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TAEKWONDO SCIENTIFIC PRODUCTION PUBLISHED ON THE WEB OF SCIENCE (1988-2016): COLLABORATION AND TOPICS

*PRODUÇÃO CIENTÍFICA DE TAEKWONDO PUBLICADA NA WEB OF SCIENCE
(1988-2016): COLABORAÇÃO E TEMAS*

*PRODUCCIÓN CIENTÍFICA DE TAEKWONDO PUBLICADA EN LA WEB OF
SCIENCE (1988-2016): COLABORACIÓN Y TEMAS*

Mikel Pérez-Gutiérrez*, Pablo Valdés-Badilla, Carlos Gutiérrez-García***,
Tomás Herrera-Valenzuela******

Keywords:
Bibliometrics.
Journal Article.
Professors.
Scientific
Communication and
Diffusion.

Abstract: This study conducted a bibliometric analysis focused on collaboration patterns and topics represented on taekwondo articles published on Web of Science until 2016. Bibliographic information was retrieved from documents and then classified according to research area, subject and topic, and characteristics of authorship and collaboration patterns were calculated. Results showed a total of 340 articles, 304 of which had multiple authors. Life Sciences and Biomechanics were the most important research area and subject respectively. Pieter was the most prolific author while Capranica obtained the highest collaboration index. In conclusion, (1) the relevance of a sporting approach to taekwondo has been corroborated through the analysis of research areas, subjects, topics, and journals' orientation and citation scores; (2) research on taekwondo has been strongly based on collaboration among authors, institutions and countries.

Palavras chave:
Bibliometria.
Artigo de revista.
Docentes.
Comunicação e
divulgação científica.

Resumo: O objetivo foi desenvolver uma análise bibliométrica sobre padrões de colaboração e temas representados em artigos sobre taekwondo publicados na Web of Science até 2016. A informação bibliográfica de documentos foi recuperada. Em seguida, foram classificados em relação à área de pesquisa, assunto e tópico e calculadas as características de autoria e padrões de colaboração. Um total de 340 artigos foram encontrados, 304 de autoria múltipla. Ciências da Vida e Biomecânica foram a área de pesquisa e a disciplina mais importantes respectivamente. Pieter foi o autor mais prolífico enquanto Capranica obteve o maior índice de colaboração. Em conclusão, (1) a relevância da abordagem esportiva de taekwondo foi corroborada através da análise de áreas de pesquisa, disciplinas, temas, orientação e pontuações de citação das revistas; e (2) a pesquisa de taekwondo baseou-se fortemente na colaboração entre autores, instituições e países.

Palabras clave:
Bibliometría. Artículo
de Revista.
Docentes.
Comunicación
y Divulgación
Científica.

Resumen: El objetivo fue desarrollar un análisis bibliométrico centrado en los patrones de colaboración y temas representados en los artículos de taekwondo publicados en la Web of Science hasta 2016. Se recuperó la información bibliográfica de los documentos. Luego se clasificaron en relación al área de investigación, disciplina y tema, y calcularon las características de la autoría y patrones de colaboración. Los resultados mostraron 340 artículos en total, 304 en coautoría. Ciencias de la Vida y Biomecánica fueron el área de investigación y la disciplina más representadas respectivamente. Pieter fue el autor más prolífico mientras que Capranica obtuvo el índice de colaboración más alto. En conclusión, (1) la relevancia del enfoque deportivo del taekwondo fue corroborado a través del análisis de las áreas de investigación, disciplinas, temas, orientación y cifras de citación de las revistas; y (2) la investigación estuvo basada fundamentalmente en la colaboración entre autores, instituciones y países.

*Universidad de Cantabria. Santander, España.
E-mail: mikel.perez@unican.es

**Universidad Autónoma de Chile. Temuco, Chile.
E-mail: pablo.valdes@uautonoma.cl

***Universidad de León. León, España.
E-mail: cgutg@unileon.es

****Universidad de Santiago de Chile. Santiago, Chile.
E-mail: tomas.herrera@usach.cl

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1 INTRODUCTION

Taekwondo has been considered one of the most important martial arts and combat sports (MA&CS) in the world because of its debut as an official Olympic sport in 2000 Sydney Olympic Games and its amount of practitioners (SVINTH, 2010). Its relevance is also depicted on the rise of scientific articles on this topic published from the last decades of the 20th century onwards and the several institutions managing the development of taekwondo (PÉREZ-GUTIÉRREZ *et al.*, 2015; WIZDOM.AI, 2017). These international organizations have also contributed to the dissemination of knowledge about taekwondo, publishing their own journals such as *Taekwondo Journal of Kukkiwon* (KUKKIWON, 2017), *Taekwon-Do Research Journal* (ITF, 2017), *Journal of the International Association for Taekwondo Research* (IATR, 2017), *Taekwondo* (WTF, 2017) and *Tae Kwon Do Journal* (ITA, 2017).

The increasing popularity and interest on taekwondo together with the rise of information about it have also triggered the appearance of several websites dedicated to the spreading of results, events, news, rankings or studies about this MA&CS in order to report its evolution and current news (ITRC, 2017; MASTAEKWONDO, 2017; TAEKWONDO RADIO, 2017; TAEKWONDODATA, 2017; TAEKWONDOSCIENCE, 2017; TKD TIMES, 2017). In addition, global scientific production has become enormous and new techniques of analysis have appeared for evaluating scientific development. In this way, bibliometrics has turned the main tool for this purpose (THOMSON REUTERS, 2008), being applied to aspects of science such as productivity, topics, collaboration and citation (ANDRÉS, 2009; LÓPEZ LÓPEZ, 1996).

To date, several works have studied martial arts from a bibliometric approach, focusing on scientific production in martial arts in Spain (GUTIÉRREZ-GARCÍA; PÉREZ-GUTIÉRREZ, 2009); Asian martial arts monographs (PÉREZ-GUTIÉRREZ, 2012; PÉREZ-GUTIÉRREZ; GUTIÉRREZ-GARCÍA, 2008) or journals (GUTIÉRREZ-GARCÍA; BRIEVA-ORTEGA; PÉREZ-GUTIÉRREZ, 2011); karate monographs published in Spain (PÉREZ-GUTIÉRREZ; GUTIÉRREZ-GARCÍA, 2009) and Czech Republic (ČIHOUNKOVÁ; REGULI, 2011; VIT; REGULI, 2011); or scientific literature about judo (PESET *et al.*, 2013).

Furthermore, bibliometrics has been also applied to taekwondo for studying its articles published in Scopus and Web of Knowledge (LEE, 2015), Science Direct, Scopus and Web of Knowledge (COTA-GUAJARDO, 2013), Web of Science (PÉREZ-GUTIÉRREZ *et al.*, 2015) as well as its Latin-American scientific production (PÉREZ-GUTIÉRREZ; VALDÉS-BADILLA, 2014). In particular, the study carried out by PÉREZ-GUTIÉRREZ *et al.* (2015) was focused on the analysis of productivity and topics depicted on taekwondo research published in the Web of Science (WoS) until 2013. Their work presented an overview of taekwondo research characteristics, depending on the information and document classification offered by the WoS. However, documents are not individually classified according to their research area, since these areas are assigned at the journal level (THOMSON REUTERS, 2009). In order to solve this problem and for deepening in the features surrounding taekwondo research published in WoS, the present study was developed.

To the best of our knowledge, no works have been carried out for studying the collaboration patterns within taekwondo, although this kind of analysis offers an overview of the social structure of the scientific community within a certain field of knowledge (LÓPEZ LÓPEZ, 1996). Therefore, the aim of the present work was to develop a bibliometric analysis focused on collaboration as well as the analysis of topics represented on taekwondo articles published in the Web of Science until 2016.

2 METHODOLOGY

Taekwondo article or review documents published from 1900 to 2016 (inclusive) in the Web of Science (WoS) databases such as Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI) and Arts & Humanities Citation Index (A&HCI) were included in the present study. Article or review documents focused on taekwondo or including taekwondo practitioners among their sample were selected.

2.1 Data mining

In relation to search strategies and attending to PÉREZ-GUTIÉRREZ; GUTIÉRREZ-GARCÍA; ESCOBAR-MOLINA (2011) recommendations, taekwondo, taekwando, tae-kwon-do, tae-kwan-do and taekwon-do terms were used for data mining and they were individually introduced in the topic field. The search was done from 1900 to 2016 (inclusive) for obtaining a comprehensive data retrieval and filtered by document type for including article and review documents only. Data mining was performed on May, 2017.

After filtering results, articles' and reviews' bibliographic information was exported and registered in Endnote X6 reference manager programme following the recommendations of the Spanish Association for Standardization and Certification (AENOR, 2013), saving the full record and cited references of each document. Before performing data analysis, duplicate records were checked and author's and institution's name were standardized for avoiding different spellings.

2.2 Data analysis

Data analysis was focused on the bibliometric analysis of topics and collaboration patterns. Firstly, documents were classified according to their subject and research area, following the criteria used by DEVÍS-DEVÍS *et al.* (2010) and the research areas proposed by the WoS (THOMSON REUTERS, 2012) respectively. Moreover, documents were classified *ad hoc* attending to their main topic for presenting articles' goals and complementing subject classification, since the same topic could be studied from different subjects or approaches.

Secondly and related to collaboration patterns, single-authored articles (SA), multi-authored articles (MA), total articles (TA), mean of authors per article and percentage of collaboration (%C) were calculated and distributed per year. Percentage of collaboration (%C) was calculated using the formula given by Valenciano Valcárcel *et al.* (2010), being: $\%C = MA / TA$. Moreover, number of articles, signatures, collaborators and collaboration index were also calculated for those authors with seven or more articles.

Then, two softwares were used for analysing the most productive journals and creating the co-authorship network. Following the same methodology used by Peset *et al.* (2013), Bibexcel and Histcite were selected for calculating the 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) as well as the co-authorship structure. Therefore, TLCS is the number of times a journal included in the present results has been cited by other papers within the present results while TGCS is the number of times that papers in a journal included in the present results has been cited in the WoS database. Finally, Pajek software was used for drawing scientific networks map, representing clusters with more than three members for the scientific network.

3 RESULTS

A total of 340 articles, published between 1988 and 2016, were selected. The bibliometric analysis carried showed four research areas and 14 subjects with a heterogeneous development in taekwondo's scientific production (Table 1). Life Sciences was the most represented area involved in taekwondo's research, obtaining 257 articles (75.6%), followed by Social Sciences with 65 (19.1%). On the other hand, Technology and Arts & Humanities areas compiled only 18 publications (5.3%). In relation to subjects, the most prominent were Biomechanics with 77 articles (22.6%), Sports Medicine with 60 (17.6%) and Physiology with 56 (16.5%); all of them pertaining to Life Sciences. Within Social Sciences, Psychology was the most represented subject with 45 articles (13.2%). On the other hand, Kinesiology and Psychomotor Education were only presented in 5 articles while 1 article was classified within Robotics subject (Table 1).

Table 1 - Frequency distribution of published articles by year of publication, research area and subject.

Research area & subject	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL
Arts & Humanities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	1	0	2	7	
History																					1			2	1	1		2	7	
Life Sciences	1	1	1	2	1	0	0	1	1	2	3	3	0	3	5	3	4	6	6	11	9	13	12	31	30	26	26	29	27	257
Biomechanics		1		1					1						1		1		2	2	2	4	3	10	10	12	5	8	14	77
Sports Medicine	1			1	1			1		2	1	3		2	2	1	2	3	1	3	2	5	2	5	6	3	3	5	5	60
Physiology			1								2			1	1		1	3	2	2	1	3	3	10	9	1	8	6	2	56
Nutrition																		1	3	2		2	3	3	4	5	2	3	28	
Sports Training Theory															1					1	2			1	2	4	3	5	3	22
Anthropometry																1								1		2	2	3		9
Kinesiology																1						1	2	1						5
Social Sciences	0	0	1	1	1	1	1	1	1	2	1	0	1	1	1	0	4	0	3	2	0	5	3	3	3	6	8	9	6	65
Psychology			1	1	1	1	1	1	1	2	1			1	1		3		2	1		3	1	3	3	4	4	6	3	45
Sociology													1									2				1	1	2	2	9
PE & ST																			1	1							2	1	1	6
Psychomotor Education																	1						2			1	1			5
Technology	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	3	1	1	1	0	0	1	11
Documentation																1			1		1	1	3	1	1	1				10
Robotics																													1	1
Total	1	1	2	3	2	1	1	2	2	4	4	3	1	4	6	4	8	6	10	13	10	20	18	35	36	34	35	38	36	340

PE & ST: Physical Education and Sports Theory.

Source: prepared by authors.

Regarding the distribution of articles per topic, 101 different topics were found, being injuries the most represented one with 61 articles (17.94%) while 76 topics appeared in three or less publications respectively and compiled 115 publications in total (33.82%) (Table 2).

Table 2 - Frequency, percentage and cumulative percentage of published articles by topic.

Topic	n	%	Cumulative %
Injuries	61	17.94	17.94
Biomechanical analysis	15	4.41	22.35
Physiological response	13	3.82	26.18
Protective gear	11	3.24	29.41
Anthropometric profile	8	2.35	31.76
Kick performance	8	2.35	34.12
Strength	8	2.35	36.47
Testing techniques	8	2.35	38.82
Weight loss	8	2.35	41.18
Balance	7	2.06	43.24
Technical-Tactical Analysis	7	2.06	45.29
Anxiety	6	1.76	47.06
Fitness	6	1.76	48.82
Food supplementation	6	1.76	50.59
Heart rate	6	1.76	52.35
Magnesium	6	1.76	54.12
Performance	6	1.76	55.88
Bone density	5	1.47	57.35
Impact force	5	1.47	58.82
Personality	5	1.47	60.29
History	4	1.18	61.47
Hydration	4	1.18	62.65
Success Factors	4	1.18	63.82
Time-motion analysis	4	1.18	65.00
Training load	4	1.18	66.18
Anaerobic Capacity	3	0.88	67.06
Anger	3	0.88	67.94
Cardiovascular Diseases	3	0.88	68.82
Hormones	3	0.88	69.71
Immune system	3	0.88	70.59
Motivation	3	0.88	71.47
Postural control	3	0.88	72.35
Torque	3	0.88	73.24
Age effect	2	0.59	73.82
Aggressiveness	2	0.59	74.41
Blood Lactate	2	0.59	75.00
Body Image	2	0.59	75.59
Caffeine	2	0.59	76.18
Cognition	2	0.59	76.76
Coordination	2	0.59	77.35
Cultural identity	2	0.59	77.94
Doping	2	0.59	78.53
Energy Demands	2	0.59	79.12
Food Habits	2	0.59	79.71
Others	69	20.29	100

n = frequency; % = in relation to total articles (340).

Source: prepared by authors.

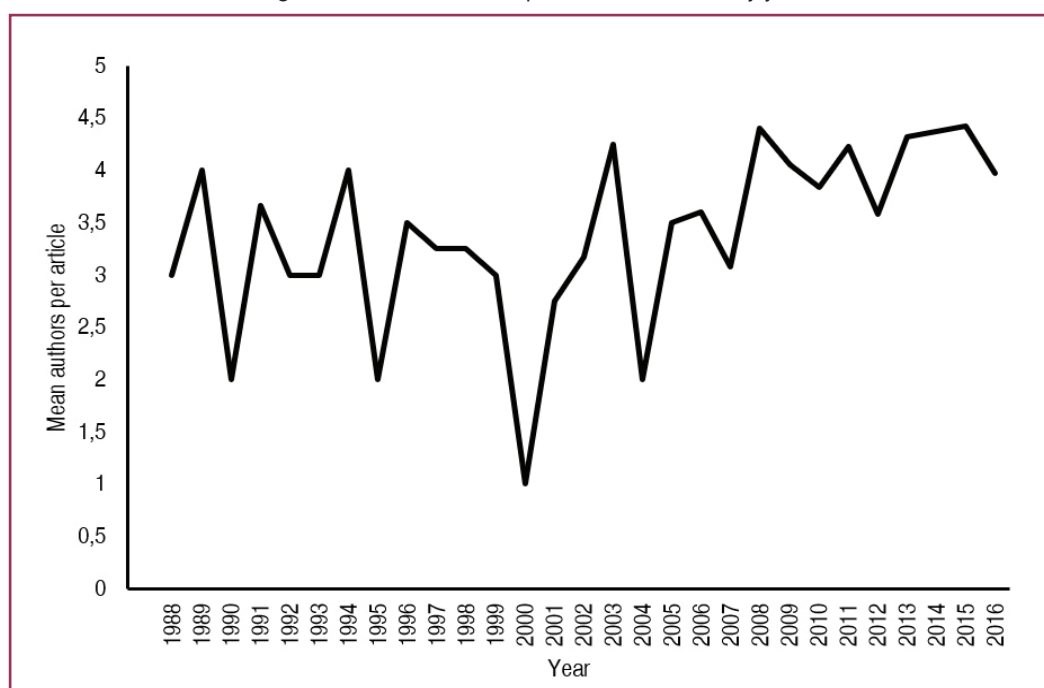
Regarding the collaboration patterns, taekwondo scientific production published in the WoS was mainly developed in groups with a total of 304 multi-authored articles. In this way, until the beginning of the 21st century the evolution of the percentage of collaboration shows that there existed a clear predominance towards collaborative works. From 2000 onwards, there has been a slight rise in the number of single-authored articles, decreasing the percentage of collaboration (Table 3).

Table 3 - Distribution of the amount of single-authored articles, multi-authored articles, total articles and percentage of collaboration per year.

Year	Single authored papers	Multi-authored papers	Total papers	% of collaboration
1988	0	1	1	100
1989	0	1	1	100
1990	1	1	2	50
1991	0	3	3	100
1992	0	2	2	100
1993	0	1	1	100
1994	0	1	1	100
1995	0	2	2	100
1996	0	2	2	100
1997	0	4	4	100
1998	0	4	4	100
1999	0	3	3	100
2000	1	0	1	0
2001	2	2	4	50
2002	0	6	6	100
2003	0	4	4	100
2004	2	6	8	75
2005	0	6	6	100
2006	2	8	10	80
2007	3	10	13	76.92
2008	0	10	10	100
2009	2	18	20	90
2010	4	14	18	77.78
2011	3	32	35	91.43
2012	6	30	36	83.33
2013	1	33	34	97.06
2014	2	33	35	94.29
2015	4	34	38	89.47
2016	3	33	36	91.67
Total	36	304	340	87.39

Source: prepared by authors.

Regarding the mean of authors per article, it ranges from 1 to 4.42 showing a considerable variability along time. However, from 2005 onwards the mean of authors per article was over 3 (Figure 1).

Figure 1 - Mean of authors per article distributed by year.

Source: prepared by authors.

Table 4 illustrates the collaboration patterns of the most productive authors, highlighting Pieter as the most prolific with 19 publications, followed by Wasik with 14 articles. The collaboration index of the most productive authors ranged from 1.36 to 7.22, but a direct relationship between the amount of published articles and the collaboration index is not appreciated, since Pieter published the largest number of articles and his collaboration index was 3.26. In the same way, the collaboration indexes of Fife and Fong were 3.43 and 3.29 respectively, lower than those obtained by other authors with the same amount of publications, such as Tessitore (6.43) and Chaouachi (6.29).

On the other hand, the number of collaborators of the most productive authors fluctuated from 5 to 56, representing the extent of their collaboration network. With the exception of Wasik, those authors with five or more articles have a collaboration network composed by at least 9 different researchers.

Table 4 - List of most productive authors (≥ 5 papers), with institutional affiliations and collaboration patterns.

Author	Papers	Signatures	Collaboration Index	Collaborators	Current institutional affiliation
W. Pieter	19	62	3.26	43	Masaryk University, Czech Republic
J. Wasik	14	19	1.36	5	Jan Dlugosz University, Poland
C. Falco	13	53	4.08	40	University of Bergen, Norway
I. Estevan	12	50	4.17	38	University of Valencia, Spain
E. Franchini	10	42	4.20	32	University of Sao Paulo, Brazil
L. Capranica	9	65	7.22	56	University of Rome Foro Italico, Italy
S. Chiodo	9	54	6.00	45	Magna Graecia University of Catanzaro, Italy
D.M. O'Sullivan	9	36	4.00	27	Pusan National University, South Korea
A.K. Baltaci	8	35	4.38	27	Selcuk University, Turkey
R. Mogulkoc	8	35	4.38	27	Selcuk University, Turkey

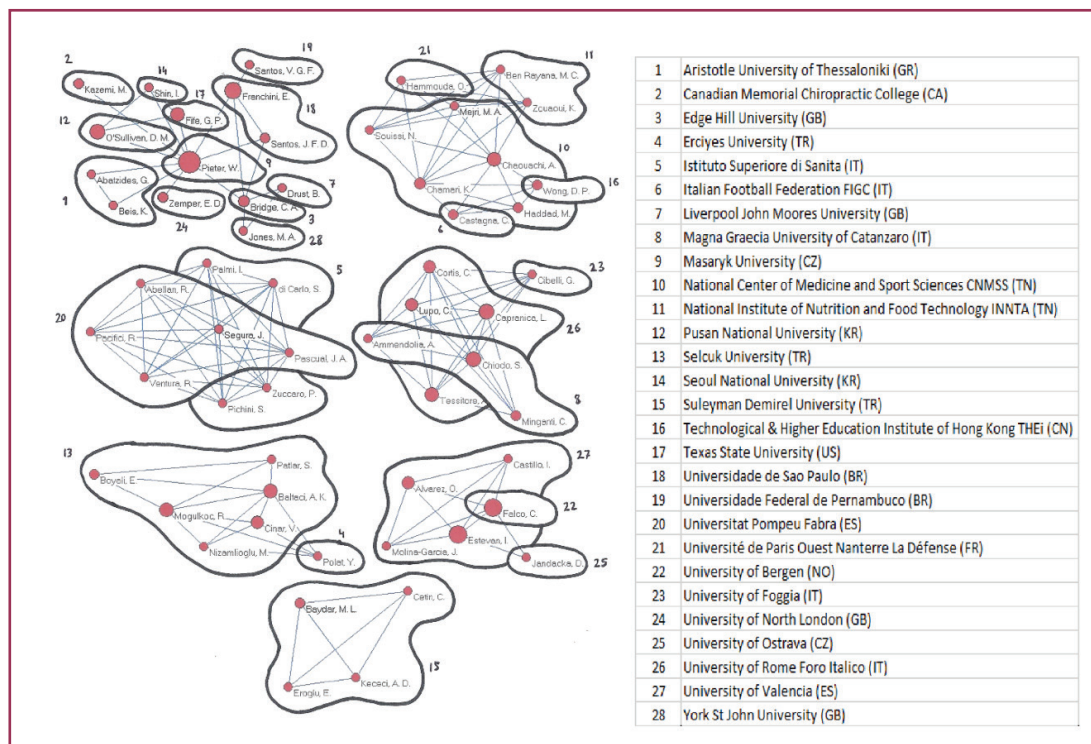
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Table 4...

A. Chaouachi	7	44	6.29	37	National Centre of Medicine & Science in Sports, Tunisia
A. Tessitore	7	45	6.43	38	University of Rome Foro Italico, Italy
G.P. Fife	7	24	3.43	17	Texas State University, United States of America
S.S.M. Fong	7	23	3.29	16	Hong Kong Institute of Education, Peoples Republic of China
C. Cortis	6	40	6.67	34	University of Rome Foro Italico, Italy
C. Lupo	6	40	6.67	34	University of Rome Foro Italico, Italy
O. Alvarez	6	28	4.67	22	University of Valencia, Spain
V. Cinar	6	22	3.67	16	Selcuk University, Turkey
C.A. Bridge	5	19	3.80	14	Edge Hill University, United Kingdom
C.K. Chang	5	25	5	20	National Taiwan University of Sport, Taiwan
G.Y.F. Ng	5	14	2.80	9	Hong Kong Polytechnic University, Peoples Republic of China
K. Chamari	5	30	6.00	25	National Center of Medicine & Science in Sports CNMSS, Tunisia
P.L. Graham	5	15	3	10	Macquarie University, Australia
R.P. Lystad	5	15	3	10	Macquarie University, Australia

Source: prepared by authors.

The map of the collaboration patterns shows the existence of seven networks with at least four academics (Figure 2). Usually, there exist a relationship among all the academics being part of the same network, but there is a case in which the network is led by an author (i.e. Pieter). Regarding the institutional collaboration networks depicted on Figure 2, five institutions are collaborating in each network at the most, with the exception of the network led by Pieter in which appears almost as many institutions (12) as authors (14) making up this network.

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

Source: prepared by authors.

Finally, nine journals have published at least eight articles on taekwondo, compiling the 35.88% of total articles, while the 29 journals shown in Table 5 collected the 60.59% of total scientific output. The *Journal of Strength and Conditioning Research* (JSCR) together with the *Journal of Sports Sciences* (JSS) and the *British Journal of Sports Medicine* (BJSM) are the journals with the highest amount of citations in the collection (TLCS), receiving 143, 80 and 75 citations respectively. They also achieved the highest citation indexes in the WoS (TGCS) with 308 (BJSM), 261 (JSCR) and 184(JSS) citations (Table 5). In general, it seems there is a similar pattern or trend among TLCS and TGCS. On the other hand, *Archives of Budo*, a specific martial arts and combat sports oriented journal, is the most important journal for the dissemination of taekwondo's research, presenting a moderate TLCS and a high TGCS in relation to the rest of journals.

Table 5- Source journals for the articles and citations.

Journal	Articles	%	Cumulative %	TLCS	TGCS
Archives of Budo	36	10.59	10.59	59	184
Journal of Strength and Conditioning Research	14	4.12	14.71	143	261
Perceptual and Motor Skills	13	3.82	18.53	37	140
British Journal of Sports Medicine	12	3.53	22.06	75	308
Journal of Sports Science and Medicine	12	3.53	25.59	53	132
Biology of Sport	10	2.94	28.53	16	49
Journal of Human Kinetics	9	2.65	31.18	13	24
Journal of Physical Therapy Science	8	2.35	33.53	4	16
Journal of Sports Sciences	8	2.35	35.88	80	184
Biological Trace Element Research	6	1.76	37.65	3	52
Journal of Sports Medicine and Physical Fitness	6	1.76	39.41	84	145
Collegium Antropologicum	5	1.47	40.88	37	64
Dental Traumatology	5	1.47	42.35	13	96
International Journal of the History of Sport	5	1.47	43.82	4	8
Medicina dello Sport	5	1.47	45.29	2	3
PLoS ONE	5	1.47	46.76	0	17
Science & Sports	5	1.47	48.24	38	66
Acta of Bioengineering and Biomechanics	4	1.18	49.41	7	14
Clinical Journal of Sport Medicine	4	1.18	50.59	16	83
European Journal of Applied Physiology	4	1.18	51.76	23	96
International Journal of Sport Psychology	4	1.18	52.94	0	267
International Journal of Sports Medicine	4	1.18	54.12	8	28
International Journal of Sports Physiology and Performance	4	1.18	55.29	39	99
American Journal of Sports Medicine	3	0.88	56.18	7	143
European Journal of Sport Science	3	0.88	57.06	8	20
International Journal of Sport Nutrition and Exercise Metabolism	3	0.88	57.94	4	61
Journal of Pharmaceutical and Biomedical Analysis	3	0.88	58.82	2	25
Journal of Science and Medicine in Sport	3	0.88	59.71	27	77
Journal of the International Society of Sports Nutrition	3	0.88	60.59	0	6
Others	134	39.41	100	-	-

TLCS – Total Local Citation Score = Total citations in the collection to the journal. TGCS – 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).

Source: prepared by authors.

4 DISCUSSION

The scientific articles about taekwondo published in the WoS has shown the existence of four research areas focusing on this MA&CS, being the Life Sciences the most represent one (75.6%). In this way, Biomechanics, Sports Medicine and Physiology were the main subjects compiling 193 articles (56.8%) (Table 1). The distribution of articles per topic showed academics' interest in biomechanical, physiological and nutritional aspects related to taekwondo (Table 2), among which the analysis of injuries was the most important one (17.94%).

These results should be compared with those found by Pérez-Gutiérrez *et al.* (2015) due to the methodological approach they used for classifying the articles. These authors followed the classification carried out by the WoS, which was based on the research area of the journal where articles were published, while the present study developed an *ad hoc* classification of each article attending to their research area, subject and topic. This methodology caused the disappearance of Sport Sciences as the main subject (57.4%) studying taekwondo (PÉREZ-GUTIÉRREZ *et al.*, 2015), being replaced by Biomechanics, Sports Medicine and Physiology, which compiled a total of 56.8% of publications. Moreover, the trend of taekwondo research towards sports field (PÉREZ-GUTIÉRREZ *et al.*, 2015) has been corroborated observing that the main analyzed topics (Table 2) are related to taekwondo's training and competition aspects.

In the same way, the study developed by Peset *et al.* (2013) used the classification of articles proposed by the WoS for pointing out a predominance of Sport Sciences followed by Physiology and Orthopedics for judo articles. Thus, the sporting side of taekwondo and judo seems to lead academics' attention and efforts to those aspects related to the performance on these MA&CS. In the case of taekwondo, its inclusion in the programme of the Olympic Games in Sydney 2000 was mentioned as one of the possible reasons explaining the development of research in this area (PÉREZ-GUTIÉRREZ *et al.*, 2015), but also it could justify researchers' attention to the sporting aspects of taekwondo. In the same way, Peset *et al.* (2013) stated the possible relationship among judo's sport results and research carried out in each country.

Regarding the collaboration patterns, the present study showed that the scientific production about taekwondo published in the WoS has been mainly developed collaboratively, achieving an 89.41% of multi-authored articles (Table 3) and a mean of 3.40 authors per article (Figure 1). However, the percentage of collaboration presented a decrease from 2000 onwards with the appearance of single-authored articles, although the mean of authors per article seems to indicate an increasing trend with values over 3 (Figure 1) and the amount of multi-authored articles also raised progressively (Table 3). Furthermore, the most productive authors also depicted a wide cooperation with other academics, ranging their collaboration index from 1.36 to 7.22 and their amount of collaborators from 5 to 56 (Table 4).

In the case of the articles about judo published in the WoS, Peset *et al.* (2013) obtained a group of 25 authors publishing five or more articles, with a mean of 2.40 authors per article, while the present study presented a total of 24 authors with a mean of 3.33 authors per article. On the one hand, the amount of the most productive authors in both MA&CS is related to the number of published articles with similar results in both cases, since judo and taekwondo publications were 383 and 340 respectively. On the other hand, the mean of authors per article seems to point out a higher collaboration in taekwondo research. Peset *et al.* (2013) did not calculate the total mean of authors per article but showed six collaboration networks for those articles written

by at least three authors, while the present study obtained a mean of 3.40 authors per article and seven networks, suggesting a more fluid collaboration in taekwondo research. However, the time span analyzed should be taken into account, since Peset *et al.* (2013) performed their search on June 2011 while the present work's time span ranged from 1900 to 2016, at least 5 years longer. As it has been depicted in both studies, from 2000 onwards there has existed a progressive increase in the amount of articles about judo and taekwondo so a similar pattern of publication should be expected from 2011 to 2016. In this way, differences between judo and taekwondo research could be higher than those shown here.

Regarding the collaboration networks, Figure 2 illustrates the collaborative bonds and networks of the publications written by at least three co-authors together with their institutional affiliations, helping to visualize the size and patterns of collaboration among academics and institutions. In taekwondo research, there exist seven clusters with more than 3 authors, collaborating 28 institutions from 13 different countries, being Italy and United Kingdom the most represented ones with 5 institutions respectively. Capranica followed by Cortis, Lupo and Tessitore were the most collaborative academics, all of them pertaining to the University of Rome Foro Italico (Italy). In the same way, Peset *et al.* (2013) depicted a similar situation in judo research, including the largest six networks the collaboration of 10 institutions from seven different countries and four authors were located in a central position in their own networks.

The collaboration structure of taekwondo showed that all researchers integrating a network tend to mix each other, being affiliated to a maximum of five different institutions. However, the most productive author (i.e. Pieter) achieved one of the lowest collaboration indexes (3.26) despite he cooperated with 43 academics, depicting his network a star distribution. As shown in Figure 2, Pieter has been the principal author and collaborated with 13 academics pertaining to different institutions. In this way, Pieter is the researcher leading and guiding taekwondo studies, not only due to the amount of published articles but for the number of authors, institutions and countries with which he has collaborated.

Finally, 60.59% of taekwondo documents have been published in 29 journals. The relevance of these journals is determined by their own citation indexes (TLCS and TGCS). The *Journal of Strength and Conditioning Research* together with the *Journal of Sports Sciences* and the *British Journal of Sports Medicine*, all of them oriented to Sport Sciences, are those journals with the highest citation indexes (Table 5) despite the differences in the amount of published articles. These data are similar to those found by PESET *et al.* (2013) where journals oriented to Sport Sciences such as the *International Journal of Sports Medicine* and the *Journal of Sports Medicine and Physical Fitness* predominated.

On the other hand, *Archives of Budo*, the only martial arts and combat sports oriented journal, published the highest number of articles (36) and achieved moderate citations from other taekwondo articles (TLCS) and one of the highest impact within the WoS (TGCS). In the case of judo, *Archives of Budo* presented a main role in the dissemination of articles, publishing 42 papers in total, but citation indexes were lower than those presented in taekwondo research (PESET *et al.*, 2013). Despite the present study included a longer time span analyzed, until 2016, judo research presented a higher number of articles but citation scores were lower. As it was mentioned before, the important rise in the number of articles from 2010 to 2016 depicted in taekwondo should be also expected for judo research and probably, to a greater extent, citation scores would be higher for all journals. Therefore, there is no relationship between

the amount of articles published in each journal and the number of cites received by the own articles and journals. A predominance of sport sciences-oriented journals was clearly observed for the spreading of taekwondo publications, suggesting MA&CS research field is in a first phase of development with a limited number – just one – of MA&CS journals being included in the selected databases. Moreover, the present results have confirmed the sporting approach guiding taekwondo research (PÉREZ-GUTIÉRREZ *et al.*, 2015), depicted on the research areas and subjects supporting these studies, the topics presented and the orientation of journals publishing these articles.

Finally, the main limitation of the present study was the use of one database (WoS) for data mining, which probably underestimated the amount of articles, authors, institutions and countries developing and collaborating on taekwondo research. The inclusion of other databases could provide a more accurate approach to the analysis of taekwondo scientific community's structure and interests, but WoS was selected as one of the most important databases, providing bibliographic data from 1900 onwards (GASPARYAN, 2013).

5 CONCLUSION

The scientific production about taekwondo published in the WoS has shown predominance of Life Sciences research area; with Biomechanics, Sports Medicine and Physiology guiding research in this field of knowledge. Academics have been focused on the analysis of the biomechanical, physiological and nutritional aspects of taekwondo, using sport sciences-oriented journals for the dissemination of their publications. In this way, the relevance of taekwondo sporting approach has been corroborated through the analysis of research areas, subjects, topics and the orientation and citation scores of journals.

Taekwondo research indexed in the WoS has been mainly developed collaboratively among authors, institutions and countries. In general, collaboration networks are characterized by all academics working together and pertaining to a maximum of five different institutions and countries. However, the most productive author showed a different pattern of collaboration, centralizing the relationships of his network, depicting the largest amount of collaborators but one of the lowest collaboration indexes.

Finally, the methodological approach developed in the present study for article classification has presented clear differences in relation to WoS classification criteria, offering a more realistic approach to research areas, subjects and topics related to taekwondo research.

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