ANALYSIS OF THE SCIENTIFIC PRODUCTION IN ARTISTIC GYMNASTICS, AND IN THE MEN'S AND WOMEN'S MODALITIES

Yeray Rodriguez-Redondo & Kiko Leon

Faculty of Sport Sciences, University of Extremadura, Spain

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Abstract

Artistic gymnastics, as a fundamental sport forming the basis for acrobatic activities in sports, art, and recreation, is the subject of this research. The aim is to scrutinize scientific studies on artistic gymnastics, both in a general context and in terms of male and female modalities. A bibliometric analysis was conducted on journals indexed in Scopus and Web of Science, following established bibliometric principles. Analysis, processing, and graph generation were carried out using Microsoft Excel and Bibliometrix software. A total of 482 documents published between 1975 and 2023 were identified, revealing exponential growth in publications. The core set of prolific journals comprised six publications. Among 1241 authors, 33 were identified as prolific (with 5 or more publications), with 12 standing out as prominent. Brazil was the most productive, and the USA was the most cited. Keywords were grouped into four main categories: "technique analysis," "physiological aspects," "gymnastics as a fundamental sport," and "exercise evaluation and scoring." In conclusion, the research community exhibits a growing interest in artistic gymnastics. Sunčica Delaš Kalinski (Croatia) was the most prolific author, and Albrecht L. Claessens (Belgium) stood out prominently. The "Science of Gymnastics Journal" proved to be the most influential publication. Four primary research lines were identified based on keyword groupings.

Keywords: *sports, acrobatics, bibliometric, review, Olympics*

INTRODUCTION

Artistic gymnastics stands as a cornerstone in sports, alongside athletics and swimming (Jiménez Bermeo, 2020). From a physical standpoint, it encompasses all fundamental physical qualities, reaching exceptional levels of development, excluding aerobic endurance (Russo et al., 2021). Strength, flexibility, and speed of execution in artistic gymnastics often achieve remarkable levels not commonly observed in other sporting events (Desai, Vance, Rosenwasser, & Ahmad, 2019; Kilijanek & Sanchez, 2020; Tayne, Bejarano-Pineda, & Hutchinson, 2021).

The physical coordinative capacities in artistic gymnastics shine prominently, particularly when executing elements of difficulty and coordinative complexity that involve rhythm, agility, orientation, coordination, and more (Abdurashidovich,

2020). These elements are integral to the "technique." The precision in linking gymnastics technical actions with the corresponding intensity in muscle contraction plays a crucial role in successful execution (Farana et al., n.d.), ultimately impacting the competition outcome (Barker-Ruchti & Schubring, 2016).

This sport comprises two distinct modalities: women's artistic gymnastics (WAG) and men's artistic gymnastics (MAG). WAG includes the floor, vault, balance beam, and uneven bars, while MAG encompasses the floor, horizontal bar, parallel bars, vault, rings, and pommel horse (FIG - Fédération Internationale de Gymnastique, 2016a, 2016b). The execution of acrobatic and aesthetic routines in various apparatuses demands cognitive and generative components more akin to the arts than traditional sports (Barker-Ruchti, 2008; Pero, Mallia, Capitani, & Scibinetti, 2022).

This discipline necessitates substantial physical and mental preparation, coupled with refined technique and precise execution (Niźnikowski & Sadowsky, 2020). Judges evaluate exercises performed on each apparatus, adhering to scoring criteria outlined in the Code of Points (CoP) for each modality (FIG - Fédération Internationale de Gymnastique, 2016a, 2016b).

Artistic gymnastics serves as the foundational basis for acrobatic activities across sports, arts, and recreation (Šalaj, Milčić, & Šimunović, 2019). The acquired movements and skills in this sport provide an excellent foundation for acrobatics in various disciplines such as dance, circus, parkour, or cheerleading, among others (Rabaglietti, Mulasso, & Arzenton, 2020).

Artistic gymnastics not only enhances muscular strength, flexibility, coordination, balance, and physical endurance but also introduces a risk component that fosters constant challenge and the overcoming of fears. This not only contributes to cognitive, emotional, and social development by promoting values like discipline, perseverance, teamwork, and self-confidence but also significantly improves self-esteem and intrinsic motivation for sports practice. This, in turn, leads to the cultivation of healthy lifestyle habits (Menegaldo & Bortoleto, 2020; Petrovska et al., 2022).

This introduction allows us to know many of the areas and characteristic aspects that artistic gymnastics contains, and which any researcher might investigate. While the literature on artistic gymnastics is extensive, the distribution of topics and research objectives remains unclear. This lack of clarity hampers our understanding of which areas are more attractive for investigation and which areas are left unexplored. Therefore, it is deemed relevant to assess the state of scientific research in artistic gymnastics, akin to previous analyses in other sports like judo (Caravaca, Hernandez-Garcia, & Garcia-de-Alcaraz, 2018), badminton (Blanca-Torres, Ortega, Nikolaidis, & Torres-Luque, 2020), or collective sports (Mamani-Jilaja, Huayanca-Medina, Casa-Coila, Vilca-Apaza, & Romero-Carazas, 2023). Through a bibliometric analysis (Denche-Zamorano et al., 2023; Leite et al., 2023; Vargas & Capraro, 2020), this study aims to analyze the growth, size, and distribution of scientific publications related to artistic gymnastics. Additionally, it seeks to identify prolific and prominent authors, journals, countries, keywords, and highly cited documents, both in the general domain of artistic gymnastics and in its male and female modalities.

METHODS

As in other research similar to ours (Díaz, Teixidó, Gil, Cabeza, & Aras, 2021; Vargas & Capraro, 2020), the Web of Science (WoS) of Clarivate Analytics and Scopus databases were used to search for documents related to artistic gymnastics (AG). Searches related to women's artistic gymnastics (WAG) and men's artistic gymnastics (MAG) were conducted in both databases. These databases are widely used by researchers due to the extensive information they provide on documents, and the large number of journals indexed in them.

For the WOS search on artistic gymnastics (AG), the search vector "TS=("artistic gymnastics")" was utilized. The "TS" tag enables locating the searched term in the title, abstract, and keywords. The search was restricted to articles and reviews within the Core Collection Database of WoS, specifically in the editions of Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), and Emerging Sources Citation Index (ESCI). This yielded 348 documents. In the Scopus search, the search vector "TITLE-ABS-KEY("artistic gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))" was employed. The "TITLE-ABS-KEY" tag locates the searched term in the title, abstract, and keywords, while the "LIMIT-TO" tag filters the search to articles and reviews. This resulted in 421 documents.

Upon combining both searches, 237 duplicates were automatically eliminated using scripts. After a subsequent manual review by researchers, 28 additional duplicates were removed, and 12 documents unrelated to the subject matter were excluded. Instances where there were differing opinions among authors were resolved through discussion. Ultimately, 482 documents were obtained.

The search for documents on Female Artistic Gymnastics (WAG) and Male Artistic Gymnastics (MAG) followed the same methodology as the main search. For WAG in WoS, a search was conducted in the Core Collection Database, specifically in the editions of SCI-Expanded, SSCI, and ESCI, limited to articles and reviews. The search vector "TS=("female's artistic gymnastics") OR TS=("female artistic gymnastics") OR TS=("women's artistic gymnastics") OR TS=("women artistic gymnastics")" yielded 67 documents. In Scopus, 80 documents, including only articles and reviews, were obtained using the search vector "TITLE-ABS-KEY("female's artistic gymnastics") OR TITLE-ABS-KEY("female artistic gymnastics") OR TITLE-ABS-KEY("women's artistic gymnastics") OR TITLE-ABS-KEY("women artistic gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))". After automatically removing 48 duplicates with scripts, a total of 99 documents remained.

For the MAG modality, the same steps were followed as for WAG, but with the search vector "TS=("male's artistic gymnastics") OR TS=("male artistic gymnastics") OR TS=("men's artistic gymnastics") OR TS=("men artistic gymnastics") OR TS=("men artistic gymnastics")", yielding 46 documents in WoS. In Scopus, the search vector "TITLE-ABS-KEY("female's artistic gymnastics") OR TITLE-ABS-KEY("female artistic gymnastics") OR TITLE-ABS-KEY("women's artistic gymnastics") OR TITLE-ABS-KEY("women artistic

gymnastics") AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "re"))" resulted in 49 documents. After automatically eliminating 35 documents, a total of 56 documents remained in Scopus.

All searches were conducted on November 15, and the results were exported from WoS in ".xlsx" format and from Scopus in ".csv" format. Data processing was performed using Microsoft® Excel® for Microsoft Office Professional Plus 2019, RStudio 2022.7.2.576 (RStudio Team, 2020), and the Bibliometrix data package (Aria & Cuccurullo, 2017). For WoS searches, the label "TS" was used, and for Scopus searches, "TITLE-ABS-KEY" was used. These labels include the keyword plus and indexed keywords, respectively. While the use of such keywords may include many unrelated documents, the researchers made efforts to avoid omitting any potentially related documents. To address this concern, all documents were meticulously reviewed by the authors.

A descriptive bibliometric study was conducted, examining various aspects in accordance with traditional bibliometric principles. The law of exponential growth of science proposed by DeSolla Price (Dobrov, Randolph, & Rauch, 1979; Price, 1976) was utilized to determine if annual publications exhibited exponential growth. The coefficient of determination (R2) adjusted to an exponential growth ratio was employed to interpret this trend. The WoS Analyse Reports tool facilitated a descriptive analysis of subject categories with the highest number of related publications and various associated characteristics. Bradford's law of the concentration of science (DeShazo, LaVallie, & Wolf, 2009; Goffman & Warren, 1969; Nash-Stewart, Kruesi, & Del Mar, 2012) was applied to identify the most prolific journals. Lotka's law (Kushairi & Ahmi, 2021) was employed to highlight authors with the highest number of publications (Yie et al., 2021). The Hirsch index (h-index) was applied to identify the most relevant articles, considering those with a number equal to or greater than h citations (Hirsch, 2005; Rodrigues-Santana et al., 2022). Prominent authors were determined based on prolific authors who were among the authors of the most cited papers. Finally, Zipf's law was applied to the set of author keywords from the analysis (Zipf, 2013) to identify the most relevant keywords for authors. The Biblioshiny tool of the Bibliometrix data package (Aria & Cuccurullo, 2017) was used for visualizing relationships between co-authors, keywords, countries, and articles, as well as generating the global productivity map and productivity plots of journals and institutions.

RESULTS

After applying the exclusion criteria, we identified 482 documents published between 1975 and 2023, including articles accepted for publication in 2023. Annual publication continuity was observed from 1996, with one document, to the present, excluding the years 2022 and 2023 from the trend analysis as they were ongoing at the time of the investigation. Between 1996 and 2021, a total of 465 documents were found. No annual publication continuity was observed in the years preceding this range, with the first article found in 1975. The total number of articles between 1975 and 1995 was 16 papers.

The trend of publications between 1996 and 2021, inclusive, was analyzed, revealing that the publications follow an

exponential growth curve during this period. The goodness-of-fit index for the growth curve was 83.18% (R^2) (Figure 1). This analysis excluded the years before 1996 and the years 2022 and 2023, which were ongoing at the time of the analysis.

When specifically searching for women's artistic gymnastics (WAG), 99 articles published between 1986 and 2022 were identified. Publication continuity was observed between 2007 and 2022, with 92 documents in this period. Similarly, in the search for male artistic gymnastics (MAG), 60 documents published between 1994 and 2022 were found, with publication continuity from 2015 onwards and a total of 38 documents in this range. Figure 2 illustrates the growth of publications in men's and women's artistic gymnastics.

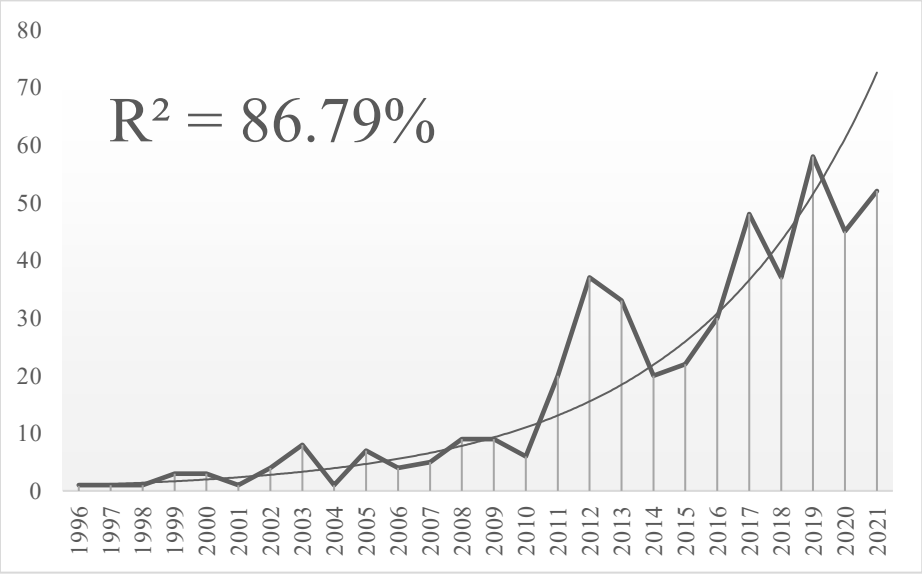

Figure 1. Annual publications trend for artistic gymnastics.

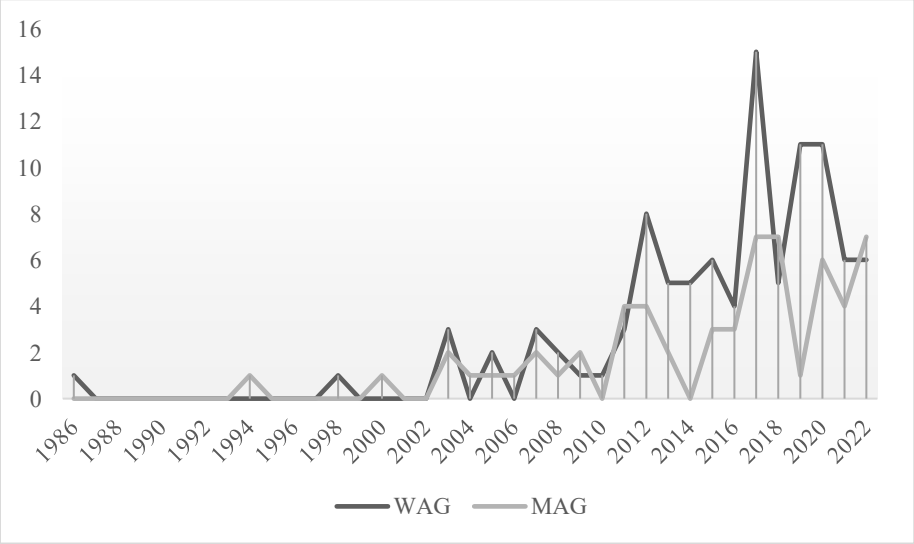

Figure 2. Annual publications trend for women's (WAG) and men's artistic gymnastics (MAG).

In the search within the WoS database, a total of 348 documents were analyzed across 56 thematic categories. The category "Sport Sciences" stands out, encompassing approximately 65% of the total publications (224 documents). Following this, "Hospitality Leisure Sport Tourism" holds 31 documents, "Engineering Biomedical" ranks third with 30 documents, and "Education Educational Research" and "Endocrinology Metabolism" each have 14 documents. Table 1 provides details on these top five categories, including the journals and publishers with the highest number of papers in each. In the specific search for female artistic gymnastics (67 documents), the top categories were "Sport Sciences" (48 documents), "Hospitality Leisure Sport Tourism" (15 documents), "Education Educational Research" (5 documents), "History" (5 documents), and "Engineering Biomedical" (4 documents). Similar categories were identified in the search for men's artistic gymnastics, with "Sport Sciences" (37 papers), "Engineering Biomedical" (10 papers), and "Biophysics" (4 papers) being the predominant categories, while the rest of the categories contained two or fewer papers.

Table 1
Top 5 WoS thematic categories with the number of documents for which publications were indexed.

WoS Categories	Doc.	Journals *(Publishers)* most prolific	Doc.	Publishers most prolific	Doc.
Sport Sciences	224	Science Of Gymnastics Journal *(Univ Ljubljana, Fac Sport)*	67	Univ Ljubljana, Fac Sport	63
Hospitality, Leisure, Sport and Tourism	31	International Journal of the History of Sport *(Routledge Journals, Taylor & Francis Ltd)*	4	Taylor & Francis	10
		International Journal of Sports Science & Coaching *(Sage Publications LTD)*	4		
Engineering, Biomedical	30	Sports Biomechanics *(Routledge Journals, Taylor & Francis Ltd)*	12	Taylor & Francis	12
Education & Educational Research	14	Sport, Education and Society *(Routledge Journals, Taylor & Francis LTD)*	2	Taylor & Francis	5
		VIREF Revista De Educación Física *(Univ Antioquia, Inst Univ Educacion Fisica & Deporte)*	2		
Endocrinology & Metabolism	14	Osteoporosis International *(Springer London LTD)*	6	Springer Nature	6

Doc. (Number of documents)

The 494 papers in our database were distributed among a total of 186 journals, ranging from 1 to 82 publications. Bradford's law was applied to identify the most prominent journals, categorizing them into three zones: the core accumulating 32.16% (6 journals), zone I comprising 30.91% (31 journals), and zone II consisting of 36.93% (149 journals), with an error ratio of 0.5% (Table 1S). The core includes journals with a publication count ranging from 82 to 10. The most prolific journal was the "Science of Gymnastics Journal" published by "Univ Ljubljana, Fac Sport,"

positioned in the first quartile of the category "Sports Science," with a total of 82 papers. It is followed by the "Journal of Physical Education and Sport" published by "Editura Universitatea Din Pitesti" (24 papers) and "Teoriya i Praktika Fizicheskoy Kultury" published by "The Committee on Physical Culture and Sports of the Council of Ministers of the USSR" (14 papers). Table 2 displays the six journals constituting the core of the most prolific ones, along with their publisher, impact indicators (JIF, JCI, or ScoreCite2021), the quartile in their respective categories, and their open access percentage where applicable. Zone I encompasses 31 journals with publication counts ranging from 9 to 3 documents, while zone II includes 149 journals with publication counts of 2 to 1.

In the analysis of the search conducted in the WAG and MAG modalities, for WAG, among a total of 46 journals, the core of prolific journals comprises 4 journals with 5 or more publications. The most prolific is "Science of Gymnastics Journal" with 24 documents and 103 total citations. It is followed by "Journal of Physical Education and Sport" with 6 documents and 18 citations. In the third and fourth positions, each with 5 publications, are "Acta Kinesiologica" with 15 total citations and "Motriz: Revista de Educação Física" with 16 total citations. In contrast, in MAG, out of a total of 28 journals, the core is represented by a single journal that accumulates 30.36% of the publications. The most prolific journal is "Science of Gymnastics Journal" with 17 papers and 65 citations. Zone I includes 7 journals, with the top three being "Journal of Biomechanics" with 4 papers and 83 citations, "Journal of Applied Biomechanics" with 3 papers and 63 citations, and "Sports Biomechanics" with 3 papers and 30 citations.

Table 2
Most prolific journals

Bradford's zone	Journals *(Publishers)*	Doc.	% Doc.	Cit.	JIF	Q.	% O.A.
Core	Science of Gymnastics Journal *(Univ Ljubljana, Fac Sport)*	82	17,01%	309	0.19*	Q4*	0.00%
	Journal of Physical Education and Sport *(Editura Universitatea Din Pitesti)*	24	4,98%	58	2.2**	n/a	n/a
	Teoriya I Praktika Fizicheskoy Kultury *(Committee on Physical Culture and Sports of the Council of Ministers of The USSR)*	14	2,90%	8	0.4**	n/a	n/a
	Sports Biomechanics *(Routledge Journals, Taylor & Francis LTD)*	13	2,70%	273	2.896	Q2	7.98%
	Journal of Sports Sciences *(Taylor & Francis LTD)*	12	2,49%	243	3.943	Q2	9.49%
	Baltic Journal of Health and Physical Activity *(Gdansk Univ Physical Education & Sport)*	10	2,07%	22	0.16*	Q4*	97.45%

Doc. (Number of documents); Cit. (Number of citations); % Doc. (Percentage of documents); JIF (Journal impact factor); % O.A. (Percentage of open access); Q. (JIF Quartile); n.a. (not application). JIF or Q. with "*" are JCI (Journal citation indicator) and JCI Quartile. JIF with "**" are CiteScore2021 by Scopus.

The analyzed publications on artistic gymnastics involve contributions from 1241 different co-authors. Notably, a majority of them, precisely 1026 authors, have only a single document in authorship (82.7%). Another 119 co-authors have contributed to 2 documents (9.6%), while 96 co-authors have been involved in at least 3 documents (7.73%), up to a maximum of 20 publications by the most prolific author. Applying Lotka's law, it was determined that the 35 most prolific authors should be highlighted. The first 33 authors, each with at least 5 publications, were selected, aligning closely with the law's recommendation. The subsequent consideration involved the top 50 authors with a minimum of 4 papers, a deviation from the number suggested by Lotka. Sunčica Delaš Kalinski, affiliated with the University of Split (Croatia), emerges as the most prolific author with a total of 20 papers. Following closely, Almir Atiković from the University of Tuzla (Bosnia and Herzegovina) takes the second position with 18 authored papers. The third author with the highest number of papers is Myriam Nunomura from the University of São Paulo (Brazil), contributing to a total of 16 papers.

Figure 3 illustrates the network of 33 prolific co-authors and their collaborations in the field of artistic gymnastics research. In this representation, nodes represent individual authors, and connecting lines depict collaborations between them. The size of each node corresponds to the author's impact or significance in the field, while the thickness of the lines indicates the frequency of collaborations. The proximity of nodes reflects the semantic or thematic relationships between authors.

The most substantial working group, highlighted in orange, consists of eight researchers, prominently featuring Myriam Nunomura. Notably, this group comprises authors from diverse countries, including Brazil, Sweden, and Australia. Additional sizable groups, highlighted in gray and pink, consist of four members each, led by Albrecht L. Claessens and Ivan Čuk, respectively. Another group in brown comprises three authors, with Sunčica Delaš Kalinski and Almir Atiković, two prolific authors, standing out. These authors also share a weak connection with Ivan Čuk, who belongs to a separate research group. The visualization further identifies four clusters of two authors and six individual authors without connections. It is essential to note that the graph exclusively showcases prolific authors, omitting groups formed by authors with fewer publications.

To identify the group of prominent authors in this research field, we cross-referenced prolific authors with those who contributed to the 31 most cited articles. The result highlighted 12 authors as prominent contributors. Albrecht L. Claessens emerges as a leading figure with 8 papers and 402 citations, affiliated with the Katholieke Universiteit Leuven (Belgium). Following closely are Gaston P. Beunen, also from the Katholieke Universiteit Leuven (Belgium), and Jeremie H. Lefevre from Hopital Saint Antoine Assistance Publique Hôpitaux de Paris (France), both with 7 papers and 395 citations each. It's noteworthy that 17 authors in total have exceeded 100 citations in the database articles. The 12 prominent authors, along with their affiliation/region, number of papers, and number of citations, are detailed in Table 3.

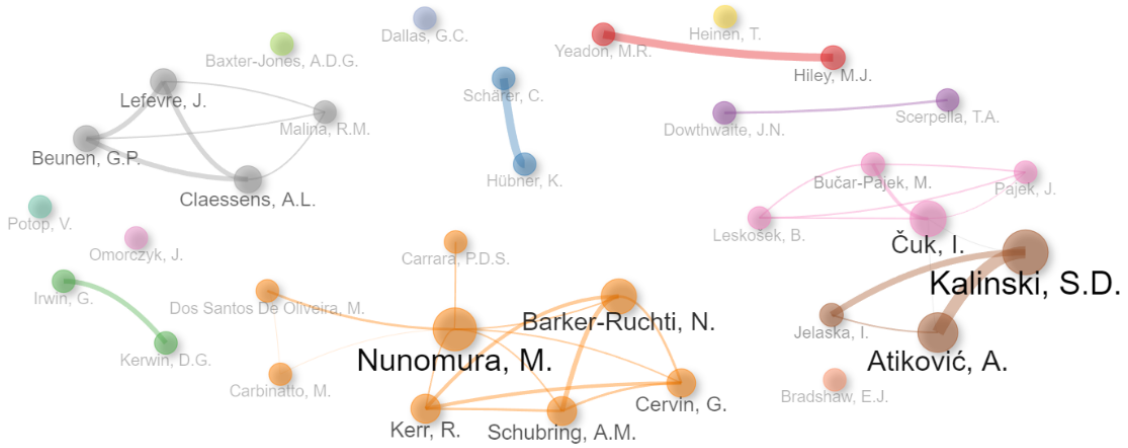

Figure 3. Graph illustrating prolific co-authors and their relationships. Bibliometrix: Analysis: Collaboration Network. Field: Authors. Network Layout: Kamada & Kawai. Clustering Algorithm: Walktrap. Normalization: Association. Number of nodes: 33. Repulsion force: 0.1. Remove isolated nodes: No. Min. number of edges: 1.

Table 3
Most prominent co-authors in artistic gymnastics.

Co-authors	Affiliation / Countries-Regions	Documents	Citations
Claessens, Albrecht L.	KU Leuven / Belgium	8	402
Beunen, Gaston P.	KU Leuven / Belgium	7	395
Lefevre, Jeremie H.	Hopital Saint Antoine Assistance Publique Hôpitaux de Paris / France	7	395
Barker-Ruchti, Natalie	University of Gothenburg / Sweden	12	261
Malina, Robert M.	University of Texas System / USA	5	259
Hiley, Michael J.	Loughborough University / England	10	238
Yeadon, Maurice R.	Loughborough University / England	9	230
Baxter-Jones, Adam D. G.	University of Saskatchewan / Canada	5	131
Schubring, Astrid M.	University of Gothenburg / Sweden	8	122
Dowthwaite, Jodi N.	State University of New York (SUNY) Binghamton / USA	5	121
Scerpella, Tamara A.	University of Wisconsin Madison / USA	5	121
Bradshaw, Elizabeth Jane	Deakin University / Australia	6	103

In the domain of MAG, we identified 145 authors associated with articles, notably recognizing Michael J. Hiley and Maurice R. Yeadon, both affiliated with Loughborough University (England), as prolific and prominent authors with 221 and 220 citations, respectively, and 9 papers each.

In WAG, a total of 199 authors were found. Notable prolific authors include Natalie Barker-Ruchti from the University of Gothenburg (Sweden), with 12 papers and 259 citations, and Almir Atiković from the University of Tuzla (Bosnia and Herzegovina), with 11 papers and 63 citations. In the realm of WAG, the most prominent authors are once again Natalie Barker-Ruchti, followed by Roslyn Kerr with 8 papers and Astrid M. Schubring with 7 papers, both accumulating 81 citations.

Table 4 presents prolific authors with the highest citation counts in each modality, calculated using the h-index for prolific authors, along with their respective number of papers and citations. Authors highlighted in gray stand out in both modalities, while those marked with an asterisk (*) do not appear as prolific in Figure 3, an analysis encompassing articles related to artistic gymnastics in general.

Table 4
Prolific co-authors with the highest number of citations in each modality.

Women's Artistic Gymnastics (14 authors)			Men's Artistic Gymnastics (13 authors)		
Co-authors	Documents	Citations	Co-authors	Documents	Citations
Barker-Ruchti, Natalie	12	259	Hiley, Michael J.	9	221
Kerr, Roslyn	8	81	Yeadon, Maurice R.	9	220
Schubring, Astrid M.	7	81	Čuk, Ivan	5	48
Čuk, Ivan	5	75	Atiković, Almir	5	40
Atiković, Almir	11	63	Bučar-Pajek, Maja	3	31
Cervin, Georgia	7	60	Amara, Samiha*	3	23
Nunomura, Myrian	9	51	Mkaouer, Bessem*	3	23
Jennings, Les*	4	38	Kalinski, Suncica Delas	3	20
Koh, Michael*	4	38	Coelho Bortoleto, Marco Antonio*	3	14
Kalinski, Suncica Delas	9	37	Hübner, Klaus	3	10
Schiavon, Laurita Marconi*	5	20	Schärer, Christoph	3	10
Potop, Vladimir	6	18	Capraro, Andre Mendes*	3	3
Jelaska, Igor	5	12	Vargas, Pauline Peixoto Iglesias*	3	3
dos Santos de Oliveira, M.	4	12			

The authors contributing to articles in our database represent a total of 51 different countries/regions. Brazil leads in article productivity with 74 documents, followed by the United Kingdom with 39 documents, the USA with 37 documents, and Italy with 34 documents. Concerning total citations, the USA takes the lead with 616 citations, followed by the United Kingdom with 526 citations, Belgium with 478 citations, Brazil with 249 citations, and Canada with 242 citations.

In Men's Artistic Gymnastics (MAG), Brazil is prominent with 14 documents, along with the United Kingdom (12 documents), and Slovenia and Tunisia, both contributing 5 documents each. In Women's Artistic Gymnastics (WAG), Brazil continues to lead with 25 documents, followed by Croatia with 11 documents, and Australia, Portugal, and the USA, each contributing 8 documents.

Figure 4 illustrates the collaborative network among countries/regions, with each node representing a country. The size of the node indicates the country's importance or impact in the field, and the connecting lines depict interactions, with the thickness representing the frequency of collaborations. Isolated nodes without connections are excluded from the graph.

Brazil and Australia exhibit the highest number of connections, each interacting with five countries. Brazil notably

collaborates strongly with Spain and holds the largest node, indicating its significant impact in the research field. Seven working groups are discernible, with the largest ones highlighted in blue (comprising New Zealand, Sweden, Australia, France, and Switzerland) and red (led by the United Kingdom and the USA, accompanied by Israel, Greece, and Italy). Another noteworthy group is highlighted in green, led by Brazil, and includes Spain, Portugal, and Colombia. There is also a group in purple, composed of Slovenia, Croatia, and Serbia. Lastly, three groups with two components each are highlighted in pink, brown, and orange.

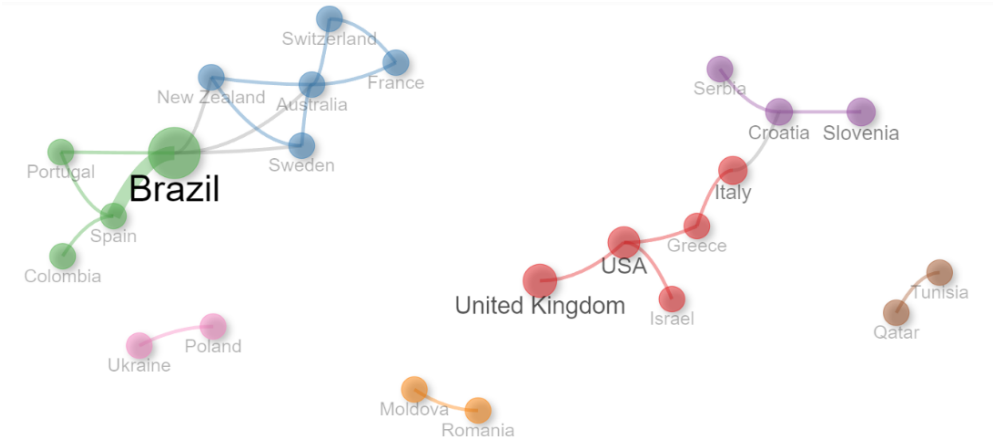

Figure 4. Collaboration networks between countries/regions. Bibliometrix: Analysis: Collaboration Network. Field: Countries. Network Layout: Automatic layout. Clustering Algorithm: Walktrap. Normalization: Association. Number of nodes: 51. Repulsion force: 0.1. Remove isolated nodes: Yes. Min. number of edges: 1.

In our database, we identified a total of 1164 unique keywords, which, after review and organization into thesauri (refer to Table 2S), were condensed to a total of 1042 keywords. To pinpoint the most pertinent keywords, Zipf's law was employed, suggesting a selection of no more than 32 words. We identified 29 words with a frequency of occurrence equal to or greater than 7, deeming them relevant. The two most frequently occurring words were "artistic gymnastics" (136 occurrences) and "gymnastics" (130 occurrences), both of which were utilized as search terms. Additionally, "women's artistic gymnastics" (18 occurrences) and "men's artistic gymnastics" (12 occurrences) were identified as relevant search terms. Other noteworthy keywords, although not incorporated as primary search terms, included "biomechanics" (27 occurrences), "performance" (24 occurrences), "judging" (20 occurrences), "athletes" (20 occurrences), "body composition" (20 occurrences), "injuries" (19 occurrences), and "coaching" (18 occurrences). Table 6 presents the relevant author keywords, adhering to Zipf's law, for both MAG (154 keywords) and WAG (227 keywords). Keywords employed as search terms are shaded in gray.

Figure 5 displays the connections among the most relevant keywords, with node size representing the frequency of occurrences and the connection line thickness indicating the frequency of their association. The "Spinglass" clustering algorithm, recommended for extensive and

intricate bibliometric networks with an ambiguous modular structure (Lancichinetti & Fortunato, 2009), was employed. Four distinct groups are discernible, with the most extensive being those centered around the terms "Gymnastics" (highlighted in red) and "Artistic Gymnastics" (highlighted in blue), both consisting of eight components. Following these are the green-highlighted group, composed of seven components, and finally, the purple-highlighted group, comprising five components.

Table 6
Relevant author keywords in each modality.

Woman's Artistic Gymnastics (227 keywords)		Man's Artistic Gymnastics (154 keywords)	
Keyword	Ocurrences	Keyword	Ocurrences
gymnastics	33	*gymnastics*	21
women's artistic gymnastics	19	*artistic gymnastics*	12
artistic gymnastics	17	*men's artistic gymnastics*	10
performance	11	*simulation*	8
biomechanics	10	*high bar*	6
coaching	8	*optimization*	6
olympic games	8	*still rings*	6
judging	6	*biomechanics*	4
aesthetic sports	4	*code of points*	4
code of points	4	*training*	4
elite sports	4		
injuries	4		

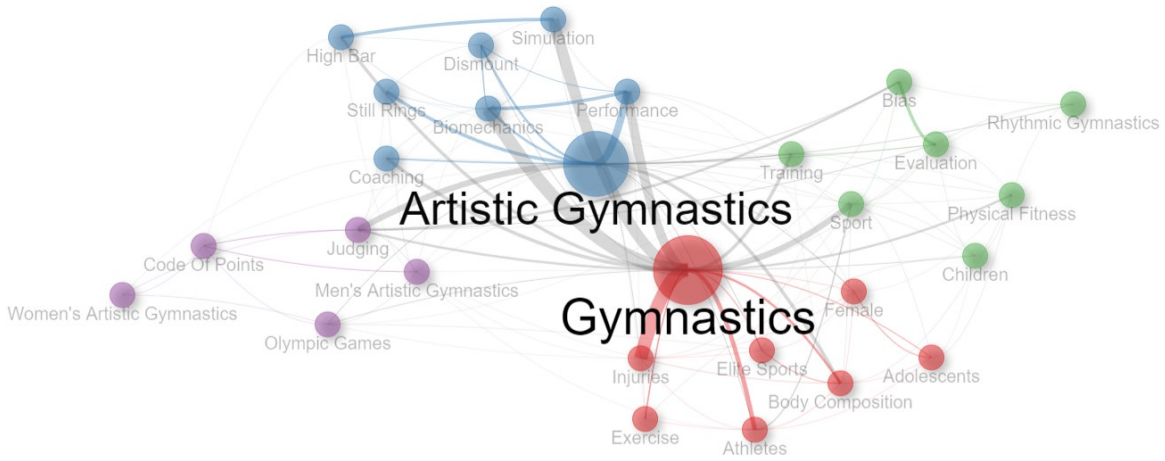

Figure 5. Most prominent author keywords and their connections. Bibliometrix: Analysis: Co-Occurrence Network. Field: Author's Keyword. Network Layout: Automatic layout. Clustering Algorithm: Spinglass. Normaization: Association. Number of nodes: 29. Repulsion force: 0.1. Remove isolated nodes: No. Min. number of edges: 1.

Table 7 highlights the 32 most relevant articles in our field based on the h-index, chosen from a total of 482 documents. The article boasting the highest citation count is "The Prevalence of Spondylolysis in the Spanish Elite Athlete" by Soler & Calderón (2000) (Soler & Calderón, 2000) published in the "American Journal of Sports

Medicine," with a cumulative citation count of 185. This work endeavors to identify the sports associated with a higher risk of spondylolysis, pinpointing artistic gymnastics (16.96%) among those with the highest risk. Following closely is the article titled "The Contribution of Anthropometric Characteristics to Performance Scores in Elite Female Gymnasts" by Claessens et al. (1999) (Claessens, Lefevre, Beunen, & Malina, 1999), published in the "Journal of Sports Medicine and Physical Fitness," accumulating a total of 122 citations. This study aims to discern anthropometric characteristics linked to performance in WAG and predict scores based on a combination of anthropometric dimensions. Occupying the third spot is "In Pursuit of an Identity: A Qualitative Exploration of Retirement from Women's Artistic Gymnastics" by Lavallee & Robinson (2007) (Lavallee & Robinson, 2007), published in the "Psychology of Sport and Exercise," with a total of 121 citations. This article delves into factors associated with the formation of self-identity and adaptation to sport retirement in elite athletes. Figure 6 visually represents the 32 most cited articles, with connecting lines indicating collaborative or influential relationships between the documents, implying that one cites the other.

In MAG, the most cited article is "The Mechanics of the Backward Giant Circle on the High Bar" by Yeadon and Hiley (2000) (Maurice R. Yeadon & Hiley, 2000), accumulating a total of 71 citations. This article focuses on the biomechanical analysis of the backward mill on the fixed bar. Notably, the top three articles with the highest citation counts are authored by Yeadon and Hiley, with two more of their works featuring in the list of highly cited papers.

Turning to the WAG literature, the previously mentioned piece by Lavallee & Robinson (2007) (Lavallee & Robinson, 2007) holds a prominent position. Following closely is the article titled "Gymnastics Injuries" by Caine and Nassar (2005) (Caine & Nassar, 2005), securing the second spot. This work aims to review the distribution and determinants of injury rates in pediatric gymnastics.

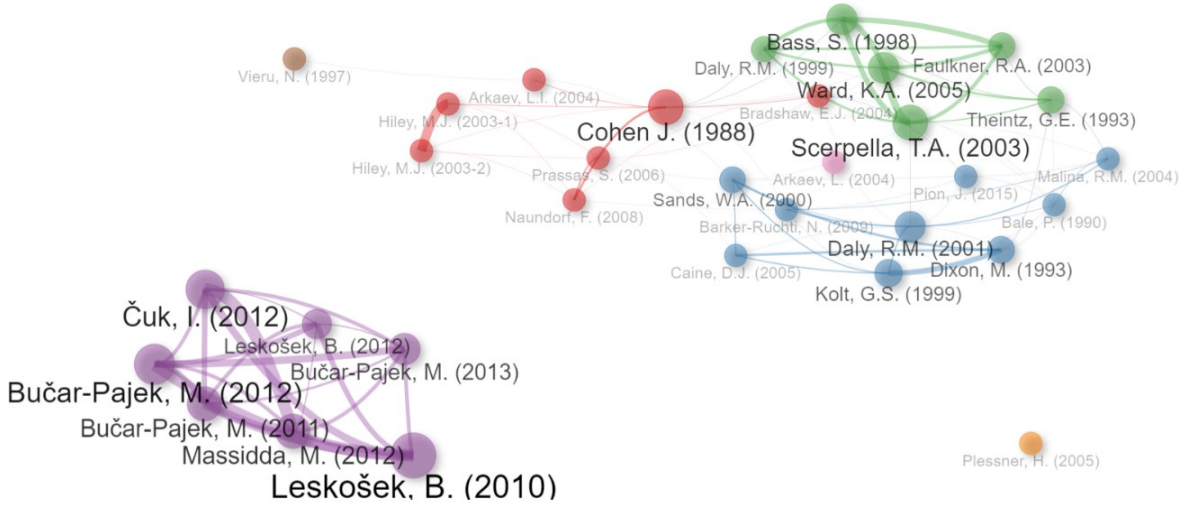

Figure 6. Graph with the most cited articles and their interrelationships. Bibliometrix: Analysis: Co-citation Network. Field: Papers. Network Layout: Kamada & Kawai. Clustering Algorithm: Walktrap. Number of nodes: 32. Repulsion force: 0. Remove isolated nodes: No. Min. number of edges: 1.

Table 7
Documents

Title. Main author (Year of publication)	Journal ISO Abbreviation	Cites
The Prevalence of Spondylolysis in the Spanish Elite Athlete. Soler & Calderón (2000)	American Journal of Sports Medicine	185
The Contribution of Anthropometric Characteristics to Performance Scores in Elite Female Gymnasts. Claessens et al. (1999)	Journal of Sports Medicine and Physical Fitness	122
In Pursuit of an Identity: A Qualitative Exploration of Retirement from Women's Artistic Gymnastics. Lavallee & Robinson (2007)	Psychology of Sport and Exercise	121
Gymnastics Injuries. Caine & Nassar (2005)	Medicine and Sport Science	115
Foucault In Leotards Corporeal Discipline in Women's Artistic Gymnastics. Barker-Ruchti & Tinning (2010)	Sociology of Sport Journal	84
Sports Disciplinary Legacy and the Challenge of Coaching Differently. Denison et al. (2017)	Sport, Education and Society	82
Anthropometric Characteristics of Outstanding Male and Female Gymnasts. Claessens et al. (1991)	Journal of Sports Sciences	79
Growth And Menarcheal Status of Elite Female Gymnasts. Claessens et al. (1992)	Medicine and Science in Sports and Exercise	79
The Mechanics of the Backward Giant Circle on the High Bar. Yeadon & Hiley (2000)	Human Movement Science	71
Initial Years of Recreational Artistic Gymnastics Training Improves Lumbar Spine Bone Mineral Accrual in 4- to 8-Year-Old Females. Laing et al. (2005)	Journal of Bone and Mineral Research	69
Gymnast Wrist an Epidemiologic Survey of Ulnar Variance and Stress Changes of The Radial Physis in Elite Female Gymnasts. De Smet et al. (1994)	The American Journal of Sports Medicine	63
Biomechanical Research in Artistic Gymnastics, A Review. Prassas et al. (2006)	Sports Biomechanics	62
A Prospective Study of Bone Mass and Body Composition in Female Adolescent Gymnasts. Laing et al. (2002)	Journal of Pediatrics	59
Energy and Nutrient Intakes of the United States National Women's Artistic Gymnastics Team. Jonnalagadda et al. (1998)	International Journal of Sport Nutrition and Exercise Metabolism	52
Biomechanical Approaches to Identify and Quantify Injury Mechanisms and Risk Factors in Women's Artistic Gymnastics. Bradshaw & Hume (2012)	Sports Biomechanics	51
Optimum Technique for Generating Angular Momentum in Accelerated Backward Giant Circles prior to a Dismount. Hiley & Yeadon (2003)	Journal of Applied Biomechanics	49
Duration of Physical and Mental Execution of Gymnastic Routines. Calmels & Fournier (2001)	Sport Psychologist	48
Higher Premenarcheal Bone Mass in Elite Gymnasts Is Maintained into Young Adulthood after Longterm Retirement from Sport. A 14-Year Followup. Erlandson et al. (2012)	Journal of Bone and Mineral Research	47
Urinary Incontinence and Other Pelvic Floor Dysfunctions in Female Athletes in Brazil A Crosssectional Study. Almeida et al. (2016)	Scandinavian Journal of Medicine & Science in Sports	44
Precompetitive and Recreational Gymnasts Have Greater Bone Density Mass and Estimated Strength at the Distal Radius in Young Childhood. Erlandson et al. (2012)	Osteoporosis International	41

Sustained Skeletal Benefit from Childhood Mechanical Loading. Scerpella et al. (2011)	Osteoporosis International	41
Reliability and Variability of Day-To-Day Vault Training Measures in Artistic Gymnastics. Elizabeth et al. (2010)	Sports Biomechanics	40
The German Young Olympic Athletes Lifestyle and Health Management Study Goal Study Design of a Mixed Method Study. Thiel et al. (2011)	Bmc Public Health	39
Ballerinas and Pixies A Genealogy of the Changing Female Gymnastics Body. Barker-Ruchti (2009)	International Journal of the History of Sport	38
The Margin for Error When Releasing the High Bar for Dismounts. Hiley & Yeadon (2003)	Journal of Biomechanics	38
Body Dissatisfaction Psychological Commitment to Exercise and Eating Behavior in Young Athletes from Aesthetic Sports. Fortes et al. (2013)	Revista Brasileira De Cineantropometria E Desempenho Humano	36
Abolished Circadian Rhythm of Salivary Cortisol in Elite Artistic Gymnasts. Georgopoulos et al. (2011)	Steroids	35
Gymnastics Injury Incidence During the 2008, 2012 and 2016 Olympic Games Analysis of Prospectively Collected Surveillance Data from 963 Registered Gymnasts during Olympic Games. Edouard et al. (2018)	British Journal of Sports Medicine	34
Postural Trials Expertise in Rhythmic Gymnastics Increases Control in Lateral Directions. Calavalle et al. (2008)	European Journal of Applied Physiology	33
Specific Injuries Induced by the Practice of Trampoline Tumbling and Acrobatic Gymnastics. Grapton et al. (2013)	Knee Surgery, Sports Traumatology, Arthroscopy	33
Evidence-Based Prerequisites and Precursors of Athletic Talent A Review. Issurin (2017)	Sports Medicine	32

DISCUSSION

The purpose of this documentary study was to examine the trajectory of scientific publications related to artistic gymnastics. The analysis aimed to identify trends in scientific output, determine the most prolific journals, recognize prolific and influential authors, highlight countries contributing significantly, identify relevant keywords, and pinpoint highly cited articles. Additionally, the study conducted separate analyses for male artistic gymnastics (MAG) and female artistic gymnastics (WAG). In the researchers' opinion, this investigation stands out as the most comprehensive and extensive to date, adhering to traditional bibliometric principles. The findings provide insights into prevalent themes, unexplored areas, and can serve as a guiding framework for future research in artistic gymnastics (Blanca-Torres et al., 2020; Job, 2008).

In the existing literature, the researchers found three documents with a descriptive bibliographic focus on artistic gymnastics or related subjects. These studies aimed to analyze the publication landscape in Brazilian journals within the field of Physical Education (Carbinatto, Chaves, Moreira, Souza de Castro Coelho, & Rovigati Simoes, 2016; Simões et al., 2016), national scientific journals in Physical Education (Carbinatto, Moreira, Chaves, Santos, & Simoes, 2016), and graduate theses and dissertations (Oliveira, Pires, Barbosa-Rinaldi, & Pizani, 2021). Another research specifically delved into the scientific production in male artistic gymnastics (Vargas & Capraro, 2020),

while another explored acrobatic gymnastics (Leite et al., 2023). Among these documentary reviews, only Leite et al. (2023) and Carbinatto et al. (2016) applied traditional bibliometric principles, specifically utilizing Bradford's law to assess journal distribution.

The initial document discovered in the search dates back to 1975 and is available in the Scopus database. Titled "Studies on the Vertebral Column in Young Female Gymnast" (Meyer, 1975), the author is Ed. Meyer, and the study investigates the condition of the spine in a sample of women's artistic gymnasts. The oldest article found in the Web of Science database is from 1988 (Pristavkina, 1988).

While modern gymnastics has its roots in 1811 with Friedrich Ludwig Jahn and was introduced to the Olympics in 1896 (Dorado García, 2003), the absence of older documents in this search may be attributed to the fact that until around 1961, when rhythmic gymnastics was officially recognized by the FIG (International Gymnastics Federation), the only recognized discipline was "Olympic gymnastics" (Dorado García, 2003; Nunomura, Nista-Piccolo, & Eunegi, 2004). Olympic gymnastics served as the precursor to artistic gymnastics, and the latter only acquired its current name after the inclusion of additional disciplines (Nunomura et al., 2004). It's suggested that searching under the name "Olympic gymnastics" might yield older documents.

Concerning the specific discipline of Women's Artistic Gymnastics (WAG), the oldest document found is from 1986, titled "Efficacy Expectations, Training Performance, and Competitive Performance in Women's Artistic Gymnastics" (Lee, 1986) by C. Lee. For Men's Artistic Gymnastics (MAG), the earliest document is from 1994, titled "Twisting Techniques Used in Dismounts from The Rings" (M. Yeadon, 1994) by M. Yeadon.

The increase in the number and frequency of publications on artistic gymnastics in recent years, as evidenced by the 83.18% (R2) goodness-of-fit index for exponential growth between 1996 and 2021, reflects a growing interest and investment in this field. The noticeable growth observed between 2010 and 2012, presented in Figures 1 and 2, can be attributed to several factors. Firstly, the proliferation of the internet and social media platforms has facilitated greater access to information about artistic gymnastics, thereby increasing public interest in this sport. This heightened visibility likely contributes to a growing curiosity and engagement from various researches. Additionally, advancements in technology, such as improved biomechanical analysis tools and high-speed recording systems, have enabled researchers to conduct more sophisticated analyses of gymnastic performances. These technological innovations provide researchers with the means to delve deeper into the intricacies of artistic gymnastics, leading to a richer understanding of the sport's mechanics and techniques.

When reviewing the current literature, exponential growth was also found in publications related to artistic gymnastics in Brazilian newspapers, as reported by Carbinatto et al. (2016) (Carbinatto, Moreira, et al., 2016) in their Graph 4. For the MAG modality, Vargas & Capraro (2020) (Vargas & Capraro, 2020) also present a graph which illustrates the growth in the frequency of publications over the years. Something similar is found in the acrobatic gymnastics modality by Leite et al. (2023) (Leite et al., 2023), where we also

observe a growth in the trend of publications, although much slower than in artistic gymnastics (global annual growth rate of scientific production is 26%). In comparing the research activity between men's and women's artistic gymnastics, it's evident that WAG attracts more scholarly attention (99 papers since 1986) compared to MAG (60 papers since 1994). Leite (Leite et al., 2023) speculates that this difference may be attributed to the greater participation of female gymnasts compared to their male counterparts, making it easier to find a consistent sample for an investigation.

When examining the thematic categories in WoS with the highest number of associated documents, "Sport Sciences" emerges as the leader, boasting seven times more associations than the second-ranking category, "Hospitality, Leisure, Sport and Tourism." These categories are particularly significant due to the inherently athletic nature of artistic gymnastics, a sport with a rich historical background. In third position, we encounter "Engineering, Biomedical," which features a comparable number of documents to the second-ranked category. Within this category, the focus predominantly revolves around biomechanical or kinematic analyses of gymnastics techniques. Some documents also explore methodologies for learning techniques through biomechanical resources (Fujihara, n.d.). Following these categories are "Education & Educational Research" and "Endocrinology & Metabolism." The former encompasses the majority of papers investigating training methodologies, the personal benefits of learning gymnastics, and the pedagogical aspects of gymnastics training. Conversely, the latter category hosts papers related to the physiology of gymnasts or the evolution of their bodies throughout the training process, including research on the impact on bones and injuries.

In terms of notable journals, "Science of Gymnastics Journal" emerges as the leader in the number of published documents, surpassing the second-ranking journal, "Journal of Physical Education And Sport," by threefold. Within the core of prolific journals, "Science of Gymnastics Journal" stands out as the sole publication dedicated specifically to the subject. In contrast, the remaining journals encompass documents across various sports disciplines, with some journals focusing on specific perspectives such as education or biomechanics. Despite its specificity, "Science of Gymnastics Journal" maintains a relatively low scientific impact, with "Journal of Sports Sciences" holding the highest impact. The most cited paper published in "Science of Gymnastics Journal" is "Parents' Support on the Sports Career of Young Gymnasts" (Nunomura & Oliveira, 2013) by Nunomura and Oliveira, emphasizing the crucial role of parental support in the development of gymnasts as athletes. Meanwhile, the most cited paper in "Journal of Sports Sciences" is "Anthropometric Characteristics of Outstanding Male and Female Gymnasts" (Claessens et al., 1991) by Claessens et al., which establishes "gymnastics-specific" anthropometric reference values after analyzing a significant sample of gymnasts. Notably, some Brazilian national journals identified as prolific by Carbinatto et al. (2016) appear in our database. However, the top-ranked journal reported in Carbinatto et al. (2016) is not indexed in our databases and is therefore absent from our analysis. The second-ranked journal, "Revista Brasileira De Ciências Do Esporte," occupies position 36 in our analysis, placing

it within Zone I according to Bradford's distribution. Discrepancies with the findings of Carbinatto et al. (2016) may stem from differences in the databases used for document searches, as well as variations in the timeframe analyzed, spanning from 2000 to 2015.

When comparing our findings on prolific journals in the MAG modality with those reported by Vargas and Capraro (2020), we observe a significant degree of overlap, particularly in the top three positions. In both analyses, "Science of Gymnastics Journal," "Journal of Biomechanics," and "Journal of Applied Biomechanics" occupy these positions. While we did not encounter other studies analyzing journals in the WAG modality, a comparison with our MAG results reveals a notable difference. In WAG, journals related to biomechanical aspects do not appear until the sixth position, where "Journal of Biomechanics" emerges. In contrast, in MAG, biomechanical aspects are represented in at least four of the top six prolific journals. This suggests that kinematic analysis of technique is more prevalent in men's artistic gymnastics than in women's artistic gymnastics. Furthermore, when comparing the journals comprising the core of prolific journals in artistic gymnastics with those in acrobatic gymnastics (Leite et al., 2023), we find overlap in "Science of Gymnastics Journal" and "Sports Biomechanics." However, their rankings differ, with the former in second position with 14 documents and the latter in sixth position with 2 documents, respectively.

The most influential author in this research field is Albrecht L. Claessens from Belgium, whose work predominantly focuses on female gymnasts, except for one study that also involves male gymnasts (Claessens et al., 1991). His most cited paper, "The Contribution Of Anthropometric Characteristics To Performance Scores In Elite Female Gymnasts" (Claessens et al., 1999), aimed to identify anthropometric variables related to performance in WAG and predict performance scores based on a combination of anthropometric dimensions. Following Claessens, Gaston P. Beunen and Jeremie H. Lefevre are notable authors, often collaborating with Claessens and contributing to many of his publications. Simões et al. (2016) analyzed authors of papers on gymnastics published in national journals indexed in the area of Physical Education by CAPES between 2000 and June 2015. They highlighted authors with three or more publications on the subject, with Myrian Nunomura being the most prolific, followed by Mauricio dos Santos de Oliveira. In our analysis, these authors are identified as prolific according to Lotka's law but not as prominent because they lack papers in the most cited category. In the realm of male artistic gymnastics, other noteworthy authors include Maurice R. Yeadon and Michael J. Hiley for the period between 1994 and 2019, as reported by Vargas and Capraro (2020). This aligns with our findings, placing them in first position. Vargas and Capraro (2020) also identify Marco Antonio Bortoleto and Ivan Čuk in third and fourth place, respectively. In our analysis, Ivan Čuk is highlighted once again, while Almir Atiković replaces Marco Antonio Bortoleto. M. A. Bortoleto's lower ranking in our study may be attributed to our search limitations, which focused on WoS Core to include only documents indexed in quality journals. This process may have resulted in a lower number of documents for that author. As for prolific authors in acrobatic gymnastics (Leite et al.,

2023), no coincidences were found in our analysis.

While the Soviet Union, United States, Japan, China, Romania, and Russia top the list of countries with the most medals in the Olympics, Brazil, the United Kingdom, and the USA lead in scientific publications, with Brazil notably producing nearly twice as many publications as the UK and USA combined. Interestingly, the USA is the only country prominent in both arenas, possibly due to its large pool of gymnasts and researchers, fostering excellence in both sports and academia. Moreover, athletic scholarships for students in the USA could fuel interest among student athletes to delve into research in their sport. Despite Brazil's prolific output, it does not match Olympic achievements in artistic gymnastics. Countries excelling in artistic gymnastics may prefer to keep research and technological advances within their organizations, limiting access to such information by other sporting powers. This could explain why, despite their athletic successes, they do not lead in research. The growing popularity of artistic gymnastics in countries like Brazil may justify their high volume of publications.

The group led by the term "Artistic Gymnastics," highlighted in blue, predominantly comprises terms related to biomechanical analysis of technique, such as "biomechanics," "simulation," or "performance." Notably, keywords related to specific apparatuses, like the horizontal bar and rings, predominantly from the MAG modality, indicate a prevalent focus on kinematic parameters analysis, especially evident in dismounts from the high bar and strength elements in the rings. Authors such as M. Hiley, M. Yeadon, C. Schärer, and K. Hübner have contributed significantly in these areas.

The following group, highlighted in red under "Gymnastics," primarily encompasses terms associated with physiological aspects like body composition or injuries, often focusing on elite and female athletes.

The green-highlighted group lacks significant keyword associations, suggesting disparate topics possibly related to gymnastics in children or non-competitive gymnastics.

Lastly, the purple-highlighted group covers aspects of evaluating gymnast performance, including terms like "judging" and "code of points," alongside references to both modalities of artistic gymnastics and the Olympics. These findings align with Carbinatto et al.'s (2016) observations on gymnastics publications in Brazilian journals, which highlight three main themes: biomechanics, psychology, and physiology.

In practical terms, this analysis offers valuable insights into the structure of publications in artistic gymnastics, including authors and keywords, among other elements. Understanding the key authors and their research areas can facilitate collaboration and help identify experts in specific topics. Moreover, it sheds light on existing collaborations among authors, providing a comprehensive overview of the research landscape.

Researchers can leverage this analysis to pinpoint prevalent research fields, emerging trends, and areas ripe for further exploration. By identifying gaps in current research, scholars can focus their efforts on unexplored or under-researched areas, thereby contributing to the advancement of knowledge in the field.

Notably, biomechanical analyses are prevalent in disciplines such as the high bar and still rings, with limited research on

apparatuses like the pommel horse. Additionally, research related to health tends to be more gender-specific, often focusing on female athletes, highlighting a potential gap in research on male athletes.

However, it's important to acknowledge the limitations of this analysis. By focusing solely on papers indexed in WoS Core and Scopus, relevant research published in smaller journals or lacking specific keywords in their titles, abstracts, or keywords may have been overlooked. Future researchers are encouraged to adopt the keywords identified in this study to enhance document identification.

Moreover, the databases used in this analysis may inherently favor content in Biological Sciences over Human Sciences and prioritize English-language publications, potentially excluding relevant research published in other languages. Therefore, researchers should remain mindful of these limitations and adopt a comprehensive approach to literature review.

CONCLUSIONS

Based on our analysis of scientific production in artistic gymnastics across the Web of Science (WoS) and Scopus platforms, several key conclusions can be drawn:

1. There is a noticeable uptrend in research interest within the scientific community. The earliest article dates back to 1975, with 2019 marking the most prolific year. A consistent interval of research activity spans from 1996 to 2022. Notably, the oldest document in the Women's Artistic Gymnastics (WAG) category dates to 1986, while in Men's Artistic Gymnastics (MAG), it dates to 1994.

2. Among prolific authors, Sunčica Delaš Kalinski (Croatia), Almir Atiković (Bosnia and Herzegovina), and Myrian Nunomura (Brazil) emerge prominently. Noteworthy figures in the field include Albrecht L. Claessens (Belgium), followed by Gaston P. Beunen (Belgium) and Jeremie H. Lefevre (France). In WAG, Natalie Barker-Ruchti (Sweden) stands out, while in MAG, Michael J. Hiley and Maurice R. Yeadon (both British) make significant contributions.

3. The journal "Science of Gymnastics Journal" leads in terms of publication volume, accounting for 17.01% of publications, followed by "Journal of Physical Education and Sport" (4.98%), "Teoriya i Praktika Fizicheskoy Kultury" (2.9%), and "Sports Biomechanics" (2.7%). Notably, "Science of Gymnastics Journal" maintains its prominence in both WAG (24.24%) and MAG (30.36%) categories.

4. Analysis of keyword clusters reveals four primary themes: "analysis of technique," "training (physiological aspects)," "gymnastics as a basic sport," and "evaluation and scoring of exercises."

DECLARATION OF INTEREST STATEMENT

The authors declare no conflict of interest.

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SUPPLEMENTARY MATERIAL

Table 1S. Bradford's zones and their number of journals, according to number of articles.

Zone	Nº journals (%)	Number articles (%)	Acc. nº journals (%)	Acc. nº articles (%)	Bradford multipliers	Journals (theoretical serie)	
CORE	6 (3,2%)	155 (32,2%)	6 (3,2%)	155 (32,2%)		n0	6
Zone 1	31 (16,7%)	149 (30,9%)	37 (19,9%)	304 (63%)	5,17	n1	30
Zone 2	149 (80,1%)	178 (36,9%)	186 (100%)	482 (100%)	4,81	n2	149
Total	186 100%	482 100%		Mean	4,99	185	
						% Error	0,5%

Nº (Number); % (Percentage); Acc (Accumulated);

Table 2S. Thesauruses created with keywords.

olympic games, 2012-2016 olympic games, olympic games 1, olympics, youth olympic games	dismount, dismounts, dismounts skill
maximum strength, absolute strength	dxa, dual-energy x-ray absorptiometry, dual-energy x-ray absorptiometry (dxa)
muscular strength, muscle strength	emotion, emotions
isometric contraction, static strength	epidemiology, épidémiologie
injuries, ankle injury, athletic injuries, head injury, injury, muscle injury, muscular and skeletal injuries, musculoskeletal injuries, sporting injuries, sports injuries, wounds and injuries, wrist injury	exercise, exercises
injury prevention, injury risk analysis	artistic gymnastics, artistic gymnastic, artistic gymnasts, key two: artistic gymnastics
female gymnasts, female gymnast, female sporting gymnastics, women's gymnastics	women's artistic gymnastics, female artistic gymnastics, woman artistic gymnastics, women artistic gymnastics, women’s artistic gymnastic, women’s artistic gymnastics
gymnastics, gymnast, gymnastic, gymnastic sports, gymnastique, gymnasts, sports gymnastics	men's artistic gymnastics, male artistic gymnastics, male artistic gymnasts, man artistic gymnastics, men artistic gymnastics, men’s artistic gymnastics, men's artistic
rhythmic gymnastics, rhythmic gymnasts	gender participation, gender-participation

children, childhood	handstand, handstand skill
aesthetic sports, aesthetic sport, aesthetics of sport	high performance, high performance athletes, high-level
elite sports, elite sport, elite, elite athlete, elite athletes, elite-level	high bar, horizontal bar
physical and sports education, physical education and sport	jump, jumping
sport, sports	landing, learning
sport results, resultados desportivos, sports result, sports results	long-term planning, long term programs of learning, long-term plan
coaching, coach, coaches, sport coaching, sports coaching	measurement system, measurement systems
judging, judge, judges, judging bias, judging system, panel judging, sports judges, sports judging	men, males
training, training process, sport training, sports training	modeling, modelling
youth sport, youth sports	motion capture, motion capturing
youth, youths	optimization, optimisation
coaches opinion, coaches' perception, opinions of gymnastic coaches	pediatric, pediatrics
acrobatics, acrobatic	peripheral quantitative computed tomography, peripheral quantitative computed tomography (pqct), pqct
adolescents, adolescence, adolescent	range of motion, range of movement, rom
body composition, anthropometrics, anthropometry	social goal orientation, social goal orientations
athletes, athlete, atletas	somersault, somersaults
athlete development, athletes' development	still rings, rings
athletic performance, athletic performances	stretching, stretch
bibliometric, bibliometrics	test, tests
bone, bones, bone and bones	trampoline, trampolining
bone mineral content, bone mineral content (bmc)	trend, trends
code of points, code of points (fig)	upper limbs, upper extremities, upper limb
coronavirus, covid-19	world championship, world championships
discipline, disciplines	

SHORT HISTORICAL NOTES XXIX

Anton Gajdoš, Bratislava, Slovakia
Ivan Čuk, Ljubljana, Slovenia

Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia športu Slovenska (www.sportency.sk). Among his passion is collecting photos and signatures of gymnasts. As we tend to forget old champions and important gymnasts, judges and coaches, we decided to publish part of his archive under title Short historical notes. All information on these pages is from Anton's archives and collected through years.

12th World Championship 1950 in Basel

The first World Championship (WC) in gymnastics after WWII was held in Basel (Switzerland) in 1950. Switzerland was determined as WC organizer already for year 1942, but war begun and all competitions were canceled. After the WWII it took quite a lot of time to start activities again, so it took 12 years from Prague in 1938 to Basel 1950.

What was so exceptional with this world championship?

The Basel WC was the last championship where other activities, disciplines besides artistic gymnastics were involved.

On the first day of competition at stadium, where 20.000 spectators were present, track and field disciplines were held for men:

- pole jump, 300 cm of height for 10 points,
- high jump, 160 cm of height for 10 points
- 100 m run, 12.2 s for 10 points.

Photo on right: Esa Seeste (FIN) was excellent in track and field disciplines