THE STATE OF THE ART IN ACROBATIC GYMNASTICS: A BIBLIOMETRIC ANALYSIS

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Abstract
Since acrobatic gymnastics is a recent gymnastics discipline, with only a few decades old, it is not yet much explored as a scientific research field. Despite its increasing popularity, and while science mapping has become an essential activity for all scientific disciplines, no bibliometric analysis on this topic was available. Therefore, this study aims to provide a static picture of the scientific research development in acrobatic gymnastics by collecting information about the main contributors as well as the main investigation topics, the publication dynamics and cooperative networks. A search conducted in the Web of Science and Scopus databases retrieved 37 journal articles between 2001-2021. Results suggest that the year of 2015 was a milestone for scientific research in acrobatic gymnastics since it marked the beginning of the dominance of authors from Spain, followed by Poland and Portugal. Countries are generally focused on their own territory and there is a limited scientific collaboration between different nations. The Spanish and the Polish research institutions are leading publishing in this sport. As a reference for future studies, our results suggest that although balance was identified as the niche investigation topic, there has been a lack of interest for the pyramids balance, which is a major feature of acrobatic gymnastics.

Keywords: *acrobatic gymnastics; bibliometric analysis; scientific production.*

INTRODUCTION

According to the Fédération Internationale de Gymnastique (2020), acrobatic gymnastics, initially called sports acrobatics, emerged as a competitive discipline from the Soviet Union, with the first national championship in 1939. Since the Second World War interrupted the development of this gymnastics discipline, the first international competition was held later, in Warsaw, in 1957, with the participation of four Eastern-bloc teams.

On November 23, 1973, the International Federation of Sports Acrobatics (IFSA) was established as the world governing body representing acrobatic gymnastics. However, in 1998, the IFSA was dissolved and the discipline was incorporated in the International Gymnastics Federation (FIG), with the overreaching goal to unite all gymnastics disciplines and to support acrobatics ultimately become an Olympic sport. The Acrobatic Gymnastics 16th World

Championship and the first world championship in the FIG era took place in Ghent, Belgium, in 1999 (Fédération Internationale de Gymnastique, 2020).

Since 2007, this discipline has been known as acrobatic gymnastics. It is characterized by the execution of static elements, such as balances and holds, and dynamic elements, such as lifts and throws with complex somersaults and twists, executed in pairs/groups, set to music and interspersed with choreography (Fédération Internationale de Gymnastique, 2020). Since acrobatic gymnastics is only a few decades old gymnastics discipline, it is not yet much explored as a scientific research field (Floria, Gomez-Landero, & Harrison, 2015; Leal Del Ojo, Floría, Harrison, & Gómez-Landero, 2020).

For a particular research domain, scholars tend to focus on the literature generated by the relevant scientific community (Aria, Misuraca, & Spano, 2020). Therefore, science mapping becomes an essential activity for scholars in all scientific disciplines (Aria & Cuccurullo, 2017) and bibliometric methods provide a quantitative perspective on the relevant literature for a given domain (Aria & Cuccurullo, 2017). They structure fields differently to the traditional literature reviews classification by providing a static field's picture at a particular moment (Aria et al., 2020). In acrobatic gymnastics, this analysis can be particularly important to identify the current research focus and which areas may be underexplored, allowing research efforts to be directed towards topics relevant to the sport development.

To the best of our knowledge, no bibliometric analysis on acrobatic gymnastics has been conducted to date despite its increase in popularity among different age groups (Taboada-Iglesias, Gutierrez-Sanchez, & Vernetta Santana, 2016; Taboada-Iglesias, Vernetta Santana, & Gutiérrez-Sánchez, 2017), underscoring a clear absence of information. Therefore, this study aims to provide a clear understanding of the current situation in acrobatic gymnastics by collecting information about the main contributors (countries, affiliations and authors), as well as the main investigation topics, the publication dynamics, and the cooperative networks between countries. This work may serve as a reference for future acrobatic gymnastics studies by identifying the areas that should be explored further.

METHODS

A database search was conducted on December 31, 2021, in the Clarivate Analytics Web of Science (WoS) and Scopus dabatases. The compatibility with the software used and the fact that WoS integrated the information from other databases while Scopus allowed the inclusion of a more comprehensive time window were the main reasons for the selection of these two databases. A topic search (article title, abstract, author keywords and keywords plus) was performed in WoS including the following search key: "gymnastic* AND (acrobatic* NOT artistic* NOT rhythmic* NOT aerobic*)". Since in the SCOPUS dabatase the operator NOT is equivalent to AND NOT and the topic search is not available, a search within the article title, abstract and author keywords was conducted, and the search key was adapted to the following: "gymnastic* AND (acrobatic* AND NOT artistic* AND NOT rhythmic* AND NOT aerobic*)". Only journal articles were selected for this study, but no time or language filters were applied.

The full record and cited references were retrieved. The resulting data were analyzed using the Bibliometrix toolbox (Aria & Cuccurullo, 2017) and its graphic user interface Biblioshiny, in RStudio 1.4.1106 (RStudio Inc., Boston, Massachusetts, USA) for a descriptive and quantitative data analysis. This process included the extraction of data set information, documents, and authors and sources information, as well as their

dynamics. For the information ranking, the top 5 elements were reported, except for the Core Sources assessment which are ranked according to the Bradford's Law (Bradford SCE, Egan M, & Shera JH, 1953).

RESULTS AND DISCUSSION

Document elegibility process is depicted in Figure 1. A total of 159 documents were retrieved (WoS, n = 79, and Scopus, n = 80), with dates ranging between 1999-2021 (WoS) and 1960-2021 (Scopus). The two databases information was merged into one single file, resulting in the authomatic detection and removal of 35 duplicated entries, leaving 124 documents. Although keywords were selected to avoid the inclusion of other gymnastics disciplines content, the results included articles from artistic gymnastics and "acrobatic elements" refering to floor routines. Therefore, the database was reviewed and only documents that included either a) acrobatic gymnasts, or b) acrobatic gymnastics content were retained for further analysis. This led us to exclude 82 and retain 42 documents. Five other documents were excluded since they were not journal articles but articles from congresses (n = 3), letters (n = 1) and editorials (n = 1).

After the database review and clean-up, 37 documents related to acrobatic gymnastics were used for this bibliometric study. These documents were written in English (n = 26), Spanish (n = 9), Portuguese (n = 1), or Russian (n = 1).

The following results and the discussion section are divided in six subsections: 1) publication dynamics according to countries' contributions and citations received; 2) the most productive and locally cited authors; 3) the most productive affiliations and collaboration networks; 4) the most locally and globally cited documents; 5) journal dynamics according to the core sources and the most cited journals, and 6) the conceptual structure, aiming to define 4 themes that may serve as a reference for future studies in this research field.

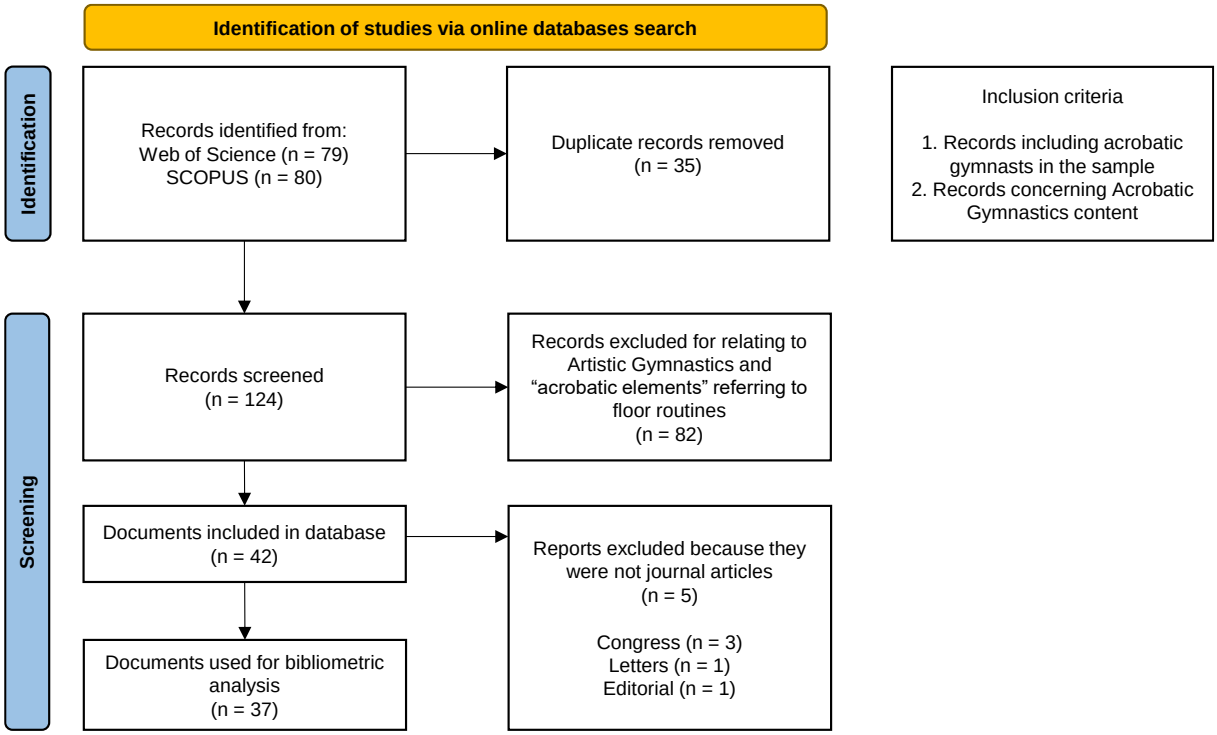

Figure 1. Document identification, screening and eligibility process.

The 37 retrieved documents were published between 2001-2021. On average, there were 2.65 citations per document and 0.76 citations per year and per document. These results suggest that acrobatic gymnastics is a recent gymnastics discipline with a limited scientific production, Documents on acrobatic gymnastics also have limited citations. The fact that each document presents an increase of only 0.76 citations per year suggests a slow progress of science in this field. A bibliometric analysis conducted in men's artistic gymnastics retrieved 52 documents distributed between 1994 and 2019 (Vargas & Capraro, 2020). In fact, between 1994 and 2014, the highest number of annual publications was 3 documents (2007, 2011 and 2021). These authors found the period between 2015 and 2018 as the most productive, totalling 5 (2015 and 2016), 8 (2017) and 9 documents published (2018). It seems that although men's artistic gymnastics was the first gymnastics discipline in the Olympic program, its scientific research field is still much less active than, e.g., women's artistic gymnastics. Although some systematic reviews about women's artistic gymnastics have been conducted (Campbell, Bradshaw, Ball, Pease, & Spratford, 2019; Prassas, Kwon, & Sands, 2006; Sterkowicz-Przybycien & Gualdi-Russo, 2018), a bibliometric review was not found for comparison. In acrobatic gymnastics, even though the overall annual growth rate of scientific production is 26%, there have been wide fluctuations over time (Figure 2). The first three journal articles in acrobatic gymnastics were published in 2001, 2008 and 2010. Although other types of publication (conference papers, letter, editorials and books) might might have been published in these years, there was no journal article. 2015 was a milestone for scientific research in acrobatic gymnastics since it marked the beginning of a continuous publication on this topic, most likely due to its increasing popularity (Taboada-Iglesias et al., 2016; Taboada-Iglesias et al., 2017). In men's artistic gymnastics (Vargas & Capraro, 2020), the scientific production also varies over time, with 2018 being the most productive year to date. These authors found an increase in publications from 2015 onwards, similarly to our results. The increase in scientific production was associated with the expansion of search platforms, especially in the last decade (Ciomaga, 2013; Lindahl, Stenling, Lindwall, & Colliander, 2015; Peset Mancebo et al., 2013; Prieto, Gómez, & Sampaio, 2015). Both men's artistic and acrobatic gymnastics disciplines share a lack of a continuous growth in publications. Nevertheless, 2015 marks the beginning of a dominance of publications in acrobatic gymnastics by authors affiliated to Spanish institutions, authoring 4 of the 6 journal articles in 2015, and 60.6% of the articles henceforth.

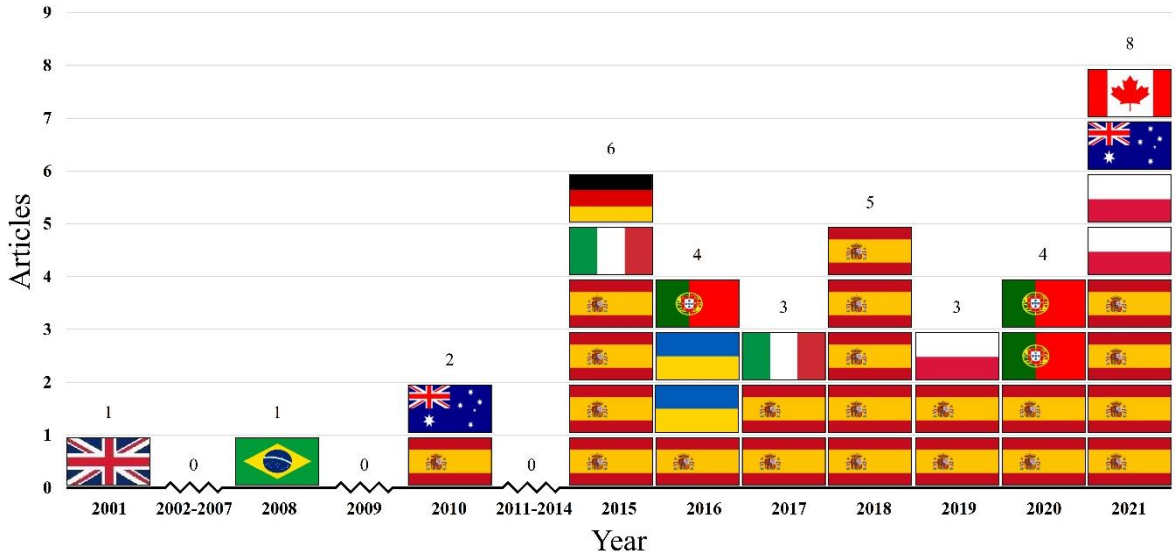

Figure 2. Number of acrobatic-gymnastics-related articles published annually by each country (2001-2021).

The prevalence of Spanish publications has a direct effect on the annual productivity. Years with fewer Spanish publications led to a decrease in the publication growth, suggesting that research in acrobatic gymnastics is mostly driven by these researchers, and that they have the greatest influence. However, the decrease in 2020 deserves further attention. In addition to an overall reduction of publications, and those affiliated with Spanish institutions in particular, the COVID-19 pandemic has negatively affected the usual research process (Radecki & Schonfeld, 2021) as can be seen in another bibliometric review (Fonseca, Goethel, Vilas-Boas, Gutierres, & Correia, 2021). Major competitions, such as the Acrobatic Gymnastics World Championship 2020 to be held in Geneva, Switzerland, were postponed to 2021, leading to a record participation of 40 nations and 1000 athletes (Fédération Internationale de Gymnastique, 2020), and providing a strong potential reason why 2021 was the most productive year. Whether this was a sporadic occurrence due to outstanding circumstances and not part of the normal publication growth can only be established in years to come. The fact is that 9 articles were published in 2021, with Spain showing again their predominance, followed by contributions from other nations, such as Poland, Australia, and the first publication from Canada. Table 1 depicts the total acrobatic gymnastics scientific production and citations count for each country.

Poland and Portugal are tied in second place in terms of productivity, each with 3 articles published. Despite its traditional position in gymnastics, particularly acrobatics, Ukraine only presented two publications. Brazil obtained great results in the latest Olympic games in women's artistic gymnastics but has no tradition in acrobatics, which can also be seen from the FIG results. Accordingly, Brazil only published one article in 2008 in acrobatic gymnastics. According to the Table 1, most publications are authored by researchers of a single country (SCP), while Spain and Canada are engaged in collaborations of multiple countries (MCP). The ratio between SCP and MCP publications suggests that countries are generally focused on their own territory, and that there is a limited scientific collaboration between nations in this domain.

In terms of citations per country, a higher number of publications is normally associated with an increased number of citations (Sandström & van den Besselaar, 2016). While this is the case for Spain, Poland and Portugal, Australian publications have received considerable attention. Out of the 31 citations Australia has received, Purnell, Shirley, Nicholson, and Adams (2010) alone had 28, which is almost the same number of citations as for all Spanish publications together. The authors addressed an issue in acrobatic gymnastics that can also be applied to other sports. Some of the citing articles are related to football, pole dancing, dancing, overall sports, injury, or pain. This is also beneficial to acrobatic gymnastics science, as it places the discipline in a position where it can serve as a reference to others. Despite numerous reasons to cite an article (Garfield, 1970), such numbers suggest important advances in the topic. Australia might have increased the number of citations in this topic, as older articles tend to gather more citations because they have been publicly available for longer (Belter, 2015).

The results found 95 distinct authors, and only one author authored 2 documents. To measure both the productivity and the citation impact of the publications (Hirsch, 2005), an authors' h-index was used based on the set of each scientist's most cited papers and the citations that they have received in other publications (Aria & Cuccurullo, 2017). These results, along with the top 5 most productive and most locally cited authors, are described in Table 2.

Table 1.
The total acrobatic gymnastics scientific production and citations count for each country.

Most productive countries	No. of articles	Frequency	SCP	MCP	MCP Ratio	Most cited countries	Total Citations
Spain	21	56.8%	18	3	14.3%	**Spain**	36
Poland	3	8.1%	3	0	0.0%	**Australia**	31
Portugal	3	8.1%	3	0	0.0%	**Poland**	10
Australia	2	5.4%	2	0	0.0%	**Portugal**	10
Italy	2	5.4%	2	0	0.0%	**Brazil**	3
Ukraine	2	5.4%	2	0	0.0%	**Canada**	3
Brazil	1	2.7%	1	0	0.0%	**Italy**	3
Canada	1	2.7%	0	1	100.0%	**Ukraine**	1
Germany	1	2.7%	1	0	0.0%	**United Kingdom**	1
United Kingdom	1	2.7%	1	0	0.0%	**Germany**	0
Total	37	100.0%	33	4	14.3%	**Total**	98

Legend: SCP: single-country publication; MCP: multiple-country publication and MCP_Ratio: the ratio between MCP and SCP (%).

Table 2.

The 5 most productive and locally cited authors and the Research Impact expressed as h-index.

Authors							
Most productive	**Affiliation**	**Articles**	**h-index**	**Most locally cited**	**Affiliation**	**Local citations**	**h-index**
Mercedes Vernetta-Santana	University of Granada	11	3	Águeda Gutierrez-Sanchez	University of Vigo	6	3
Águeda Gutierrez-Sanchez	University of Vigo	9	3	Yaiza Taboada-Iglesias	University of Vigo	6	3
Yaiza Taboada-Iglesias	University of Vigo	7	3	Mercedes Vernetta-Santana	University of Granada	6	3
Jesús Lopez-Bedoya	University of Granada	4	1	Roger Adams	University of Sydney	3	1
Diego Alonso-Fernandez	University of Vigo	3	1	Pablo Floría	Pablo de Olavide University	3	2

In Table 2, Mercedes Vernetta-Santana, from the University of Granada (Spain), is classified as the most productive author with 11 publications, followed by Águeda Gutierrez-Sanchez and Yaiza Taboada-Iglesias, both from the University of Vigo (Spain), with 9 and 7 publications, respectively. These three authors are the most locally cited, with 6 citations each and an h-index of 3. This measure was selected since it is the most widely used ranking metric, although its limitations are known and extensively reported (Kreiner, 2016). These results are evidence of domination of authors with Spanish affiliations. They are very different from those found in men's artistic gymnastics (Vargas & Capraro, 2020), where the most productive authors are from British (2 authors with 8 documents each), Brazilian and Slovenian universities (1 author, 5 documents for each country). Since the same study estimated the journals' h-index and not the authors' h-index, the results are not comparable in the present study.

Compared to other research topics, sports bibliometrics, sports psychology and women sports topics belong to a small-scale and small-range research field compared with other subject fields (Zheng & Liu, 2020), which is also the case for acrobatic gymnastics. Therefore, this h-index provides a low numerical distinction between authors, since they are limited to the number of documents published. A literature analysis of judo showed that an average researcher focusing exclusively on one field has limited possibility to achieve an h-index higher than 12 or 13, considering that the mean citation for a given paper is around this number, and goes even lower if a researcher is focused on a single sport (Peset Mancebo et al., 2013).

Finally, because bibliometric reviews in gymnastics disciplines are scarce, this is possibly the first time that the h-index is estimated for authors in acrobatic gymnastics, providing specific data for future comparisons.

Geography is an important factor for collaboration, and academics tend to

collaborate more frequently with those geographically near to them, particularly within their own country (Katz, 1994) or abroad (Luukkonen, Persson, & Sivertsen, 1992). It should be noted, though, that this situation has changed since the internet brought about global opportunites. In acrobatic gymnastics, cooperation normally takes place among different research institutions in the same country. When ordering the most productive institutions in acrobatic gymnastics, the Universities of Vigo, Granada, and Valencia are the leading Spanish research institutions, with 15, 10 and 3 documents published, respectively, and the Jerzy Kukuczka Academy of Physical Education and the Josef Pilsudski University of Physical Education are the leading Polish institutions, with 3 and 2 documents published, respectively.

The collaboration networks were assessed in three different fields: countries, affiliations and authors. Regarding the countries, the results revealed one single collaboration network between Spain and Ireland. In terms of affiliations, two networks were identified, one between the University of Granada and Vigo and another between the University of Limerick and Pablo de Olavide. Figure 3 presents the collaboration networks among authors from different institutions.

Figure 3 presents three different nerworks. Network 1 (upper-left corner) consists of 5 authors, including the 3 most productive and locally cited, affiliated with the University of Vigo and Granada, and two authors from Vigo and the Escuela Universitaria San Pablo CEU. Network 2 (lower-left corner) comprises two authors from the University of Granada. Network 3 (lower-right corner) consists of 2 authors from the Pablo de Olavide University (Seville), one fom San Isidoro University Center (Seville), and one from the University of Limerick (Ireland). While Networks 1 and 2 are connected, Network 3 is an exclusive collaboration between Seville (Spain) and Ireland. The lack of collaboration between all authors from distinct Spanish institutions may be a consequence of of different major areas of interest of each group. While Network 1 has investigated the anthropometric profile (Taboada-Iglesias et al., 2016; Taboada-Iglesias, Vernetta-Santana, Alonso-Fernandez, & Gutierrez-Sanchez, 2019; Taboada-Iglesias et al., 2017) and Network 2 investigated diverse subjects, such as injury incidence, jumping ability and body image (Ariza-Vargas, Salas-Morillas, Lopez-Bedoya, & Vernetta-Santana, 2021; Vernetta-Santana, Rojas, Montosa, & López-Bedoya, 2018; Vernetta, Montosa, & López-Bedoya, 2019), Network 3 has investigated balance abilities of acrobatic gymnasts as well as the pyramids balance (Floria et al., 2015; Gómez-Landero, Leal Del Ojo, Walker, & Floría, 2021; Leal Del Ojo et al., 2020).

The collaboration networks found have boosted publications in acrobatic gymnastics. The results revealed an average of 0.39 document per author, 2.57 authors per document and 3.57 co-authors per document. The divergence in the number of authors and co-authors per documents is related to the different ways used to count authors, e.g., if an author has written three publications, he/she will be counted only once in the authors per document ratio but he/she will be counted three times in the co-authors per document ratio (Aria et al., 2020). The collaboration index was 2.66, considering the total number of authors of multi-authored documents and the total number of multi-authored documents (Aria et al., 2020). The 5 most cited documents are described in Table 3.

Figure 3. Collaboration networks among authors from different institutions and countries (Network 1: upper-left corner; Network 2: lower-left corner and Network 3: lower-right corner).

The most locally and globally cited document is focused on acrobatic gymnastics injuries (Purnell et al., 2010) with a clear advantage in terms of global citations (GC). However, higher GC indicates that it is mostly cited in articles outside the dataset used in this study (i.e., cited in non-acrobatic gymnastics articles). Considering the number of local citations (LC), its impact in the field is comparable to that of Taboada-Iglesias et al. (2017). This article, along with Taboada-Iglesias et al. (2015), has investigated the anthropometric profile and the remaining articles have evaluated the pyramid balance (Floria et al., 2015) or individual gymnasts' balance (Opala-Berdzik et al., 2018). The LC/GC ratio indicates that the most cited documents have more global than local citations, that is, these documents have more citations from documents outside of this data set (WoS and Scopus databases). The 3 local citations put Purnell's article on the same level as the other 3 listed articles, however, it has had a higher impact outside gymnastics. This may indicate that while the scientific community, relating to gymnastics in particular, may find such articles usefull, acrobatic gymnastics has not yet matured enough to recognise such articles as its seminal works.

The articles in this dataset have been published in 29 distinct journals. According to the Bradford's Law (Bradford SCE et al., 1953), there are core sources, this is, the journals that comprise most publications: for acrobatic gymnastics, there are 6 (Table 4). This table presents the most locally cited sources, i.e., how many times a source included in this collection has been cited by other sources also included in the collection (Aria & Cuccurullo, 2017).

The Retos and the Science of Gymnastics Journal are the primary sources, with 3 articles each. The remaining core sources published two articles each. The Retos journal focuses on physical education, sports and recreational activities, and the Science of Gymnastics Journal is gymnastics-specific. In contrast, the remaining sources publish documents with general themes and are highly reputable (e.g. Acta of Bioengineering and Biomechanics, and Sports Sciences for Health). There may be two reasons for this distinction: researchers published their studies in less reputable journals because the field is not consolidated enough for the big journals to be strongly interested, or the authors published in journals with topics closer to their interests.

Table 3

The 5 most cited documents, local and global citations and the respective ratio (%)

First author (Year)	Most cited documents	TC per year	LC	GC	LC/GC Ratio
Purnell et al. (2010)	Acrobatic Gymnastics injury: occurrence, site and training risk factors	2.33	3	28	10.71 %
Taboada-Iglesias et al. (2017)	Anthropometric profile in different event categories of Acrobatic Gymnastics	2.00	3	10	30.00 %
Floria et al. (2015)	Centre of pressure correlates with pyramid performance in Acrobatic Gymnastics	0.71	3	5	60.00 %
Taboada-Iglesias, Gutierrez-Sanchez, and Vernetta (2015)	Proportionality indices and body composition of elite Acrobatic Gymnasts	1.25	3	5	60.00 %
Opala-Berdzik et al. (2018)	Quiet standing postural sway of 10- to 13-year-old, national-level, female acrobatic gymnasts	2.00	1	6	16.67 %

Legend: TC – total citation; LC – local citation; GC – global citation; LC/GC ratio – ratio between LC and GC (%).

Table 4.

Core sources (Bradford's Law) and most locally cited sources

Core sources (Bradford's Law)	Articles	Most locally cited sources	Citations
Retos-Nuevas Tendencias En Educacion Fisica Deporte Y Recreacion	3	Gait & Posture	19
Science of Gymnastics Journal	3	Thesis	14
Acta of Bioengineering and Biomechanics	2	Journal of Human Kinetics	12
International Journal of Morphology	2	Journal of Sports Sciences	12
Sport Sciences for Health	2	Sports Medicine	12
Sports Biomechanics	2		

The only source with 2 publications in the last 2 years is the Science of Gymnastics Journal. The Acta of Bioengineering and Biomechanics and Sports Biomechanics published one document in 2021 and in 2020, respectively. The remaining journals published acrobatic gymnastics-related articles sporadically, i.e., both the International Journal Of Morphology and Sport Sciences For Health published 2

documents in 2015, and in 2018 and 2019, respectively. Finally, the Retos published one article per annum between 2017 and 2019.

Regarding the citations, the most locally cited sources are different from the core sources (Table 4). Nineteen documents cited Gait & Posture, the most cited source, followed by Thesis, with 14 citations. The remaining most locally cited sources indicate that the gymnastics researchers cited high quality sources. As stated previously, there are different reasons to cite an article, namely, providing background reading, substantiating claims, authenticating data and classes of facts, and naming original publications in which an idea or concept was first discussed (Garfield, 1970).

For the conceptual structure analysis, 119 author's keywords were considered. The thematic map (Figure 4) presented below was created to define four themes, according to the quadrant in which they are placed (Cahlik, 2000; Callon, Courtial, & Laville, 1991; Coulter, Monarch, & Konda, 1998; Courtial, 1994; He, 1999): 1) upper-right quadrant: motor-themes; 2) lower-right quadrant: basic themes; 3) lower-left quadrant: emerging or declining themes, and 4) upper-left quadrant: very specialized/niche themes.

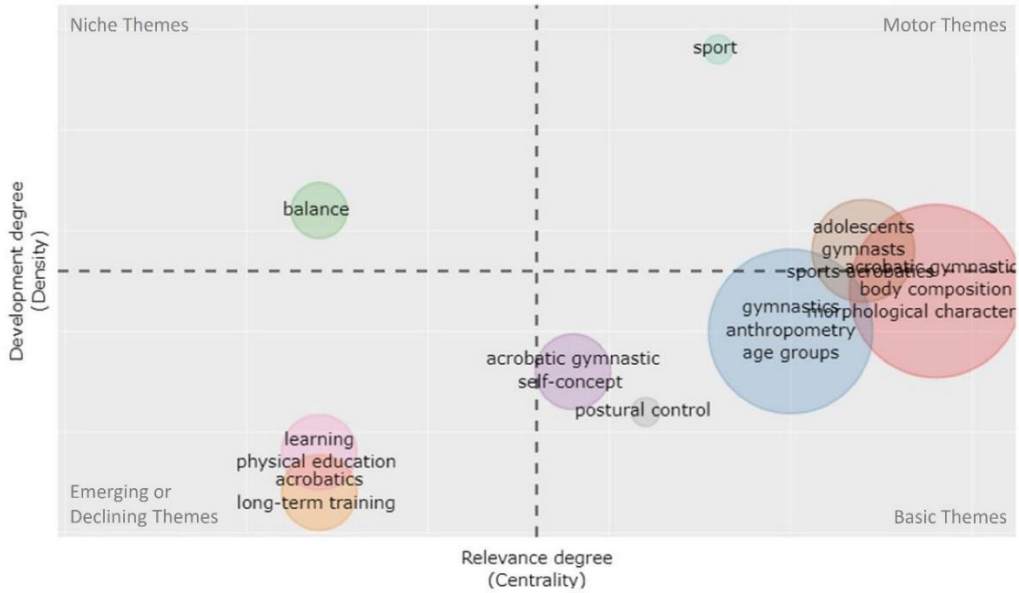

Figure 4. Thematic map for acrobatic gymnastics scientific research

Interpretation of each theme placement within the thematic map is essential to characterize each theme in terms of relevance (centrality) and development (density), according to the author keywords used in the documents within this data set (Figure 4). For the Motor Themes, 1) they are usually both well developed and important for a research field structuring given that they present strong centrality and high density, and 2) they are externally related to concepts applicable to other themes that are conceptually related (Cobo, López-Herrera, Herrera Viedma, & Herrera, 2011). Motor themes in acrobatic gymnastics are described as sport, refering to sports sciences and adolescent gymnasts from sports acrobatics.

The basic themes of this gymnastics discipline consist of self-concept, postural control, anthropometric characteristics in different age groups, and gymnasts' morphological characteristics, including body composition, which is positioned roughly in the middle, between the motor and the basic theme. A few studies have

investigated self-concept in the context of acrobatic gymnastics programs in physical education classes to promote team work and collaboration between students (López de la Osa & Gutiérrez-Sánchez, 2015; Xoana Reguera López, Gutiérrez-Sánchez, & Portela-Pino, 2016).

The main area that has contributed to the postural control research is Sports Biomechanics. Studies underline the need to employ comprehensive measuring techniques to provide a detailed kinematic and dynamic analysis to understand how the centre of pressure displacement is countered by continuous postural control of the two gymnasts who form the pyramid, having significant practical implications for training (Floria et al., 2015). Since the anthropometric profile has been investigated a lot (Silva, Silva, & Luemba, 2020; Taboada-Iglesias et al., 2016; Taboada-Iglesias et al., 2019; Taboada-Iglesias et al., 2017), the thematic map suggests that this basic theme is shifting to a motor theme.

The lower-left quadrant indicates that the learning process in physical education classes of acrobatic gymnastics and long-term training are becoming either an emerging or declining theme, suggesting that this area is both weakly developed and marginal since the themes in this quadrant have low density and low centrality (Cobo et al., 2011). While some studies investigated the learning process in physical education classes (Bores-Calle, Escudero, & Bores-Garcia, 2020; Gaudreau, Louvet, & Kljajic, 2019; Ramos, Ruiz, & Molina, 2015) and long term-training in acrobatic gymnastics (Bachinska, 2016; Bachinskaya, 2015), the results sugest that these subjects are declining in terms of significance.

The upper-left quadrant shows that balance is a specialized/niche theme. Sports Biomechanics is the main area responsible for analysing acrobatic gymnastics individual balance abilities (Opala-Berdzik, Głowacka, & Juras, 2021; Opala-Berdzik et al., 2018), and assessment of skill-specific balance positions such as the handstand (Sobera, Serafin, & Rutkowska-Kucharska, 2019) and the headstand (Gómez-Landero et al., 2021).

Regarding balance control in acrobatic gymnastics pyramids, only two studies were found (Floria et al., 2015; Leal Del Ojo et al., 2020). Due to its importance for performance, more studies are needed to understand balance control when two or more gymnasts stand together and form pyramids (Leal Del Ojo et al., 2020). This indicates a clear lack of attention for the specifics of this gymnastics discipline. Although balance is considered a major topic for investigation, there has been a lack of interest for the pyramids balance, a major feature of acrobatic gymnastics.

The main limitation of this work is that it does not incorporate high volumes of information. Since this is a modern gymnastics discipline in its preliminary developmental phase, the inclusion of resources from two databases was a strategy to address this limitation. The most challenging phase was the manual selection of articles. Since terms such as "acrobatic elements" and "acrobatic exercises" are frequently misused in articles pertaining to other gymnastic disciplines, a manual selection was required, which is not ideal. We would also like to highlight the limitation of using search keys to query databases. While we selected a generic approach to the term "gymnastics", changing two characters in a search key can affect the outcome. For instance, using "gymnastic*" instead of "gymnast*" may result in missing potentially relevant works, such as Taboada-Iglesias, Abalo-Nunez, Vernetta-Santana, & Gutierrez-Sanchez (2020). Although unfortunate, some articles are always left out of reviews due to the database or the search key used. In this manuscript, we present the results obtained with our search keys. Additionally, more advanced analysis, such as co-citation networks, were not conducted since the amount of information is not sufficient to

do so. This bibliometric analysis provides a static picture of the acrobatic gymnastics field development. Only a systematic review can provide a more detailed analysis, as it is the case for systematic reviews focused on biomechanical research methods used in acrobatic gymnastics to date (Leite et al., 2023). We hope that this bibliometric analysis provides tools for accurate use of terms distinguishing each gymnastics discipline.

CONCLUSIONS

The bibliometric data from this study present the first insight into the state and dynamics of publications of articles on acrobatic gymnastics. The results have shown that 2015 was a milestone year for scientific research in acrobatic gymnastics since it marked the beginning of continuous publication by Spanish authors, followed by those from Poland and Portugal. In terms of collaboration, countries are generally focused on their own territory and there is a limited scientific interaction between different nations. Only one such collaboration network between two countries was identified, namely betwen Spain and Ireland. Spanish and Polish universities are the leading research institutions publishing in this sport. This work may serve as a reference for future studies in acrobatic gymnastics, and balance has been identified as one of the key specialization topics of investigation. However, there has been a lack of interest in the pyramids balance, which is a major feature of acrobatic gymnastics.

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