

# Scientific literature analysis of Judo in *Web of Science*<sup>®</sup>

## Authors' Contribution:

- A Study Design
- B Data Collection
- C Statistical Analysis
- D Manuscript Preparation
- E Funds Collection

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## Abstract

### Background

Although *judo* is a sport with great tradition that is practised worldwide, the state of the art and scientific advances have not been analysed from a bibliometric point of view up to now.

### & Study Aim:

The aim of the present article is the status of the scientific production, collaboration, and impact of scientific papers on *judo*, as well as the most active research groups working on this topic.

### Material & Methods:

Our analysis was based on documents retrieved from the Science Citation Index and Social Science Citation Index. Bibliometric analysis and network construction were performed using Histcite and Bibexcel software.

### Results:

As a result, 383 original papers and scientific reviews were retrieved from 162 journals in 78 *Web of Science*<sup>®</sup> categories. *Archives of Budo* had the highest number of articles (56), and *International Journal of Sports Medicine* had the highest number of citations (192). More than half of the articles were within the area of sports science. The co-authorship network (threshold  $\geq 3$  articles) enabled us to identify 6 clusters of authors written in partnership. The citation network was formed mainly by 14 authors.

### Conclusions:

Although research on *judo* is still at an early stage and has a lower profile than other sports, its development has potential interest to many scientific fields and sports in general. *Judo* research is mainly published in journals covering sport science and sport medicine topics; the latter being the most cited ones. The co-authorship networks tended to be centralized, with a single lead author, while citation networks between authors were usually directed towards other areas of research.

### Key words:

judo • combat sport • martial arts • bibliometrics • cooperative behaviour • social networks • citation network • scientific literature databases • sport journals • sports medicine journals

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**Judo** – Literally meaning “the way of gentleness”, is a dynamic combat sport that demands both physical prowess and great mental discipline. Furthermore, Judo is commonly described as a fighting art, a spiritual discipline, a system of physical education, and a recreational activity.

## BACKGROUND

*Judo* has been defined as “a combat sport based on direct encounter of two opponents” [1]. It is an Olympic sport with great physical, technical, and tactical complexity [2] and has spread worldwide during the past 50 years. More than 180 countries are now affiliated to the Judo Federation [3]. Although there are no exact

data about the number of practitioners of *judo*, its popularity is unquestionable [4]. This popularity is due to the fact that *judo* not only develops the physical capability of its practitioners but is also useful as an educational and social tool [5–9].

In *judo*, the cultural aspects that surround the practice of the sport are important, mainly owing to its traditional

origin, in Japan. Knowledge about the discipline of *judo* has been transmitted mainly through practice, from *judo* master to practitioners. This fact is confirmed by the small number of scientific or technical documents about *judo* until approximately 20 years ago. The scientific aspects of *judo* did not appear until the 1960s, with the emergence of the former Iron Curtain countries, which applied new training methodologies [10]. In these methods, the physical components of *judo* became relevant, being a revulsive for the beginning of research in *judo*. Nevertheless, the sport of *judo* has been characterised by its resistance to changes, whether these changes are due to developments in society or to the application of scientific principles. Until recently, there were practically no scientific congresses that brought together knowledge of this sport.

Despite these limitations, a search in the main scientific databases (e.g. *Web of Science*<sup>®</sup>, *Scopus*) has revealed that *judo* studies have been published in high ranked peer-reviewed journals. However, a closer look shows that the number of original contributions is reduced and there are only a few reviews concerning particular and concrete aspects of *judo* [11–16]. This situation also affects research on other sports leading to low quality papers in sports science [17].

It seems clear that there are difficulties in understanding the general state of research on *judo*. However, it might be useful to apply bibliometric methods, which refers to the mathematical and statistical analyses of scientific publications [18]. Such methods enable the identification of papers that deal with a specific topic and the social and logical relationships among the main actors that are involved in a particular science.

According to Broadus [19], **bibliometrics** can be defined as “the quantitative study of physical published units, bibliographic units, or surrogates for either. Bibliometric techniques have been used primarily by information scientists to study the growth and distribution of the scientific articles. Researchers may use bibliometric methods of evaluation to determine the influence of a single writer, for example, or to describe the relationship between two or more writers or works” [20].

To the best of our knowledge, there has been no previous bibliometric analysis of *judo*. Beginning this complex task might help to identify the strengths and weaknesses of *judo* as a research topic. Therefore the aim of the present article is the status of the scientific production, collaboration, and impact of scientific papers on *judo*, as well as the most active research groups working on this topic.

## MATERIAL AND METHODS

### Data collection

The articles for the study were extracted from the Science Citation Index (SCI) and Social Science Citation Index (SSCI), which were accessed via WoS (*Web of Science*<sup>®</sup>, Thomson Reuters, New York, USA). The search strategy used the general term *judo*. We decided to use only one term to achieve a greater precision about the contents [21]. This strategy was used previously in one of the reviews that exist on this subject [16]. *Judo* is a widely used and accepted word in most of the languages that are represented in the above databases. Consequently, any search about this sport will use *judo* in any of the fields encompassed by the meta-field topic.

The study was limited to research articles in the strict sense, including original papers and reviews. The following was excluded: letters, editorials, book reviews, conference abstracts, and news and bibliographic articles. The search was performed on June 18, 2011. There was no limit on publication year or language. The initial search retrieved 384 items. All records were stored on hard disk in plain text format for further analysis.

### Bibliometric analysis and construction of a scientific and citation network

Before performing the bibliometric analysis, we checked for any duplicate records. The authors' names were standardized, accounting for possible misspellings of names and initials.

For resolving synonymy or homonymy phenomena in author names, we used other specific fields, such as “author address” [22]. Unfortunately, the WoS database does not provide addresses for all co-authors; therefore, in those cases where the question could not be resolved, an additional search was done through Google to clarify this question. In order to organise the names of the institutions of the authors, the ones that were found in the articles were selected. In case that a research changed the institution address with time, the most current was chosen.

To perform the bibliometric analysis and build a citation network two softwares were used Histcite (version 10.12.6; HistCite Software LLC, New York, USA) and Bibexcel (version 2011-02-03; Olle Persson, Umeå University, Umeå, SWE). The analysis was conducted in two parts: (1) the basic bibliometric indicators were calculated; and (2) a co-occurrence analysis was performed to establish the relationships between the authors and the citation of scientific papers.

**Bibliometrics** – The use of statistical methods in the analysis of a body of literature to reveal the historical development of subject fields and patterns of authorship, publication, and use. Formerly called statistical bibliography.

The following categories of indicators were calculated for the papers on *judo*:

1. Scientific productivity ranking and patterns of author collaboration: number of published documents, number of published documents per year, number of authors, citation analysis, collaboration index or average number of authors per document, number of collaborators.
2. Analysis of the most productive journals: number of published documents, number of citations in the collection to the journal (Total Local Citation Score; TLCS), total citations in WoS to papers in the journal in the collection (Total Global Citation Score; TGCS).
3. Analysis of topical areas: number of documents in each area.
4. Analysis of the most usual words: number of words in the title field.

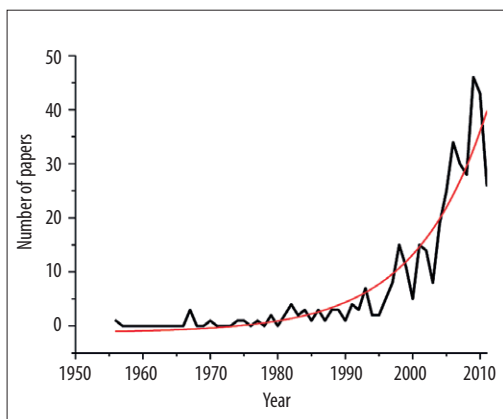
In the second phase, a structural analysis was carried out in which networks were established. For each document, all co-authorships (combinations of pairs of authors) were identified, the number of such relationships being in proportion to the number of authors. Thus, in a publication with a single author there was no co-authorship; with two authors there was a single co-author relationship; with three authors, three relationships (A with B, A with C, B with C); with four authors, six relationships (A with B, A with C, A with D, B with C, B with D and C with D), and so on [23].

With regard to the references in the papers, a citation map was generated that showed the citation relationships among various papers.

### Representation of the scientific and citation networks

To represent the scientific and citation networks that were obtained, we used the program Pajek (version 1.28; Batagelj and Mrvar, University of Ljubljana, Ljubljana, Slovenia). The number of co-occurrences between authors and between citations was high, and this made graphic representation difficult. For a simplified representation of the network, only those which reached a minimum intensity between the relationships are shown. Thus, the representation only shows clusters that contained at least three members for the scientific network or references for the citation network

In addition to the network maps, we generated a density map of citations with VOSviewer (version 1.3.2; Nees Jan van Eck and Ludo Waltman, Leiden University, Leiden and Erasmus University, Rotterdam, Netherlands). The colour of each point in the map depended on the density of items at that point (i.e. red colour means greater



**Figure 1.** Number of articles published on judo in the SCI and SSCI. The black line represents the number of articles published every year. The red line represents the exponential adjustment of the article series.

density while blue colour refers to lower density). The density of the point on the map was calculated using the number of neighbouring items and the weight of the items (using a Gaussian kernel function). A more detailed explanation of this algorithm can be found in the article of Van Eck and Waltman [24]. The larger the number of items in the neighbourhood of a point and the higher the weights of the items, the closer the colour of the point was to red. Conversely, the smaller the number of items in the neighbourhood of a point and the lower the weights of the items, the closer the colour was to blue.

In those cases where the subject allowed it, the maps were depicted in areas of the institution affiliation of each author.

## RESULTS

### General data

The search of the WoS database retrieved 384 articles. After review, we discarded one duplicate item, being  $n=383$  the total of articles analysed in this study. The first original article on *judo* that was indexed in the database was dated 1956 [25], but most of the papers were published during the decade 2001–2010 (74.93% of the total). Figure 1 presents the number of articles published since 1956.

Of the 383 articles retrieved, 369 were original articles and 14 were reviews. The most common language was English (87.2%), followed by French and German (4.9% and 3.9%, respectively), and other languages such as Portuguese, Italian, Japanese, and Spanish. All 383 articles were published in 162 journals. A total of 78 subject categories were found, with most articles being in the sports sciences item, followed by physiology

and orthopaedics or, in other words, sports medicine. Overall, the articles had received 2304 citations, with an average of 6.03 citations per paper.

#### **Analysis of productivity, collaboration patterns, and citations received by the authors**

The articles retrieved in our search were produced by 1066 researchers, although only 25 of them produced  $\geq 5$  items. These 25 authors collaborated in their published articles with 413 other authors, which provided an author/article index of 2.40. The complete results for these authors and other collaboration indexes are shown in Table 1. It should be noted that 76.5% of the authors appeared in  $\leq 2$  articles. Thus, only a small percentage of authors were responsible for most of the papers.

The three most productive authors in descending order were: Emerson Franchini, Stanislaw Sterkowicz, and Edith Filaire, all of whom have published  $>10$  papers, mostly in the past decade (2001–2010). The subject areas in which these authors have published include sports history, physiology, sports medicine, and nutrition.

Edith Filaire was in third position, with 151 citations for her 12 papers; in addition, this researcher had the highest number of citations (62 citations) when local citations were analysed. However, the most cited authors were Alicia Salvador and Ferran Suay; both of whom accumulated 168 citations for the five papers in which they appeared as co-authors.

The most cited article was written by Kujala et al. [26] in 1995 and has been referenced 101 times. This article was published in the *British Medical Journal*, and reports an epidemiological study of acute injuries in different sports. It includes a sample of judokas, among other athletes. Curiously, the authors of this article have not had any further involvement with the topic *judo*. It should be emphasised that this article is not the one that has received the most recognition from specialist authors in the field. In particular, the most referenced article cited by the scientific community that publishes on *judo* (i.e. the local citation score) was an article by Thomas et al. [27] that was published in the *Canadian Journal of Sport Sciences* in 1989, with 31 local citations.

#### **Analysis of the most representative journals and citations received**

Among all the journals that have published articles that contain the word *judo*, only 13 had published more than five articles in this field (Table 2). *Archives of Budo* is one and the only journal indexed in the WoS that focuses on the martial arts and combat sports. This specialisation is

reflected in the high number of *judo*-specific items (42) that appear in the journal, which was sufficient to make it the most productive journal in terms of *judo*, despite the fact that it was first published in only 2005. The most impressive fact is that *Archives of Budo* coverage in WoS started 6 years after the start of the journal publishing, what is an evidence of importance to the field. The most visible effect and at the most convincing empirical argument is boosting the number of articles devoted to *judo* after 2005, since the first edition of the *Archives of Budo* (Figure 1).

The dispersion of articles on *judo* among the different journals was high, with  $>50\%$  of all papers being distributed in 149 journals, with frequencies of between 1 and 4 articles per journal. Three journals stand out on the basis that they received  $>150$  citations, the *International Journal of Sports Medicine* (192 citations), *Psychoneuroendocrinology* (178 citations), and *Medicine and Science in Sports and Exercise* (156 citations).

*Medicine and Science in Sports and Exercise* is the one with more citations in the set of articles analysed in the search (our collection): 65 citations altogether.

#### **Analysis of topical areas and most common words**

The topical area sports sciences included 224 articles, which accounted for more than half of the papers identified in the search. Another 11 subject areas were represented by at least 10 types of articles; in descending order: physiology; orthopaedics; experimental psychology; biochemistry and molecular biology; general and internal medicine; neurosciences; rehabilitation; multidisciplinary psychology; nutrition and dietetics; hospitality, leisure, sport and tourism; endocrinology and metabolism. Most of these areas belonged to the health sciences. The social sciences were represented mostly by the field of hospitality, leisure, sport and tourism, although there were also other areas that were represented by 2–6 articles, such as economics, management, anthropology, and history of social sciences.

With regard to the combination of subject areas, the subject areas listed above were combined most often with sports sciences (e.g. physiology/sports sciences or orthopaedics/sports sciences). Other representative combinations were: neurosciences/psychiatry, psychology/ applied psychology, biochemistry and molecular biology/endocrinology and metabolism, and orthopaedics/surgery.

With regard to the 10 words that were used most often in the article titles, *judo* appeared 170 times, followed by athletes, elite, training, performance, sports, judoists, male, and judokas.

**Table 1.** Most productive authors ( $\geq 5$  papers), with institutional affiliations and collaboration patterns.

Author	Papers	Signatures	Collaboration index*	Collaborators†	Institutional affiliation
Franchini, Emerson	18	64	3.56	32	Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil
Sterkowicz, Stanislaw	16	48	3.00	30	Department of Theory of Sport and Kinesiology, Institute of Sport, University School of Physical Education, Kraków, Poland
Filaire, Edith	12	46	3.83	26	Laboratoire CIAMS, Université Paris-Sud, Université Orléans, UFR STAPS, Orléans Cedex, France
Yamamoto, Yousuke	8	56	7	31	Department of Physical Education, Nippon Sport Science University, Tokyo, Japan
Jagiello, Wladyslaw	7	19	2.71	14	Faculty of Physical Education, Gdańsk University of Physical Education and Sports, Gdańsk, Poland
Tanabe, Masaru	7	48	6.86	24	Department of Physical Education, Nippon Sport Science University, Tokyo, Japan
Artioli, Guilherme Giannini	6	32	5.33	17	Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of São Paulo, Sao Paulo, Brazil // Laboratory of Applied Nutrition and Metabolism, School of Physical Education and Sport, University of São Paulo, Sao Paulo, Brazil
Del Vecchio, Fabricio Boscolo	6	16	2.67	11	Superior School of Physical Education, Federal University of Pelotas, Pelotas, Brazil
Drid, Patrick	6	22	3.67	15	Faculty of Sport and Physical Education, University of Novi Sad, Serbia
Kojima, Arata	6	43	7.17	19	Department of Physical Education, Nippon Sport Science University, Tokyo, Japan
Nakaji, Shigeyuki	6	43	7.17	19	Department of Social Medicine, Hirosaki University Graduate School of Medicine, Hirosaki, Japan
Nakajima, Hiroyuki	6	29	4.83	13	Graduate School of Health and Sport Science, Nippon Sport Science University, Tokyo, Japan
Nakazato, Koichi	6	28	4.67	14	Graduate School of Health and Sport Science, Nippon Sport Science University, Tokyo, Japan

**Table 1 continued.** Most productive authors ( $\geq 5$  papers), with institutional affiliations and collaboration patterns.

Author	Papers	Signatures	Collaboration index*	Collaborators†	Institutional affiliation
Raschka, Christoph	6	13	2.17	8	Institute of Sports Sciences, Julius-Maximilians-University Würzburg, Germany
Umeda, Takashi	6	43	7.17	19	Graduate School of Medicine, Department of Social Medicine, Hiroasaki University, Japan
Almansba, Ramdane	5	17	3.40	10	Exercise Physiology Laboratory, Kinanthropology Department, University of Québec in Montreal, Montreal, Canada
Degoutte, Fabrice	5	20	4.00	12	Laboratoire BAPS, UFR Recherche, Université Blaise Pascal, Les Cézeaux, Aubière Cedex, France
Gualano, Bruno	5	29	5.80	15	School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil
Hiruma, Masataro	5	22	4.40	15	Department of Dermatology and Allergology, Juntendo University Nerima Hospital, Tokyo, Japan
Kalina, Roman Maciej	5	15	3.00	10	Faculty of Physiotherapy, Department of Health Promotion & Research Methodology, Academy of Physical Education, Katowice, Poland
Lac, Gerard	5	24	4.80	15	Clermont University, Blaise Pascal University, Laboratory of Metabolic Adaptations to Exercise in Physiological and Pathological conditions, Clermont-Ferrand, France
Lancha, Antonio Herbert	5	29	5.80	15	Laboratory of Applied Nutrition and Metabolism, School of Physical Education and Sports, University of Sao Paulo, Sao Paulo, Brasil
Salvador, Alicia	5	22	4.40	11	Department of Psychobiology, University of Valencia, Spain
Suay, Ferran	5	22	4.40	11	Department of Psychobiology, University of Valencia, Spain
Takito, Monica Yuri	5	17	3.40	7	School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil

\* Average signatures/paper; †total number of authors collaborating (an indicator that shows the size of an author's collaborative team).

### Scientific and citation networks

To represent the co-author network it was established a threshold of 3 or more citations written in collaboration. Using this criterion, 74 authors were identified. The authors were gathered into 19 clusters and/or research

groups. The largest group had 12 members. In Figure 2, the larger research groups are plotted ( $>3$  members).

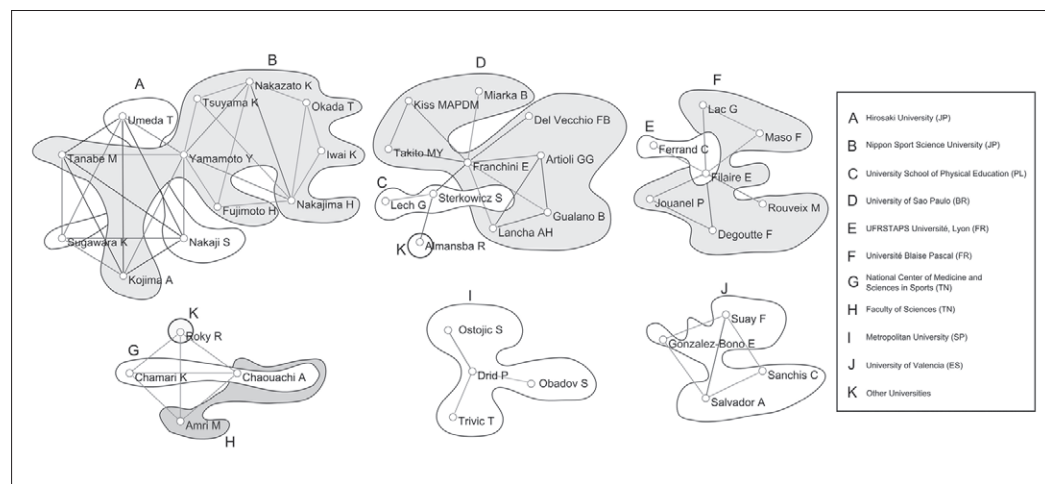
Yousuke Yamamoto, Emerson Franchini, and Edith Filaire were the most collaborative authors and they were placed in a central position in their respective clusters. The three



**Table 2.** Source journals for the articles and citations.

ISSN	Journal	Original articles	T LCS	TGCS
1643-8698	<i>Archives of Budo</i>	42	37	56
0022-4707	<i>Journal of Sports Medicine and Physical Fitness</i>	17	65	135
0031-5125	<i>Perceptual and Motor Skills</i>	16	32	56
0765-1597	<i>Science and Sports</i>	15	19	28
0172-4622	<i>International Journal of Sports Medicine</i>	14	63	192
1303-2968	<i>Journal of Sports Science and Medicine</i>	13	14	21
1439-6319	<i>European Journal of Applied Physiology</i>	12	10	114
0860-021X	<i>Biology of Sport</i>	12	40	62
1064-8011	<i>Journal of Strength and Conditioning Research</i>	10	16	41
0306-3674	<i>British Journal of Sports Medicine</i>	7	16	79
0264-0414	<i>Journal of Sports Sciences</i>	6	2	6
0195-9131	<i>Medicine and Science in Sports and Exercise</i>	6	22	156
0025-7826	<i>Medicina dello Sport</i>	5	4	7
	8 journals with 4 publications	32	–	–
	4 journals with 3 publications	12	–	–
	27 journals with 2 publications	54	–	–
	110 journals with 1 publications	110	–	–
	<b>Total</b>	<b>383</b>	<b>–</b>	<b>–</b>

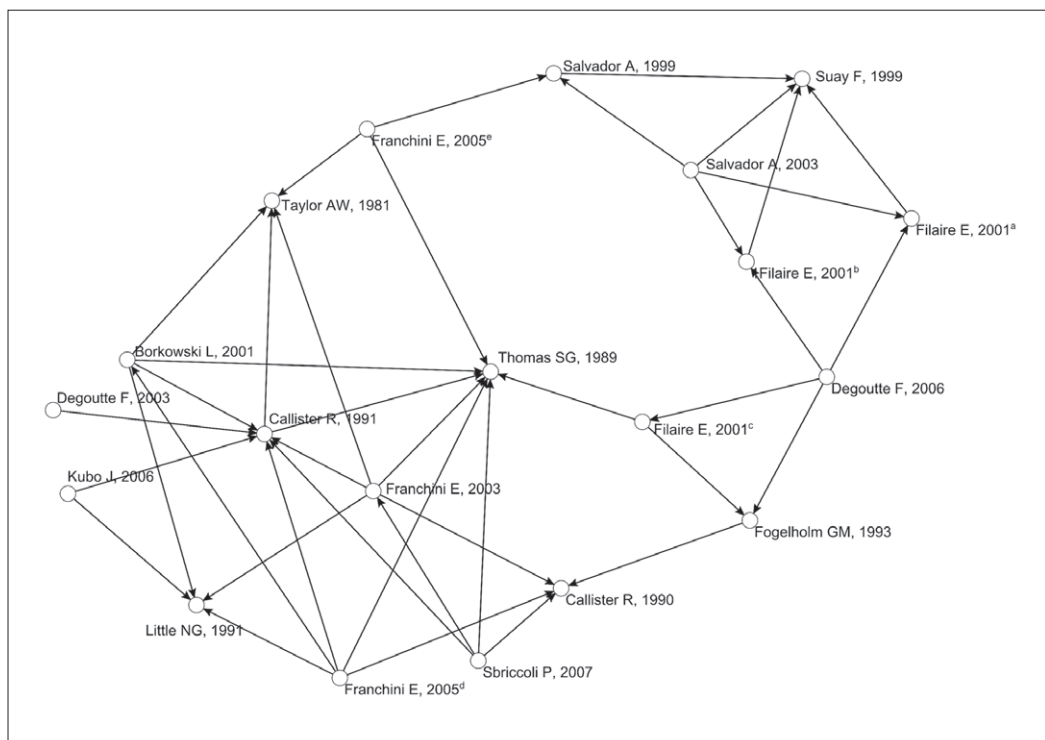
T LCS – Total Local Citation Score = Total citations in the collection to the journal. T GCS – Total Global Citation Score = Total citations in WoS to papers in the journal in the collection. (Note that this is not necessarily the total citations to the journal in WoS; only to those papers in the journal included in the collection).



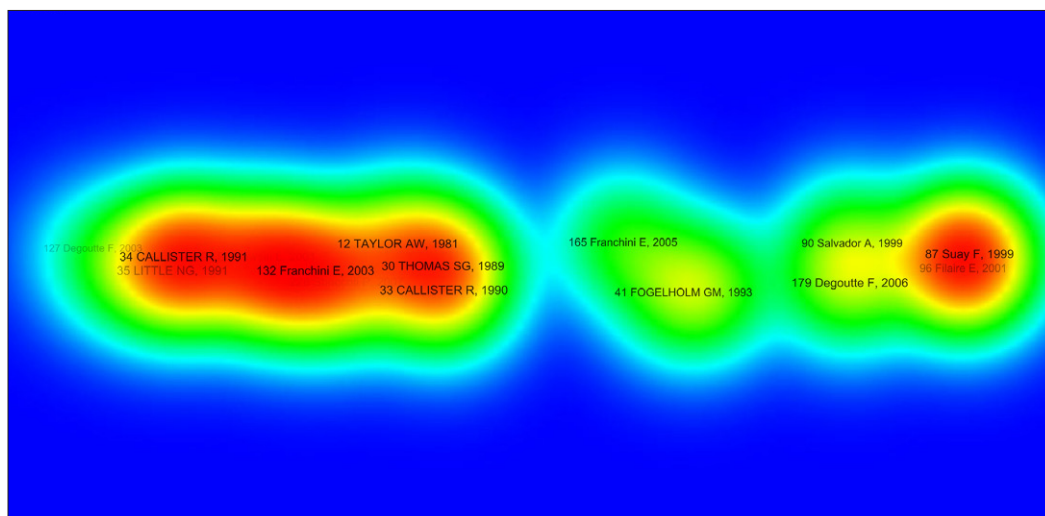
**Figure 2.** Author clusters (>3 members) when a threshold of  $\geq 3$  co-authored publications is applied.

clusters to which these authors belonged were the larger ones. Six different research centres in four countries were represented in these three clusters. It should be noted that sometimes the authors changed research centre, or worked in two centres at the same time. Figure 2 shows the usual affiliations of these authors.

The three smallest groups showed slightly different behaviour. One of these, as in the larger groups, had a star distribution, with Patrick Drid as the principal author collaborating with three other authors. However, the other two clusters analysed (in Tunisia and Spain)



**Figure 3.** Citation map between the works published in the search (>3 members), without restriction of the citation number.



**Figure 4.** Density citation map of the articles published on judo.

had a polyhedric structure which represented a stable research group with no outside collaborations.

Figure 3 shows the citation network among the articles analysed. Despite the high number of authors and works analysed in the study, it should be emphasised that the citation relationships among the works are quite inconsistent. In fact, the network constituted only 14 authors. There were two major centres of citation (Figure 4). The first group was formed by authors who investigated issues related to neuroendocrinology (Alicia Salvador, Ferran Suay, and Edith Filaire) and

the other citation centre included authors who mainly cited two papers that were related to the physiological profile of judokas [27,28]. There seems to be very little appreciation by authors of previous work published on the study topic; on the contrary, it seems that the authors support their study hypotheses mainly with articles that focus on other areas. Only two authors (Fabrice Degoutte and Emerson Franchini) adopted a mixed strategy, in which they based their work on both previous *judo*-specific studies and articles that dealt with other areas.



## DISCUSSION

The present study shows that research into *judo* is still in its early stages. In quantitative terms, it is obvious that the results exposed above show an insufficient number of documents and citations for stating that is a visible knowledge field. Even the qualitative analysis about the relationships among researchers revealed that there is very little interaction among groups compared to other knowledge areas. The lack of similar studies is one of the main limitations in discussing the results obtained in the present study. As indicated in the introduction, bibliometry has been applied rarely to sport; hence, many of the statements in this discussion are based on bibliometric studies that were carried out in other research fields.

The first issue to discuss is related to the absolute number of papers that have been published on *judo* (383 articles). To analyse properly the data obtained in the present study, it is necessary to reflect on previous articles. During the past 50 years, the importance and presence of sport has increased exponentially in many areas of everyday life. Nevertheless, until recently, there was not much interest from the scientific community in developing the field of sports science [17].

Despite this boom in sport in general, not all sports have developed to the same extent. For example, they do not all have equal media coverage and financial support. This inequality is also obvious when any scientific database is consulted. For example, the terms *basketball* and *soccer* retrieve >3000 articles in the WoS in the first case and double that number in the second case. Thus, it appears that research in sports science is linked closely to the economic importance of the particular sport and its promotion. The higher number of scientific publications about sports that are popular in the media has been highlighted previously and should be confirmed in future studies [29]. However, the present study was limited to one sport; therefore, we cannot prove this hypothesis empirically now.

When *judo* is compared with other sports with the same social and economic characteristics, the low level of scientific knowledge about *judo* becomes apparent. For other Olympic sports, such as the triathlon or wrestling, a larger number of articles have been published. This disparity can be explained as follows:

1. *Judo* is a combat sport, which presents several methodological and technical difficulties in the development of scientific studies. The direct interaction that occurs during combat makes it difficult to measure most anatomical and physiological parameters. In addition, this interaction produces much uncertainty because it generates many confounding variables that

hamper the development of well-controlled scientific studies. These characteristics do not occur in other sports such as swimming, or the triathlon, which despite its short existence has a greater scientific visibility than *judo*.

2. A second reason for this disparity is less intuitive. *Judo*, together with other martial arts such as *taekwondo*, has a high cultural and traditional content, as can be observed in the different rituals that precede the combat. Although most of these rituals have lost their traditional meaning, it is likely that the martial arts have been immersed for many years in an environment that is resistant to change. These attitudes are obvious when the martial arts are compared with other combat sports such as wrestling; the origin and development of which have been completely unlinked to ancestral traditions. Wrestling has a modern conception and therefore its development has been more open to the acceptance of new ideas about the training and performance of its athletes.

With regard to the languages in which the articles were written, the most frequent language was English, as in other similar studies [30]. However, contrary to expectations based on previous studies in other areas [31], French was the second most used language and not German as we could have expected.

The countries that contributed most of the articles were Japan and France. Interestingly, three of the four most prolific authors and the authors with more clusters worked in universities in France, Brazil, and Japan; namely, the three countries from which teams won medals in the last World Judo Championships in Paris (2011) [32]. Similar pattern can be found after the celebration of the Summer Olympic Games in London (2012), where France and Japan reached the first and second place respectively in the total of medals won, being Brazil the fourth country in this ranking [33].

It could be argued that there is a clear two-way relationship between the importance that is given to a particular sport, the results achieved, and the scientific emphasis that is placed on that sport.

With regard to the authors who were most productive, it should be emphasized that they fulfil almost exactly the **Price law** [34]. The most successful authors were responsible for 50% of the publications. To test the Price law, it is necessary to determine the square root of the number of authors identified in the study, i.e. the square root of 1066 (=32) and the number of papers that correspond to 50% of those analysed, i.e. 50% of 383 (=192). If the Price law is fulfilled, 192 publications should be produced by only 32 authors. In the present study, 32

**Price Law** – This law asserts, on the basis of the Lotka distribution, that the top  $\sqrt{P}$  authors will produce at least half the total papers published by the population  $P$  [35].

authors actually generated 202 articles; or just over half the publications retrieved.

These 32 authors received more citations over the years. One important aspect about the number of citations received by the authors is that the authors who received the most global citations did not match those who received the most local citations. Furthermore, the most referenced work was from an author who had only written one article about *judo*. It seems that recognition of published work on *judo* is not related directly to the corpus of knowledge about this subject, but rather each author who publishes on *judo* receives support and recognition within his/her own area of knowledge. For instance, works on the psychology of *judo* are cited in psychology papers, and articles on physiology in relation to *judo* are cited in physiology papers. Thus, the sports sciences use methodologies and work-specific patterns from other related areas of more traditional knowledge. Only some journals, as *Archives of Budo*, focused its editorial strategy in recognizing the articles about judo independently of the discipline area where were generated.

Despite the number of published on *judo* is low, one of the strengths arising from this study is that *judo* has interested a number of journals unusually high. Moreover, the variety of knowledge fields (subject categories) with which the journals are associated shows a wide range of knowledge and different approaches to the analysis of *judo*. However, the distribution of papers that was identified in our analysis was close to fulfilling partially **Bradford's Law** of Scattering [35,36]. This law has been proved previously in the field of sport sociology [37], and is based on three assumptions, namely: (i) the vast majority of journals publish only one article; (ii) a few journals contribute 5–10 articles; and (iii) an even smaller number of journals publish most of the papers in the field of interest. As shown in Table 2, the findings of our study fulfilled the first two assumptions, although the third assumption was not fulfilled completely, because the number of journals was slightly higher than expected. This broad range of journals means that researchers in *judo* cannot reliably identify the core journals for their field of study [38]. It is necessary to reverse these trends and it would be advisable for authors to focus on sending their papers to a smaller number of journals.

Contrary to the situation in other scientific fields, the most representative journal with respect to research into *judo* was not the one that had gained the highest number of citations [39]. This suggests that the knowledge that has accumulated in the most representative journals

is not the knowledge that is recognized most widely by authors in this field.

A basic journal analysis revealed an unusual situation in the area of sports science. The journal *Archives of Budo* is the only publication that is aimed at minority sports, with *judo* being one of them. The majority of the 79 journals that are indexed in the area of sports science show an interest in a specific scientific approach to any type of sport. In contrast, *Archives of Budo* declares an interest in a few sports (e.g. martial arts) with different approaches. However, to date, it seems that the most important papers on *judo* have been published in non-specific journals. This situation is certainly a paradox and possibly it is an indicator of weakness in scientific knowledge in the field.

The final aspect of the work to be discussed is linked to the relationships established by the authors. Usually, these types of social relations are defined as scientific collaboration networks [40], and the two most common representations are the co-author network and the citation map. The co-authorship network shows clusters composed of 1 or 2 universities in the country in which the authors work. This study has found networks with a short distance between authors (3–5 authors separated the maximal distance). This maximal distance represents the number of hops that has to be performed to join most separated authors of each network. Sometimes, this distance is also called “*diameter*”. In addition, the results confirmed that most of the co-authorship networks were very centralized, with a lead author who was very active in relationships with other co-authors. The lack of previous studies including collaboration networks makes comparison with our results difficult. The described networks on *judo* are clearly inferior in number and distribution to those in other studies with a long tradition of research such as biology, physics, and mathematics [23,40]. Furthermore, the citation maps presented herein confirm that there was no strong coherence between the published works and how citations and authors are related.

Our study had some limitations that need to be considered when interpreting the data in further studies. The first limitation was that we only used one database. This decision was taken to simplify the technical aspects of the analysis. The main advantage was that we standardized the authors' names and institutions, to eliminate duplicate records more reliably and reproducibly. Nevertheless, we should point out that our procedure led to the fact that some authors and papers were not retrieved or were undervalued.

**Bradford's Law of Scattering** – This law claimed that for a given subject area there are a few very productive periodicals, a larger number of more moderate producers, and a still larger number of constantly diminishing productivity [36].

**Cooperative Behaviour** – The interaction of two or more persons or organizations directed toward a common goal which is mutually beneficial. An act or instance of working or acting together for a common purpose or benefit, i.e., joint action.

**Social network** – Social structure made up of a set of actors (such as individuals or organizations) and the ties between these actors.

The search profile used is possibly one of the most controversial aspects of the study [41]. As explained, the choice of a single word search term is not new in *judo* research. This decision improved the relation of the articles and the topic. Of course, if different words were used or the term *judo*\* with truncation, the results would have been different. Nevertheless, a broader search strategy could have masked the results, because it is usual to use the term *judoka* or *judoist* as the subject in studies for which *judo* is not the main focus. However, future studies may quantify this assumption, adding to the series proceedings, thesis, monographs, etc.

## CONCLUSIONS

Global research on *judo* has not been as prolific as that on other sports, but has increased exponentially in recent years. The most productive authors and those with more clusters were affiliated to universities in France, Brazil, and Japan. Research articles on *judo* have been published mainly in journals specific to *judo*, sport, and sports medicine, with the highest number of citations in the latter category. The citation network is limited and papers published in other areas are cited more frequently in papers on *judo* than those in the same field.

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