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The Frontiers and Hotspots of Global Judo in the Last Decade: A CiteSpace-Based Visualization Analysis

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Abstract: *Judo, founded by Jigoro Kano in 1882, originated in Japan and has since grown to be globally popular. Young people display a high level of involvement in judo practice, while research on the sport varies over time and participation. In this study, we utilized the CiteSpace software for literature visualization and analysis. We set the time slice to 2012-2022 with a yearly increment and selected "Node Types" including "Country", "Institution", "Author", and "Keyword", with "Top N"=50. The other values remained at their default settings, resulting in the generation of a relevant knowledge graph. The LLR algorithm, which stands for Logarithmic Great Likelihood Ratio, is used to cluster keywords. Timeline, landscape, and burstiness demonstrate the temporal and sudden keyword changes. This study summarizes the research hotspots and development trends of global Judo programs in the Web of Science core collection in the last decade.*

Keywords: *Judo; CiteSpace; Visualization Analysis; Keyword Clustering*

1. Introduction

Judo has its origins in Japan and was established in 1882 by Jigoro Kano. He blended different techniques from Chinese martial arts, such as kicking, punching, wrestling, and holding, with elements from Japanese martial arts and jujutsu to create this unique form of martial arts. Judo made its first appearance as an official Olympic event at the 18th Olympic Games hosted in Tokyo, Japan, in 1964. Judo was excluded from the subsequent 1968 Mexico City Olympics and was reintroduced to the Olympic Games at the 1972 Munich Olympics. Women's Judo made its Olympic debut at the 1992 Barcelona Games. Today, Judo enjoys worldwide popularity, and there is a high participation rate in the sport, especially among young people. Consequently, research in this field has evolved with the passage of time and the increase in participation.

This study examines the research literature on Judo in the Web of Science core collection. Using CiteSpace document visualization and analysis software, it provides a summary of the latest development frontiers and global hotspots in Judo over the past decade, exploring patterns to provide data support for future Judo research.

2. Materials and Methods

2.1 Bibliometric method

The information of document publication, research country, research institution, author and keywords were analyzed using Excel (Microsoft 365).

2.2 Visualized Analysis

CiteSpace is a multi-component, time-sharing and dynamic citation visualization analysis software

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focusing on uncovering latent knowledge embedded in scientific literature. It has evolved within the context of scientometrics, data, and information visualization[1]. The software version utilized in this study is CiteSpace 6.1.R6. Knowledge maps were generated and visualized using the software, examining facets such as country, institution, author, and keywords. Through visual analysis, this study aims to delineate and summarize the forefront and hotspots in global judo research over the past decade.

2.3 Data Sources

Utilizing the Web of Science Core Collection as the data source, which includes SCI and SSCI, a specialized search for "Judo" across all fields was conducted. The temporal scope of the search spans from 2012 to 2022, a total of 1209 articles were retrieved. At the same time, the paper type (Article or Review paper) and language (English) are selected from the retrieved data, after removing 122 literatures, 1087 literatures were obtained. The retrieval was conducted as of February 21, 2023.

2.4 Process

According to the requirements of software calculation, 1087 literatures were imported into CiteSpace 6.1.R6 software. Within the functional parameters section, the time range (Time Slicing) was set from 2012 to 2022, with a time slice of 1 year. Node types were selected as Country, Institution, Author, and Keyword. The threshold for "Top N" was set to 50, generate the corresponding knowledge graph with the other values as default. Furthermore, for keyword analysis, clustering labels were generated using the LLR (log-likelihood ratio) algorithm and noun terms extracted from keywords. The timeline, landscape, and burstness methods were employed to present the temporal changes in keywords and the occurrence of burst keywords.

3. Results

3.1 The basic overview of global judo project research in the past decade

3.1.1 The publication of research literature

Using the Web of Science Core Collection, which includes SCI and SSCI, as the retrieval source for research literature, the annual publication count of judo studies from 2012 to 2022 was extracted through CiteSpace software. In addition, Excel was used to perform a statistical analysis of research documents with the theme "Judo" from 2012 to 2022, as shown in figure 1.

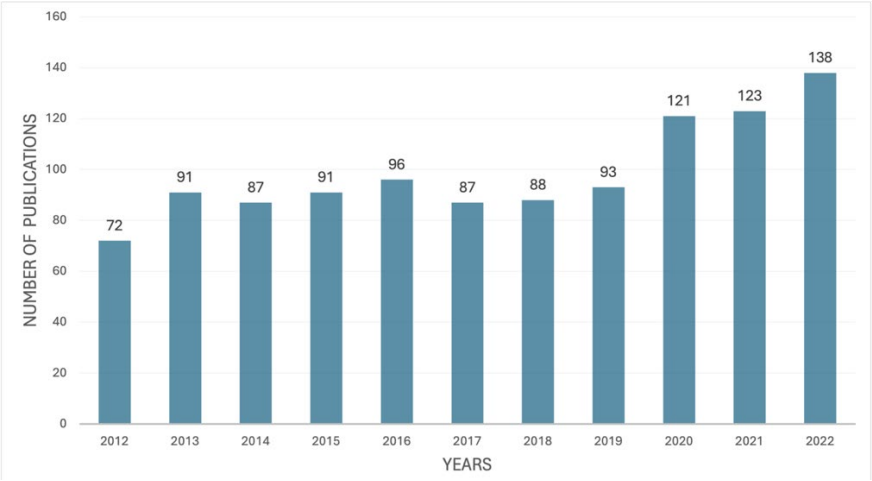

Figure 1: Annual publications of judo projects included in WOS from 2012 to 2022.

The change in the number of papers over time is an important indicator of the research output in a particular field and reflects the attention paid to that field of research. Analyzing the annual publication count provides an overall understanding of the research trends in "Judo". According to the analysis of 1087 literatures obtained, it can be concluded from figure 1 that the research literatures on "Judo" experienced two notable surges from 2012 to 2022. The first surge occurred between 2012 and 2013, with the publication count increasing from 72 to 91, representing a growth rate of 26%. The second surge transpired between 2019 and 2020, where the publication count surged from 93 to 121, reflecting a

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growth rate of 30%. Meanwhile, the annual publication count remained relatively stable between these two surges, showing minor fluctuations. Additionally, the lowest publication count was recorded in 2012 at 72 papers, while the peak was reached in 2022 with 138 papers. In summary, the overall trend in the publication count of "Judo" literature shows an increasing trend from 2012 to 2022. This suggests a sustained increase in attention to Judo during this period. According to the development trend in Figure 1, it is expected that the publication count for global Judo project research will continue to show an upward trend in the future.

3.1.2 Primary countries conducting Judo research.

Utilizing the CiteSpace visualization software, a co-occurrence knowledge map of countries involved in Judo project research from 2012 to 2022 was generated, as showed in figure 2. Additionally, a table summarizing the primary countries engaged in Judo project research during the period 2012-2022 has been compiled and is presented in table 1.

Figure 2: Map of national co-occurrence knowledge in the Judo Project from 2012 to 2022.

Table 1: Primary countries studied in the Judo project 2012-2022

No.	Frequency	Year	Country	Intermediation centrality	Year	Country
1	225	2012	Brazil	0.22	2012	USA
2	179	2012	Japan	0.16	2012	Spain
3	161	2012	Poland	0.15	2012	Poland
4	124	2012	USA	0.14	2012	England
5	121	2012	Spain	0.11	2012	Brazil
6	73	2012	England	0.11	2012	Australia
7	65	2012	Germany	0.07	2012	Italy
8	63	2012	Italy	0.07	2012	Sweden
9	58	2012	Australia	0.07	2012	Russia
10	50	2012	France	0.06	2012	Japan

In figure 2, each node represents a country, and nodes are represented by annual rings. The size of the concentric circle corresponds to the publication count of the respective country; larger circles indicate higher publication counts. The connections between nodes represent co-occurrence relationships, with the thickness of the lines indicating the strength of co-occurrence. The width of the purple rings describes the magnitude of intermediary centrality. Notably, in figure 2, nodes representing countries such as the United States (USA), Spain, Poland, England, Brazil, and Australia feature purple outer rings. This suggests close collaborative relationships and significant impact in judo project research among these countries.

We analyzed the primary countries of the published literature. The data obtained from the knowledge map was organized to create a table summarizing the primary countries involved in judo project research from 2012 to 2022, as shown in table 1. It can be observed that Brazil had the highest publication frequency during the period, reaching 225 publications. Japan, Poland, the United States, and Spain all had publication frequencies exceeding 100, with 179, 161, 124, and 121 publications, respectively. In contrast, England, Germany, Italy, Australia, and France had publication frequencies below 100. Moreover, the centrality of intermediaries in countries such as the United States, Spain, Poland, England,

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Brazil, and Australia exceeds 0.1, with a maximum centrality of 0.22 in the United States; Spain, Poland, England, Brazil and Australia are all in the range of 0.2-0.1; The centrality of intermediaries in Italy, Sweden, Russia, and Japan has not reached 0.1. The results indicate that in recent years, although Brazil has the highest publication frequency in judo projects, the United States possesses the greatest influence in the field of judo, followed by Spain, Poland, England, Brazil, and Australia.

3.1.3 Primary research institutes

In figure 3, each node represents an institution, and the node size reflects the corresponding institution's publication count. The connections between nodes indicate the strength of collaborative relationships between research institutions. Notably, larger nodes represent prolific institutions such as Univ Sao Paulo, Univ Sch Phys Educ, and Univ Fed Santa Catarina. Examining intermediary centrality, a collaborative network of institutions has emerged in the field of judo, with key contributors including Univ Sao Paulo, Univ Cent Florida, Univ Sch Phys Educ, Univ Fed Santa Catarina, Vrije Univ Amsterdam, and Univ Southern Denmark. In the area of judo research, a collaborative network of institutions has formed, with Univ Sao Paulo at the forefront.

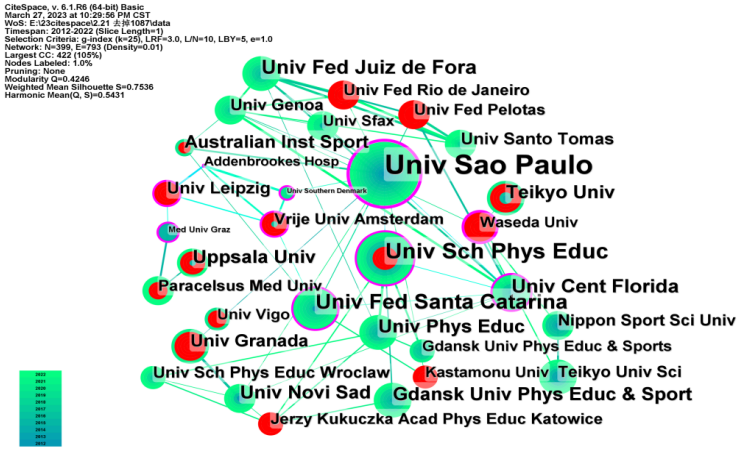

Figure 3: Map of institutional co-occurrence knowledge of Judo project research from 2012 to 2022.

Table 2: Primary Research Institutions of Judo Projects 2012-2022

No.	Frequency	Year	Institution	Intermediation centrality	Year	Institution
1	108	2012	Univ Sao Paulo	0.42	2012	Univ Sao Paulo
2	37	2012	Univ Sch Phys Educ	0.24	2020	Waseda Univ
3	30	2012	Univ Fed Santa Catarina	0.19	2014	Univ Cent Florida
4	24	2016	Univ Fed Juiz de Fora	0.14	2012	Univ Sch Phys Educ
5	22	2014	Univ Cent Florida	0.14	2013	Univ Leipzig
6	21	2012	Univ Novi Sad	0.13	2012	Univ Fed Santa Catarina
7	21	2014	Teikyo Univ	0.13	2016	Vrije Univ Amsterdam
8	20	2015	Uppsala Univ	0.13	2020	Univ Southern Denmark
9	19	2015	Univ Phys Educ	0.12	2013	Addenbrookes Hosp
10	19	2012	Gdansk Univ Phys Educ & Sport	0.1	2015	Med Univ Graz

Table 2 presents the main research institutions involved in judo projects from 2012 to 2022. It is evident that in terms of publication frequency, Univ Sao Paulo stands out with the highest frequency at 108, being the only institution over 100 publications, while others below 50. Regarding intermediary centrality, 10 institutions all exhibit intermediary centrality values ≥0.1, with Univ Sao Paulo having the highest intermediary centrality at 0.42. In summary, whether considering publication frequency or intermediary centrality, Univ Sao Paulo consistently holds the top position, indicating significant achievements and influence in the field of judo research.

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3.1.4 Primary author of the literature

In figure 4, each node is represented by concentric circles, where each circle corresponds to an author, and the size of the circle is proportional to the author's publication count. The connections between nodes represent the relationships between authors, with the thickness of the lines indicating the degree of collaboration. The width of the purple rings describes the magnitude of intermediary centrality. It is suggested that the largest node in the figure corresponds to Franchini, Emerson, and it is the only node with a purple outer ring. Therefore, in the field of judo research, Franchini, Emerson, makes a substantial contribution with a wide-reaching influence.

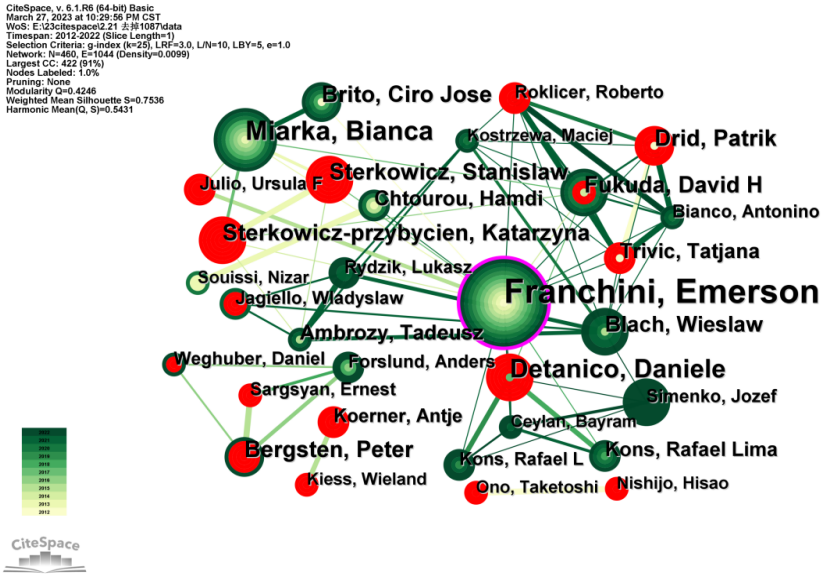

Figure 4: The co-occurrence knowledge map of authors in judo project research 2012-2022.

Table 3: The top 10 authors in Judo project research based on publication frequency 2012 -2022.

No.	Frequency	Year	Author	Intermediation centrality	Year	Author
1	85	2012	Franchini, Emerson	0.14	2012	Franchini, Emerson
2	30	2013	Miarka, Bianca	0.04	2015	Blach, Wieslaw
3	27	2017	Detanico, Daniele	0.03	2013	Chtourou, Hamdi
4	18	2012	Sterkowicz-przybycien, Katarzyna	0.02	2013	Miarka, Bianca
5	18	2012	Sterkowicz, Stanislaw	0.02	2017	Detanico, Daniele
6	18	2015	Bergsten, Peter	0.02	2014	Fukuda, David H
7	18	2014	Fukuda, David H	0.02	2014	Ambrozy, Tadeusz
8	17	2012	Drid, Patrik	0.01	2012	Sterkowicz-przybycien, Katarzyna
9	17	2012	Brito, Ciro Jose	0.01	2012	Sterkowicz, Stanislaw
10	16	2015	Blach, Wieslaw	0.01	2012	Drid, Patrik

Table 3 shows the top 10 authors in Judo project research based on publication frequency from 2012 to 2022. Franchini, Emerson tops the list with a publication frequency of 85. In terms of intermediary centrality, only Franchini, Emerson exceeds 0.1, with an intermediary centrality of 0.14. Both in terms of frequency and intermediary centrality, the other scholars exhibit a considerable gap compared to Franchini, Emerson. Therefore, Franchini, Emerson stands out as a highly influential scholar in the field of Judo research.

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3.2 The frontier of the past decade Judo project research

3.2.1 Visual analysis of keywords clustering

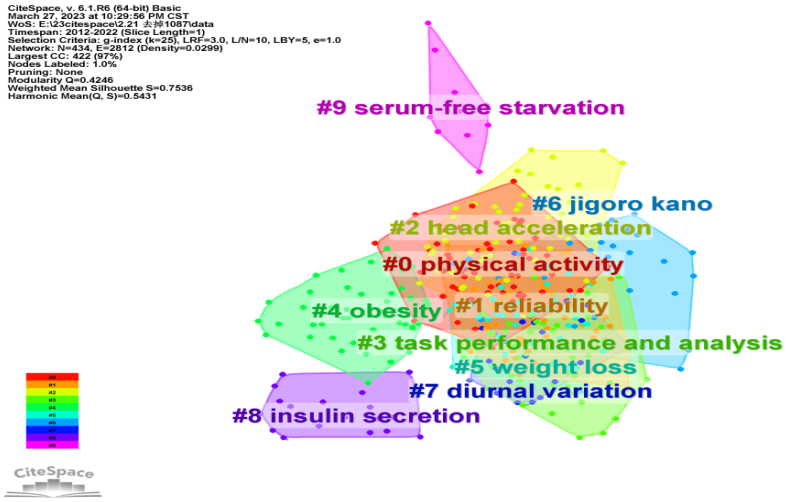

Figure 5: The clustered knowledge map of keywords in Judo project research 2012-2022.

Table 4: Keyword Cluster Information for Judo Project Research 2012-2022

Cluster No.	Count	S value	Average Year	Keyword(LLR)
0	65	0.691	2017	physical activity; bone mineral density; adolescent; exercise; health promotion
1	64	0.647	2015	reliability; muscle power; hand strength; physical fitness; sports performance
2	60	0.708	2016	head acceleration; concussion; acute subdural hematoma; sports injury; epidemiology
3	57	0.768	2016	task performance and analysis; time and motion studies; athletic performance; motor control; martial arts
4	44	0.808	2016	obesity; martial arts; pediatric obesity; combat sports; insulin resistance
5	42	0.757	2015	weight loss; dehydration; wrestling; body composition; rapid weight loss
6	34	0.802	2015	Jigoro Kano; Kyuzo Mifune; Kaeshi-waza; reactive oxygen species; Kazuo Ito
7	22	0.819	2014	diurnal variation; anaerobic performance; mood states; strength; specific testing
8	19	0.941	2014	insulin secretion; structural properties of body; human pancreatic islets; female Judoka; aerobic power
9	10	0.993	2014	serum-free starvation; l6 myoblasts; signal transduction; cofilin; pkb/akt
10	7	1	2017	flexor carpi radialis; human spinal cord; oligosynaptic inhibition; flexor digitorum superficialis; emg-averaging method
11	5	0.996	2020	chondrocyte; collagen fibers; scanning electron microscopy; bipolar hemiarthroplasty

In this study, keyword clustering was conducted based on keyword co-occurrence using the K (Keyword) clustering method. The LLR algorithm provided by CiteSpace 6.1R6 was used for keyword clustering. The top 10 keyword clusters were selected for the visualization of the knowledge map, as shown in figure 5. CiteSpace provides the modularity value (Q value = Modularity) and the average silhouette value (S value = Weighted Mean Silhouette) to evaluate clustering effectiveness. Modularity is an assessment metric for network modularity, where a higher modularity value indicates better clustering. The range of Q values is [0, 1]. The Silhouette value measures the homogeneity of the network and is used to evaluate clustering; a higher S value, approaching 1, reflects higher homogeneity of the

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network[1].

In figure 5, the Q value is 0.4246, and the S value is 0.7536. Q > 0.3 indicates a significant community structure in the obtained network, and S > 0.7 indicates high confidence in the clustering results. According to clustering principles, this suggests that the knowledge map of keyword clusters in Judo project research from 2012 to 2022 has a reasonable network community structure, reliable clustering results, and overall good clustering effectiveness. It can be observed that Judo project research, after keyword co-occurrence, forms multiple clusters, with some clusters overlapping. The keyword clusters in Judo project research for the years 2021-2022 include several key topics: #0 physical activity, #1 reliability, #2 head acceleration, #3 task performance and analysis, #4 obesity, #5 weight loss, #6 Jigoro Kano, #7 diurnal variation, #8 insulin secretion, and #9 serum-free starvation.

Table 4 presents the keyword cluster information for Judo project research from 2012 to 2022, aiming to provide a clearer expression of the characteristics of keyword clustering. The cluster ranked first is "physical activity" (#0), with the largest cluster size of 65. The keywords within this cluster exhibit high similarity, with a silhouette value of 0.691. The average publication year of keywords in this cluster is 2017. The cluster with the highest keyword similarity is "flexor carpi radialis" (#10), with a silhouette value of 1, although its cluster size is smaller at 7, and the average publication year is 2017. The cluster with the most recent average publication year is 2020, the keyword is "chondrocyte", with a silhouette value of 0.996 and a cluster size of 5. In summary, it can be stated that among the research themes in Judo projects from 2012 to 2022, the largest cluster is related to "physical activity".

3.2.2 Keyword Burst Detection

"Burst" refers to a sudden increase in the frequency of a specific type of event in a given time series. In this study, further analysis was conducted on bursty keywords based on the keyword co-occurrence network. Bursty keywords refer to critical terms whose occurrence frequency suddenly increases or shows a noticeable growth within a short period. The principle of bursty keyword detection can provide insights into the dynamic trends in the forefront of Judo project research. In this research, burst detection revealed the 27 strongest bursty keywords in the field of Judo research from 2012 to 2022, along with their start and end years.

Top 27 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2012 - 2022
men	2012	3.62	2012	2017	
women	2012	3.3	2012	2014	
stress	2012	3.25	2012	2014	
elite	2012	3.12	2012	2014	
expression	2012	3.05	2012	2018	
behavior	2012	3	2012	2014	
somatotype	2012	2.93	2012	2014	
collegiate wrestler	2012	2.82	2012	2013	
grip strength	2012	2.55	2012	2013	
perceived exertion	2013	3.04	2015	2017	
adaptation	2015	3.04	2015	2017	
body mass index	2015	2.68	2015	2017	
lactate concentration	2015	2.5	2015	2018	
association	2016	3.7	2016	2017	
prevention	2016	3.23	2016	2018	
gene	2016	3.14	2016	2017	
insulin secretion	2016	3.04	2016	2018	
championship	2016	2.61	2016	2018	
player	2012	3.32	2017	2018	
program	2013	2.54	2017	2020	
time	2018	3.36	2018	2019	
validation	2018	3.29	2018	2020	
training load	2019	3.46	2019	2022	
prevalence	2013	2.89	2019	2020	
intensity	2013	2.61	2019	2022	
performance response	2019	2.5	2019	2020	
mineral density	2019	2.5	2019	2020	

Figure 6: Burst Detection of Keywords in Judo Research from 2012 to 2022.

As shown in figure 6, the beginning of the red line segment marks the start of the burst period, while the end of the red line segment indicates the end of the burst period. We observe that there were 27 bursty keywords in the field of Judo research over the past decade. Keywords with earlier burst times include

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"male", "female", "stress", "elite", "expression", "behavior", "somatotype", "college wrestler", and "grip strength". These keywords started as early as 2012 and ended no later than 2018, indicating that these topics received early attention. In the middle, keywords with higher burst intensity include "perceived exertion", "adaptation", "body mass index", "association", "prevention", "gene", "insulin secretion", "championship", "player", "program", "time", "validation", "prevalence", "performance response", and "mineral density". These keywords started as early as 2015 and ended no later than 2020. The keyword with the highest burst intensity is "association", which occurred from 2016 to 2017. The keyword with the longest burst duration is "expression", which started in 2012 and ended in 2018. Keywords with more recent burst times include "training load" and "intensity", which started in 2019 and continued until 2022.

In figure 7, it is evident that the burst keyword "training load" emerged in 2013, experienced a sudden increase from 2017 to 2020, but began to decline from 2021 to 2022. Similarly, the burst keyword "intensity" appeared in 2019, remained stable until 2021, and then experienced a sudden decrease from 2021 to 2022. Therefore, it can be concluded that "training load" and "intensity" are topics that have gained attention in recent years.

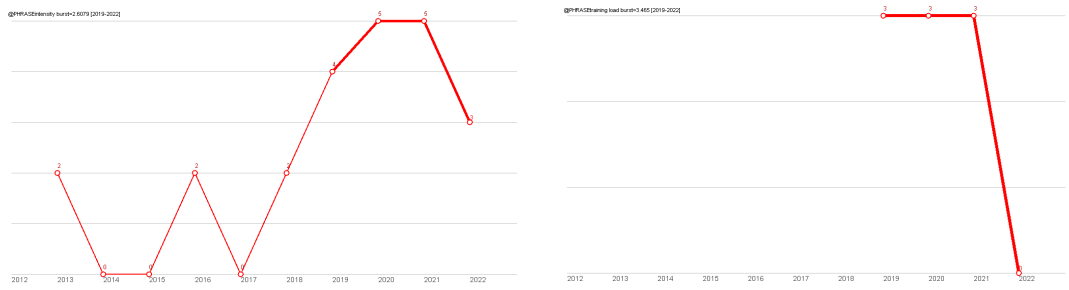

Figure 7: Historical Chart of Bursty Keywords in Judo Projects from 2012 to 2022

3.2.3 Highly cited literature

Figure 8 shows the top 25 highly cited publications in Judo research from 2012 to 2022. It can be observed that the development of highly cited publications went through three phases: (Early Research) 2012–2016, (Mid-term Research) 2013–2020, and (Late Research) 2018–2022. Upon reading the literature, it was found that these publications mainly cover three aspects: time-motion and energy supply in Judo, rapid weight loss, and sports injuries.

In the aspect of time-motion patterns and energy supply: in the early research stage, attention was given to the impact of different recovery methods after Judo matches on athletes' subsequent performance. This included the comparison between active and passive recovery methods. In the mid-term research stage, there was a focus on analyzing the match demands in each time-motion pattern during Judo competitions. A comparison was made across four different age groups (13-14 years, 15-16 years, 19 years, and 20 years). Overall, there was a comprehensive analysis of time-motion patterns in Judo competitions along with the evaluation of physiological and physical functions. Additionally, during training or competitions, the use of objective symbol analysis systems, computer-based analysis and observation were deemed necessary. These methods were helpful in optimizing athletes' performance or movements and could be utilized in designing more specific training plans to enhance performance during competitions. Examples of computer programs include FRAMI software, SaatsTM (Structural Analysis of Actions and Time-Motion), and others. In the late research stage, the focus shifted to the impact of Judo competitions or consecutive matches on athletes' physiological performance. This included aspects such as grip strength reduction and increased fatigue.

In the context of rapid weight loss: In the early research stage, there was a concentration on the negative impacts of rapid weight loss on athletes' health. The necessity of weight/body control in Judo was emphasized, and recommendations were made to establish new rules based on successful NCAA plans. In the later research stage, the focus shifted to the prevalence of rapid weight loss and the introduction of safe recommendations and appropriate decisions to achieve specific weight goals. In addition to the health impacts of rapid weight loss on athletes, there was an emphasis on the significant ethical implications, specifically the spirit of sports and fair competition. This included consideration related to Judo competition rules, emphasizing that all rule modifications aim to encourage athletes' "positive" behaviors, such as continuous attacks to seek "ippon" (the highest score in Judo), rather than engaging in "negative" behaviors of avoiding opponents' attacks.

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References	Year	Strength	Begin	End	2012 - 2022
Franchini E, 2011, SPORTS MED, V41, P147, DOI 10.2165/11538580-000000000-00000, DOI	2011	21.31	2012	2016	
Franchini E, 2009, EUR J APPL PHYSIOL, V107, P377, DOI 10.1007/s00421-009-1134-2, DOI	2009	9.32	2012	2014	
Artioli GG, 2010, J INT SOC SPORT NUTR, V7, P0, DOI 10.1186/1550-2783-7-15, DOI	2010	7.28	2012	2015	
Artioli GG, 2010, MED SCI SPORT EXER, V42, P436, DOI 10.1249/MSS.0b013e3181ba8055, DOI	2010	7.28	2012	2015	
Artioli GG, 2010, J SPORT SCI, V28, P21, DOI 10.1080/02640410903428574, DOI	2010	6.12	2012	2015	
Franchini E, 2009, ARCH BUDO, V5, P127	2009	5.1	2012	2014	
Franchini E, 2011, INT J SPORT PHYSIOL, V6, P334, DOI 10.1123/ijspp.6.3.334, DOI	2011	5.7	2013	2016	
Marcon G, 2010, J QUANT ANAL SPORTS, V6, P0, DOI 10.2202/1559-0410.1226, DOI	2010	5.68	2013	2015	
Calmet M, 2010, INT J PERF ANAL SPOR, V10, P229, DOI 10.1080/24748668.2010.11868518, DOI	2010	5.68	2013	2015	
Miarka B, 2012, J SPORT SCI, V30, P899, DOI 10.1080/02640414.2012.679675, DOI	2012	12.74	2014	2017	
Pocecco E, 2013, BRIT J SPORT MED, V47, P1139, DOI 10.1136/bjsports-2013-092886, DOI	2013	7.37	2014	2018	
Miarka B, 2011, INT J PERF ANAL SPOR, V11, P254, DOI 10.1080/24748668.2011.11868546, DOI	2011	5.62	2014	2016	
Franchini E, 2013, INT J PERF ANAL SPOR, V13, P624, DOI 10.1080/24748668.2013.11868676, DOI	2013	12.24	2015	2018	
Branco Braulio H M, 2013, ASIAN J SPORTS MED, V4, P125	2013	5.04	2015	2018	
Bonitch-Gongora JG, 2012, J STRENGTH COND RES, V26, P1863, DOI 10.1519/JSC.0b013e318238ebac, DOI	2012	4.95	2015	2017	
Miarka B, 2014, J SPORT SCI, V32, P1529, DOI 10.1080/02640414.2014.903335, DOI	2014	8.98	2016	2018	
Franchini E, 2014, J STRENGTH COND RES, V28, P1474, DOI 10.1519/JSC.0000000000000281, DOI	2014	8.16	2016	2019	
Detanico D, 2012, SCI SPORT, V27, P16, DOI 10.1016/j.scispo.2011.01.010, DOI	2012	4.82	2016	2017	
Detanico D, 2015, J STRENGTH COND RES, V29, P1010, DOI 10.1519/JSC.0000000000000746, DOI	2015	5.56	2017	2020	
Julio UF, 2017, INT J SPORT PHYSIOL, V12, P676, DOI 10.1123/ijspp.2015-0750, DOI	2017	7.16	2018	2022	
Artioli GG, 2016, SPORTS MED, V46, P1579, DOI 10.1007/s40279-016-0541-x, DOI	2016	5.88	2018	2022	
Berkovich BE, 2016, INT J SPORT NUTR EXE, V26, P276, DOI 10.1123/ijsnem.2015-0196, DOI	2016	5.14	2018	2022	
Franchini E, 2016, FRONT PHYSIOL, V7, P0, DOI 10.3389/fphys.2016.00268, DOI	2016	6.73	2019	2022	
Calmet M, 2017, INT J PERF ANAL SPOR, V17, P458, DOI 10.1080/24748668.2017.1350489, DOI	2017	5.87	2019	2022	
Akoto R, 2018, BRIT J SPORT MED, V52, P0, DOI 10.1136/bjsports-2016-096849, DOI	2018	6.55	2020	2022	

Figure 8: Top 25 highly cited publications in Judo research 2012-2022.

Regarding sports injuries: In the mid-term research phase, many studies investigated the epidemiology of injuries in Judo, emphasizing the importance of developing effective injury prevention strategies in Judo and introducing continuous injury monitoring systems. In the later phase, the research primarily focused on the severity of sports injuries, emphasizing that further studies should concentrate on developing better treatment options and prevention strategies for these injuries.

3.3 Research Trends in Global Judo Projects Over the Past Decade

The research hotspots refer to issues or phenomena that have gained widespread attention during a specific period, leading to a considerable number of literature discussions. In the field of Judo projects, these hotspots evolve over time and research progress, reflecting changes that can be expressed through keywords. Keywords, being the most concise core of a paper, provide a highly summarized representation of the main meaning of the research.

The Judo keyword co-occurrence knowledge graph covers the period from 2012 to 2022, with a yearly time slice. The node type selected is “Keyword”, and the threshold is set to “Top N” for 50. Using default values for other parameters, the knowledge graph visualizes the co-occurrence of keywords in Judo research. Additionally, the research hotspots in this field are assessed using the frequency of keyword usage and centrality as two key indicators.

3.3.1 Analysis of the Knowledge Graph of Keyword Co-occurrence

To provide a clearer presentation of the research hotspots in the field of Judo, the selected literature was imported into Citespace 6.1.R6 for the visualization of the keyword co-occurrence knowledge graph in Judo research from 2012 to 2022. The data extracted from the graph were organized to create a table (table 5) listing the top 10 keywords in the literature on Judo research from 2012 to 2022.

Figure 9: Keyword co-occurrence knowledge graph of Judo research 2012-2022.

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In figure 9, each node represents a keyword, and the thickness of the annual rings is proportional to the keyword's frequency in that year. The connections between nodes indicate the degree of closeness, and the thickness of the purple ring outside the nodes describes the value of betweenness centrality. The resulting keyword co-occurrence graph consists of 434 nodes and 2812 edges. It is evident that keywords such as “performance”, “martial art”, “combat sport”, “exercise”,and “sport” are prominent, indicating that these are the main hotspots in Judo research during the specified period.

Table 5 shows that in terms of keyword frequency, “performance” and “martial art” have frequencies greater than 200, with “performance” having the highest frequency at 237; “combat sport” and “exercise” have frequencies ranging from 100 to 200, with values of 194 and 131 respectively. Keywords such as “sport”, “Judo”, “strength”, “elite”, “injury” and “physical fitness” have frequencies below 100. In terms of betweenness centrality, “injury” and “physical activity” have betweenness centralities exceeding 0.1, while others do not meet the 0.1 standard. Through the analysis of high-frequency and high-betweenness centrality keywords, it is evident that in the past decade, research in the field of Judo has primarily focused on keywords such as “performance”, “martial art”, “combat sport”, “exercise” and “injury”.

Table 5: Top 10 keywords in Judo research literature 2012-2022

Rank	Frequency	Year of appearance	Keywords	Intermediation centrality	Year of appearance	Keywords
1	237	2012	performance	0.1	2012	injury
2	203	2012	martial art	0.1	2012	physical activity
3	194	2012	combat sport	0.09	2012	behavior
4	131	2012	exercise	0.08	2012	expression
5	90	2012	sport	0.08	2014	skeletal muscle
6	90	2012	Judo	0.07	2012	body composition
7	88	2012	strength	0.07	2013	children
8	83	2012	elite	0.07	2012	oxidative stress
9	60	2012	injury	0.07	2012	growth
10	57	2012	physical fitness	0.06	2012	performance

3.3.2 Keywords time chart

Based on keyword clustering, a timeline analysis was conducted using the “TimeLine” feature in CiteSpace 6.1.R6. The timeline graph (figure 10) shows the appearance and end times of different keyword clusters. The top 10 clusters were selected for the timeline graph to provide a clear representation of the chronological trends.

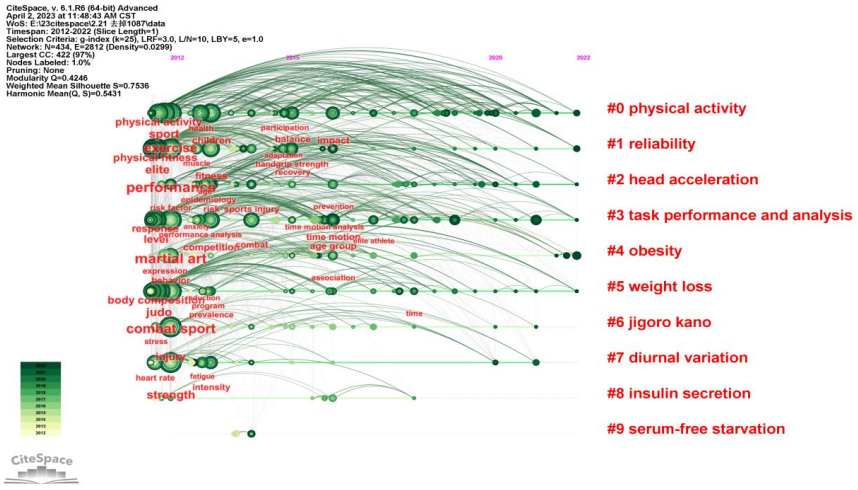

Figure 10: The keyword timeline graph for Judo research from 2012 to 2022.

It can be observed that the cluster “physical activity”, “reliability”, “head acceleration”, “task performance and analysis”, “obesity”, “weight loss” has been consistently developing from 2012 to 2022. On the other hand, the cluster “Jigoro kano”, “diurnal variation” has been continuously evolving from

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2012 to 2021 and has since entered a cooling-off phase. The cluster “insulin secretion” began its development in 2021 and continued until 2018, followed by a decline. The cluster “serum-free starvation” had a small-scale development starting from 2014 and has shown minimal fluctuations thereafter.

Additionally, except for the cluster “serum-free starvation”, which emerged in 2014 with its first reference, most clusters appeared in 2012, with the majority of cluster developments concentrated in 2012-2013. In summary, “physical activity”, “reliability”, “head acceleration”, ”task performance and analysis“, ”obesity“, ”weight loss" represent the recent focus of Judo research. Among them, the cluster associated with “physical activity” has the most developments and the highest attention. “physical activity” emerged in 2012, with the peak of cluster developments in 2012-2013. In comparison to that period, later results have declined but have remained relatively stable.

After reading relevant literature, it was found that the application of various martial arts projects significantly contributes to improving the physical fitness of preschool and school-age children.[2,3] Judo, as a martial art, is beneficial for individuals across different age groups. For example, practicing Judo has a positive impact on movement skills and psychosocial abilities in children with Autism Spectrum Disorder (ASD).[4–6] Judo exhibits an externalizing effect[7], and plays a positive role in cognitive control processes related to response inhibition. Judo training can enhance response inhibition in pre-adolescent children.[8] For the elderly, learning Judo helps improve physiological function, as well as physical and mental health, preventing fall-related injuries.[9–12] In overweight or obese populations, Judo practice can improve cardiovascular risks and health.[13,14] Regular Judo training induces positive changes in body posture development,[15–17] promoting skeletal health, such as the accumulation of bone density.[18–21] Additionally, Judo has proven effective in improving sleep quality and certain aspects of daily life.[22]

3.3.3 Key words landscape Knowledge map

It can be observed (figure 11) that the cluster “physical activity” had relatively stable attention from 2012 to 2017, with a noticeable increase in attention from 2018 to 2022. The “reliability” cluster received higher attention from 2012 to 2015, particularly in 2012, and remained relatively flat after 2015. The “head acceleration” cluster experienced two development stages, the first from 2012 to 2015 and the second from 2017 to 2022, with a gap in 2016. The “task performance and analysis” cluster had a relatively flat attention level before 2015, experienced a high-development period from 2015 to 2017, and then declined with minor fluctuations. The “obesity” cluster started in 2012 and showed good development from 2014 to 2017, but experienced stagnation from 2018 to 2021 before starting the next wave of development. The “weight loss” cluster peaked in 2012 and then began a gradual decline. The “Jigoro kano” cluster developed steadily from 2012 to 2017 and then cooled down. The “diurnal variation” cluster experienced a peak from 2012 to 2014, followed by a decline, stagnation from 2016 to 2019, a small development, and another gap. The “insulin secretion” cluster reached a peak in 2012, had a small development phase in the middle, and has remained largely stagnant. The “serum-free starvation” cluster remained blank from 2012 to 2022.

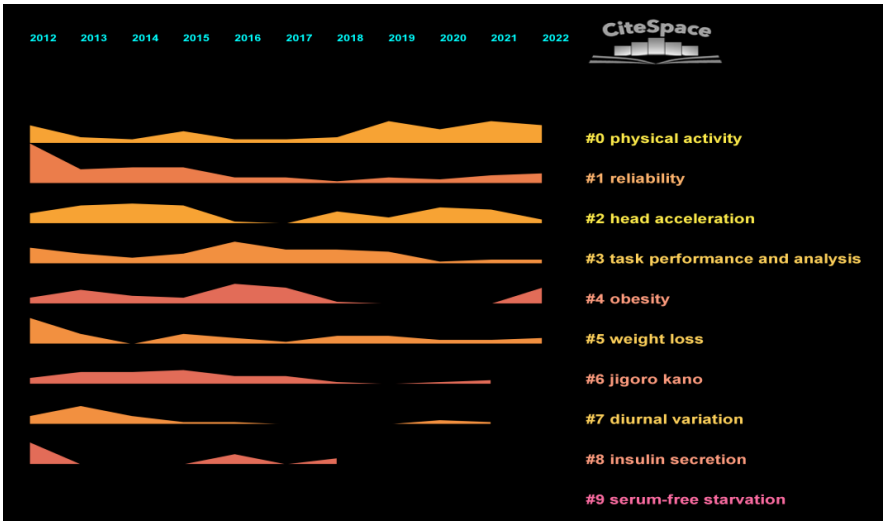

Figure 11: Landscape view knowledge graph of Judo research keywords 2012-2022

In summary “physical activity”, “reliability”, “task performance and analysis”, “obesity”, and “weight loss” have continued to develop from 2012 to 2022, while “head acceleration”, “obesity” and “weight loss” experienced brief interruptions but continued to develop. “Jigoro kano”, “diurnal variation”,

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"insulin secretion", and "serum-free starvation" received concentrated attention in the early stages from 2012 to 2022, with a subsequent decline in attention. It can be seen that "physical activity", "reliability", "task performance and analysis", "obesity" and "weight loss" are recent and ongoing topics of interest, especially "physical activity" and "obesity".

4. Conclusions

Through the analysis of information such as the number of publications, countries, institutions, authors, and keywords in Judo research from 2012 to 2022, it is found that the attention to Judo has been consistently increasing. It is expected that the number of global Judo research publications will continue to grow in the future. The United States has the broadest scope of collaboration with other countries and holds a leading position in the field of Judo. In terms of publishing institutions, a collaborative network led by the University of Sao Paulo has been formed, and the University of Sao Paulo has made significant achievements and impact in Judo research. Regarding key authors in Judo research, Emerson Franchini has made significant contributions and has a wide-ranging influence. In summary, in the global Judo research over the past decade, the research focus has mainly centered around keywords such as "performance", "martial arts", "combat sports", "physical activity" and "injury". "Physical activity", "reliability", "head acceleration", "task performance and analysis", "obesity" and "weight loss" are continuous focal points in Judo research, with "physical activity" and "obesity" being persistent hot topics in the Judo research community.

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