

Bibliometric analysis of plyometrics in sport: 40 years of scientific production

Análisis bibliométrico de la pliometría en el deporte: 40 años de producción científica

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Abstract. Introduction. The study of the effects of plyometric training may be related to the incidence of other physical capacities, physical fitness, and sport-specific performance variables, which is why knowledge production has been linked to the study in different populations, sports, and areas of knowledge. Objective. To analyze the scientific work of the effect of plyometric training in sports during the last 40 years (1983-2023), taking into account a bibliometric analysis in the Scopus database. Methodology. The descriptive bibliometric analysis of the scientific production took into consideration the following indicators for each of the documents: 1) type of document; 2) year of publication; 3) principal author; 4) subject area; 5) journal name; 6) number of publications per journal; 7) quartile; 8) H index; 9) SCI 2022 index; 10) citations; 11) average number of citations per published article; 12) institutional affiliation; 13) sports; 14) language; 15; keywords. Likewise, co-occurrence maps were created from the keywords and co-authorship through the VOSviewer program. The following MeSH terms were used to search the documents: "Sports", "Plyometric" and the search equations "Plyometric AND Sport". Results. A total of 820 documents were obtained. The results reflect that the highest production is in research articles (81.09%) and review articles (13.65%). For the publication period, a systematic increase in scientific production is established from 2014 onwards, finding that 2021 was the year of highest production with 104 documents. The author with the highest making is Rodríguez-Campillo (5.97%). Regarding the thematic area, the making is concentrated between Medicine (49%) and Health professions (40%). The journal that has published the most papers and has the highest number of citations (7844) is the Journal of Strength and Conditioning Research. The journals with the highest number of citations are those with a category of Q1. The University of the Lakes is the institution with the most research, with 49 papers. The sport with the most investigation is running (12.92%) and soccer (12.68%). The prevailing language in scientific production is English (96.09%). Conclusions. Plyometric training is considered an effective means for the development of physical capacities and sport-specific performance. Likewise, the present study reveals the research tendencies of plyometric training according to the authors, institutions, journals, thematic areas, and keywords used during the investigation. In this way, the bibliometric analysis serves as a reference for future studies because it helps to determine research needs.

Key Words: sport, plyometric, sports science, evaluation.

Resumen. Introducción. El estudio de los efectos del entrenamiento pliométrico puede estar relacionado con la incidencia de otras capacidades físicas, aptitud física y variables de rendimiento específicas del deporte, por lo que la producción de conocimiento ha estado ligada al estudio en diferentes poblaciones, deportes y áreas del conocimiento. Objetivo. Analizar los trabajos científicos del efecto del entrenamiento pliométrico en el deporte durante los últimos 40 años (1983-2023), teniendo en cuenta un análisis bibliométrico en la base de datos Scopus. Metodología. El análisis bibliométrico descriptivo de la producción científica tuvo en cuenta los siguientes indicadores para cada uno de los documentos: 1) tipo de documento; 2) año de publicación; 3) autor principal; 4) área temática; 5) nombre de la revista; 6) número de publicaciones por revista; 7) cuartil; 8) índice H; 9) índice SCI 2022; 10) citas; 11) número medio de citas por artículo publicado; 12) afiliación institucional; 13) deportes; 14) idioma; 15; palabras clave. Asimismo, se crearon mapas de co-ocurrencia a partir de las palabras clave y la co-autoría mediante el programa VOSviewer. Se utilizaron los siguientes términos MeSH para buscar en los documentos: "Deportes", "Pliometría" y las ecuaciones de búsqueda "pliometría AND Deporte". Resultados. Se obtuvo un total de 820 documentos. Los resultados reflejan que la mayor producción se encuentra en artículos de investigación (81,09%) y artículos de revisión (13,65%). Para el periodo de publicación, se establece un aumento sistemático de la producción científica a partir de 2014, encontrando que 2021 fue el año de mayor producción con 104 documentos. El autor con mayor elaboración es Rodríguez-Campillo (5,97%). En cuanto al área temática, la elaboración se concentra entre Medicina (49%) y Profesiones sanitarias (40%). La revista que más trabajos ha publicado y que mayor número de citas tiene (7844) es Journal of Strength and Conditioning Research. Las revistas con mayor número de citas son las de categoría Q1. La Universidad de los Lagos es la institución con más investigación, con 49 artículos. El deporte con más investigación es el atletismo (12,92%) y el fútbol (12,68%). El idioma predominante en la producción científica es el inglés (96,09%). Conclusiones. El entrenamiento pliométrico se considera un medio eficaz para el desarrollo de las capacidades físicas y el rendimiento específico del deporte. Asimismo, el presente estudio revela las tendencias de investigación del entrenamiento pliométrico según los autores, instituciones, revistas, áreas temáticas y palabras clave utilizadas durante la investigación. De esta forma, el análisis bibliométrico sirve de referencia para futuros estudios porque ayuda a determinar las necesidades de investigación.

Palabras clave: deporte, pliometría, ciencias del deporte, evaluación.

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Introduction

The different areas of knowledge among which medicine, biochemistry, and social sciences, among others, have allowed the study of sports over time and with this, sports science has sought to promote the understanding of the

adaptive processes of athletes in response to training and competition (Bishop, 2008; Ford et al., 2011; Fullagar et al., 2019; Becerra Patiño et al., 2020; Becerra Patiño & Escorcía, 2023; Becerra-Patiño et al., 2023). Within the processes that have been advancing in short, medium, and long-term sports preparation (Balyi & Way, 1995; Balyi &

Hamilton, 2004) the development of physical capacities has been a common denominator in the different research proposals (García-Pinillos, Ruiz-Ariza & Latorre-Román, 2015; Falces-Prieto et al., 2021; Fonseca et al., 2021; Becerra Patiño, Sarria Lozano & Prada Clavijo, 2022; Becerra Patiño, Sarria Lozano & Palomino, 2023).

Plyometrics is considered a type of training that has been developed for several decades, mainly in track and field athletes in countries such as Russia and Eastern Europe (Chu & Plummer, 1984; Chu & Panariello, 1989; Lundin & Berg, 1991). It was the Russian athletic trainer Verkhoshanski who referred to the concept of shock or jump training (Verkhoshanski, 1969; Verkhoshanski, 1973). However, it was the former women's track and field coach Fred Wilt belonging to Purdue University, who first indicated the term plyometric in 1975 (Davies, Riemann & Manske, 2015). Thus, the term plyometrics is a conjugation of the Greek words "*plythein*" or "*plyo*" meaning to increase and "*metric*" referring to measurement. In essence, the objective of plyometrics in Sport is to "*increase the measure*" and, to this end, the manifestation of sport performance is expressed in competitions from actions such as throws, speed of hits, displacements or serves, as well, as with jump height, sprint speed (Davies & Dickoff-Hoffman, 1993; Goldbeck & Davies, 2000) and manifestation of power (Verkhoshanski, 2006).

Thus, plyometric training has been studied since the 1980s with the following research proposals: i) Effects of three combinations of plyometric and weight training programs on selected physical fitness test items (Ford et al., 1983); ii) the Effect of plyometric and weight training programs on selected physical fitness test items (Ford et al., 1983); ii) Effect of plyometric training on vertical jump performance in high school basketball players (Brown, Mayhew & Boleach, 1986); iii) The combined effects of weight training and plyometrics on dynamic leg strength and leg power (Blakey & Southard, 1987); iv) The effects of six weeks of squat, plyometric and squat-plyometric training on power production (Adams et al., 1992).

Thus, research proposals related to plyometrics in sports have been associated mainly with the effects of plyometric training on other capacities. In that sense, the different research proposals refer to the training effects between 6 and 8 weeks, ideally. In that sense, there are proposals of aquatic plyometric training with and without resistance in volleyball players to impact physical fitness (Kamalakkannan, Azeem & Arumugan, 2011), influence of plyometric training on repeated strength and power performance in elite Karate athletes (Margaritopoulos et al., 2015), effects of plyometric training on speed and lower limb explosive strength in adolescent athletes (Fischetti et al., 2018), out-come of plyometric training on performance in 5 km athletes (Fernandes Machado et al., 2019). Plyometric training has explored multiple fields of action through research, mostly processes related to the evaluation of physical performance, effects on other capacities such as speed, muscle power, acceleration, agility, and

asymmetries, and incidence of plyometric training programs on specific variables characteristic of each sport (Asadi et al., 2017; Moran et al., 2017; Cañas-Jamett et al., 2020; Cazan et al., 2022; Becerra-Patiño et al., 2023b; Ospina León et al., 2023).

In the same way, the scientific literature has also studied the effects of plyometric training based on jumps on specific performance variables (maximum strength in squat, Squat Jump, Countermovement Jump, body mass, fat mass, thigh circumference) in aquatic sports, finding that the training programs have a duration ranging between 4 and 36 weeks, likewise, plyometric jump training is the most effective to improve fitness and specific performance in aquatic sports athletes (Ramirez-Campillo et al., 2022).

The scoping review conducted by Ramirez-Campillo et al. (2020) on the methodological characteristics and future directions in the scientific production of plyometric jump training suggests that the different plyometric training programs in which jumping is required, have a high methodological quality, suggesting the development of studies based on randomized controlled trials that allow obtaining reliable information based on scientific evidence, likewise, it means that the study of women, individual sports and elite level athletes are limited, this opens the possibility to develop studies on these identified needs. In turn, plyometric training has not only been based on determining the effects of physical performance variables.

However, the weekly training frequency seems to moderate the effects, as well as other variables that may lead to different adaptations, such as the duration and number of weekly sessions (Arntz et al., 2022). Consequently, the objective was to analyze the scientific work of the effect of plyometric training in sports during the last 40 years (1983-2023), taking into account a bibliometric analysis in the Scopus database.

Methodology

The present bibliometric study is based on a descriptive and mixed-approach analysis of the scientific production of the effects of plyometric training in sports in the last 40 years (1983-2023) using bibliometrics as a research technique and with the help of the Scopus database (Salinas-Ríos & García-López, 2022; Martínez-Benítez & Becerra-Patiño, 2023; Becerra Patiño et al., 2024). The following MeSH terms "Plyometric", and "Sport", and the search equations ("Plyometric" AND "Sport"; "Effect AND training AND plyometric) in the Scopus database were used to search for the documents. In addition, filters were applied to the descriptors used related to the year of publication, open-access documents, and document types. Based on bibliometric criteria that provided valuable information (Mazzardo et al., 2022; Van Eck & Waltman, 2014), an analysis matrix was developed for the documents selection.

The inclusion criteria taken into account were: i) date of publication, between January 1, 1983, and August 20,

2023; ii) language English, Spanish; German, Russian, Italian, French, Ukrainian, Portuguese, Bosnian; iii) that the journal is indexed in Scimago in quartiles Q1, Q2, Q3, Q4; iv) access to the full paper; v) published papers and articles in press; vi). Papers that did not meet any of the above inclusion criteria were discarded. Thus, to select the documents, an analysis matrix was developed in Microsoft Excel based on the following categories: 1) type of document; 2) year of publication; 3) principal author; 4) subject area; 5) journal name; 6) number of publications per journal; 7) quartile; 8) H index; 9) SCI 2022 index; 10) citations; 11) average number of citations per published article; 12) institutional affiliation; 13) sports; 14) language; 15) keywords.

Finally, for statistical analysis, Excel was used to generate tables and figures (frequency/percentage), and the VOSviewer program to create co-occurrence maps for keywords and co-authorship (Van Eck & Waltman, 2011; 2020). Bibliographic networks were prepared, which are composed of nodes that are the units of analysis, in this case the authors and the links to analyze the relationships of citations between authors or elaboration by documents. Statistically, the percentages take into account the total sum of the documents, depending on the type of document, country or region, descriptors, sources, university and citations per author. The operationalization of the same is done to represent the amount of a small fraction and compare that fraction in percentages with the total result of the analyzed documents.

Results

The Scopus database provided 820 documents that were submitted to the metatests regulation process, to eliminate documents for duplicity and/or for not having access to the complete paper.

Regarding the type of documents, it is shown in table 1 that the lowest production of documents is related to the categories: letter, book, note, and erratum, being the book chapter and conference paper the ones with the highest production. Finally, review articles have a good proportion of the total number of documents (13.65%), being research articles the highest scientific productions (81.09%) (see table 1).

Table 1.

Documents by type.		
Type	Number of publication	Percentage %
Letter	1	0.12
Book	2	0.24
Note	2	0.24
Erratum	3	0.36
Book Chapter	16	1.95
Conference paper	19	2.31
Review	112	13.65
Article	665	81.09
	820	100%

About the bibliometric analysis developed, figure 1 reveals the behavior of the scientific production of the effect

of plyometric training concerning the publication period between 1983 and 2023. In total, 820 studies were collected. Thus, it can be observed that the number of publications remained low between the year of the first referenced study in 1983 and 2005 with a total of 58 studies (7.07%). Between the years 2006-2013, there was a moderate increase in the number of studies developed with 146 (17.80%). Finally, from 2014 there is an exponential increase until 2021 with 473 studies (57.68%), and then a decrease between 2022 and 2023 (17.43%) (see figure 1).

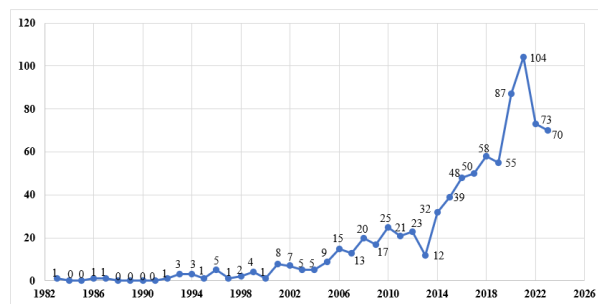


Figure 1. Number of publications per year

Concerning the principal author, table 2 compiles the authors with the highest citation per document, taking into account the scientific production of published documents. It is highlighted that the five authors with the highest scientific production on the effect of plyometrics in sport are: 1) Ramirez-Campillo with 49 documents (5.97%); 2) Granacher with 33 documents (4.02%); Moran with 24 documents (2.92%); Loturco with 20 documents (2.43%) and Chaabene with 17 documents (2.07%) (see table 2).

Table 2.

Documents by author

Author	Number of publication	Percentage %
Ramirez-Campillo, R.	49	5.97
Granacher, U.	33	4.02
Moran, J.	24	2.92
Loturco, I.	20	2.43
Chaabene, H.	17	2.07
Izquierdo, M.	16	1.95
Pereira, L.A.	13	1.58
Chelly, M.S.	13	1.58
Nakamura, F.Y.	12	1.46
Myer, G.D.	11	1.34
Clemente, F.M.	11	1.34
Hewett, T.E.	10	1.21
Ford, K.R.	10	1.21
Newton, R.U.	9	1.09
Negra, Y.	9	1.09
Hermassi, S.	9	1.09
Ebben, W.P.	9	1.09
Behm, D.G.	9	1.09
Lloyd, R.S.	8	0.97
Kobal, R.	8	0.97
Herrera-Valenzuela, T.	8	0.97
Freitas, T.T.	8	0.97
Andrade, D.C.	8	0.97
Alcaraz, P.E.	8	0.97
Thapa, R.K.	7	0.85
Sanchez-Sanchez, J.	7	0.85
Padulo, J.	7	0.85
Nikolaidis, P.T.	7	0.85
Bishop, C.	7	0.85
Aloui, G.	7	0.85
Total: 30 authors	374/820	45.45/100%

Likewise, concerning the relationship of authors with documents published in Scopus on plyometrics in sports, the VOSviewer program (Van Eck & Waltman, 2020) is used to show the compilation by quotations, establishing the nodes map to recognize the relationship with other authors who have written on the same subject. For the co-citation analysis, the minimum number of documents by the same author was taken as a reference. The total number of authors selected for the analysis was 464 using the VOSviewer program. Thus, some of the 464 elements of the network

were not connected, so the largest set of connected elements consists of 267 authors (see figure 2). Regarding the thematic area, figure 3 shows the type and area in which scientific knowledge of plyometrics in sport is being produced. Revealing that, when reviewing the five main areas, the ones that obtain a higher percentage are medicine (49%) and health professions (40%), while the others have low numbers of published documents; Biochemistry, Genetics, and Molecular Biology (6%), Social Sciences (3%) and Environmental Science (2%) (see figure 3).

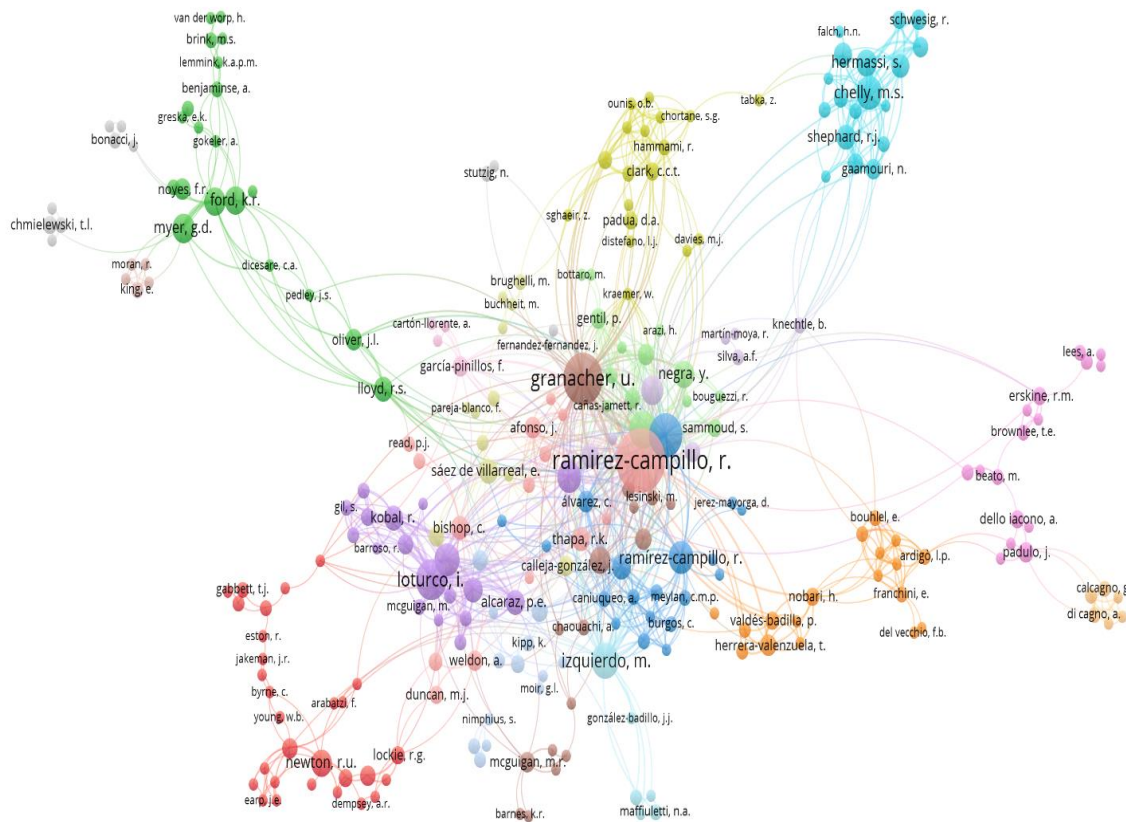


Figure 2. Node map for the relationship between the authors. Source: VOSviewer

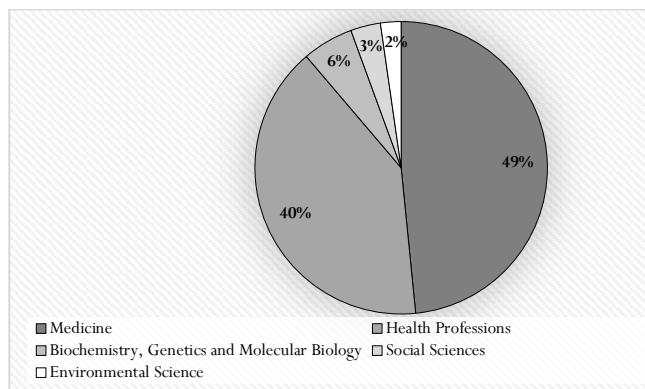


Figure 3. Total number of documents concerning the subject

To establish the relationship between the name of the journals that publish scientific knowledge, the country and

the quartile of this, as well as the H index, SCI index for the year 2022, the number of citations per journal, and the average number of citations per published article, table 3 was prepared. Thus, table 3 compiles the information corresponding to 532 of the 820 eligible documents (64.87%).

In the same table 3, it is revealed that the countries that generate the highest scientific production on plyometrics in sport and at the same time receive the highest citations are the United States with 249 publications and 15,014 quotations, Journal of Strength and Conditioning Research the journal with the highest production with 124 documents and 7844 quotations for an average number of citations per published article of 63.25.

On the other hand, among the journals or countries with the highest number of published papers are the United States with 249 publications, Switzerland with 97, Italy

with 48, the United Kingdom with 45, Germany with 20, Poland with 18, and Turkey with 15: American Journal of Sports Medicine with 13 papers and 2718 citations (209.07), Medicine and Science in Sports and Exercise with 21 papers and 1870 citations (89.04), Sports Medicine with 23 papers and 2022 citations (87.91), Journal of Science and Medicine in Sport with 11 papers and 747 citations (67.90) and finally Journal of Athletic Training with 6 papers and 386 citations (64.83).

On the other hand, among the journals with the highest number of published documents, the United States ranked first with 249 publications, Switzerland with 97, Italy with 48, the United Kingdom with 45, Germany with 20, Poland with 18, and Turkey with 15. Similarly, of the 28 journals selected, 20 correspond to Q1, five to Q2, two to Q3, and

one to Q4, which shows that the scientific production and number of citations correspond to journals categorized in Q1.

The most cited articles in the Journal of Strength and Conditioning Research are: "*Neuromuscular training improves performance and lower-extremity biomechanics in female athletes*" with 518 citations (Myer et al., 2005) and "*Strength and power predictors of sports speed*" with 444 citations (Cronin & Hansen, 2005). For the Journal of Sports Medicine and Physical Fitness, the most cited articles are: "*Effects of Plyometric Training on jumping performance in Junior Basketball Players*" with 173 citations (Matavulj et al., 2001) and "*Effects of Plyometric Training followed by a reduced training program on physical performance in prepubescent soccer players*" with 157 citations (Diallo et al., 2001).

Table 3.

Total number of publications, article quotations and average number of citations per published article

Journal	Country Journal	Number of publication	Quartil	H-Index	SJR 2022	Citations	Average number of citations per published article
Journal of Strength and Conditioning Research	United States	124	Q1	151	1.3	7844	63.25
Journal of Sports Medicine and Physical Fitness	Italy	42	Q3	74	0.50	901	21.45
International Journal of Sports Physiology and Performance	United States	35	Q1	85	1.33	875	25
International Journal of Environmental Research and Public Health	Switzerland	30	Q2	167	0.83	214	7.13
Journal of Sports Sciences	United Kingdom	25	Q1	153	1.14	836	33.44
Frontiers in Physiology	Switzerland	25	Q1	140	1.03	476	19.04
Sports Medicine	Switzerland	23	Q1	213	3.29	2022	87.91
Medicine and Science in Sports and Exercise	United States	21	Q1	251	1.73	1870	89.04
International Journal of Sports Medicine	Germany	20	Q1	118	0.97	579	28.95
Sports Biomechanics	United Kingdom	16	Q2	48	0.69	252	15.75
Journal of Sports Science and Medicine	Turkey	15	Q1	77	1.03	702	46.8
Journal of Orthopaedic & Sports Physical Therapy	United States	14	Q1	136	1.4	799	57.07
American Journal of Sports Medicine	United States	13	Q1	252	2.48	2718	209.07
Sports	Switzerland	12	Q1	33	0.88	56	4.66
Journal of Human Kinetics	Poland	12	Q2	51	0.73	176	14.66
Strength and Conditioning Journal	United States	11	Q1	52	0.93	136	12.36
Journal of Sport Rehabilitation	United States	11	Q2	58	0.54	136	12.36
Journal of Science And Medicine In Sport	Netherlands	11	Q1	117	1.32	747	67.90
Scandinavian Journal of Medicine and Science in Sports	Denmark	10	Q1	132	1.13	286	28.6
Journal of Physical Education and Sport	Romania	9	Q3	32	0.31	60	6.66
Sports Medicine Open	United Kingdom	8	Q1	40	1.54	196	12
Sports Health	United States	7	Q1	60	1.13	143	20.42
Plos ONE	United States	7	Q1	404	0.89	107	15.28
Physical Therapy in Sport	Netherlands	7	Q1	56	0.88	102	14.57
Applied Sciences Switzerland	Switzerland	7	Q2	102	0.49	35	5
Journal of Athletic Training	United States	6	Q1	124	1.43	386	64.33
Gazzetta Medica Italiana Archivio Per Le Scienze Mediche	Italy	6	Q4	10	0.12	9	1.5
Biology of Sport	Poland	6	Q1	38	1.48	59	9.83
Total		532/820	Q1 Q2 Q3 Q4				22.722
			20 5 2 1				

The most cited article in the International Journal of Sports Physiology and Performance is "*Transfer of Strength and Power Training to Sports Performance*" with 226 citations (Young, 2006). For the Journal of Sports Sciences, the most cited article is "*Effects of inter-limb asymmetries on physical and sports performance: a systematic review*" with 212 citations (Bishop, Turner & Read, 2018). The journal Sports Medicine has two articles with an average of 400 citations, "*Developing maximal neuromuscular power: Part 2 training considerations for improving maximal power production*" with 432 (Cormie, McGuigan & Newton, 2011) and "*Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training*" with 395 (Markovic & Mikulic, 2010).

The most cited article in the Medicine and Science in

Sports and Exercise journal is "*The Optimal Training Load for the Development of dynamic athletic performance*" with 607 citations (Wilson et al., 1993). The study of plyometrics in female sports has two antecedents that have an average of 1000 citations per article, these are "*The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study*" with 1189 citations (Hewett et al., 1999) and "*Plyometric training in female athletes: decreased impact forces and increased hamstring torques*" with 820 quotations (Hewett et al., 1996). In terms of scientific production by institutional affiliation Universidad de los Lagos with 49 papers (5.97%), Institut Supérieur du Sport et de l'Education with 32 (3.90%), Universität Potsdam and Auckland University of Technology with 31 respectively (3.78%),

followed by Universidad Andres Bello and Université de la Manouba with 27 papers each (3.29%). Similarly, analysis by country/territory of the institutions reveals that of the top 10 institutions, four institutions are European (Spain, United Kingdom, Germany), two African institutions (Tunisia), two South American institutions (Chile) and two Oceania institutions (New Zealand, Australia) (see figure 4).

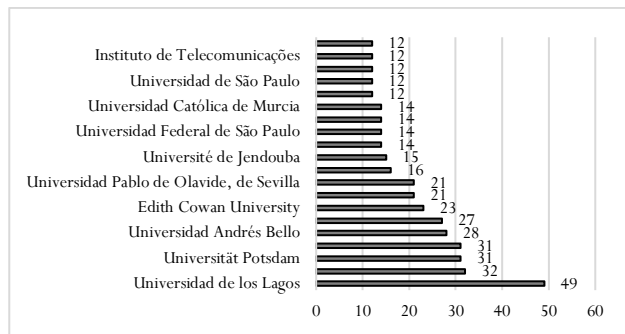


Figure 4. Documents by affiliation. Comparison of the document count in the first 20 affiliations

Meanwhile, in table 4, the information related to the number of documents by sport was compiled, where 549 out of 820, the 20.48 addressed topics related to plyometrics and resistance training, 12.92% between plyometrics and running, 12.68% between plyometrics and soccer, 9.14% between plyometrics and football, 6.46% between plyometrics and basketball, and, finally, 5.23% between plyometrics and volleyball. In short, the studies that address plyometrics with collective sports according to the 549 documents collected out of the 820, is 33.51%.

Table 4.

Number of documents per sport

Sport keyword	Number of documents	Percentage (%)
Resistance training	168	20.48
Running	106	12.92
Soccer	104	12.68
Football	75	9.14
Basketball	53	6.46
Volleyball	43	5.24
Total	549/820	66.95/100

Table 5 shows the number of documents by language, highlighting a major production in English (96.09%), followed by Spanish (1.09%). Thus, of the 820 studies analyzed, only 31 documents do not correspond to the English language.

Table 5.

Number of documents per language

Language	Number of publication	Percentage %
English	788	96.09
Spanish	9	1.09
German	7	0.85
Russian	5	0.60
Italian	4	0.48
French	4	0.48
Ukrainian	1	0.12
Portuguese	1	0.12
Bosnian	1	0.12
Total	820	100%

Finally, for the analysis of the node map for the co-occurrence relationship between the different keywords related to plyometrics and sport, the minimum number of occurrences was taken to be three. Thus, of the 2959 keywords, 686 met the threshold by analysis in the VOSviewer program (Van Eck & Waltman, 2020).

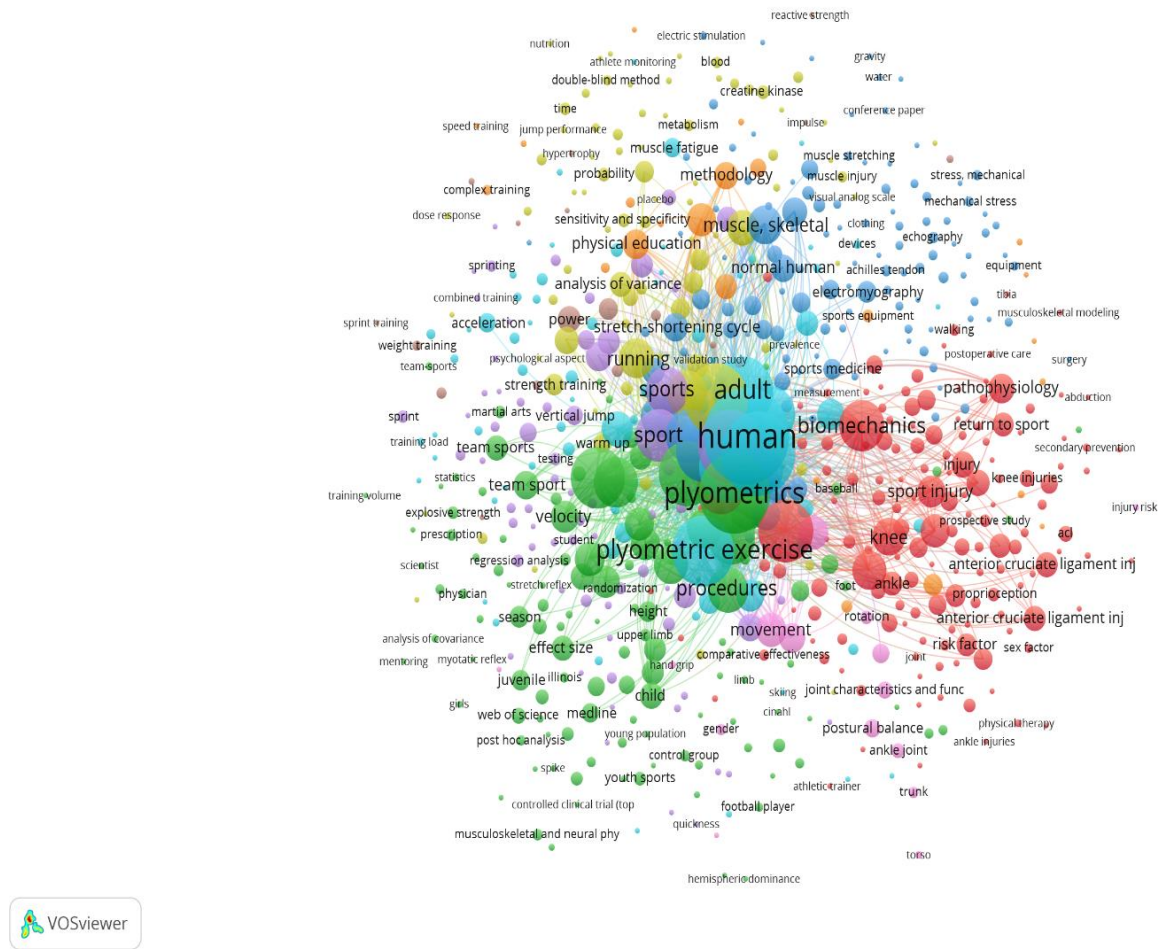


Figure 5. Node map for the co-occurrence relationship between the different keywords. Source: VOSviewer

Discussion and conclusions

Initially, scientific production related to sport is gradually gaining greater prominence, and as a consequence, knowledge development has increased over the years (Ramirez-Campillo et al., 2018; Dudagoitia et al., 2023). Likewise, scientific advances related to plyometrics in sports have allowed access to quality information, thus seeking to favor the processes that are developed in general sports preparation, specific preparation, and physical performance related to vertical jumping, linear sprinting, and changes of direction of athletes (Pardos-Mainer et al., 2021; Markovic & Mikulic, 2010). Similarly, the effects of plyometric training in response to female athletes' performance in vertical jumping (Stojanović et al., 2017), on agility in male soccer players (Čaprić et al., 2022) and the effects of the maturation period on adaptations in sprint speed abilities through plyometric jumping in young athletes in team sports (Silva et al., 2022) have been examined.

Knowledge production has been increasing in recent years to understand the effects of plyometric training on physical performance (Kons et al., 2023; Akbar et al., 2023). This stands up for the optimization of exercise

from plyometric jump training and its influence on sports performance (Barrio et al., 2023). This scientific production has been generating a slight increase between 1983 and 2005, a moderate increase between 2006 and 2014, and an exponential increase between 2015 and 2021. Precisely in 2021 the maximum number of annual publications was reached with 104, including "Effects of Strength vs. Plyometric Training Programs on Vertical Jumping, Linear Sprint and Change of Direction Speed Performance in Female Soccer Players: A Systematic Review and Meta-Analysis" with 28 citations (Pardos-Mainer et al., 2021), "Effects of Vertically and Horizontally Orientated Plyometric Training on Physical Performance: A Meta-analytical Comparison" with 21 quotations (Moran et al., 2021).

In the same pathway, the authors who have generated the highest scientific production are Ramirez-Campillo, R., Granacher, U., Morán, J., Loturco, I., Chaabene, H., Izquierdo, M., & Pereira, L.A. The first 30 authors published 45.45% of the total number of documents in the Scopus base (374/820 papers). The higher percentage of publications by subject area reveals that scientific production is associated with two major categories: medicine and health professions, while other areas present low percentages, such as biochemistry (Huang et al., 2021),

genetics and molecular biology, social sciences, and environmental sciences. This opens the possibility to develop studies on these subject areas, seeking to understand other possible incidences and effects of plyometrics in sport (Eraslan et al., 2021). The results of this bibliometric study show a high scientific production in the last 40 years and, after analyzing the 20 institutions, it is detailed that those with the highest production are the Universidad de los Lagos, Institut Supérieur du Sport et de l'Education, Universität Potsdam, Auckland University of Technology, Universidad Andrés Bello and Université de la Manouba. Similarly, the analysis by country/territory of the institutions reveals that the continents that produce the most knowledge are Europe, Africa, South America, and Oceania.

Meanwhile, the analysis of the 29 primary journals that have published research on plyometrics and its relationship with sports positions the United States, Switzerland, Italy, and the United Kingdom as the countries with the highest scientific production. This is similar to the scientific production in swimming (Orejuela Aristizabal et al., 2023) and in contrast to the scientific making in team sports, where it was found that the countries producing the most knowledge are Spain, Brazil, and the United States (Mamani-Jilaja et al., 2023).

The articles are preferably written and cited in the English language with 96.09% of the total number of documents, which leads to thinking that there is a low level of collaboration between researchers and institutions from different countries to publish in languages other than English, such as Spanish, German, Russian, Italian, French, Ukrainian, Portuguese and Bosnian. Also, the highest scientific production is generated with research articles (81.09%) and review articles (13.65%), findings similar to that of other bibliometric studies on scientific production on collective sports (92%) (Mamani-Jilaja et al., 2023). About the analysis carried out with the VOSviewer program, in which the publications were compiled by keyword co-citations, the most used words in the study of plyometrics in sports are: human, plyometric, plyometric exercise, adult, sport, sports, and biomechanics. On the other hand, the node maps for the relationship of co-citations between authors reveal that Ramírez-Campillo is positioned in the center as the largest bibliometric size among the analyzed papers, while Granacher & Loturco are authors who are also located near the center of the image, revealing that they have a high incidence in the scientific production related to plyometrics in sport.

The present study has shown that there is a high number of papers that have studied the relationship between plyometrics and sport, including research and/or popular science articles, review articles, and book chapters, according to the analysis of the Scopus database. This may help researchers to recognize areas where research on plyometrics and sport is needed. Finally, this research is a valuable contribution to recognizing the importance of plyometrics in sports, highlighting the need to continue

researching and analyzing the different effects in various sports and athlete-specific capacities.

A meta-analytic study determined that variables such as gender, sport, type of test used for evaluation, intervention protocols, total jump volume, number of weekly workouts and age, are variables to be considered in the evaluation of the effects of plyometric training in collective sports (Alfaro-Jiménez et al., 2018). In the same line, another meta-analytical study studied the effect of plyometric training in adolescent athletes, concluding that this type of training produces significant improvements in the countermovement jump, squat jump, standing long jump and sprint in 10 and 20 meters (Chen et al., 2023).

The effects of plyometric training in sprinting sports teams have also been studied, concluding that strength training through vertical jumping and the development of strength, power, and explosive performance could lead to improved sprinting performance (Murphy et al., 2023). About determining the effects of plyometric training on the physical form of combat sports athletes, it can be concluded that plyometric jump training programs with a duration between 4 and 12 weeks with 2 to 3 weekly sessions, led to small-moderate improvements in maximum strength, vertical jump height, change of direction and specific athletic performance, and, at the same time, these effects did not affect the body mass, fat mass and muscle mass of the athletes evaluated (Ojeda-Aravena et al., 2023).

The adaptations that occur in body composition through lower body plyometric training have been studied, concluding that plyometric jump training is an effective means to increase the muscle volume of the legs and thigh, especially the circumference of the thigh, calf, and the angle of pennate of the muscle (Ramírez-Campillo et al., 2022b). Finally, the investigation of the effects of plyometric training on muscle hypertrophy, concluded that plyometric training is an efficient means to produce hypertrophy beyond age and sex.

It has been demonstrated that plyometry is useful in team sports such as soccer, volleyball, ultimate, basketball, etc. A study revealed that a plyometric training program adjusted to the playing position in soccer with a duration of 14 weeks with 2 sessions per week in 17 and 18 years old players evidenced improvements between positions for jumping ability (Ospina León et al., 2023). It is suggested for future studies to take into consideration that the results of the different plyometric training protocols are adjusted to the particularity of each context, sports level, experience in the technical execution of jumping, age and sex of the athletes. Therefore, it is necessary to consider in the different plyometric training protocols variables related to the height of the jumps, the duration of the executions, the total work time, the number of jumps per session, the number of weekly sessions, the morpho functional requirements of the sport, the demands and needs of the playing positions, mainly in team sports, and the evaluation variables to continue recognizing that sports performance is integrated with other variables beyond the physical, such as the technical,

physiological, biomechanical and biochemical.

As main recommendations for plyometric training it is concluded that it is an effective method to favor physical fitness and sports performance of athletes, through specific improvements in maximal dynamic strength, sprint speed, horizontal jump, reactive strength index (Ramirez-Campillo et al., 2023), change of direction and postural control (Jlid et al., 2019), agility, jump height and endurance (Van de Hoef et al., 2019).

Likewise, recommendations from a meta-analytic study that included a total of 744 participants and 11 studies, seven in men and 4 in women determine that the minimum training to produce adaptations from plyometric jumping is 4 weeks, 8 weeks of work and a minimum of 92 jumps per week (Ramirez-Campillo et al., 2023).

After the review, it is suggested to take into consideration the neuromuscular overload for the design of plyometric programs. In that sense, the applied load is modified by the total work performed in sets, repetitions, movements, and, especially, by the range of motion (ROM) developed by the athlete in the different sports actions leading to the determination of the total amount of overload generated (Davies et al., 2015).

Likewise, there are other components of the load that must be considered, among which stand out (Davies et al., 2015):

- The spatial overload produced by ROM, where what is sought is to generate a wider range to use muscle activation and stretch reflex
- The temporal overload generated by synchronization, focused on favoring the execution of the movement as fast and intense as possible
- The intensity determined by the actual effort produced in the action
- The volume determined by the total work according to the periodization (training session or work cycle)
- Frequency defined by the number of sessions performed in the training and/or rehabilitation cycles
- Recovery understood as the adequate recovery times (48-72 hours) between sessions and the specificity of the sport actions that will depend not only on the nature of the sport, role of the athlete, but also on the objectives of the training program (Davies et al., 2015).

Finally, as conclusions of the present bibliometric study, several important aspects are detailed, among which the following stand out

- Regarding the type of document, there has been an interest over time in the development of applied research based on articles; however, review studies have been gaining more prominence, mainly in recent years.
- Regarding the year of publication, between 1986 and 2005 the number of research studies did not exceed 10 per year. From 2006 to 2019 there is a considerable

increase, reaching 2020 (87 studies) and 2021 (104 studies) as the years with the highest production in relation to plyometric training.

- Regarding the authors with the greatest production, 13 authors stand out with at least 10 studies, being Ramirez-Campillo, R., Granacher, U., Moran, J., and Loturco, I., those with more than 20 published papers.

- As for the subject area, the area in which scientific knowledge of plyometrics in sport is being produced is preferably related to medicine and health professionals. Likewise, areas related to biochemistry, genetics and molecular biology have begun to gain more prominence in recent years. The area of social sciences has a lack of studies on this subject.

- The journals with the highest scientific production in the study of plyometrics are the Journal of Strength and Conditioning Research, Journal of Sports Medicine and Physical Fitness, International Journal of Sports Physiology and Performance, International Journal of Environmental Research and Public Health, Journal of Sports Sciences, Frontiers in Physiology, Sports Medicine and International Journal of Sports Medicine. Each of these journals has at least 20 publications.

- In relation to the number of publications per journal, the Journal of Strength and Conditioning Research has 15% of the total scientific production on plyometrics (124 publications). The other contributing journals are Journal of Sports Medicine and Physical Fitness (42 publications) with 5.12% and International Journal of Sport Physiology and Performance (35 publications) with 4.26%. Here, it is highlighted that there is a tendency of the main journals to produce knowledge on plyometrics are journals from Europe and the United States.

- Of the top 28 journals that have published research related to plyometrics, quartile 1 journals prevail with 71.42%, followed by quartile 2 with 17.85%. In this, it is highlighted that quartile 3 and 4 journals do not generate much production related to plyometrics, with only 3 journals out of the 28 main journals.

- Considering the number of citations per journal, it is found that the American Journal of Sports Medicine has a total of 13 publications and 2718 citations for an average of 209.07 citations per published article. Following this, it is found that the journals Medicine and Science in Sports and Exercise has 21 publications and 1870 citations for an average number of citations per article of 89.04, while, the journal Sports Medicine has 23 publications, 2022 total citations and an average of 87.91 citations per published article. There, within the top five in relation to total citations is not the journal with the highest scientific production on plyometrics (Journal of Strength and Conditioning Research).

- About institutional affiliations, there is a universal interest in the study of plyometrics and its relation to sport. As a result, out of the top 10 institutions, there are 4 European institutions, two African, two from South America

and two from Oceania. Curiously, none of the top 20 institutions is related to the United States, knowing that the journals that contribute the most publications to the study of plyometrics is precisely the United States with 249 publications out of the total of 820 studies analyzed.

- With respect to sport and its relation to the study of plyometry, it is detailed that there is a tendency to only six sports (resistance training, running, soccer, football, basketball, volleyball) with a total of 66.95%. This allows us to expand the research horizon to consider other sports that will help us to continue to understand the adaptations produced by plyometry.

- For language, it is generalized that scientific production revolves around the English language, with few studies in Spanish, German, Russian and French.

- Finally, the study of the key words of the studies shows that the concepts most used to refer to the study of plyometrics are related to; *human, plyometrics, plyometric exercise, adult, sport, sports, biomechanics and procedures*. Likewise, a great majority of the concepts relate physiological, biomechanical and training processes.

Limitations

The study's main limitations are focused on not recognizing the totality of authors, institutions, and thematic areas related to plyometrics and sports. The research group prioritizes the generality of the findings, leading to all of this.

Future prospects

For future studies related to bibliometric analysis, a qualitative analysis that links the keywords of the titles, objectives and main conclusions of each study could be explored.

With the present study's findings, the need for research to reveal the effects of plyometrics in other sports such as field tennis, ultimate, baseball, cycling, skating, field hockey, etc. is evident.

Likewise, the results found allow investigators to recognize the research possibilities that plyometrics have about sport and, in the same way, seek to decentralize the research in search of other contexts, countries, institutions, sports, population samples, and capabilities to relate.

Conflicts of interest

The authors have no conflict of interest.

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