within the field, we constructed a chart depicting the annual output from 1924 to 2024. This systematic approach highlights the evolution and shifts in the focus of wrestling research, simultaneously contributing to an understanding of broader influences and developments. As can be observed from the analysis in Figure 2, the development of the research field is divided into three distinct stages:

Initial period (1924-1996). Wrestling research received scant academic attention during this period, with an average of only about two papers published annually. This lack of focus can be attributed to the perception that wrestling holds a different scientific urgency than sports like athletics, soccer, or basketball [McDonald *et al.* 2019]. Additionally, sports science and performance research were not prioritized similarly to traditional disciplines such as medicine, physics, or chemistry [Heggie 2016]. Technological limitations hindered effective data collection on wrestlers' performance, training methods, and competition outcomes. At the same time, existing research techniques must be improved to analyze this complex sport more deeply [James *et al.* 2013]. Wrestling's traditional and non-commercial nature, policy,

and funding inadequacies further constrained research development [Resnik *et al.* 2016]. The absence of specialized wrestling research sections in academic journals and a scarcity of interdisciplinary studies limited exposure. They restricted the potential for comprehensive wrestling research incorporating fields such as biomechanics, psychology, and nutrition [Martín-Rodríguez *et al.* 2024].

Growth Period (1997-2009). This era saw a fluctuating but generally upward trend in wrestling research publications, averaging about eight papers per year, indicating growing scholarly interest. The globalization of culture and sports facilitated international recognition of Wrestling [Franchini *et al.* 2018]. Advances in information technology simplified research methodologies, particularly in data collection and analysis [Sutton, Austin 2015]. The sport's professionalization and commercialization attracted more commercial sponsorships and media attention, boosting research activities [Manoli 2018]. The emergence of interdisciplinary research allowed wrestling studies to benefit from insights across biomechanics, psychology, nutrition, and sociology [Islas, Jennings 2023]. Improvements in education and training systems heightened the demand for scientific training methods, and the global proliferation of wrestling through international competitions spurred further research. Additionally, wrestling's promotion as a beneficial physical and mental exercise aligned with growing health consciousness [Pierce *et al.* 2016]

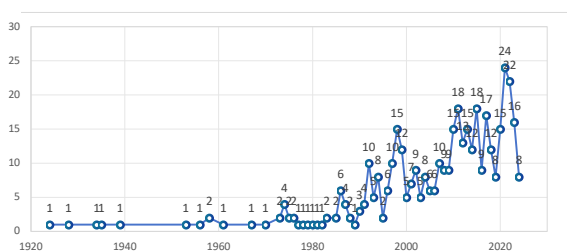


Fig. 2. [From 1924 to 2024, several wrestling publications were indexed by the Web of Science Core Collection, Scopus, PubMed, and Google Scholar databases.]

Rapid Development Period (2010-2024). The average annual publication volume in wrestling research rose to approximately 14 papers, signaling broader recognition and accelerated development in the field. Technological advances provided sophisticated tools for data analysis, biomechanical measurements, and athlete health tracking [Smith 2016]. Social media and online platforms boosted the sport's popularity and research interest [Dart 2014]. Progress in sports medicine deepened the focus on injury prevention and performance optimization [Tai *et al.* 2023]. The need for international cooperation and increased funding became evident to support ongoing research and resource sharing [Sally *et al.* 2016]. The public's sustained interest in health and fitness recognized wrestling as a valuable form of exercise [Keller

2019]. Events like the Olympics enhanced wrestling's visibility, stimulating further academic research. Using interdisciplinary methods improved the scientific basis of training and competitive strategies [Trinova *et al.* 2023]. Moreover, wrestling's global cultural diversity has gained acknowledgment, enhancing respect for and research into wrestling traditions [Giulianotti, Robertson 2007]. These factors propelled the vigorous development of wrestling research, attracting more scholars to the field.

Journal co-citation analysis

Journal co-citation analysis is a critical bibliometric tool to assess scholarly journals' academic relevance and impact [Suban 2022]. This method involves counting instances where two or more journal articles are cited within academic papers, elucidating these journals' interactions and academic standing [Indulska *et al.* 2012]. In our study, we employed the g-index with a threshold set at 20 and selected "cited journal" as the node type. The analysis covered the period from January 1924 to December 2024, using one year as the time slice unit. We utilized the pathfinder pruning method and pruning of sliced networks as auxiliary pruning strategies, with other settings left at default. This analysis was performed using Cite Space software, a tool that offers detailed insights into the co-citation patterns of journals. The results of this analysis are comprehensively detailed in Table 2.

The results highlighted that journals such as "Medicine and Science in Sports and Exercise" (MED SCI SPORT EXER), "Sports Medicine" (SPORTS MED), "Journal of Strength and Conditioning Research" (J STRENGTH COND RES), and "American Journal of Sports Medicine" (AM J SPORT MED) have notably high citation frequencies, all exceeding 80 citations. Specifically, "Medicine and Science in Sports and Exercise" achieved a citation frequency of 137 times. Furthermore, the "American Journal of Sports Medicine" (AM J SPORTS MED) and the "International Journal of Sports Medicine" (INT J SPORTS MED) demonstrated centrality values of 0.12 and 0.11, respectively, indicating their pivotal roles within the co-citation network and underscoring their substantial influence within the academic community.

The prominent frequency and centrality of these journals in the co-citation network indicate they are critical publishers of seminal and highly influential research in exercise science, sports medicine, strength, and conditioning, among others. Their central positions in the network suggest that research published in these journals frequently serves as a foundation for subsequent studies and is a vital information source for researchers exploring various facets of physical activity, sports performance, and sports health.

For researchers and scholars in the field, understanding which journals are frequently cited provides valuable guidance on where to publish their work, where

to access the latest and most impactful research, and which journals to consult for a comprehensive understanding of the state of the art in their areas of interest. This knowledge is instrumental in effectively navigating the landscape of academic literature.

Table 2. Journal co-citation

serial number	frequency	centrality	Year	Commonly Cited Journals
1	137	0.09	1975	MED SCI SPORT EXER
2	102	0.03	1996	SPORTS MED
3	88	0.03	2001	J STRENGTH COND RES
4	80	0.12	1992	AM J SPORT MED
5	76	0.07	1970	J APPL PHYSIOL
6	71	0.07	2007	BRIT J SPORT MED
7	70	0.11	1990	INT J SPORTS MED
8	56	0.04	2001	EUR J APPL PHYSIOL
9	50	0.07	2000	J ATHL TRAINING
10	49	0.09	1958	JAMA-J AM MED ASSOC

Author Collaboration

Author collaboration networks are pivotal in analyzing research collaboration patterns and their influence, revealing cooperation strength, network structure, and dynamic changes among researchers [Chen *et al.* 2010]. Quantitative analysis of these networks offers a macro view of research cooperation and insights into the structural characteristics of academic communities [Kienast 2023].

In this study, we employed the g-index with a threshold of $k=20$ to identify key collaborating authors. The node type analyzed was ‘Author,’ covering the period from January 1924 to December 2024, with annual time slices. We used the pathfinder pruning algorithm and pruned sliced networks strategy for network pruning, with other parameters set to default. The author collaboration network maps, generated by Cite Space software, visually represent collaboration patterns among authors.

The network maps depict individual authors as nodes, where the node size corresponds to publication volume. Lines between nodes indicate collaborative relationships, with line thickness reflecting the intensity of collaboration. The analysis yielded a node count of $N=271$ and a link count of $E=338$, resulting in a network density of $D=0.0092$. These metrics demonstrate existing collaborative relationships among authors, though the network’s concentration is relatively low, suggesting that co-authored work significantly impacts the literature compared to independent research.

As shown in Figure 3, authors such as Michael Pluess, Francesca Lionetti, Elaine N. Aron, and Arthur Aron occupy a central position in the largest collaborative subnetwork, indicating their high publication volume and critical role in wrestling research. Their research results are highly recognized and utilized. Michael Pluess has authored 25 papers highlighting his leadership and active

involvement in the field. Francesca Lionetti, Arthur Aron, and Elaine N. Aron have written over a dozen publications that attest to their significant academic influence.

Quantitative metrics allow us to assess the academic contributions of individual researchers and understand the structure and dynamics of the collaborative network within the research field. Tight collaboration clusters and central positions in the network are influenced by factors such as the concentration of research resources, academic influence, appealing research directions, individual capacity and social skills, frequent scholarly exchanges, an open culture of collaboration, the network effect of mentors, and positive feedback loops generated by success.

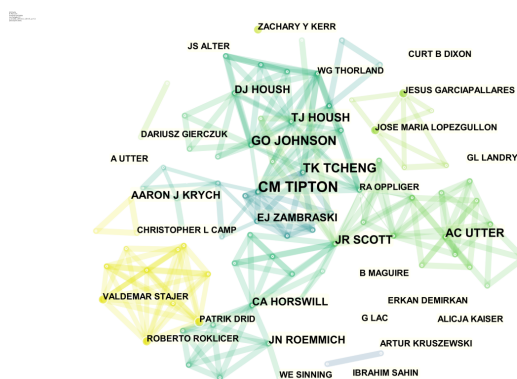


Fig. 3. [Trends in author collaboration]

National Collaboration Network

The National Collaboration Network map is a visual tool illustrating relationships between countries in academic research collaboration [Liu *et al.* 2021]. This tool helps identify countries with close collaborations in specific research areas and their scholarly outputs. For this study, data were filtered using the g-index with a threshold set at 20, and ‘country’ was designated as the node type. The analysis spanned from January 1924 to December 2024, using one-year increments as time slices. Pathfinder and pruning sliced networks were the selected pruning methods, with other parameters maintained at default settings. The map was generated using Cite Space software.

The resulting map, shown in Figure 4, shows countries as circular nodes; The size of each node corresponds to the number of publications in that country. Lines of varying thickness between nodes represent the strength of cooperation between countries. The analysis shows that the network contains 292 nodes, 288 links, and a network density of 0.0068, indicating relatively close and concentrated collaboration between countries. The United States, Turkey, and Poland have the highest number of publications, with 165, 24, and 23, respectively. The United States is at the center of the network.

Nodes with a centrality value greater than 0.1 are considered highly central, indicating a pivotal role in the national collaboration network. According to our data, the United States exhibited a centrality of 1.04, followed

by the United Kingdom at 0.39, Poland at 0.21, and Turkey at 0.19, underscoring their prominent roles in the global academic collaboration network.

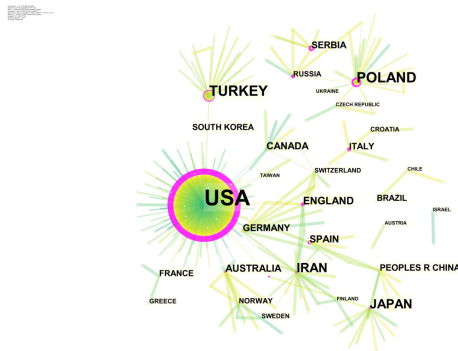


Fig. 4. [National Collaboration Network]

Institutional Collaboration

Analyzing institutional collaboration is essential for understanding research collaboration patterns and making informed decisions. This analysis reflects the extent and scope of cooperation between research institutions toward common goals or projects and their evolutionary trends [Katz, Martin 1997]. It provides insights into the roles and statuses of various research institutions in scientific cooperation [Lang *et al.* 2012].

This study used the g-index with a threshold value of $k=20$ to select data for institutional collaboration. The node type analyzed was ‘Institution,’ covering the period from January 1924 to December 2024, with annual increments as the time slice unit. The pathfinder algorithm and the pruning sliced networks strategy were employed for network pruning, with other parameters set to default. The institutional collaboration network maps, created using Cite Space software, clearly illustrate collaboration patterns among institutions. These maps depict institutions as annular nodes, with node size proportional to each institution’s publication volume. Lines between nodes indicate collaborative relationships and their intensity.

Network analysis consensus 235 nodes, 237 links, network density $D=0.0086$. As shown in Figure 5, these indicators indicate that wrestling research institutions are relatively concentrated and have established stable collaborative relationships. Among the largest institutional partner sub-networks, Queen Mary University of London, Stony Brook University of New York, Utrecht University, and Nijmegen University hold vital positions, demonstrating strong partnerships and recognized contributions to wrestling research. In addition, the University of Rochester is a core institution with many publications showing potential for growth in smaller collaborative networks.

From the data analysis, Queen Mary University of London, SUNY Stony Brook, and the University of Utrecht stand out with significant publication volumes, particularly Queen Mary University of London, which

has 29 publications, highlighting its leading role and substantial contributions to wrestling research.

In summary, the institutional collaboration network analysis reveals the leading roles of core research institutions and provides a foundation for understanding their research directions and influence. This analysis is valuable for establishing or strengthening collaborative relationships between research institutions and for research managers in resource allocation and policy formulation.

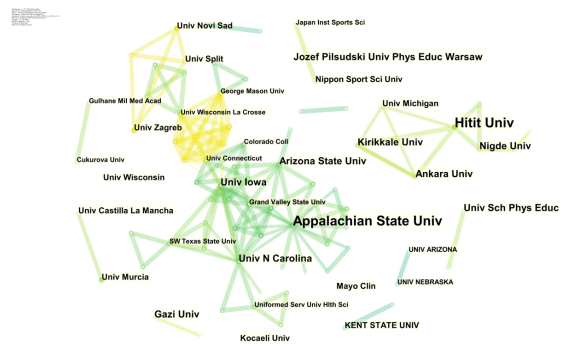


Fig. 5. [Collaborative network of academic institutions]

Author co-citation analysis

Author co-citation analysis is a crucial bibliometric tool that elucidates academic connections and mutual influence among authors [Velastegui-Montoya *et al.* 2023]. In this study, we filtered data using the g-index with a threshold set at 20 and selected ‘cited author’ as the node type. The analysis spanned from January 1924 to December 2024, with annual increments used for time slicing. We employed the Pathfinder method and pruned sliced networks for network pruning while other parameters remained at their default settings. This analysis was conducted using the Cite Space software, which provided detailed insights into the authors’ co-citations.

Table 3. Author Co-citation

serial number	frequency	centrality	year	Co-cited authors
1	42	0.1	1994	HORSWILL CA
2	31	0.08	1991	OPPLIGER RA
3	27	0.04	2010	KRAEMER WJ
4	23	0.01	2011	YOON J
5	19	0.03	2011	GARCÍA-PALLARÉS J
6	18	0.13	1973	BROZEK J
7	18	0.09	2001	UTTER AC
8	17	0.01	2007	PASQUE CB
9	17	0.03	2013	FRANCHINI E
10	16	0.02	2011	KARNINCIC H

After analysis, as shown in Table 3, authors such as HORSWILL CA, OPPLIGER RA, KRAEMER WJ, and YOON J were cited more than 20 times, highlighting

their comprehensive visibility in this field and classified as highly cited authors. Notably, HORSWILL CA's work achieved a reference frequency of 42. BROZEK J and HORSWILL CA had centrality values of 0.13 and 0.1, respectively, exceeding the centrality threshold of 0.1. This demonstrates their centrality in academic networks, reflecting their work's significant impact and high citation rates in recent years. It can provide us with more persuasive essays in academic writing.

Co-citation of references

Co-citation analysis of references is a pivotal technique in bibliometrics, designed to uncover connections between research documents and assess their impact within an academic field [Wai-Chan 2017]. For this study, the data selection was governed by the g-index, set with a threshold of 20, and the chosen node type was "reference." The analysis covered the period from January 1924 to December 2024, each year serving as a time slice. We employed 'pathfinder' as the primary pruning method, supplemented by 'pruning sliced networks,' while other parameters remained at their default settings. The Cite Space software facilitated the acquisition of data relevant to the co-citation of references.

As shown in Figure 6, such as García-Pallarés J (2011), Oppliger RA (1996), Barbas I (2011), and Artioli GG (2016) were co-cited over five times. Notably, García-Pallarés J (2011) reached a co-citation frequency of 11 times. These references, displayed in shades of green, indicate that they have achieved high citation frequencies in earlier years, signifying their widespread recognition and potential lasting impact on subsequent research.

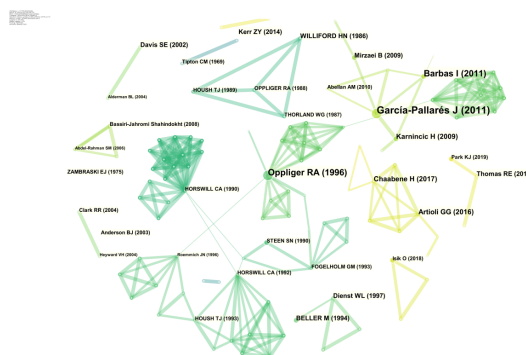


Fig. 6. [Literature co-citation network]

These references in co-citation networks may contain groundbreaking or foundational research, methodological innovations, or critical literature reviews that have significantly influenced research in wrestling or related sports sciences. The frequency with which these references are co-cited points to their role as central works, frequently consulted by researchers to build upon existing knowledge, formulate new research questions, or locate authoritative information on specific topics.

By identifying and analyzing key co-cited references, researchers can gain a deeper understanding of

the historical context and genealogy of knowledge in their field and the essential ideas and debates driving its development. These insights are crucial for researchers who aim to contribute new perspectives to discourse or identify gaps in existing knowledge systems for future research exploration. This process enriches the researchers' understanding and enhances the academic dialogue by highlighting areas ripe for further study.

Keyword Co-occurrence

Keyword co-occurrence analysis is valuable for uncovering core research concepts and themes in academic papers [Yuan *et al.* 2022]. This technique involves statistically analyzing keywords and their co-occurrences in literature to identify prominent topics and trends within a research field [Narong, Hallinger 2023]. Frequently, co-occurring keywords highlight the research content that is currently attracting significant attention.

In this study, the data for keyword co-occurrence analysis was selected based on the G-index of threshold $k=20$. The analysis spans from January 1924 to December 2024, using annual time slices. The network pruning strategy includes a router and a pruning slice network, with other parameters set to default values. The Cite Space software was used to generate a keyword co-occurrence map. As shown in Figure 7, keywords appear in the form of circular nodes, and the size of the nodes reflects the frequency of keyword occurrence. The network consists of $N=526$ nodes and $E=1524$ links, and the network density is $D=0.011$, indicating that the interconnection between keywords is strong. Prominent keywords included "wrestling," "performance," "sport," "body composition," "martial arts," "weight class," "injury," "wrestler," "athlete," "power," "dehydration," "elite," and "endurance," with "wrestling" appearing the most frequently with 94.

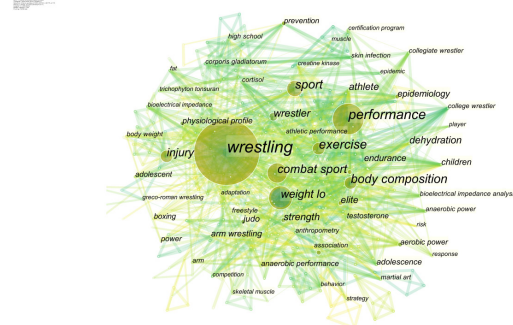


Fig. 7. [Co-occurrence of keywords]

Further analysis reveals that the outer rings of nodes for keywords such as 'wrestling,' 'sports,' 'martial arts,' 'performance,' and 'body composition' are darker in color. In Cite Space, the intensity of node color indicates keyword centrality; darker colors denote higher centrality within the network. These are pivotal links to other keywords and significantly influence research within their respective domains.

These analyses not only aid researchers in understanding the dynamics of wrestling and related sports research but also provide a crucial resource for newcomers to the field, helping them quickly identify key research topics and potential collaborators.

Keyword Clustering

Keyword clustering is a method used to identify and represent clusters of themes or concepts in literature, revealing patterns and relationships in the knowledge structure within a research field [Huang, Liew 2021]. In this study, data selection was based on the g-index ($k=20$) with 'keywords' as the selected node type, covering the period from January 1924 to December 2024. Each time slice was set to one year, and the "pathfinder" pruning method was used, supplemented by "pruning sliced networks." All other settings were left at default. After processing with Cite Space, a keyword clustering map was generated.

The map displayed a modularity value (Q) of 0.6588, indicating a significant clustering structure, and an average silhouette value (S) of 0.8784, suggesting that the clusters are well-defined and the results are reliable. The clustering map effectively shows overlapping, distinct, yet closely related clusters.

As shown in Figure 8, 11 clusters are identified, which are labeled as follows: #0 Testosterone, #1 Inflammation, #2 Herpes Simplex Virus, #3 Greco-Roman Wrestling, #4 Arm Wrestling, #5 Task Participation, #6 Anterior Superior Iliac Spine Avulsion Fracture, #7 Asymptomatic Carrier, #8 Health Assessment, #9 Martial Arts, #10 Anaerobic Work. Notably, clusters #0 Testosterone and #1 Inflammation are recognized as current hot topics in research. There is a significant overlap between different research directions, particularly clusters #0 Testosterone, #1 Inflammation, and #6 Anterior Superior Iliac Spine Avulsion Fracture, indicating a close inter-relationship among these themes.

By analyzing the clusters on the map in conjunction with identified research hotspots and themes, researchers in the field are concentrating their efforts on several key areas, as represented by these clusters. This focus highlights the dynamic nature of research interests and the evolving priorities within the field.

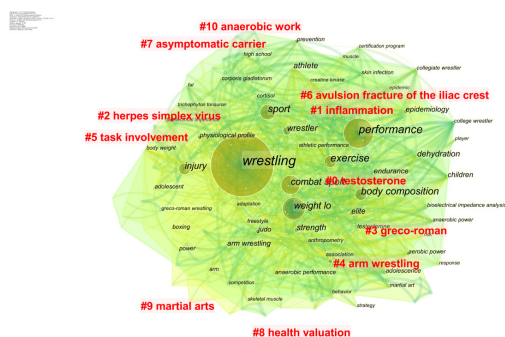


Fig. 8. [Keyword clustering]

Timeline

Timeline visualization is a powerful tool for organizing and visualizing information [van Staden 2019], offering an intuitive means to observe and comprehend the continuity of historical developments [Bordwell 2002], thereby facilitating rapid analysis of the temporal dimension within complex information flows. In this study, data were selected based on the g-index (threshold set at 20), with 'keywords' as the node type for analysis. The research period spans from January 1924 to December 2024, using one year as the time slice unit. The primary pruning method is "pathfinder," supplemented by "pruning sliced networks," with other parameters remaining at default. After processing with Cite Space software, a timeline visualization was constructed.

The resulting timeline visualization reveals a modularity score (Q) of 0.6588, indicating a well-defined clustering structure, and an average silhouette score (S) of 0.8784, suggesting highly efficient clusters with credible results. These metrics demonstrate the effectiveness of the timeline, and the overlapping clusters on the map show that while each cluster's topics are diverse, they are closely related.

As shown in Figure 9, a detailed analysis of the timeline shows 11 clusters: #0 testosterone, #1 inflammation, #2 herpes simplex virus, #3 Greco-Roman wrestling, #4 arm wrestling, #5 task participation, #6 avulsion fracture of the anterior superior iliac spine, #7 asymptomatic carrier, #8 health assessment, #9 martial arts, and #10 anaerobic work. Notably, the #0 testosterone cluster shows a temporal shift in focus: initially focused on topics such as extraversion, individual differences, and childhood, it shifted around 1924 to hot-button issues such as persistence and adolescence, and in recent years, it has moved to emerging topics such as encapsulation and hydration status.

The analysis of timeline trends, alongside the identification of research hotspots and themes, clearly delineates the current focal points in the field, emphasizing several vital aspects:

1. **Testosterone's Impact.** Testosterone significantly influences both physiological and psychological aspects of athletic performance, especially in sports requiring intense muscle activity like wrestling. It promotes protein synthesis, muscle recovery, competitiveness, and aggression, all crucial for sports like wrestling, where optimal performance is essential [Turnagol *et al.* 2022].
2. **Inflammation in Recovery.** Inflammation has a dual role in the recovery from wrestling injuries. It is essential for the repair and healing of tissues, yet excessive inflammation can prolong recovery and cause long-term damage, significantly affecting athletes' health and careers [Close *et al.* 2019].
3. **Managing Viral Infections.** Effective prevention and treatment of herpes simplex virus, common among wrestlers, involve maintaining excellent personal hygiene, regularly disinfecting contact surfaces, and

using antiviral medications promptly when infections arise.

4. Evolution of Wrestling Techniques. Traditional wrestling techniques have evolved from basic force application to incorporating scientific training and technological innovations [Worsey *et al.* 2019].
5. Task Participation in Sports Psychology. In wrestling, task participation is critical as it boosts focus, motivation, and resilience, significantly enhancing performance [Pierce *et al.* 2016].
6. Epidemiology and Treatment of Injuries. Avulsion fractures are more prevalent in young wrestlers. Depending on the severity, treatment typically includes rest, physical therapy, and possibly surgery [Sattler *et al.* 2011].
7. Asymptomatic Carriers in Disease Spread. Wrestlers, often asymptomatic carriers, are crucial in transmitting diseases within sports communities, potentially spreading pathogens unknowingly [Chisholm *et al.* 2018].
8. Health Assessment Methods. Regular physical tests, medical examinations, and psychological evaluations are vital for assessing wrestlers' health and preventing injuries [Chaabene *et al.* 2018].
9. Martial arts and wrestling enrich athletes culturally and psychologically, emphasizing discipline, respect, mental toughness, and strategic thinking, which are integral to personal and athletic development.
10. Anaerobic Exercise in Sports. In wrestling, anaerobic exercise significantly enhances performance by improving explosive power, speed, and strength, which is crucial during competitive matches. It prepares athletes to excel during critical moments [Maki *et al.* 2021].

This analysis of keyword clustering over time deepens understanding of historical and current research focuses on the field and provides insights into potential future research directions. Such analysis enables researchers to track the evolution of academic discourse, identify enduring interests and emerging trends, and better position their research within the field.

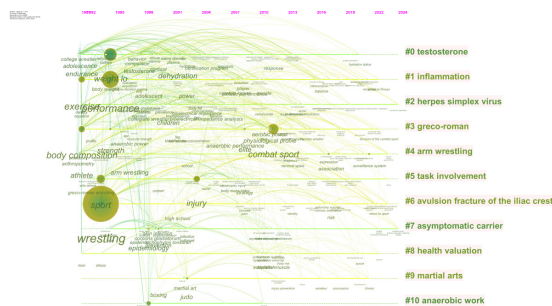


Fig. 9. [1924–2024 Keyword timeline map]

The TOP20 Bursts

The term “Top 20 emerging keywords” refers to the 20 keywords that show the most significant increase in frequency over a given period compared to the previous keyword.

This significant growth, often called a “burst”, highlights the newest and most active research topics or concepts within the academic field [Chen 2006]. Keywords are the core of research articles, and their appearance can indicate cutting-edge trends and developments within a discipline [Tao, Tao 2024]. This approach to identifying emerging keywords is essential to understanding the evolving landscape of academic research and identifying areas of rapid development and interest. We use Cite Space for keyword co-occurrence and clustering map analysis to identify the TOP20 burst keywords by setting the burstiness parameter γ to 0.5 and the minimum duration to 2 years. These keywords are visually represented on the maps, where the strength of the burst, the beginning and end years of the research on the keyword, and dark blocks marking the burst periods are displayed, with light blocks indicating the annual time slices. Keywords are organized by burst start, year, duration, and intensity, providing various perspectives. Typically, viewing the map sorted by burst start year offers sufficient insight.

As shown in Figure 10, the analysis results show that keywords such as “martial arts,” “practice,” “epidemiology,” and “injury” have high outbreak intensity, indicating that they are highly concerned by the academic community in a specific period. It is observed that before 2015, the focus of research primarily included topics such as ‘adolescence,’ ‘physical fitness,’ ‘skin infections,’ ‘weight class,’ ‘dehydration,’ ‘injury,’ ‘wrestlers,’ ‘physiological characteristics,’ ‘aerobic capacity,’ ‘elite,’ ‘freestyle wrestling,’ and ‘arm strength.’ From 2015 onwards, the research emphasis shifted to more specialized topics like “combat sports,” “epidemiology,” “martial arts,” “sport,” “sports performance,” and “arm wrestling.” This transition underscores the dynamic evolution of interests and the shifting research priorities within the academic community. It offers valuable insights into the educational trajectory of the field and informs future research directions.

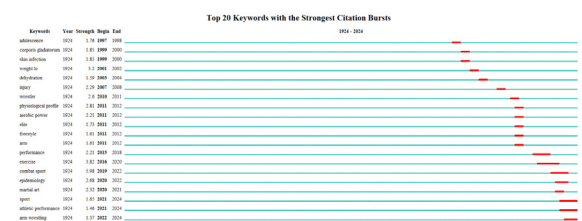


Fig. 10. [The 20 keywords with the most robust citation bursts]

Conclusions, recommendations, and limitations of the study

Conclusions

In this study, we employed Cite Space software to perform a systematic visual analysis of the literature on wrestling, mapping the knowledge landscape and pinpointing crit-

ical research hotspots. The results of the studies revealed several crucial areas of focus:

1. **Technical and Tactical Research:** This domain is fundamental to wrestling, concentrating on the impact of various techniques and tactics on competition outcomes. Discussions extend to improvements in training methodologies and strategic enhancements to boost athlete performance.
2. **Sports Physiology and Medicine:** Research has identified physiological indicators crucial for athletes, including fitness, metabolism, endurance, heart rate, tendon activity, body fat, and bone density. These findings provide a scientific foundation for personalized training regimes and enhancements in athletes' physical condition. Additionally, sports medicine research covers sports injuries, inflammation, and infectious diseases. Future research should deepen our understanding of sports physiology and medicine by leveraging advanced technology and medical equipment to assess athletes' physiological characteristics, optimizing training and management.
3. **Importance of Psychological Factors:** The significance of psychological elements in wrestling has been widely acknowledged, with studies examining how athletes' mental states, concentration, and stress-coping abilities influence performance. Insights into these psychological characteristics offer valuable information for developing mental resilience in athletes. Future studies should explore athletes' psychological traits and devise intervention strategies tailored to various psychological conditions to enhance mental quality and competitive performance.
4. **International Collaboration:** International collaboration has significantly contributed to advancements in wrestling research, with notable progress achieved through exchanges between researchers from multiple countries. Studies highlighting international collaborative networks serve as valuable references for future transnational collaborations, underscoring the importance of strengthening international partnerships and pursuing interdisciplinary and cross-border projects to promote the globalization of wrestling.

In summary, the bibliometric analysis provided by Cite Space clarifies the development trends and pivotal areas within the wrestling field. Research domains such as technique and tactics, sports physiology, medicine, psychological factors, and international cooperation hold substantial reference value for enhancing athlete performance and guiding future research directions. It is hoped that more scientists will engage in wrestling research, contributing to the sport's development and progress.

Recommendations

Following an integrated analysis of the current state of wrestling scholarship, we propose several directions for future study:

1. **Promote International Exchange and Collaboration:** To advance wrestling scholarship, it is crucial to encourage international academic exchange and collaboration. This can be facilitated through conferences, seminars, and forums that promote knowledge sharing among scholars from different nations. Additionally, supporting the establishment of international wrestling journals would provide platforms for disseminating research findings and fostering academic discourse, thus promoting the internationalization of the field.

2. **Establish an International Research Network:** It is essential to form an international research network using online platforms and collaborative projects. This network would facilitate communication and enable transnational research efforts, enhancing the cohesion and reach of wrestling studies.

3. **Encourage multidisciplinary research:** Given wrestling's multifaceted nature, multidisciplinary and interdisciplinary research should be promoted. Exploring wrestling's applications and impacts from the perspectives of biomechanics, nutrition, psychology, sociology, and management can provide deeper insights and broader implications.

4. **Increase Funding and Incentives:** Governments and institutions should provide increased funding and incentives to attract outstanding researchers to wrestling studies and to promote international academic development. This support is crucial for advancing research quality and innovation in the field.

5. **Emphasize Practical Application of Research:** Scholars should be encouraged to translate their research findings into scientific guidelines for wrestling training and competition. This emphasis on practical application can significantly benefit athletes and coaches, improving training methodologies and competitive strategies.

6. **Study Wrestling Culture and Values:** Emphasizing the study of wrestling culture and values can broaden the sport's appeal and increase public interest and understanding. This approach enriches the academic exploration of wrestling and enhances its societal impact.

7. **Integrate Advanced Technologies:** It is recommended that advanced technologies such as motion capture, biomechanical analysis, and virtual reality be integrated. These technologies can help identify critical factors in athletic performance and provide scientific guidance to athletes and coaches.

8. **Use of new technologies and media platforms:** To improve research efficiency and accuracy, new technologies such as big data and artificial intelligence should be used, as should social media and live broadcasting, to improve the coverage and visibility of wrestling research. This approach will attract more young scientists and broaden the audience for wrestling research.

These initiatives will lay a solid foundation for the future development of wrestling research, enhancing its academic contributions and global impact. By implement-

ing these strategies, the wrestling research community can achieve significant advancements and foster a more dynamic and interconnected academic environment.

Limitations of the study

This study summarizes the research progress and wrestling trend in the last hundred years, but some things could be improved in the research process. First, the scope of keyword search may be narrow and too subjective, which may lead to incomplete literature coverage and affect the comprehensiveness of the review. Second, despite using analytical tools like Cite Space, their design and application limitations can result in incomplete keyword dynamic representations or require more in-depth expert interpretation. In addition, research focuses primarily on English-language publications and mainstream channels, potentially ignoring necessary research in other languages or emerging platforms. To overcome these limitations and improve understanding of wrestling research, future research should adopt a systematic multilingual literature search method, combine multiple sources of knowledge, apply advanced analytical techniques, integrate interdisciplinary theories, and carefully evaluate research constraints to ensure scientific rigor and practicality.

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Bibliometryczna analiza postępu badań nad zapasami w minionym stuleciu (1924-2024)

Słowa kluczowe: zapasy, postęp badań, trendy badawcze, analiza bibliometryczna

Streszczenie.

Tło. Zapasy cieszą się światową sławą, ale badania naukowe nad tym sportem wciąż wymagają rozszerzenia. Niniejsze badanie ma na celu określenie istniejącego zbioru badań nad zapasami, wskazanie kluczowych kwestii i przesłedzenie ich ewolucji w celu ukierunkowania przyszłych przedsięwzięć akademickich. Materiały i metody. Używając słów kluczowych „wrestling/zapasy”, „profesjonalny wrestling” i „sporty walki”, przeprowadzono kompleksowe wyszukiwanie w bazach danych Web of Science Core Collection, Scopus, PubMed i Google Scholar. W badaniu systematycznie analizowano podstawową literaturę w tych bazach danych opublikowaną między styczniem 1924 r. a marcem 2024 r. Do analizy bibliometrycznej i wizualizacji danych wykorzystano oprogramowanie CiteSpace. Łącznie przejrano i przeanalizowano 431 badań.

Wyniki. Literatura dotycząca badań nad zapasami doświadczyła znacznego wzrostu, przechodząc od wczesnego etapu do fazy rozwoju, a następnie przechodząc szybki rozwój. Znaczący wkład ze strony Stanów Zjednoczonych i Queen Mary University of London w znacznym stopniu wpłynął na ten postęp. Przed 2015 rokiem badania koncentrowały się na podstawowych tematach, takich jak rozwój nastolatów, trening zdrowotny, dermatologia, zarządzanie wagą, odwodnienie, urazy sportowe i wytrzymałość fizjologiczna. Jednak od 2015 roku nastąpił zauważalny zwrot w kierunku bardziej wyspecjalizowanych i zaawansowanych obszarów badań, w tym analizy technicznej i taktycznej, epidemiologii, sztuk walki i badań wyników sportowych. Kluczowe dziedziny badań nad zapasami obejmują obecnie analizę techniczną i taktyczną, fizjologię wysiłku fizycznego, medycynę sportową, psychologię i współpracę międzynarodową. Rozwój ten wskazuje, że sport ten stale się rozwija i staje się coraz bardziej wyrafinowany. Wnioski. Badania nad zapasami znacznie ewoluowały w ciągu ostatniego stulecia, przechodząc od podstawowych tematów związanych ze zdrowiem i bezpieczeństwem do wyspecjalizowanych obszarów współczesnego zainteresowania, takich jak analiza techniczna i taktyczna, medycyna sportowa, fizjologia wysiłku fizycznego, badania psychologiczne i współpraca międzynarodowa. Zmiana ta podkreśla coraz bardziej skomplikowany i interdyscyplinarny charakter sportu. Rozszerzająca się sfera badań oferuje praktyczne podstawy naukowe i metodologię dla trenerów, sportowców i profesjonalistów, zapewniając jednocześnie jasną mapę dla przyszłych przedsięwzięć badawczych.