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Bibliometric analysis of worldwide scientific production in taekwondo

Luis A. CARDOZO[1,5*], Gino SALCEDO-GÓMEZ[2,3], Jehison MATEUS-BARRETO[4], Eduardo SÁEZ DE VILLARREAL[5] & Diego A. BONILLA[6,7]

[1] *Research and Measurement Group in Sports Training - IMED, Faculty of Health Sciences and Sports, Fundación Universitaria del Área Andina (Colombia)*

[2] *Liga de Taekwondo de Bogotá (Colombia)*

[3] *Universidad del Rosario (Colombia)*

[4] *Programa Profesional en Entrenamiento Deportivo, Fundación Universitaria del Área Andina (Colombia)*

[5] *Physical Performance Sports Research Center (PPSRC), Universidad Pablo de Olavide (Spain)*

[6] *Research Division, Dynamical Business & Science Society - DBSS International SAS (Colombia)*

[7] *Hologenomiks Research Group, Department of Genetics, Physical Anthropology and Animal Physiology, University of the Basque Country - UPV/EHU (Spain)*

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ORIGINAL PAPER

Abstract

Taekwondo has experienced rapid growth over the last three decades, solidifying its position as one of the most prominent combat sports worldwide. The objective of this study was to analyze the academic output on taekwondo published in scientific journals using bibliometric methods. The search included publications up to December 31, 2024. Data was collected in the Scopus and Web of Science databases using Bibliometrix and VOSviewer software. The results showed that the oldest publication date back to 1979, with a notable upward trend in publications starting in 2010. A total of 1982 publications were found, of which 26 have 100 or more citations. Up to 689 scientific journals, 4979 authors and co-authors were associated with the publications. A total of 2480 academic institutions from 80 countries were identified, with South Korea, China, and Brazil being the countries with the highest number of publications. Additionally, South Korea and Brazil had the largest number of international collaboration networks. Despite the growing scientific production, the field presents structural weaknesses, such as an uneven distribution of author productivity and limited long-term engagement in taekwondo research from most researchers. Furthermore, some research domains within taekwondo, particularly those related to physical performance, appear to be developing faster than others, such as sociocultural or pedagogical perspectives.

Keywords: Martial arts; combat sports; taekwondo; bibliometrics; scientometrics; academic production; scientific literature.

Análisis bibliométrico de la producción científica mundial en taekwondo

Resumen

El taekwondo ha experimentado un rápido crecimiento en las últimas tres décadas, consolidando su posición como uno de los deportes de combate más destacados a nivel

Análise bibliométrica da produção científica mundial em taekwondo

Resumo

O taekwondo teve um rápido crescimento nas últimas três décadas, solidificando sua posição como um dos esportes de combate mais proeminentes do mundo. O objetivo

[*] *Corresponding author*: Luis Alberto Cardozo (lcardozo11@areandina.edu.co)

Contributions: Luis A. Cardozo (ABCDEFGHIJKLMN), Gino Salcedo-Gómez (AELMN), Jehison Mateus-Barreto (ABCELM), Eduardo Sáez de Villarreal (JKMN), Diego A. Bonilla (FKMN). Codes according to CRediT (Contributor Roles Taxonomy): (A) Conceptualization. (B) Data curation. (C) Formal Analysis. (D) Funding acquisition. (E) Investigation. (F) Methodology. (G) Project administration. (H) Resources. (I) Software. (J) Supervision. (K) Validation. (L) Visualization. (M) Writing – original draft. (N) Writing – review & editing.

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mundial. El objetivo de este estudio fue analizar la producción académica sobre taekwondo publicada en revistas científicas utilizando métodos bibliométricos. La búsqueda incluyó publicaciones hasta el 31 de diciembre de 2024. Los datos se recogieron de las bases de datos Scopus y Web of Science utilizando los programas Bibliometrix y VOSviewer. Los resultados mostraron que la publicación más antigua data de 1979, con una notable tendencia al alza de publicaciones desde 2010. Se encontraron un total de 1982 referencias, de las cuales 26 acumulan 100 o más citas. Hasta 689 revistas científicas y 4979 autores y coautores estaban asociados a las publicaciones. Se identificaron 2480 instituciones académicas de 80 países, siendo Corea del Sur, China y Brasil los países con mayor número de publicaciones. Además, Corea del Sur y Brasil tenían el mayor número de redes de colaboración internacional. A pesar de la creciente producción científica, este ámbito presenta debilidades estructurales, como una distribución desigual de la productividad de los autores y un compromiso limitado a largo plazo de la mayoría de investigadores para mantener su investigación en taekwondo. Además, algunos ámbitos de investigación dentro del taekwondo, en particular los relacionados con el rendimiento físico, parecen desarrollarse más rápidamente que otros, como las perspectivas socioculturales o pedagógicas.

Palabras clave: Artes marciales; deportes de combate; taekwondo; bibliometría; cienciometría; producción académica; literatura científica.

deste estudo foi analisar a produção académica sobre taekwondo publicada em revistas científicas utilizando métodos bibliométricos. A pesquisa incluiu publicações até 31 de dezembro de 2024. Os dados foram coletados nos bancos de dados Scopus e Web of Science usando os softwares Bibliometrix e VOSviewer. Os resultados mostraram que o manuscrito mais antigo data de 1979, com uma notável tendência de aumento nas publicações a partir de 2010. Foi encontrado um total de 1982 manuscritos, dos quais 26 têm 100 ou mais citações. Até 689 periódicos científicos, 4979 autores e coautores foram associados às publicações. Um total de 2480 instituições acadêmicas de 80 países foi identificado, sendo a Coreia do Sul, a China e o Brasil os países com o maior número de publicações. Além disso, a Coreia do Sul e o Brasil apresentaram o maior número de redes de colaboração internacional. Apesar da crescente produção científica, este domínio apresenta deficiências estruturais, tais como uma distribuição desigual da produtividade dos autores e um compromisso limitado a longo prazo da maioria dos investigadores para manter a sua investigação no taekwondo. Além disso, alguns domínios de pesquisa no taekwondo, especialmente aqueles relacionados ao desempenho físico, parecem estar se desenvolvendo mais rapidamente do que outros, como as perspectivas socioculturais ou pedagógicas.

Palavras-chave: Artes marciais; desportos de combate; taekwondo; bibliometria; cienciometria; produção académica; literatura científica.

1. Introduction

Taekwondo has experienced an important rise in the last three decades, establishing itself as one of the foremost combat sports worldwide, with a prominent presence in prestigious events such as the Olympic Games and World Championships. This success is reflected not only in the significant increase in practitioners but also in the growing audience and prestige achieved in international competitions. Currently, taekwondo is one of the five combat sports in the Olympic program, along with boxing, fencing, judo, and wrestling. Karate, which made its Olympic debut at Tokyo 2020 (International Olympic Committee, 2016), was excluded from Paris 2024.

Scientific and research advancements in taekwondo have also experienced significant growth over time. Undoubtedly, the introduction of sensors and electronic devices in athletes' attire has marked a considerable shift. Innovations such as new competition formats (e.g., the Grand Prix and Kombat Taekwondo), designed to broaden audience appeal through adjusted regulations, alongside increased private-sector sponsorship, have further propelled taekwondo's development and global popularity (Moenig, 2019). These advancements align with broader institutional efforts documented by Choi et al. (2024), who highlight how South Korea's unique integration of taekwondo into education, military, and professional sectors has fostered both technical innovation and cultural prestige. In line with this expanding sports trend, scientific research dedicated to performance analysis in sports has experienced notable growth (Martin et al., 2021). Exploring performance through combat analysis and studying psychophysiological variables influencing sporting success has become a central theme in taekwondo applied sciences (Maloney et al., 2021; Miarka et al., 2015). Combat analysis emerges as a crucial tool for coaches, occupying a prominent place in the scientific literature related to knowledge production in sports (Janowski et al., 2021; Santos et al., 2020).

The significant increase in scientific research in this area positions taekwondo as a fascinating subject for bibliometric analysis. Bibliometric studies comprise quantitative analyses that examine the production, growth, maturation, and consumption of scientific publications through specific techniques (Moral-Muñoz et al., 2020). Researchers, research groups, institutions, and countries resort to bibliographic indices based on various metrics, such as titles, journals, authors, institutions, and number of citations, among others, to assess their impact and relevance in the scientific community (Rubin & Rubin, 2020; Tramullas, 2020). This approach enables a comprehensive

analysis of academic literature, tracking the trajectory of studies at a statistical level and monitoring authors across their various contributions, whether in specialized journals, theses, books, or other sources (Reyes Rodríguez et al., 2019). In this context, bibliometric indicators emerge as valuable measures that provide detailed information on the outcomes of scientific activity in its different manifestations, offering a comprehensive and quantifiable view of the impact and scope of research in the study area (Tomás-Górriz & Tomás-Casterá, 2018).

Bibliometric analysis has become a fundamental tool for evaluating scientific production in various disciplines, including combat sports. Its application has made it possible to identify trends, collaborations, and priority research areas, as evidenced by previous studies on martial arts and combat sports (MA&CS). In this field, research has been developed oriented to the analysis of scientific production in different disciplines, including Olympic combat sports (Correia & Franchini, 2010; Franchini et al., 2018; Gutiérrez-García et al., 2011). Likewise, specific studies have been conducted in disciplines such as karate, both in national and international contexts (Amaral et al., 2022; Gutiérrez-García, Figueiredo, et al., 2018; Pérez-Gutiérrez & Gutiérrez García, 2009), aikido (Gutiérrez-García, Pérez-Gutiérrez, et al., 2018), judo (Peset et al., 2013; Reis et al., 2022) and muay Thai (Muller-Junior & Capraro, 2024).

In the case of taekwondo, studies such as Pérez-Gutiérrez et al. (2015) and Pérez-Gutiérrez et al. (2017) have provided an overview of scientific production up to 2016, identifying predominant themes such as sports performance and collaborative networks. However, these studies have been limited to specific time periods and databases such as the Web of Science (WoS), leaving gaps in understanding recent trends and integrating multiple data sources. For example, Pérez-Gutiérrez et al. (2017) analyzed 340 manuscripts in WoS, identifying seven collaborative networks with a minimum of four authors. However, they acknowledged that using a single database likely underestimated the number of articles, authors, and institutions involved in taekwondo research. Similarly, Pérez-Gutiérrez et al. (2015) highlighted the need to include other databases such as Scopus, PubMed, and Google Scholar to obtain a more complete and realistic view of international research in this field. In addition, studies such as Valdés-Badilla et al. (2014) focused on scientific production in Ibero-America, identifying Cuba, Spain, Brazil, and Mexico as the countries with the highest representation in academic publications on taekwondo. However, this study prioritized the Spanish and Portuguese languages, which limited its scope in a field where most scientific production is published in English. On the other hand, Zong et al. (2023) compared scientific production in China with that of the rest of the world, highlighting that international studies have focused on sports performance and physiological characteristics, while in China, technical and tactical aspects predominate. However, this study only explored in a short period (2010 to 2020) in WoS databases.

In view of the characteristics of the studies mentioned above, there is a need for an updated and comprehensive bibliometric analysis that covers to more recent times and integrates multiple databases, such as Scopus and Web of Science. This approach will make it possible to identify not only thematic trends and international collaborations but also the most influential institutions and authors, as well as emerging research areas. In addition, the use of advanced tools such as Bibliometrix and VOSviewer will facilitate a multidimensional and visual analysis of the scientific production in taekwondo. Therefore, this study aims to analyze academic publications in taekwondo scientific journals indexed in the Scopus and Web of Science databases. In doing so, it will help identify characteristics that guide scientists, highlighting possible research areas, prominent authors and institutions, gaps in scientific knowledge, and opportunities for future collaborations.

2. Methods

This research is part of a larger project approved by Fundación Universitaria del Área Andina. The "Preferred Reporting Items for Bibliometric Analysis" (PRIBA), a set of proposed guidelines to standardize and improve the rigor and transparency in the presentation of bibliometric studies (Koo & Lin, 2023), was considered.

2.1. Data source

Scopus of Elsevier, and Web of Science Core Collection by Clarivate Analytics (this including the Science Citation Index Expanded – SCI-EXPANDED, the Social Sciences Citation Index – SSCI, the

Arts & Humanities Citation Index – AHCI and the Emerging Sources Citation Index – ESCI) databases were used for data retrieval. These databases, which include many high-quality academic publications, guarantee a comprehensive and reliable search. The compatibility of these databases with Bibliometrix and VOSviewer software facilitates data export and subsequent analysis.

The selection of these databases is justified by their suitability for systematic reviews and bibliometric analyses, as demonstrated by the study by Gusenbauer and Haddaway (2020) which classifies them as leading search systems due to their broad coverage, advanced search functionalities (such as Boolean operators, filters, and field codes), and their ability to ensure reproducibility and accuracy in retrieving results.

2.2. Search strategy

The following free terms, suggested in the literature (Pérez-Gutiérrez et al., 2011), were considered for the database search: "taekwondo", "taekwon do", "tae kwon do", "taekwando", "tae kwan do", together with other terms observed in Spanish-speaking literature, such as "taekwon-do", "taekwondistas", and "taekwondocas". The generic boolean search algorithm used in the databases was the following: (taekwondo OR "tae kwondo" OR "taekwon-do" OR "tae kwon do" OR "taekwondistas" OR "taekwondocas" OR "taekwando" OR "tae kwan do")[1].

2.3. Eligibility criteria

The sample of articles included all those published in scientific journals indexed in the selected databases until December 31, 2024, with information retrieval completed on February 8, 2025. Inclusion criteria covered manuscripts in any language and research designs whose main topic was taekwondo. Various types of documents were considered, including original articles, conference papers, reviews, meta-analyses, book chapters, corrections, errata, retractions, case reports, and books. These documents were included because of their importance in producing and disseminating scientific knowledge. Original articles, reviews, and meta-analyses provide key information on taekwondo development, while conference papers, book chapters, and books complement these findings with broader or emerging approaches. Corrections, errata, and retractions were considered to assess scientific transparency, and case reports allow documentation of the specific conclusions of interest. In addition, studies exclusively focused on taekwondo were included, as well as comparative studies in which taekwondo had a significant focus. This process was carried out independently by the researchers LAC and JM-B; in case of disagreement, a third researcher (DAB) was used to make the final decision.

2.4. Bibliometric variables

In this study, several bibliometric variables were analyzed to evaluate the scientific production on taekwondo. These variables included: (i) annual scientific production, which made it possible to identify patterns of growth or decline in research over time; (ii) language of publications, which reflected the linguistic diversity of the scientific literature; (iii) scientific journals, the main sources of knowledge dissemination in this field were highlighted; (iv) authors, whose contributions were evaluated in terms of productivity; (v) most cited papers, which served as indicators of influence in the scientific community; (vi) institutional affiliations, which identified the institutions most active in taekwondo research; vii) scientific production by country, which made it possible to recognize the geographic regions with the greatest scientific activity; viii) collaboration networks between authors and countries, which showed patterns of scientific cooperation; and ix) keywords, both those provided by the authors ("Author's Keywords") and those extracted automatically ("Keywords Plus"), are keywords extracted by algorithms by the Bibliometrix software from the

[1] The specific search chain for Scopus was: (TITLE-ABS-KEY (taekwondo) OR TITLE-ABS-KEY ("tae kwondo") OR TITLE-ABS-KEY ("taekwon-do") OR TITLE-ABS-KEY ("tae kwon do") OR TITLE-ABS-KEY (taekwondistas) OR TITLE-ABS-KEY (taekwondocas) OR TITLE-ABS-KEY (taekwando) OR TITLE-ABS-KEY ("tae kwan do")). For the Web of Science was: taekwondo (All Fields) or "tae kwondo" (All Fields) or "taekwon-do" (All Fields) or "tae kwon do" (All Fields) or taekwondists (All Fields) or taekwondokas (All Fields) or taekwondo (All Fields) or "tae kwan do" (All Fields).

content of the title and abstract of the articles; which made it possible to identify the main themes and emerging trends in the research.

2.5. Analysis of the information

Relevant information from the selected sources was downloaded from the Scopus and Web of Science databases in BibTex format files. The databases were merged, duplicates were removed using RStudio programming software and the 'tosr' and 'tidyverse' packages, using the mergeDbSources functions and the remove.duplicated argument. Subsequently, the resulting documents were subjected to an exhaustive manual review by the researchers, in which the presence of the search terms in the title, abstract, and keywords of each manuscript was verified. This second check aimed to guarantee the accuracy and thoroughness of the selection process, ensuring that the articles included in the analysis strictly met the established criteria. For bibliometric analyses, the 'biblioshiny' package was used, along with specialized software such as Bibliometrix and VOSviewer (Aria & Cuccurullo, 2017; Van Eck & Waltman, 2010).

The average age of the documents was calculated, this metric allows the assessment of the currency of scientific literature in taekwondo. The Bibliometrix software calculated this metric by taking the difference between the year of analysis (2024) and the year of publication of each document and then averaging these values. This indicator is relevant because a low average age suggests that research in an specific field is mostly based on recent publications, indicating a dynamic and constantly updating field, while a high average age could point to a reliance on older studies (Bornmann & Mutz, 2015; Glänzel & Schubert, 2004). In addition, the coefficients of Lotka's Law proposed by Lotka in 1926 were calculated, which described the distribution of scientific productivity among authors, revealing distribution patterns over time and showing the number of authors who contributed the most to the scientific development of taekwondo. This law states that the number of authors publishing *n* articles is inversely proportional to the square of *n*. To evaluate its applicability in the field of taekwondo, the observed data were compared with the values predicted by Lotka's Law, using the formula $y = C/n^2$, where y is the proportion of authors publishing *n* articles and C is a normalization constant (Egghe, 2005; Glänzel, 2007).

The analysis of co-authorship networks was represented by maps where the nodes (circles) represent the authors, and their size reflects the number of papers published by each one. In contrast, the links between nodes indicate co-authorship relationships (Van Eck & Waltman, 2010, 2014). Link strength was calculated, which refers to the intensity of the connection between authors within a cluster and quantifies the number of documents shared between two or more authors. The higher the link strength, the closer the co-authorship relationship between them. At the cluster level, the total link strength was calculated by summing the connections between all the authors belonging to that cluster, making it possible to evaluate the cohesion and collaboration within each group.

A map was drawn up, where the countries with a darker shade correspond to those with a higher representation in authorship and co-authorship of scientific publications in this field, suggesting a greater participation of their researchers in knowledge generation. The additional keywords used by the authors, “Keywords Plus”, were represented visually, where the font size is proportional to the number of times they have been mentioned in the publications.

3. Results

3.1. Search process

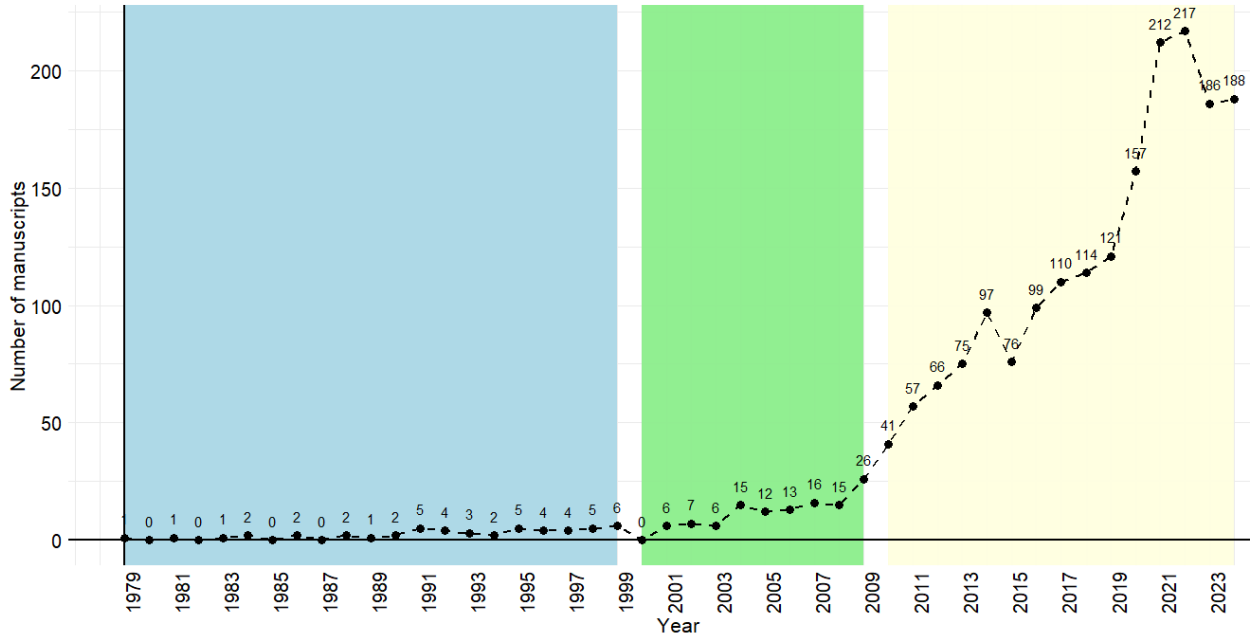
After an initial search using title, abstract and keywords provided by the authors, 1939 manuscripts were identified in Scopus and 1271 in Web of Science, resulting in 3210 records. Software was then used to remove duplicates, reducing the number of potentially eligible manuscripts to 2210. Finally, after manual verification by the authors, the final sample consisted of 1982 manuscripts.

The data analysis revealed the existence of specific publications on taekwondo from 1979 to the data collection date. These manuscripts were classified as follows: 1612 articles (81.3%), 203 conference proceedings (10.2%), 112 reviews and meta-analyses (5.7%), 28 book chapters (1.4%), 10 corrections and errata (0.5%), 10 retractions (0.5%), six commentaries, editorials, and notes

(0.3%), plus a smaller proportion represented by one book (< 0.1%). Of these, 246 documents were by a single author (12.4%), while the rest resulted from collaboration between two or more authors (n = 1736; 87.6%).

The average annual growth rate was 12.34%, with an average document age of 7.54 years. The analysis of the annual scientific production of taekwondo from 1979 to 2024, represented in Figure 1, revealed an irregular evolution marked by three phases: an initial period of very low output (1979–1999, n = 50), moderate growth during the first decade of the 21st century (2000–2009, n = 116), and a remarkable increase after 2010, which peaked in 2022 (total manuscripts in this period = 1816).

Figure 1. Temporal evolution of scientific production on taekwondo.



Research on taekwondo was published in 21 different languages. English stood out significantly, with 1772 publications (89.4%), followed by Spanish (65 publications; 3.3%), Russian (54 publications; 2.7%), Korean (18 publications; 0.9%), Portuguese, Chinese (14 and 13 publications; 0.7% each) and German (10 publications; 0.5%). Other languages were less represented, such as Persian, Ukrainian, French, Italian, Turkish, Czech, Catalan, Croatian, Bulgarian, Polish, Arabic, Slovak, Hebrew, and Danish, each accounting for less than 0.5% of the publications.

3.2. Scientific journals and authorship

As for the scientific journals that have disseminated manuscripts on taekwondo, 689 journals or sources were identified. Of these, the top 20 journals concentrated on 613 manuscripts, representing 30.9% of the total production (Table 1). However, it is important to note that a significant proportion of the journals published few articles on taekwondo, suggesting that the topic, although relevant, was addressed occasionally in many of them. In this regard, 449 journals (65.2%) have published a single article on taekwondo, and 200 journals (29.0%) have disseminated between 2 and 9 articles. On the other hand, 28 journals (4,1%) have published between 10 and 19 articles, 10 journals (1.5%) had between 20 and 47 publications, and only two journals had published more than 64 articles (0.3%).

In terms of authors, 4979 were counted. The average number of authors per document stood at 4.23, with an international co-authorship rate of 17.0%. Additionally, it is noteworthy that the top ten authors with the greatest scientific contribution to this sport accumulated 357 manuscripts (18%). The scientific output of the 10 authors mentioned above exhibited variable behavior over time. Although Emerson Franchini was the author who had contributed most significantly to scientific publications, it was observed that Willy Pieter was the author with the longest research dedication in this field, accumulating approximately 31 years, as depicted in Figure 2.

Table 1. Scientific journals publishing more studies on taekwondo.

Journal	Articles	%	H-index	TC
Archives of Budo	73	3.7%	15	697
Ido Movement for Culture	65	3.3%	11	422
Int. J. of Environmental Research and Public Health	47	2.4%	14	484
Teoriya I Praktika Fizicheskoy Kultury	47	2.4%	4	63
Retos	44	2.2%	6	119
Medicine and Science in Sports and Exercise	40	2.0%	0	7
Revista Brasileira de Medicina do Esporte	38	1.9%	5	92
Journal of Sports Medicine and Physical Fitness	32	1.6%	14	509
Journal of Physical Education and Sport	29	1.5%	8	185
Journal of Strength and Conditioning Research	27	1.4%	22	1192
British Journal of Sports Medicine	20	1.0%	18	1815
PLOS One	20	1.0%	11	341
Perceptual and Motor Skills	19	1.0%	12	509
International Journal of Morphology	18	0.9%	4	66
Science and Sports	18	0.9%	7	253
Journal of Sports Science and Medicine	17	0.9%	11	493
Physical Activity Review	16	0.8%	6	138
Frontiers in Psychology	15	0.8%	7	152
Biology of Sport	14	0.7%	9	226
Journal of Human Kinetics	14	0.7%	10	225

Note: H-index: Maximum number h of articles published in the journal on taekwondo that have been cited at least h times in WoS and Scopus; TC: Total citations in WoS and Scopus.

Figure 2. Author production over time. The size of the circle is proportional to the number of articles published per year (the larger the size, the greater the number of articles in a specific year). The color is proportional to the total number of citations per year (darker color indicates higher citation count)—values expressed in the number of articles and percentage [n (%)].

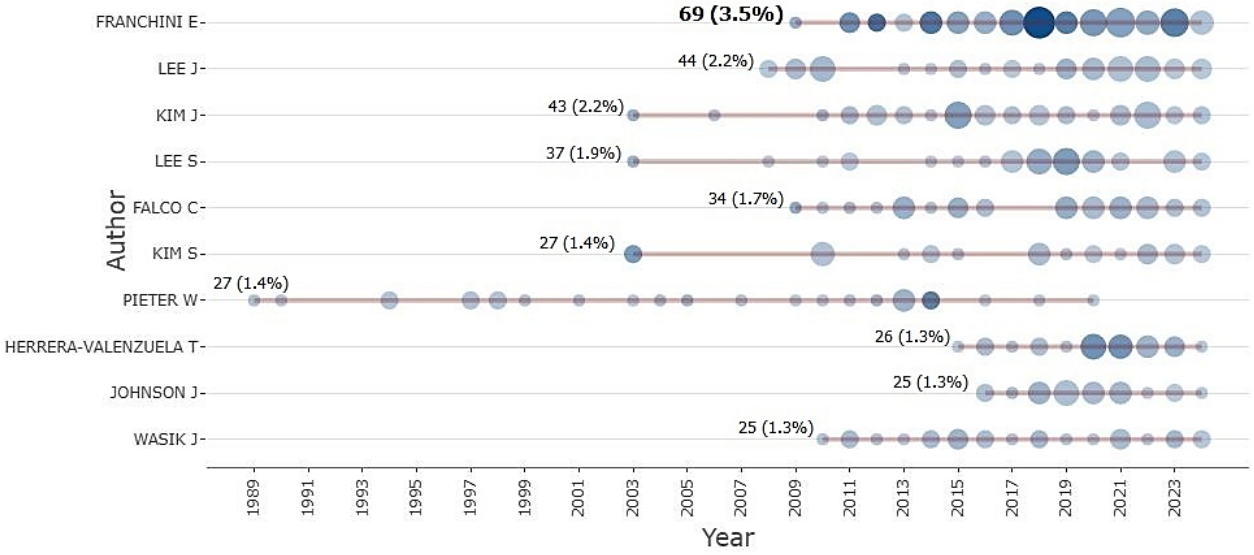


Table 2 shows the frequency distribution of scientific productivity according to the observed data and the values predicted by Lotka's Law. The results show that, although 75.20% of the authors published only one article (which coincides with the prediction of Lotka's Law), the proportion of authors publishing two or more articles is significantly lower than predicted by the law. For example, while 13.60% of authors published two articles, Lotka's Law predicts 18.80%. This discrepancy suggests that taekwondo's scientific productivity distribution does not strictly follow Lotka's Law.

Table 2. Frequency distribution of scientific productivity in taekwondo.

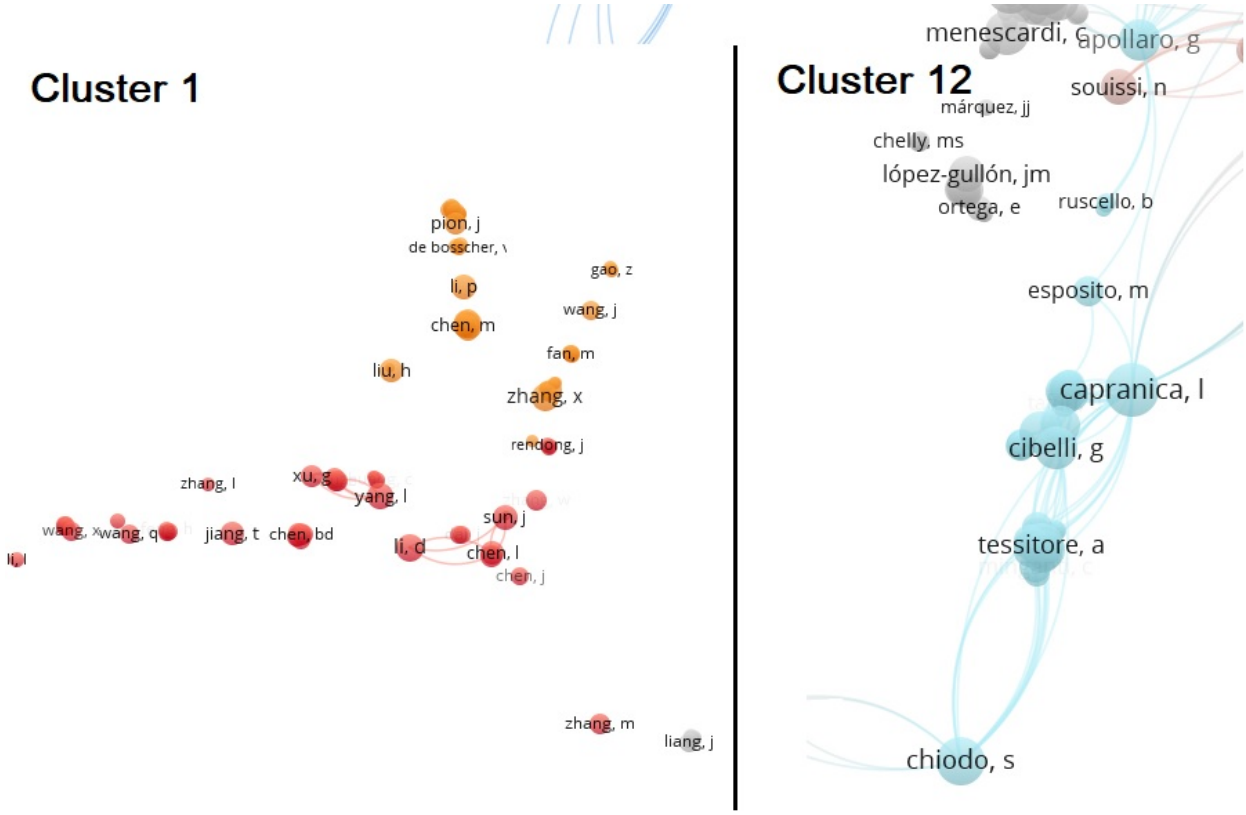
DW	NA	PA	PL	DW	NA	PA	PL
1	3744	75.20%	62.21%	16	3	0.06%	0.24%
2	677	13.60%	15.55%	17	1	0.02%	0.22%
3	224	4.50%	6.91%	18	2	0.04%	0.19%
4	108	2.17%	3.89%	19	2	0.04%	0.17%
5	57	1.14%	2.49%	20	1	0.02%	0.16%
6	45	0.90%	1.73%	21	4	0.08%	0.14%
7	24	0.48%	1.27%	24	3	0.06%	0.11%
8	19	0.38%	0.97%	25	2	0.04%	0.10%
9	12	0.24%	0.77%	26	1	0.02%	0.09%
10	8	0.16%	0.62%	27	2	0.04%	0.09%
11	12	0.24%	0.51%	34	1	0.02%	0.05%
12	10	0.20%	0.43%	37	1	0.02%	0.05%
13	5	0.10%	0.37%	43	1	0.02%	0.03%
14	5	0.10%	0.32%	44	1	0.02%	0.03%
15	3	0.06%	0.28%	75	1	0.02%	0.01%

DW: Documents Written; NA: Number of Authors; PA: Proportion of Authors; PL: Predicted by Lotka's Law.

3.3. Co-authorship networks

The analysis of co-authorship networks resulted in creating an author map using VOSviewer. In this map, the number of documents for each author is visualized through the circle size (node), which is also highlighted with colors (Figure 3).

Figure 3. Examples of scientific collaboration networks in the field of taekwondo (co-authorships). Cluster 1: greater number of authors, cluster 12: greater link strength.



In total, 54 clusters were identified, consisting of 1678 authors whose co-authorship networks were constructed from papers written by a minimum of four authors. The analysis details the co-authorship connections within these clusters, exemplified in Figure 3 through four of the

identified clusters. Table 3 presents the top 24 clusters, organized according to the number of researchers within them. In addition, information on the strength of the links within the network is included and the two researchers with the strongest links are highlighted.

Table 3. Cluster (Networks) and outstanding researchers in each cluster.

Clusters	Leading researchers	nº authors	Link strength
Cluster 1	Li, D and Yang, L	54	352
Cluster 2	Ma, Y and Liu, L	53	640
Cluster 3	Romanenko, V and Podrigalo, I	53	495
Cluster 4	Brito, C and Aedo-Muñoz E	52	713
Cluster 5	Lee, SH and Kim, D	50	303
Cluster 6	Zhang, X and Li, P	49	316
Cluster 7	Cular, D and Nikolaidis, P	48	293
Cluster 8	Herrera-Valenzuela, T and Valdés-Badilla, P	45	702
Cluster 9	Kim, J and Kim, Y	44	366
Cluster 10	Szmuchrowski, L and Couto, B	44	461
Cluster 11	O'Sullivan, D and Lee, SY	43	323
Cluster 12	Capranica, I and Chiodo, S.	41	909
Cluster 13	Park, S and Yoo, S	41	230
Cluster 14	Chou, K and Chen, C	41	358
Cluster 15	Lee, S and Lee, JH	41	284
Cluster 16	Lee, J and Kim, HJ	40	240
Cluster 17	Jeon, M and Kim, E	40	420
Cluster 18	Chaouachi, A and Mejri, M	40	732
Cluster 19	Ouergui, I and Ardigò, L	37	800
Cluster 20	Moenig, U and Kim, M	37	209
Cluster 21	Franchini, E and Alburquerque, M	36	555
Cluster 22	Bertollo, M and Vicente-Salar, N	35	447
Cluster 23	Bridge, C and Hausen, M	35	404
Cluster 24	Reale, R and Naderi, A	32	442

3.4. Citations

As for citations, these correspond to the references received for manuscripts published in journals indexed in the selected databases (Scopus and WoS). The average number of citations per document was 11.42. Of the manuscripts analyzed, 511 manuscripts received no citations (25.8%), 260 received only one citation (13.1%), 172 have had two citations (8.7%), 145 manuscripts have received 3 citations (7.3%), 385 manuscripts have obtained between 4 and 10 citations (19.4%), 222 manuscripts have received between 11 to 20 citations (11.1%), 194 manuscripts between 21 to 50 citations (9.8%), 67 manuscripts between 51 to 99 citations (3.4%). It should be noted that only 26 articles received 100 or more citations (1.3%), for a total of 22627 citations. Table 4 shows the 10 most cited articles, totaling 3180 citations.

Likewise, among the manuscripts analyzed, the ten most cited authors in the bibliography consulted were Emerson Franchini with 1907 citations, followed by Willy Pieter with 976. They are followed by Junhyoung Kim (n = 583), Coral Falco (n = 578), and Suhyun Kim (n = 419). Rounding out the list are Sae Yong Lee (n = 365), Tomás Herrera-Valenzuela (n = 282), Jacek Wąsik (n = 299), Jung-Min Lee (n = 267), and John Arthur Johnson, with a total of 159 citations.

3.5. Institutions and countries represented

Regarding the authors' institutional affiliations, 2480 institutions that contributed to taekwondo's scientific knowledge were identified. The 15 institutions with the highest scientific

production are detailed in Table 5, accumulating 844 manuscripts. This represents 42.6% of the total production in this field.

Table 4. Most cited documents on taekwondo.

Author	Article	TC	TC/year
Ryan et al. (1997)	Intrinsic motivation and exercise adherence.	678	23,4
Engebretsen et al. (2013)	Sports injuries and illnesses during the London Summer Olympic Games 2012.	470	36,2
Junge et al. (2009)	Sports injuries during the Summer Olympic Games 2008.	414	24,4
Soligard et al. (2017)	Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: A prospective study of 11274 athletes from 207 countries.	286	31,8
Lakes & Hoyt (2004)	Promoting self-regulation through school-based martial arts training.	283	12,9
Pfister et al. (2016)	The incidence of concussion in youth sports: a systematic review and meta-analysis.	247	24,7
Bridge et al. (2014)	Physical and physiological profiles of taekwondo athletes.	226	18,8
Blouin & Goldfield (1995)	Body image and steroid use in male bodybuilders.	201	6,5
Iso-Ahola & Park (1996)	Leisure-related social support and self-determination as buffers of stress-illness relationship.	197	6,6
Brito et al. (2012)	Methods of body mass reduction by combat sport athletes.	178	12,7

TC: total number of citations the manuscript has received since its publication; TC / year: average number of total citations per year.

Table 5. Universities with the highest scientific productivity in taekwondo.

Institution	Country	Articles
University of São Paulo	Brazil	88
Kyung Hee University	South Korea	85
Selcuk University	Turkey	69
Korea National Sport University	South Korea	57
Yonsei University	South Korea	57
University of Jendouba	Tunisia	56
Universidade Federal de Minas Gerais	Brazil	55
National Taiwan Sport University	Taiwan	53
Youngsan University	South Korea	51
Jan Dlugosz University of Czestochowa	Poland	48
University of Valencia	Spain	48
Dong-A University	South Korea	46
University of Split	Croatia	45
Keimyung University	South Korea	44
Universidad de Santiago de Chile	Chile	42

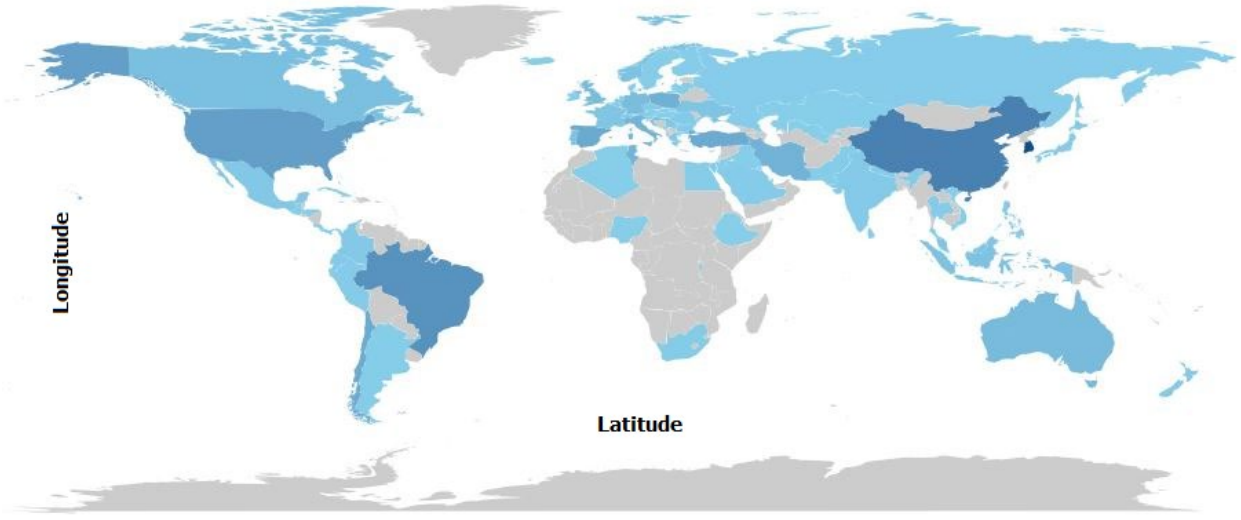
On the other hand, with respect to the institutional affiliations mentioned in the articles analyzed, 1420 institutions appear in a single article (57.7%), while 498 appear in two articles (20.2%) and 199 in three articles (8.1%). Likewise, 116 institutions are present in four articles (4.7%) and 147 in a range of five to ten articles (6.0%). In smaller proportions, 54 institutions are found in 11 to 20 articles (2.2%), 11 in 21 to 30 articles (0.4%), 8 in 31 to 50 articles (0.3%) and, finally, only 9 institutions have been mentioned in more than 50 articles (0.4%). Figure 4 visually represents the geographical distribution of scientific production in taekwondo research based on the affiliation of the authors and co-authors of the analyzed manuscripts.

The geographic distribution of researchers publishing on taekwondo encompassed 80 countries. Analysis revealed a highly uneven production pattern:

- *High-output countries* (>100 publications): South Korea dominated significantly (n=937), followed by China (543), Brazil (422), the United States (326), Spain (251), Turkey (242), Chile (237), Poland (200), Iran (188), Ukraine (187), Tunisia (180), and Italy (179).
- *Moderate output* (50-100 publications): Australia (129), Germany (118), Canada (98), Croatia (94), Indonesia (79), Norway (79), and Portugal (78).
- *Limited output* (20-50 publications): Malaysia (57), France (53), Mexico (36), Serbia (35), Greece (33), Colombia (30), Romania (24), Ecuador (22), New Zealand (22), India (21), Czech Republic (20), and Japan (20).
- *Minimal output* (10-19 publications): 18 countries, including Belgium (19), Israel (18), Switzerland (18), Jordan (16), the Netherlands (16), South Africa (16), Bulgaria (15), Costa Rica (14), Thailand (14), Philippines (13), Peru (12), Saudi Arabia (12), Singapore (12), Argentina (11), Denmark (10), Pakistan (10), Slovakia (10), and Sweden (10).
- *Marginal output* (<10 publications): Among the 37 countries demonstrating limited contributions, the distribution was as follows: two nations had 9 publications each (Cuba, Qatar), one country had 8 (Slovenia), four countries showed 7 publications each (Egypt, Iceland, Latvia, Sri Lanka), two countries had 6 (Austria, Nepal), three countries produced 5 publications each (Finland, Lithuania, Russia), two countries registered 3 publications (Kazakhstan, Panama), eight countries had 2 publications (Bahamas, Guatemala, Honduras, Hungary, Ireland, Lebanon, Montenegro, Vietnam), and eight countries appeared with just 1 publication (Algeria, Burundi, Ethiopia, Iraq, Kuwait, Monaco, Nigeria, Uzbekistan).

This distribution reflected a strong geographic concentration, with 81.3% of total output originating from just 15 countries. Additionally, researchers from 69 countries have collaborated on scientific publications in this field. Among the top ten countries with the highest number of international research collaborations (authorships and co-authorships) are Brazil (n = 170), the United States (n = 165), and the United Kingdom (n = 123). Other countries with significant participation in collaborative research networks include Tunisia (n = 109), Norway (n = 100), Spain (n = 98), Canada (n = 96), Italy (n = 87), South Korea (n = 80), and China (n = 79).

Figure 4. Geographical distribution of authorship and co-authorship in taekwondo research. The countries with a darker shade correspond to those with a higher representation in this field.



3.6. Keywords ("Author's Keywords" and "Keywords Plus")

The authors have provided a total of 4252 keywords in their respective publications. The 10 most used keywords, excluding "taekwondo", "martial arts" and "combat sports" (Author's Keywords), are: "athletic performance", "exercise", "sport injury", "body composition", "physical fitness", "biomechanics", "muscle strength", "postural balance", "heart rate" y "adolescent". In addition, Figure 5 shows the 50 most frequent additional keywords or "Keywords Plus".

Figure 5. Most frequent keywords in academic publications.

4. Discussion

This study aimed to analyze academic publications in scientific journals on taekwondo using bibliometric methods. The results reveal that scientific production in taekwondo has experienced progressive growth since 2000, with a significant increase in the last decade. This growth can be attributed to multiple factors, both internal and external to the field of taekwondo. On the one hand, its inclusion in the Sydney 2000 Olympic Games and subsequent modifications to competition rules, such as the elimination of the "golden point" and the reduction in the number of rounds, have altered the dynamics of the sport, making it more attractive to spectators and practitioners while simultaneously driving research interest in this sport (World Taekwondo Council, 2024). Also, the increase in academic literature on taekwondo can be explained by the proliferation of English as the academic lingua franca, which has facilitated greater collaboration and dissemination of research findings internationally. Advances in internet communication have also reduced barriers to collaboration among researchers, fostering joint projects and publications. Furthermore, academic evaluation criteria, which require researchers to publish in journals indexed in databases such as Scopus and Web of Science, have motivated an increase in scientific production (Wang et al., 2015).

This significant rise in scientific publications over the last two decades can be attributed not only to the general development of sports sciences but also to the expansion of database coverage, which includes the incorporation of new journals and the strengthening of existing ones (Wang et al., 2015). As suggested by Gutiérrez-García et al. (2018) in studies on karate, this growth may be due to specific factors related to the "sportification" of taekwondo. This process, understood as the transformation of a traditional martial art into a modern and competitive sport (Villamón et al., 2002), has been influenced by multiple elements, including administrative and logistical aspects, generating growing interest in the scientific community and motivating increased research focused on analyzing these changes' effects on athletic performance, tactics, and physiology. Similar trends have been observed in judo, likely due to its own process of sportification (Villamón et al., 2002).

Consistent with previous research on MA&CS, the results of this bibliometric study on taekwondo confirm the predominance of articles as the primary medium for scientific dissemination. For example, Gutiérrez-García et al. (2018) reported that 85.6% of research on aikido was published in the form of articles, while book chapters and books accounted for only 11.1% and 3.3%, respectively. Similarly, Franchini et al. (2018) noted that in Olympic combat sports, 75.14% of research was disseminated through articles. In the present study, this trend persists, with 81.5% of scientific production on taekwondo published as articles (1834 articles), reinforcing the importance of this communication channel in the academic and scientific realm. This pattern reflects a preference for articles due to their accessibility, global reach and rapid dissemination of research advances.

However, the constant annual increase in academic publications related to taekwondo poses a significant challenge, as many manuscripts tend to become obsolete over time. The half-life of publications varies significantly depending on the field of study: in areas such as health sciences, where innovation is rapid, documents often have a shorter half-life, while in humanities and some

social sciences, publications may remain relevant for decades (Larivière et al., 2008). In the case of taekwondo, which combines aspects of sports science, health, and humanities, this phenomenon is particularly complex. On the one hand, the rapid evolution of the field may render previous research less relevant, especially in areas related to athletic performance and physiology. On the other hand, there is a valuable body of classical literature that preserves essential theoretical and philosophical principles, given that taekwondo is not only a combat sport but also originates from a martial art deeply rooted in history (Martínez Guirao, 2018). This duality highlights the need for strategies to adequately preserve and contextualize these foundations within the current landscape of taekwondo research, balancing scientific innovation with respect for its historical and philosophical roots.

As expected, English is the predominant language in academic publications on taekwondo. This phenomenon reflects the publication norms adopted by scientific journal editorial teams, which aim to enhance visibility, scientific dissemination, and meet the metrics used by databases and other organizations to evaluate the impact of such publications (Wang et al., 2015). The widespread use of English as the primary language in academic research contributes to the global accessibility of findings, facilitating their dissemination and promoting communication among the international scientific community (Di Bitetti & Ferreras, 2017).

However, it is important to acknowledge a potential bias in this study due to the selection of databases such as Scopus and Web of Science (WoS), which prioritize English-language publications. This bias may lead to the under-representation of research published in other languages, particularly in disciplines where publishing in local languages is more common, such as history, literature, philosophy, law, etc., and the under-representation of the literature produced in countries where specific martial arts were born. For example, in combat sports like capoeira and hapkido, the predominant language for dissemination has been the native language of each discipline, Portuguese and Korean, respectively (Ferreira da Cruz & Correa, 2024; Johnson & Kang, 2018). Despite this limitation, the predominance of English has been consistently observed in bibliometric studies of other combat sports, such as judo, where 87.2% of articles indexed in WoS were in English (Peset et al., 2013); karate, with 90.89%; and Muay Thai, indexed in Scopus and WoS with 82% (Amaral et al., 2022; Muller-Junior & Capraro, 2024). These results highlight the global trend toward English as the lingua franca of scientific communication, while underscoring the need for future studies to consider alternative databases or multilingual approaches to capture a more comprehensive picture of research in taekwondo and related disciplines.

On the other hand, the data suggest that knowledge about taekwondo is distributed across multiple journals, with only 30.9% of publications concentrated in a small group of specialized journals (20 journals), while the majority are dispersed across various sources. This pattern has also been observed in academic publications on karate, where 12 journals accounted for only 34.8% of a total of 202 journals (Amaral et al., 2022). A similar phenomenon was reported in judo publications up to 2011 (Peset et al., 2013). In contrast, Pérez-Gutiérrez et al. (2017) found a higher percentage of academic publications concentrated in a smaller group of journals compared to the present study on taekwondo. In their research, covering the period from 1988 to 2016, they identified that a smaller number of journals (29 in total) housed a significantly larger proportion of publications (60.59%).

The current study identified *Archives of Budo* (n=73) and *Ido Movement for Culture* (n=65) as the journals with the highest publication output on taekwondo, aligning with Pérez-Gutiérrez et al. (2017) findings where *Archives of Budo* was the primary dissemination source (n=36). Notably, we observed significant dispersion of literature across 689 distinct journals and sources, indicating both substantial growth in scientific production and diversification of dissemination channels. This pattern mirrors trends in other combat sports: Franchini et al. (2018) documented 189 sources for Olympic combat sports, Reis et al. (2022) reported 191 for judo, and Amaral et al. (2022) identified 202 for karate. Comparative analysis reveals *Archives of Budo* consistent prominence across disciplines, being top-ranked in judo studies (Caravaca et al., 2018; Peset et al., 2013) and second-ranked for Olympic combat sports (Franchini et al., 2018), though Pérez-Gutiérrez et al. (2015) found more general journals (*Journal of Strength and Conditioning Research*, *British Journal of Sports Medicine*) leading during 1989-2013. These findings demonstrate not only a growth in scientific production related to MA&CS such as taekwondo, but also an increase in specialized journals in this field.

The analysis of authorship patterns in taekwondo research reveals a distinctive productivity distribution characterized by: (1) a substantial transient researcher base (75.2% of authors, n=3744, producing single publications, aligning partially with Lotka's predicted 62.2%), and (2) an exceptionally small core of dedicated scholars - evidenced by only 13.6% authoring two papers (vs. 15.6% predicted) and a 4.5% producing three papers (vs. 6.9% predicted). This structural imbalance is personified by the extreme productivity differential between occasional contributors and leading researchers, such as Emerson Franchini (highest output) and Willy Pieter (sustained longitudinal contributions), who exemplify the limited cohort driving the field's development. The observed 17.0% international co-authorship rate primarily reflects collaboration patterns within this small, productive core rather than widespread networking across the discipline. Collectively, these findings suggest that taekwondo research faces not a shortage of researchers, but rather a critical challenge in retaining scholars for sustained engagement, a pattern substantiated by bibliometric theory (Egghe, 2005; Glänzel, 2007).

These findings partially contrast with previous studies on taekwondo. For instance, earlier research identified Pieter as one of the most prolific authors (Pérez-Gutiérrez et al., 2015, 2017), but did not analyze in depth the distribution patterns of multi-publication authors as this study does. The deviation from Lotka's Law observed here does not necessarily suggest that taekwondo has unique characteristics affecting scientific productivity. Rather, it reflects the early developmental stage of taekwondo as an academic field. As a relatively young and still-consolidating area of study, it is expected to exhibit a less balanced authorship structure, with a heavy reliance on a small group of prolific contributors and limited long-term engagement from the broader scholarly community. This interpretation aligns with bibliometric theory, which associates such patterns with emerging disciplines (Egghe, 2005).

In relation to institutions, most articles originate from universities in South Korea, followed by Brazilian universities, an aspect previously noted in the study by Pérez-Gutiérrez et al. (2015), where South Korea accounted for 17.6% of total publications. These results provide a unique perspective, as other bibliometric studies in this sport had not identified specific institutions. For example, in previous studies, institutions were primarily presented based on the co-authorships of the most productive researchers (with more than 5 publications) and collaboration networks (with more than 3 members), which could marginalize novice researchers or those with lower scientific output (Pérez-Gutiérrez et al., 2017; Valdés-Badilla et al., 2014). In contrast, the present study ranks institutions based on the count of affiliations mentioned in manuscripts, providing a broader and more representative view of institutional contributions. In total, 2462 institutions were recorded in this study, reflecting the geographical diversity and global reach of taekwondo research. The most prominent institutions include the University of São Paulo (Brazil), Kyung Hee University (South Korea), and Selcuk University (Turkey). These figures not only highlight the leadership of institutions in Asia and South America, but also the active participation of universities from other world regions, such as the University of Jendouba (Tunisia), Jan Dlugosz University of Czestochowa (Poland), and the University of Valencia (Spain). Notably, Selçuk University, located in Turkey, a transcontinental country bridging Asia and Europe, also illustrates the discipline's expanding academic footprint across multiple continents.

When examining the geographical location of the institutions listed as authors' affiliations, they come from most continents, including the Americas, Europe, Asia, Oceania, and, to a lesser extent, Africa. This panorama reflects the remarkable global expansion that taekwondo has experienced over the years, as well as the growing collaboration among institutions from different regions, which enriches knowledge and innovation in this field, an aspect already noted in previous studies on scientific production in this sport (Pérez-Gutiérrez et al., 2017). The geographical diversity of the institutions involved in taekwondo research underscores its international relevance and increasing academic interest.

Looking at co-authorship networks, clusters tend to be composed of researchers from the same institutions or from nearby institutions in the same geographical region. A clear example of this trend is observed in clusters 1, 2, 5, 6, and 9, among others, which are primarily composed of authors from South Korea, clusters 10 and 21, which include authors from Portuguese-speaking countries (Brazil and Portugal), and clusters 17 and 18, mainly composed of authors from Tunisia. While the

native language of authors could be considered a potential barrier to international collaboration, 89.5% of published articles are written in English, suggesting that most researchers are capable of communicating in this language (Amano et al., 2016). However, it is more plausible that the formation of these co-authorship networks is driven by practical factors, such as geographical proximity, shared access to resources (e.g., laboratories and equipment), joint funding acquisition, and the ease of local collaboration (Jones et al., 2008). These factors promote frequent interaction and teamwork, promoting the formation of research clusters based on specific institutions or regions.

Similarly, Peset et al. (2013), in their analysis of judo, identified that the largest clusters were centered around authors such as Yamamoto, Franchini and Filaire, who occupied central positions in transnational co-authorship networks. These clusters included researchers from up to six research centers located in four different countries, highlighting greater geographical diversity. However, these cases also reflected limitations in overall connectivity, as only a small percentage of authors (74, with a threshold of ≥3 collaborations) were part of these networks. Overcoming these barriers, including linguistic and logistical ones, could foster greater diversity and global collaboration in taekwondo research, as has been observed in other martial arts (Peset et al., 2013).

These findings partially coincide with those of Pérez-Gutiérrez et al. (2017), who identified co-authorship networks in taekwondo centered around authors such as Pieter and Wasik, who occupied central positions in transnational clusters. However, in their study, most collaborations were also concentrated in institutions from the same geographical region, reinforcing the idea that proximity and shared resources are key factors in the formation of co-authorship networks. Although both studies show a trend toward local collaboration, the work of Pérez-Gutiérrez et al. (2017) also highlights the presence of some clusters with greater geographical diversity, suggesting that while local collaboration is predominant, opportunities exist to expand these networks globally.

The most cited documents in this study reflect key themes that have significantly influenced research on taekwondo. The most cited article, Ryan et al. (1997), which addresses intrinsic motivation and exercise adherence, has laid the groundwork for understanding the psychological factors influencing participation and performance in sports like taekwondo. Similarly, studies such as Engebretsen et al. (2013) and Junge et al. (2009), which analyze sports injuries during the Olympic Games, have provided crucial evidence on the epidemiology of injuries in combat sports, driving the implementation of preventive measures and safety protocols. Other highly cited works, such as Lakes and Hoyt (2004), which explores the impact of martial arts on self-regulation and personal development, and Bridge et al. (2014), which describes the physical and physiological profiles of taekwondo athletes, have contributed to expanding knowledge on the psychological benefits and specific physical demands of this sport. These studies have not only had a lasting impact on the scientific literature but have also guided clinical practice and training in taekwondo.

The analysis of “Author's Keywords” reveals a high degree of variability in the terms used, with a total of 4,347 registered keywords. The most frequently used keywords reflect a predominant focus on physical and performance-related dimensions in taekwondo research, consistent with broader trends in the combat sports literature. Additionally, the inclusion of supplementary terms through “Keywords Plus” in both taekwondo and other combat sports, such as judo, reinforces the relevance of topics related to physical preparation, training, and injury prevention within the scientific literature (Amaral et al., 2022; Reis et al., 2022). Our data show that eight of the top ten keywords (excluding generic terms like “taekwondo”) refer directly to physiological or biomechanical aspects, whereas psychological and pedagogical elements appear only marginally. This emphasis on physical performance mirrors patterns found in karate research, where biodynamic and training-related terms dominate the thematic landscape, although with a comparatively greater representation of technical-tactical components (Amaral et al., 2022).

Notably, there is an almost complete absence of keywords related to the philosophical foundations or sociocultural dimensions of taekwondo, suggesting a disconnection between the traditional values of the sport and contemporary scientific research (Zong et al., 2023). While the prevalence of studies focusing on injury prevention and physiological adaptation reflects the evolution of taekwondo as an Olympic sport, this narrow focus may overlook critical aspects of athlete development, particularly psychological resilience and pedagogical approaches unique to martial arts.

5. Limitations and future directions

One limitation of the study lies in the difficulty that databases sometimes encounter in unifying authorships. This occasionally depends on the variability with which authors report their authorship in a manuscript or on journal citation norms. For instance, databases and data analysis software may consider two or more distinct authors with the same last name and initials as a single author. This situation is also reflected in how institutional affiliations are mentioned in publications, leading to biases in the reported data. To address this difficulty, the results of the software analyses were subsequently reviewed manually, making the necessary adjustments. Additionally, it was not possible to consolidate and clearly define the study subareas according to Scopus and Web of Science databases due to the lack of standardization between them; each presents its own classification.

6. Conclusions

This bibliometric study provides a detailed overview of research in taekwondo, highlighting key aspects such as the distribution of authors, institutions, co-authorship networks, languages, journals, and countries. The results show a progressive growth in scientific production, with a significant increase in the number of publications over the last two decades. This growth reflects the growing interest of the scientific community in taekwondo, solidifying it as a relevant field of study. Authorship patterns reveal a high proportion of transient contributors and a remarkably small group of prolific researchers. Although the observed distribution partially aligns with Lotka's Law, notable deviations, such as a lower-than-expected number of multi-publication authors, suggest structural features typical of emerging academic disciplines. These include limited long-term engagement from most researchers and a strong dependence on a small core of highly productive authors.

The most prominent institutions are primarily concentrated in South Korea, China, Brazil, and Turkey, reflecting the leadership of these regions in taekwondo research. Additionally, the analysis of co-authorship networks revealed that collaborations tend to cluster by geographic proximity or institutional affiliation, suggesting that practical factors, such as shared access to resources and the ease of local collaboration, play an important role in the formation of these networks. The predominant language in publications is English, which facilitates the global dissemination of findings and promotes international collaboration.

Finally, this research provides a solid foundation for academics, institutions, and sports organizations to identify collaboration opportunities, prioritize research areas, and develop evidence-based policies. The information presented not only contributes to a better understanding of the structure and dynamics of taekwondo research but also serves as a guide to strengthen the field and promote a more comprehensive and sustainable development of this sport globally.

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Authors' biographical data

Luis A. Cardozo (Colombia). PhD student, academic researcher and professor at the Fundación Universitaria del Área Andina. Researcher in the fields of combat sports, taekwondo and sport. E-mail: lcardozo11@areandina.edu.co

Gino Salcedo-Gómez (Colombia). National technical coach of the Bogota Taekwondo team and university coach. Taekwondo League of Bogota and Universidad del Rosario. VIII DAN Taekwondo. E-mail: ginosalcedo2003@yahoo.es

Jehison Mateus-Barreto (Colombia). Athlete of the Colombian Taekwondo team. Taekwondo coach. Professional Program in Sports Training, Fundación Universitaria del Área Andina. III DAN Taekwondo. E-mail: jmateus14@estudiantes.areandina.edu.co

Eduardo Sáez de Villarreal (Spain). Doctor Full Time at Pablo de Olavide University. Full Professor of the University. E-mail: esaesae@upo.es

Diego A. Bonilla (Colombia). PhD candidate. Scientific Director at Dynamical Business & Science Society – DBSS International SAS. Senior researcher (MinCiencias #957 SNCTI) and NSCA Colombia Board Advisor. E-mail: dabonilla@dbss.pro