

## Scientific production on the relative age effect in sport: bibliometric analysis of the last 9 years (2015-2023)

### Producción científica sobre el efecto de la edad relativa en el deporte: análisis bibliométrico de los últimos 9 años (2015-2023)

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**Abstract.** Objective. To conduct a bibliometric analysis of scientific production regarding the relative age effect in sport, using data from the PubMed and Scopus databases spanning from January 1, 2015, to April 30, 2023. Methodology. It was based on a descriptive bibliometric analysis of the scientific production having as indicators the following categories: 1) database; 2) year of publication; 3) journal name; 4) journal country; 5) H-index; 6) SCI index (2021); 7) Quartile (Q1; Q2; Q3; Q4); 8); Number of articles per Journal; 9) Scopus citations; 10) Countries evaluated; 11) Collective sports; 12) Individual sports; 13) number of times the sample of a country was evaluated according to journals; 14) Area of knowledge; 15) Gender; 16) Number of authors; 17) Name authors; 18) Instruments used to determine the relative age effect of athletes; 19) Research approach; 20) Research design; 21) Statistical Software package; 22) Statistical test; 23) Language; 24) Sample Size. The following MeSH terms were used to search for the documents: "Sport", "relative age", "sports performance", and the search equations ("sport competition" AND "relative age effect"), ("sports talent" AND "relative age effect"), ("physical differences" AND "relative age effect") to search for documents in the Scopus and PubMed databases, obtaining a total of 597 documents. In the end, after applying the criteria, 185 documents were accepted. Results. The number of publications per year has exhibited fluctuating behavior, with 2018 being the year with the highest production (16.09%) and 2016 the lowest (6.32%). In front of the journal, we found those with the most publications, were PloS One with 24 papers (12.97%), Sports with 15 (8.10%), and Journal of Human Kinetics with 13 (7.02%). PloS One (591) and the Journal of Sports Sciences (478) received the highest number of citations. Regarding sports, the ones with the highest number of publications are Soccer with 61 (32.90%), various sports with 24 (12.90%), and basketball with 16 documents (8.64%). Taking into account the countries evaluated, the World Cup (13.008%) and Spain (12.195%) have the highest number of documents. As for the total number of documents by area of knowledge, sports talent (25.40%), sports competition (22.70%), and sports training (15.13%) are the highest. Finally, about gender, it is found that the highest production is about men (74.26%), women-men (20.46%), and women (7.01%). Conclusions. It is concluded that the bibliometric study contributes substantially to the scientific community from the findings found in the study and the change of focus with which relative age has recently been studied. Likewise, it can guide future studies aimed at characterizing and determining the effect of relative age in sports.

**Key Words:** relative age, sport, sports science, sports competition, sports talent

**Resumen.** Objetivo. Desarrollar un análisis bibliométrico de la producción científica sobre el efecto de la edad relativa en el deporte a partir de las bases de datos PubMed y Scopus entre el 1 de enero de 2015 y el 30 de abril de 2023. Metodología. Se partió de un análisis bibliométrico descriptivo sobre la producción científica teniendo como indicadores las siguientes categorías: 1) Base de datos; 2) Año de publicación; 3) Nombre de la revista; 4) País de la revista; 5) Índice H; 6) Índice SCI (2021); 7) Cuartil (Q1; Q2; Q3; Q4); 8) Número de artículos por revista; 9) Citas en Scopus; 10) Países evaluados; 11) Deportes colectivos; 12) Deportes individuales; 13) Número de veces que la muestra de un país fue evaluada según las revistas; 14) Área de conocimiento; 15) Género; 16) Número de autores; 17) Nombre autores; 18) Instrumentos utilizados para determinar el efecto de la edad relativa de los deportistas; 19) Enfoque de la investigación; 20) Diseño de la investigación; 21) Paquete de software estadístico; 22) Test estadístico; 23) Idioma; 24) Tamaño de la muestra. Se utilizaron los siguientes términos MeSH para buscar los documentos: "Deporte", "edad relativa", "rendimiento deportivo", y las ecuaciones de búsqueda ("competición deportiva" AND "efecto de la edad relativa"), ("talento deportivo" AND "efecto de la edad relativa"), ("diferencias físicas" AND "efecto de la edad relativa") para buscar documentos en las bases de datos Scopus y PubMed, obteniendo un total de 597 documentos. Finalmente, tras aplicar los criterios, se aceptaron 185 documentos. Resultados. El número de publicaciones por año ha tenido un comportamiento fluctuante, siendo 2018 el año de mayor producción (16,09%) y 2016 el de menor (6,32%). Frente a la revista, se encontró que las de mayor número de publicaciones fueron Plos One con 24 trabajos (12,97%), Sports con 15 trabajos (8,10%) y Journal of Human Kinetics con 13 (7,02%). Las revistas con mayor número de citas fueron PloS One (591) y Journal of Sports Sciences (478). En cuanto a los deportes, los que tienen mayor número de publicaciones son: fútbol con 61 (32,90%), deportes varios con 24 (12,89%) y baloncesto con 16 documentos (8,64%) respectivamente. En cuanto al país evaluado, la Copa del Mundo (13,008%) y España (12,195%) tienen el mayor número de documentos. En cuanto al número total de documentos por área de conocimiento, el talento deportivo (25,40%), la competición deportiva (22,70%) y el entrenamiento deportivo (15,13%) son los más elevados. Por último, en cuanto al género, se observa que la mayor producción es en relación con los hombres (74,26%), mujeres-hombres (20,46%) y mujeres (7,01%). Conclusiones. Se concluye que el estudio bibliométrico aporta sustancialmente a la comunidad científica a partir de los hallazgos encontrados en el estudio y el cambio de enfoque con el que se ha estudiado recientemente la edad relativa. Asimismo, permite orientar futuros estudios dirigidos a caracterizar y determinar el efecto de la edad relativa en el deporte.

**Palabras clave:** edad relativa, deporte, ciencia del deporte, competición deportiva, talento deportivo.

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## Introduction

Scientific production and its relationship with research are based on new findings across various areas of study. In that sense, numerous academic research endeavors, primarily scientific articles, occur in two ways: first, by collecting and analyzing the produced information, and second, by exploring new research fields (Magadán-Díaz & Rivas-García, 2022). There, conducting bibliometric studies makes it possible to explore topics, make themes visible, and recognize authors and studies with a high impact on science based on the documents consulted (Delgado et al., 2019; Donthu et al., 2021).

Thus, librarianship utilizes mathematical and statistical methods in bibliometrics to enable an understanding of changes in scientific production (Paz & Caramés, 2020). Therefore, the bibliometric analysis seeks the study of reference patterns for the categorization of criteria in response to the scope of each study (Salinas-Ríos & García-López, 2022), among criteria such as abstracts, citations, indexes of journal titles (García et al., 2021) and keywords, authors, collaborative networks, institutions, countries, and topics stand out (Nicolaisen, 2009).

The advancement of sports science has allowed increasingly closer to the study of research focused on the recognition of the areas of knowledge that contribute to sport (Ferreira, Fernández & Benítez, 2019), thus, seeking to substantiate the different processes that are developed from sports medicine (Pujalte & Maynard, 2020) sports training, sports talent (Ntozis et al., 2021; Fernandez Ortega, Rodriguez Buitrago & Sanchez Rodriguez, 2021), physical condition (Drew et al., 2023), personal and social factors (Andronikos et al., 2021) among others to continue to understand the demands and needs of sports competition (Correa-Torres, 2021; Becerra et al., 2022).

This way, these scientific advances allow discussions within the sports processes, applying that knowledge and analysis based on research evidence. Scientific advances have been incorporating multidisciplinary in favor of all areas contributing to favor sport development (Becerra-Patiño & Escorcía-Clavijo, 2023; Becerra-Patiño, Sarria-Lozano & Palomino, 2023; Mamani-Jilaja et al., 2023).

Consequently, the needs of sports have been arousing the interest of the scientific community seeking to know their requirements and demands of competitive type from retrospective studies to evaluate the impact on the results obtained (Becerra-Patiño & Escorcía-Clavijo, 2023b) and the different processes integrated into the preparation of the athlete (Becerra Patiño, Sarria Lozano & Prada Clavijo, 2022; Ospina León et al., 2023; Becerra-Patiño et al., 2023c).

One of these processes is the study of the relative age effect (RAE) in sports, which has been well documented (Coble et al., 2009b; Musch & Grondin, 2000; Till et al., 2010). Considering this, there are several bibliometric studies on scientific production related to sports, among them are collective sports (Mamani-Jilaja et al., 2023;

Martínez-Benítez & Becerra-Patiño, 2023), swimming (Orejuela Aristizabal, Cardona Orejuela & Rengifo Cruz, 2023), badminton (Blanca-Torres et al., 2019), women's soccer (Adan et al., 2020), futsal (Palazón, Ortega & García-Angulo, 2015), sport and exercise psychology (Coimbra et al., 2022; Rodríguez & Ibarzábal, 2018), Olympic sport sciences on summer and winter Olympic sports (Millet, Brocherie & Burtcher, 2021).

One of the main reasons to which sports science has responded is to the study of the RAE because, within the same year of birth, competitive advantages of up to 12 months can be seen between selected and non-selected athletes (Andronikos et al., 2015). This leads to establishing differences at cognitive (Huertas et al., 2019), physical, and emotional levels between athletes of the same age for similar competitive categories (Coble et al., 2009a).

Similarly, it has been reported in the scientific literature that team sports, among which soccer and basketball stand out, present a greater number of investigations about volleyball and handball in the study RAE (Fonseca, Figueiredo, Gantois, Lima-Junior & Fortes, 2019; Kelly et al., 2021). In that sense, a tendency towards the selection of athletes born in the first months of the year is presented for male teams, although this effect was not observed in female teams (Papadopoulou et al., 2019; Leonardi et al., 2022). On the other hand, another study developed by Saavedra-García et al. (2015) sought to assess whether the RAE remains present throughout the history of FIBA basketball world championships in the lower categories, determining that it not only decreases over time (as occurs in the male U19 category), but for the female U19 category, it increases.

Another study developed by Maciel et al. (2021) determined that athletes in the U13 category who were born in the first months were more likely to enter a high performance, meanwhile there is a lower percentage of players born in the fourth quarter of the year within Handball (Gómez-López et al., 2017), which in turn is corroborated by the study of Nunes Rabelo et al. (2016) by stating that the teams that achieved a better classification had more players born in the first six months of the year. However, another study did not find RAE in both male and female senior elite beach handball athletes and failed to establish an association with competitive success as determined by the final position achieved in world championships (Savassi et al., 2020). On the other hand, the study developed by Ginés et al. (2023) that, although age and maturation are important in elite youth soccer, there are other important factors that are related to the competitive level and gender of the athletes.

The RAE is presented both in the lower categories of the national teams for the sports of basketball and soccer, finding that athletes born in the first trimester have greater opportunities to practice and compete, and, this effect tends to decrease at the professional level (López de Subijana & Lorenzo, 2018; Brustio et al., 2018; Brustio et al., 2021). In this regard, studies have found that the RAE

decreases progressively throughout the stages of development (Bjørndal et al., 2018; Figueiredo et al., 2020; Sá et al., 2020).

Likewise, it has been determined that the effects of RAE on long-term performance do not seem to be affected, and, at the same time it was determined that younger athletes performed better as the sport level increased (De la Rubia et al., 2021), which is why various strategies should be promoted to minimize the effect of RAE in categories prior to competitive levels (Rubajczyk, Świerzko & Rokita, 2017). In this regard, it has been corroborated in the study by Müller et al. (2018) that the selection process of athletes under 9 years of age is related to relative age and biological maturation status, which is why athletes who enter puberty early have a higher chance of being selected (Müller, Hildebrandt & Raschner et al., 2015). Given this, it was proposed to conduct the present study to develop a bibliometric analysis of the scientific production on the RAE in sport.

## Methodology

The present bibliometric study is based on a descriptive and mixed-approach analysis of the scientific production on RAE in sport in the last eight years (2015-2023) from the use of bibliometrics as a research technique and with the help of the PubMed and Scopus databases (Salinas-Ríos & García-López, 2022; Tomás-Górriz & Tomás-Casterá, 2018) between January 1, 2015, and April 30, 2023.

The following MeSH terms were used: "sport", "relative age", "sports performance", "sports competition" "relative age effect" along with the search equations ("sport competition" AND "relative age effect"), ("sports talent" AND "relative age effect"), ("physical differences" AND "relative age effect") to search for documents in the Scopus and PubMed databases. In addition, filters were applied to the descriptors related to the year of publication, open-access documents, and types of documents. A flowchart showing the step-by-step selection process was developed (see figure 1), based on PRISMA considerations that allowed to delimit the search and select those documents that provided valuable information (Mazzardo et al., 2022).

The inclusion criteria considered the following: i) publication date between January 1, 2015, and April 30, 2023 seeking to recognize the latest scientific advances; ii) English and Spanish language; iii) the journal being indexed in Scimago quartiles Q1, Q2, Q3, or Q4; iv) access to the complete document. Papers not meeting any of these criteria were excluded. Meanwhile, the exclusion criteria were: i) systematic reviews, meta-analyses, or document reviews; ii) books, book chapters, or conference proceedings; iii) undergraduate or doctoral theses; iv) in a database other than Scopus and PubMed.

To select the documents, an analysis matrix was developed in Microsoft Excel based on the following categories: 1) database; 2) year of publication; 3) journal name; 4) journal country; 5) H-index; 6) SCI index (2021);

7) Quartile (Q1; Q2; Q3; Q4); 8) Number of articles per Journal; 9) Scopus citations; 10) Countries evaluated; 11) Collective sports; 12) Individual sports; 13) number of times the sample of a country was evaluated according to journals; 14) Area of knowledge; 15) Gender; 16) Number of authors; 17) Name authors; 18) Instruments used to determine the RAE of athletes; 19) Research approach; 20) Research design; 21) Statistical Software package; 22) Statistical test; 23) Language; 24) Sample Size.

The Scopus database yielded 165 documents, while PubMed provided 432 documents, which were submitted to the meta-tests regulation process, to eliminate documents for duplicity, for not having access to the entire document, or for being review articles and/or meta-analyses. Finally, Excel was used to generate tables and figures (frequency/percentage) related to the statistical analysis. At last, after the PRISMA procedure, only 185 documents remained that met the inclusion and exclusion criteria established for the present study. The VOSviewer program was used to create the co-occurrence map based on co-authorship (Van Eck & Waltman, 2011; 2014).

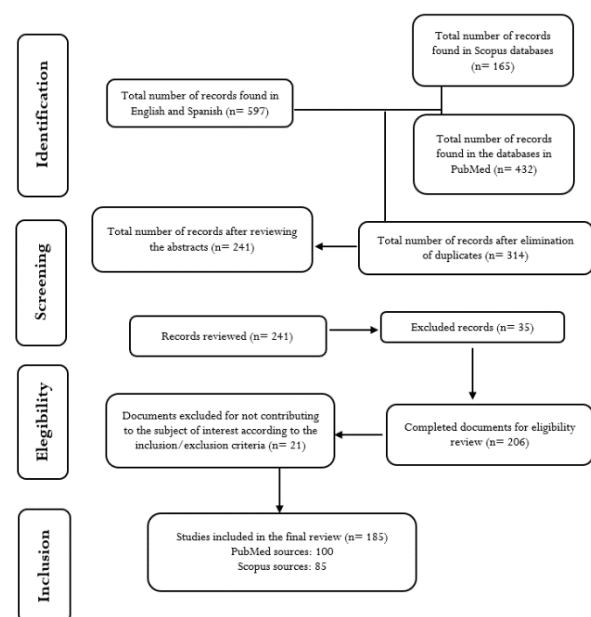


Figure 1. Study selection process following the flow chart.

## Results

Concerning the bibliometric analysis developed, figure 2 shows the behavior of scientific production and its distribution by year (2015-2023). It can be observed that the lowest percentage of publications was in 2016 (6.48%) and 2017 (8.10%), while the year with the highest scientific production was in 2022 (14.05%). Finally, the highest academic production is reported for the years 2018 and 2021 with the same percentage (15.13%). For the year 2023 when considering publications up to April 30, it has the lowest number of scientific production in the RAE study.

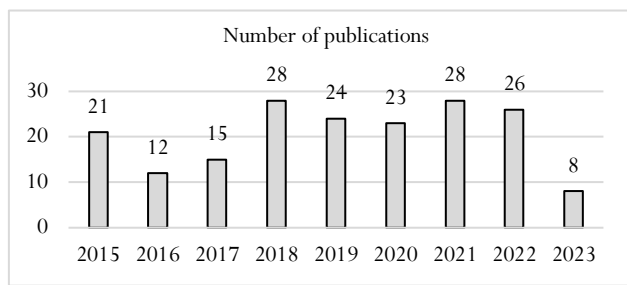


Figure 2. Number of publications per year

According to table 1, the publications on the RAE in sport have a higher percentage of articles in the PubMed database (70.69%), compared to Scopus (29.31%). Regarding the number of citations for each journal, it is possible to detail that those with the highest number of quotations are PloS One with 24 documents and 591 citations (24.62 citations on average per article), Journal of Sports Science with 12 documents and 478 citations (39.83 citations on average per article). On the other hand, other journals with more than 100 citations are Sports with 15 papers and 109 citations (7.26 citations on average per article), Journal of Human Kinetics with 13 papers and 193 citations (14.84 citations on average per article), Frontiers in Psychology with 10 papers and 144 citations (14.4 citations on average per article) and finally, Journal of Sports Science & Medicine with 9 papers and 198 citations (22 citations on average per article).

Meanwhile, about the journal in which the highest scientific production has been produced, the citations of each journal and the countries evaluated in each of the studies

reveal that the journals with the highest production for English are: PloS One (12.97%), Sports (8.10%), Journal of Human Kinetics (7.02%), Journal of Sports Science (6.48%), Frontiers in Psychology (5.40%) and Journal of Sports Science & Medicine (4.86%). On the other hand, the journals with the highest production in Spanish are Apunts. Educación Física y Deporte, Cuadernos de Psicología del Deporte and Retos (1.62%) each (table 1).

Table 1 shows the population samples that have been evaluated the most: World (13.008%), Spain (12.195%), the United Kingdom (8.943%), Brazil (6.504%), and the United States (5.691%). Concerning the journals with the highest quartile, the publications selected for this bibliometric analysis show a higher percentage in quartile one journal (62.64%), compared to quartile two (15.51%), quartile three (13.79%) and quartile four (8.045%).

Finally, out of the 51 journals consulted, the ones from the United Kingdom (21.56%), the United States (19.60%), Switzerland (11.76%), Spain (9.80%), Brazil (7.84%), same as Poland and Germany with the same percentage (3.92%), are the ones with the highest scientific production in the study of the RAE in sports. Concerning the number of articles per journal, table 1 shows a significant diversity in several journals that have publications with at least one study. Thus, out of the 51 journals consulted, 46 have less than ten publications, and only five have published more than ten studies, these being from Switzerland (Frontiers in Psychology and Sports), Poland (Journal of Human Kinetics), United Kingdom (Journal of Sports Sciences) and the United States (PloS One).

Table 1. Total documents of each according to the number of citations and countries evaluated

Journal	Magazine country	Index H	Index SCI	Quartile	Number of articles per journal	Scopus citations	Countries evaluated
American Journal of Lifestyle Medicine	United States	45	0.46	Q3	1	3	World cup
Annals of Applied Sport Science	Iran	8	0.20	Q4	1	0	South Korea
Apunts. Educación Física y Deporte	Spain	11	0.40	Q1	3	10	Spain
BMC Public Health	United Kingdom	159	1.16	Q1	1	1	Japan
Cuadernos de Psicología del Deporte	Spain	21	0.39	Q3	3	30	Brazil, Spain
Children (Basel)	Switzerland	31	0.65	Q2	2	6	Spain, World Cup
Cultura, Ciencia y Deporte	Spain	16	0.18	Q4	1	4	Brazil
E-Balonmano	Spain	19	0.32	Q3	1	3	Portugal
Economic and Social Review	United Kingdom	31	0.35	Q2	1	5	United Kingdom
European Journal of Human Movement	Spain	5	0.19	Q4	1	1	Spain
European Journal of Sport Science	United Kingdom	157	1.16	Q1	2	28	Denmark, United Kingdom
Frontiers in Physiology	Switzerland	122	1.13	Q1	3	49	Portugal, Norway, United Kingdom
Frontiers in Psychology	Switzerland	133	0.87	Q1	10	144	Germany, Greece, Italy, Poland, Scotland, Spain, World Cup
Frontiers in Sport and Active Living	Switzerland	13	0.62	Q2	8	51	Austria, Belgium, Canada, United Kingdom, Switzerland, World Cup
International Journal of Environmental Research and Public Health	Switzerland	138	0.81	Q1	7	57	Hungary, Italy, Russia, Spain, Italy, Russia, Europe, World Cup
International Journal of Exercise Science	United States	12	0.35	Q3	1	10	United States
International Journal of Performance Analysis in Sport	United Kingdom	34	0.71	Q2	2	20	Spain, World Cup
International Journal of Sports Physiology and Performance	United States	76	1.62	Q1	1	5	Switzerland
International Journal of Sports Science & Coaching	United Kingdom	38	0.63	Q3	6	64	Austria, Japan, United Kingdom
International Journal of Sports Medicine	Germany	112	0.97	Q1	1	56	United Kingdom
International Journal of Sports Science & Coaching	United Kingdom	38	0.63	Q3	6	64	Austria, Japan, United Kingdom

Journal for the Study of Sports and Athletes in Education	United States	13	0.21	Q4	1	0	Canada
Journal of Aging and Physical Activity	United States	66	0.50	Q3	1	2	Europe
Journal of Human Kinetics	Poland	44	0.82	Q1	13	193	Brazil, Denmark, Greece, Norway, Poland, Portugal, Spain, United States, World Cup
Journal of Physical Education (Maringa)	Brazil	32	0.31	Q3	1	3	World cup
Journal of Physical Education and Sport	Romania	12	0.17	Q4	1	11	Brazil
Journal of Sports Sciences	United Kingdom	145	1.16	Q1	12	478	Spain, United States, Netherlands, Portugal, United Kingdom, Switzerland, Europe, World Cup
Journal of Sport and Health Research	Spain	7	0.21	Q3	2	4	Chile, World Cup
Journal of Science and Medicine in Sport	Netherlands	108	1.38	Q1	2	51	Australia
Journal of Sports Medicine and Physical Fitness	Italy	68	0.49	Q2	1	1	Australia
Journal of Sports Science & Medicine	Turkey	72	0.95	Q2	9	198	Austria, Germany, Spain, United States, World Cup
Journal of Strength and Conditioning Research	United States	140	1.47	Q1	4	101	Spain, Russia, United States, World Cup
Journal of Youth Development	United States	8	0.32	Q3	1	3	Canada
Motriz. Revista de Educacao Física	Brazil	16	0.21	Q4	4	31	Brazil
PeerJ	United States	83	0.77	Q1	1	6	Australia
Perceptual and Motor Skills	United States	73	0.50	Q3	1	0	Japan
Physical Culture and Sport, Studies and Research	Poland	9	0.28	Q3	1	5	Hungary
PloS One	United States	367	0.85	Q1	24	591	Austria, China, Italy, Luxembourg, Jamaica, United States, United Kingdom, Norway, Spain, Europe, World
Research Quarterly for Exercise and Sport	United Kingdom	96	0.66	Q2	1	17	World cup
Retos	Spain	19	0.32	Q3	3	14	Brazil
Revista Brasileira de Ciencias do Esporte	Brazil	9	0.20	Q4	1	3	Brazil
Revista Brasileira de Cineantropometria e Desempenho Humano	Brazil	23	0.26	Q4	1	9	Brazil
Revista de Psicologia del Deporte	Spain	30	0.28	Q3	1	2	Spain
Revista Internacional en Medicina y Ciencias de la Actividad Física y del Deporte	Spain	21	0.30	Q3	1	0	Spain
Scandinavian Journal of Medicine & Science in Sports	Denmark	123	1.38	Q1	2	36	United Kingdom, Europe
Sports	Switzerland	25	0.89	Q1	15	109	Australia, Canada, Norway, United Kingdom, Russia, Sweden, Switzerland, World Cup
Science & Medicine in Football	United Kingdom	22	1.18	Q1	5	11	Spain, Italy, Portugal, United Kingdom, World Cup
Soccer and Society	United Kingdom	33	0.49	Q2	1	3	Argentina
Sports Medicine - Open	United Kingdom	31	1.42	Q1	5	47	Japan, Sweden, North America
Studia Sportiva	Czech Republic	2	0.13	Q4	2	0	Czech Republic
Talent Development and Excellence	Germany	19	0.11	Q4	1	8	Australia

According to table 2, the sports with the highest scientific production are soccer (32.90%), various sports (12.90%), basketball (8.64%), handball (7.02%), and Rugby (5.40%). In that sense, sports with low academic production are Water Polo with only one study published in the journal Motriz Revista de Educacao Física, Baseball with two papers published in the same journal (Sports Medicine - Open), and Cricket with three papers published in Sports, Journal of Sports Sciences and PeerJ. It is possible to determine that 79.46% of the academic productivity based on the 185 documents included in the present study

belongs to collective sports, with soccer being the one with the highest production at 32.9%, whereas the rest of collective sports have 46.38%. Likewise, the journals that have generated considerable production in the study of RAE in collective sports are PloS One (10.27%) with 19 investigations, as well as Sports (6.49%), Journal of Human Kinetics (6.49%) and Journal of Sports Sciences (6.49%), all with the same amount of investigations (n:12). Finally, research determined that 43 journals mainly classified the 148 publications in collective sports within Q1 and Q2.

Table 2. Total documents of each magazine for collective sports

Sport	Waterpolo	Baseball	Cricket	Indoor soccer	Volleyball	Field Hockey	Rugby	Handball	Basketball	Various sports	Soccer	%
Journal PloS One						1	1	2	1	2	12	10.27
Sports			1			1	1	2	1	2	4	6.49
Journal of Human Kinetics					2	2		3		1	4	6.49
Journal of Sports Sciences			1		1		1		2	4	3	6.49
Frontiers in Psychology					2			2		2	3	4.86
Frontiers in Sport and Active Living						1	2		1		3	3.78
International Journal of Environmental Research and Public Health								1		1	4	3.24

Sports Medicine - Open	2												1	3	3.24	
Journal of Sports Science & Medicine													2	1	2	2.70
International Journal of Sports Science & Coaching													1		4	2.70
Science & Medicine in Football													1		4	2.70
Motriz. Revista de Educacao Física	1	2												1		2.16
Journal of Strength and Conditioning Research													1	2	1	2.16
Apunts. Educación Física y Deporte													1		2	1.62
Cuadernos de Psicología del Deporte Retos	1												1	1	1	1.62
Children (Basel)	1														1	1.08
European Journal of Sport Science	1													1		1.08
International Journal of Performance Analysis in Sport															2	1.08
Journal of Science and Medicine in Sport															2	1.08
Journal of Sport and Health Research													1	1		1.08
Scandinavian Journal of Medicine & Science in Sports															2	1.08
Frontiers in Physiology															1	0.54
American Journal of Lifestyle Medicine															1	0.54
BMC Public Health															1	0.54
Cultura, Ciencia y Deporte															1	0.54
E-Balonmano													1			0.54
Economic and Social Review															1	0.54
European Journal of Human Movement															1	0.54
International Journal of Exercise Science	1															0.54
International Journal of Sports Medicine															1	0.54
Journal for the Study of Sports and Athletes in Education															1	0.54
Journal of Physical Education (Maringá)	1															0.54
Journal of Physical Education and Sport															1	0.54
Journal of Youth Development													1			0.54
PeerJ	1															0.54
Perceptual and Motor Skills															1	0.54
Research Quarterly for Exercise and Sport													1			0.54
Revista Brasileira de Ciências do Esporte															1	0.54
Revista Brasileira de Cineantropometria e Desempenho Humano														1		0.54
Revista de Psicología del Deporte Soccer and Society													1			0.54
Revista Internacional en Medicina y Ciencias de la Actividad Física y del Deporte														1		0.54
Total documents	1	2	3	4	6	7	10	13	16	24	61	148				
Porcentaje by sport	0.54	1.08	1.62	2.16	3.24	3.78	5.40	7.02	8.64	12.9	32.9	79.46/ 100%				

Table 3 shows 13 individual sports, among which athletics (5.81%) and skiing (4.86%) stand out as the sports with the highest academic productivity in the RAE study. Other sports including swimming (1.62%), Taekwondo (1.62%), and tennis (1.62%), have the same amount of research (n: 3). The journals with the highest production on

RAE in individual sports are PloS One with five papers (2.70%) and Journal of Sports Science & Medicine with four papers (2.16%). Of the 185 papers analyzed in the present study, only 37 (20.0%) were found. Likewise, it was determined that 22 journals mainly categorized the 37 publications in individual sports within Q1 and Q2.

Table 3. Total documents of each magazine for individual sports

	Athletics	Chess	Hammer throw	Judo	Pádel	Shooting sports	Ski	Squash	Swimming	Taekwondo	Tennis	Triatlón	Weightlifting	%
Annals of Applied Sport Science										1				0.54
Cuadernos de Psicología del Deporte	1		1											1.08

Frontiers in Physiology	2														1.08
Frontiers in Psychology								1							0.54
Frontiers in Sport and Active Living								1	1						1.08
High Ability Studies	1														0.54
International Journal of Environmental Research and Public Health								1			1				1.08
International Journal of Sports Physiology and Performance								1							0.54
International Journal of Sports Physiology and Performance								1							0.54
International Journal of Sports Science & Coaching								1							0.54
Journal of Human Kinetics								1							0.54
Journal of Sports Medicine and Physical Fitness													1		0.54
Journal of Sports Science & Medicine								2		1		1			2.16
Journal of Sports Sciences	1														0.54
Journal of Strength and Conditioning Research													1		0.54
Motriz. Revista de Educação Física	1														0.54
Perceptual and Motor Skills													1		0.54
Physical Culture and Sport, Studies and Research													1		0.54
PloS One	3							2							2.70
Retos								1					1		1.08
Sports	2												1		1.62
Studia Sportiva													1	1	1.08
Total documents	10	1	1	2	1	1	9	1	3	3	3	1	1		37.00
Porcentaje by sport	5.41	0.54	0.54	1.08	0.54	0.54	4.86	0.54	1.62	1.62	1.62	0.54	0.54		20.00/100

On the other hand, concerning the percentage of samples for each of the evaluated countries, it was found that the largest number of assessed athletes hail from various countries and continents (World Cup) (13.008%).

Among the most frequently evaluated countries, Spain leads with 12.195%, followed by the United Kingdom (8.943%), Brazil (6.504%), the United States (5.691%), Australia (4.878%), and Portugal, along with several athletes from the same European continent, all at 4.065% (refer to

table 4). Meanwhile, about the areas of knowledge, it was determined that the scientific production of the RAE in sports is closely related to sports talent (25.40%), sports competition (22.70%), and, to a lesser extent, sports training (15.13%), sports medicine (13.51%) and physical condition (11.89%) (see table 5). Thus, the lowest academic productivity in the RAE study concerning the area of knowledge is related to sports management, sociodemographic factors, and sports physiology.

Table 4.  
Percentage of samples evaluated for each country according to Journals

Country	Number of times the sample was evaluated	%
World Cup	16	13.00
Spain	15	12.19
United Kingdom	11	8.94
Brazil	8	6.50
United States	7	5.69
Australia	6	4.87
Portugal	5	4.06
Europe	5	4.06
Switzerland	4	3.25
Norway	4	3.25
Japan	4	3.25
Italy	4	3.25
Canada	4	3.25
Austria	4	3.25
Russia	3	2.43
Sweden	2	1.62
Poland	2	1.62
Hungary	2	1.62
Greece	2	1.62
Germany	2	1.62
Denmark	2	1.62
Chile	2	1.62
Scotland	1	0.81
North America	1	0.81
Netherlands	1	0.81
Korea	1	0.81
Jamaica	1	0.81
Czech Republic	1	0.81
China	1	0.81
Belgium	1	0.81
Argentina	1	0.81
Total: 3 continents and 29 countries	123	100.00

Regarding the number of total documents concerning the gender of the samples evaluated in the research that relates to the RAE in sport, it is determined that the largest production is generated in the male gender (74.26%), female-male (20.46%) and only 7.01% of the studies are developed in the female gender (see table 6).

Finally, regarding the number of authors, this bibliometric analysis shows that the highest percentage of authors who publish their studies are four authors (29.31%), five authors (18.96%), three authors (16.66%) and six authors (12.06%) (see table 7).

The lowest percentage found is for researchers who decided to publish individually, while other low percentages are found when research is done by pairs (8.620%), with eight authors (4.597%), and when there are more than nine authors (3.448%). Likewise, the main author who has done the most research has been Lisa Müller (4,022%), Paolo Brustio (2,298%) and Alfonso de la Rubia (2,298%) (see table 8).

Table 9 shows the instruments used to determine the RAE, the main sources being the Sports Federation with 56 documents, the database with 51, and the web page with 41, while the least used are the questionnaire and the interview.

Table 5.  
Total number of documents for each of the areas of knowledge

Area of knowledge	Total documents	%
Sports talent	47	25.40
Sports competition	42	22.70
Sports training	28	15.13
Sports medicine	25	13.51
Physical condition	22	11.89
Sports management	14	8.18
Socio-demographic factors	4	2.33
Sports physiology	3	1.75
Total	185	100.0

Table 6.  
Total number of documents by gender

Gender	Total documents	%
Male	129	69.72
Female-Male	39	21.08
Female	17	9.18
Total	185	100.0

Table 7.  
Percentage for number of authors

Number for authors	%
1 author	1.14
2 authors	8.62
3 authors	16.66
4 authors	29.31
5 authors	18.96
6 authors	12.06
7 authors	5.17
8 authors	4.59
More than 9 authors	3.44
Total	100

Table 8.  
Name of authors

Primary author's name	Number for studies	%
Müller, Lisa	7	4.02
Brustio, Paolo	4	2.29
De la Rubia, Alfonso	4	2.29
Kelly, Adam	3	1.72
Doyle, John	3	1.72
Bezuglov, Eduard	3	1.72
McCarthy, Neil	2	1.14
Rossing, Neils	2	1.14
Romann, Michael	2	1.14
Steingröver, Christina	2	1.14
Helsen, Werner	2	1.14
Lemoyne, Jean	2	1.14
Total	28	20.68/100

Likewise, regarding the relationship of the authors with the documents published in Scopus and PubMed on the study of the RAE in sport, the VOSviewer program (Van Eck & Waltman, 2011; 2014) shows the collection by citations and documents of the authors with more than two citations per scientific article and, at the same time, the map of nodes is established to recognize the relationship with other authors who have written on the same topic (see figure 3). As a result, authors Kelly, Adam, de la Rubia, Alfonso and Brustio, Paolo Ricardo have the largest bibliometric size among the 185 papers analyzed.



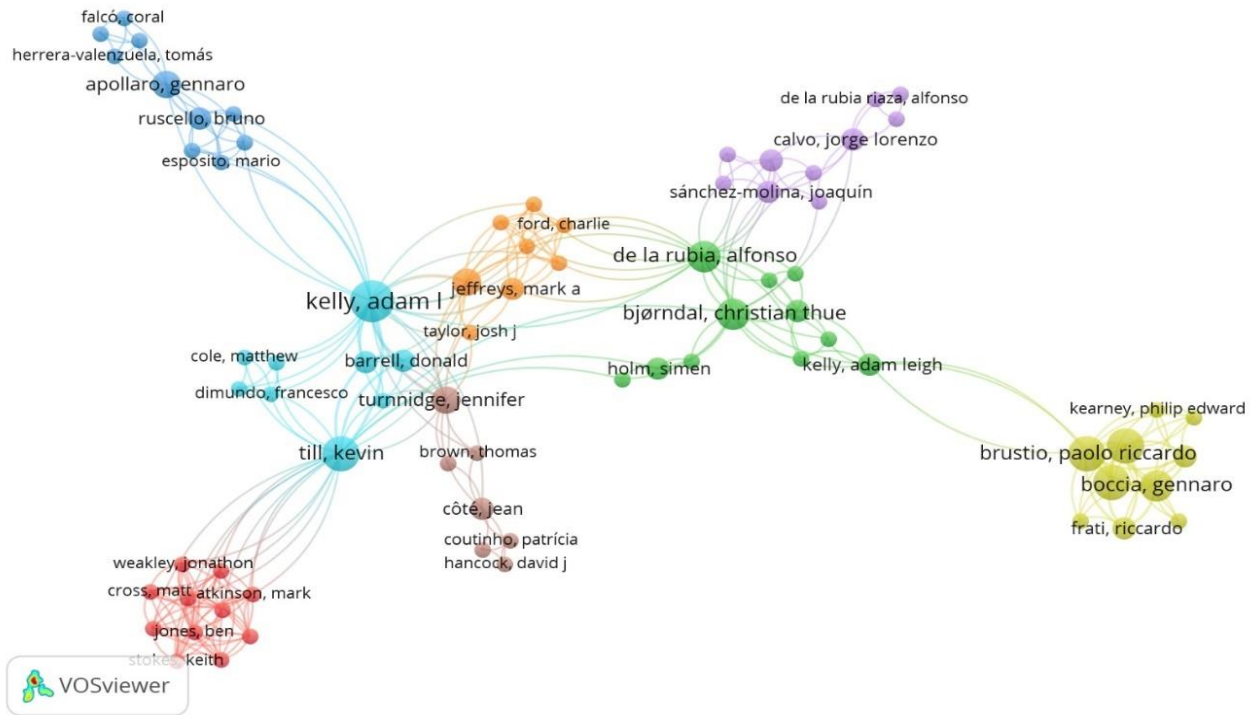


Figure 3. Co-authorship map. Source: VOSViewer.

Table 9. Percentage of the number of instruments used to determine the RAE of athletes

Tool to get to know the RAE	Total	%
Federation	56	30.27
Database	51	27.56
Website	41	22.16
Questionnaire	34	18.31
Interview	3	1.62
Total	185	100

On the other hand, concerning the research approach of the documents analyzed for the present study, it has been determined that the quantitative approach predominates with 179 documents, which reveals the research trend in sports sciences (see table 10). These data indicate that researchers developed few qualitative or mixed approaches for studying RAE. In the same way, the research design in the study of RAE is more diverse, with a descriptive retrospective, observational cross-sectional, descriptive retrospective cross-sectional, correlational retrospective and retrospective studies being the most used (see table 11).

Regarding the statistical analysis used to carry out the RAE study, table 12 shows the statistical programs used, highlighting the use of SPSS with more than half of the studies and the ® program with only 14 studies. It's worth noting that 44 of the 185 documents analyzed in this study do not detail which program was used for data analysis. Similarly, about the statistical tests used, the Kolmogorov-Smirnov tests stand out in 22 studies, Cramer's V in 25 studies, Cohen's d to determine the effect size in 29 studies, Odds ratio in 48 studies, and, finally, the Chi-square test as the most widely used, found in 133 out of the 185 studies

analyzed. It should also be mentioned that, in recent years, the use of other statistical tests for the study of RAE, such as Poisson regression, has been gaining momentum (see table 13).

Table 10. Percentage of the number of approaches used for the RAE study

Research approach	Total	%
Quantitative	179	96.75
Qualitative	4	2.16
Mixed	2	1.08
Total	185	100

Table 11. Percentage of the number of research designs for the study of the RAE

Research design	Total	%
Descriptive argumentative	1	0.54
Descriptive non-experimental	2	1.08
Multiple method sequences	2	1.08
Interpretative hermeneutic	3	1.62
Descriptive correlational	3	1.62
Longitudinal correlational	3	1.62
Cross-sectional correlational	4	2.16
Longitudinal descriptive	4	2.16
Cross-sectional descriptive	5	2.70
Longitudinal experimental	15	8.10
Retrospective descriptive	21	11.35
Cross-sectional observational	23	12.43
Retrospective cross-sectional descriptive	31	16.75
Retrospective correlational	33	17.83
Retrospective	35	18.91
Total	185	99.95/100

In relation to language, it has been determined that 89.18% of the total number of studies analyzed in this study were in English, followed by Spanish, and only one study was in Portuguese.

Table 12.

Percentage of the number of statistical programs used for the investigation of the RAE

Statistical software package	Total	%
Stata	1	0.54
Nvivo	1	0.54
JASP	1	0.54
Irish Central Statistics Office	1	0.54
Microsoft Excel	3	1.62
Jamovi	3	1.62
Statistics	5	2.70
PASW Statistics	5	2.70
MATLAB	7	3.78
RStudio®	14	7.56
Does not refer	44	23.78
SPSS	100	54.05
Total	185	99.97/100

Table 13.

Percentage of the number of statistical tests used to investigate the RAE

Statistical tests	Total	Percentage of the 185 studies evaluated
Category analysis	1	0.54
Inductive method	1	0.54
Nonlinear least squares	1	0.54
Reflective thematic analysis	1	0.54
Intraclass correlation coefficient	1	0.54
Lilliefors	1	0.54
Wald test	1	0.54
Z test	1	0.54
Scheffé method	1	0.54
Dunn's test	1	0.54
Omnibus test	1	0.54
Jonckheere -Terpstra test	1	0.54
Bayesian logistic multilevel regression	1	0.54
Tails of the Travelling Gaussian model (TTG)	1	0.54
Eta Square	1	0.54
Multiple Factor Ahalysis	1	0.54
Levene's test	2	1.08
Discrimination index	2	1.08
Linear hierarchical models	2	1.08
Generalized linear models	2	1.08
Generalized Linear Mixed Models	2	1.08
Binary Logistic Regression	2	1.08
ANCOVA	3	1.62
Shapiro Wilk	3	1.62
Pearson correlation coefficient	3	1.62
Omega Square	4	2.16
Spearman correlation coefficient	5	2.70
Linear regression	5	2.70
Multinomial logistic regression	5	2.70
Tukey test	6	3.24
Poisson regression	6	3.24
t Student	6	3.24
MANOVA	7	3.78
Bonferroni	8	4.32
Mann-Whitney U test	11	5.94
Kruskall-Wallis	17	9.18
Kolmogorov-Smirnov test	22	11.89
Cramer's V	25	13.51
d Cohen	29	15.67
ANOVA	30	16.21
Odds ratio	48	25.94
Chi-square test	133	71.89

Table 14.

Percentage of the number of studies by language used to investigate the RAE

Language	Total	%
English	165	89.18
Spanish	19	10.27
Portuguese	1	0.54
Total	185	99.99/100

Another important finding is related to the sample size used in each of the 185 documents analyzed, detailing a significant academic production in the RAE study that focuses

on population samples ranging from 1001 to 10,000 athletes (41.62%), followed by population samples ranging from 101-500 athletes (21.08%) and 501 and 1000 athletes (15.67%). Finally, out of the 185 studies of the present investigation, a total of 1.930.000 athletes were evaluated, with the lowest population values being those at the extremes, between 7 and 100 athletes and those using more than 50.000 athletes.

Table 15.

Percentage of the number of studies by sample size evaluated the RAE study

Sample size	Total number of athletes evaluated	Total number of investigations in relation to the 185 studies analyzed	%
7-100	747	13	7.02
101-500	10.584	39	21.08
501-1000	21.555	29	15.67
1001-10.000	253.808	77	41.62
10.001-50.000	377.164	19	10.27
>50.000	1.266.881	8	4.32
Total	1.930.739	185	99.98/100

## Discussion and conclusions

In attention to the results of the present bibliometric study in which the publication period between 2015 and 2023 was considered, a production that decreased in the years 2016 and 2017 stands out, finding its highest number of publications in 2018, then decreasing again in 2019 and 2020 and remaining the same in 2021 and 2022. This phenomenon related to the number of studies per year is not related to other studies in which a considerable increase in the number of investigations is maintained throughout the years (Blanca-Torres et al., 2019; Mamani-Jilaja et al., 2023). In comparison with the two consulted databases, it is evident that PubMed has a higher scientific output than Scopus when it comes to assessing the effect of RAE on sport. On the other hand, the journals with the highest number of citations per article are PloS One from the United States, the Journal of Sports Science from the United Kingdom, Sports from Switzerland, the Journal of Human Kinetics from Poland, Frontiers in Psychology from Switzerland and Journal of Sports Science and Medicine from Turkey. This shows that most knowledge produced on the effect of RAE is produced and cited based on European and North American journals.

The different findings shared by the specialized scientific literature are mainly due to the considerable increase that has the application of that knowledge (Silva et al., 2022), this responds to the need that certain sports have to be recognized by research for their low level of scientific production such as taekwondo, tennis and cricket (1.72%), compared to the recognition of other sports that have a much higher scientific evidence such as soccer (35.63%). On the other hand, what is striking when studying the RAE is centered on the consideration of several sports (13.79%).

One of the main conclusions of the study highlights a great difference in research trends in the last eight years of studies of the effect of RAE in the male population (74.26%), and even in the female-male population

(20.46%). However, the lowest percentage is found when evaluating the female population (7.01%), which generates a call to the scientific community to proliferate studies that evaluate female athletes and based on this, continue to contribute to the professionalization and development of sport practiced by women. In another sense, the total number of countries evaluated was 28 countries and four continents, with results different from the findings of another study that used the methodology of bibliometric analysis in collective sports (Mamani-Jilaja et al., 2023), determining that the greatest scientific production when studying the effect of RAE is in Europe and North America and to a lesser extent in South America. Of the total number of papers (100%) 18 countries were evaluated in Europe (64.28%), three in South America (10.71%), three in North America (10.71%), three in Asia (10.71%), and only one in Oceania (3.57%). Therefore, the cooperation established between countries helps to direct the focus of the studies (Ntozis et al., 2021; Orejuela Aristizabal, 2023). All this demonstrates the tendency of certain countries and continents to show research interest in specific topics relevant to the study of sport, such as the effect of the RAE.

The great diversity in the number of authors at the time of scientific publication reveals that between three and five authors are the highest percentage found in the studies considered, with four authors being the highest percentage (19.31%), five authors (18.96%) and three authors (16.66%). Likewise, the smallest number of studies published was by a single author (1.149%) and more than nine authors (3.448%). This leads to reflecting on research trends when developing professional cooperation seeking to solve an identified problem. The present study demonstrates the importance of the effect of RAE on sports and finds that some possibilities could be explored by sports scientists, among which the following stand out: (i) developing a greater research production on women's sports; (ii) greater participation of countries in Oceania, South America, Asia, and Africa in research on the effect of RAE; (iii) consideration of population samples from countries other than those evaluated; (iv) greater impact of publications in a language other than Spanish or journals that publish in Spanish should consider publishing exclusively in English; (v) consideration of sports other than team sports: soccer, basketball, and volleyball; (vi) explore other sports not considered in this study such as ultimate, skating, cycling, etc).

Regarding the area of knowledge for the study of the RAE in sport, it is highlighted how studies focused on the consideration of sociodemographic factors have a low scientific production, compared to other areas such as sport talent and sport competition. There, the study developed by Brustio et al. (2022) has been directed to the study of the influence of contextual factors on the RAE, concluding that older athletes are more likely to develop higher levels of performance in contrast to younger ones, and this effect is confirmed in various socio-cultural contexts. On the other hand, the study developed by Hancock, Adler & Côté (2013) shows that there are other factors capable of

exacerbating the RAE, such as social factors, family nucleus, sports environment, etc.

For the statistical programs used in data analysis, SPSS software is the most widely used, and, curiously, seven of the 12 studies with the highest number of citations in Scopus use it.

The diversity in the use of statistical tests for the study of the RAE determines that there is indeed a great diversity in the analysis of the data. Likewise, it is recognized that there are other specific models that have been used such as Poisson regression (Doyle & Bottomley, 2019; Pérez-González, León-Quismondo, Bonal, Burillo & Fernández-Luna, 2021), multinomial logistic regression (Mendes et al., 2021) and generalized linear mixed models. The Chi-square test and Odds ratio are still the most commonly used in most studies and for the determination of effect size the Cohen's d test was the most frequently found.

There continues to be a great predominance of studies in English, not only in the total number of studies, but also in the disparity in the number of citations. Thus, for the English language there are 165 of the 185 studies analyzed, these in turn, have a total number of citations of 2454, while there are only 19 studies for the Spanish language and a low number of citations (n:100).

Regarding the size of the samples evaluated, the studies that have covered the largest populations are Kelly, Jackson, Barrell, Burke and Till (2022) with 251,769 athletes in men's and women's rugby, Jakobsson, Julin, Persson and Malm (2021) with 244,560 athletes in various sports, Figueiredo, Seabra, Brito, Galvão and Brito (2021) in soccer and indoor soccer with 158,106 athletes, and Figueiredo, Seabra, Brito, Galvão and Brito (2021) in soccer and futsal with 158,106 athletes in men's and women's rugby.

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

1) The database from which it was possible to extract more information was PubMed, compared to Scopus.

2) The evolution of the number of publications per year between 2015 and 2023 has fluctuated, meaning that scientific production continues to consider the study of RAE as a topic of interest.

3) The journals with the highest scientific production in the study of the RAE are PloS One, Sports, and Journal of Human Kinetics.

4) The countries with the highest scientific production are the United Kingdom, the United States, and Switzerland.

5) Of the 51 journals found according to the 185 documents analyzed in this study, those with the highest SCI index are PloS One, European Journal of Sport Science, Journal of Sports Sciences, and Journal of Strength and Conditioning Research.

6) Of the 51 journals found according to the 185 documents analyzed in the present study, those with the highest

H-Index are the International Journal of Sports Physiology and Performance, Journal of Science and Medicine in Sport, Journal of Strength and Conditioning Research, Scandinavian Journal of Medicine & Science in Sports and Science & Medicine in Football.

7) About quartiles, it is detailed that there is an overrepresentation of Q1 and Q2 compared to Q3 and Q4 in studies aimed at evaluating the effect of RAE found in the PubMed and Scopus databases.

8) For the number of articles per journal, the journals with the highest production are PloS One, Sports, Journal of Human Kinetics, Journal of Sports Sciences, and Frontiers in Psychology.

9) For the journals with the highest number of citations in Scopus and which have at least 100 citations, the following are detailed: PloS One, Journal of Sports Sciences, Journal of Sports Science & Medicine, Journal of Human Kinetics, Frontiers in Psychology, Sports and Journal of Strength and Conditioning Research.

10) Regarding the population samples of the countries and/or continents evaluated in the 185 documents of the present study, it is detailed that these samples are distributed in the World, Spain, the United Kingdom, Brazil, and the United States.

11) The collective sports identified were 10, highlighting that the most significant scientific production developed is in soccer, basketball, handball, rugby, and, to a lesser extent, in other sports such as field hockey, volleyball, indoor soccer, cricket, baseball, and water polo.

12) The individual sports identified were 13, among which athletics and skiing stand out as those with the highest production and a low number of publications in the other sports (Chess, Hammer throw, Judo, Paddle tennis, Shooting sports, Squash, Swimming, Taekwondo, Tennis, Triathlon and Weightlifting).

13) Concerning the number of articles by country and/or continent evaluated, it is determined that World Cup appears in 16, Spain in 15, the United Kingdom in 11, Brazil in 8, the United States in 7, and Australia in 6 studies respectively.

14) Regarding the area of knowledge, there is a significant number of studies on sports talent, sports competition, sports training, sports medicine, and physical condition. Likewise, there are low levels of scientific production for sports management, sociodemographic factors, and sports physiology.

15) For gender, there is an overrepresentation of studies for the male gender compared to the female, which invites further development of studies that consider the female athlete.

16) For the total number of authors per published article, those studies in which there are between 3 and 6 authors stand out, with four authors being the highest percentage. Similarly, the lowest percentage found is in publications with only one author or more than nine authors.

17) The authors who have generated considerable scientific production in the 185 documents analyzed are Müller,

Lisa, Brustio, Paolo, and De la Rubia, Alfonso.

18) The instruments most used to determine the RAE are the Federation, Database, Website, and Questionnaire. Thus, only three studies use a different means, employing the interview.

19) There is an overrepresentation of studies with a quantitative approach versus qualitative or mixed approach studies.

20) For the research designs used in the RAE study, it is determined that there is indeed a high number of these, among which the following stand out: Longitudinal experimental, retrospective descriptive, cross-sectional observational, retrospective cross-sectional descriptive, retrospective correlational.

21) The most commonly used statistical programs were SPSS and Studio ®. However, some studies do not refer to the type of statistical software used.

22) The most commonly used statistical tests are the Chi-square test, Odds ratio, and ANOVA, while Cohen's d test is the main one for effect size determination.

23) For language, there is an overrepresentation of English versus Spanish. Thus, only one study was found in a different language (Portuguese).

24) The most prevalent sample sizes in the RAE study are 1001-10,000 with 77 publications, 101-500 athletes in 39 publications, and 501-1000 with 29 publications.

## Limitations

The primary limitations of this study revolve around the omission of other sports like skating, cycling, and ultimate, along with various alternative sports. These limitations stem from the inclusion criteria used in this research, which required a minimum of two studies for each sport. Similarly, the restriction of document search to the last eight years (2015-2023) may have limited the availability of additional scientific evidence that could have further reinforced the study's conclusions.

## Future perspectives and practical applications

To address the perspectives of studies aimed at assessing, identifying, and recognizing the RAE in sports, it is necessary to increase the number of experimental studies. These studies should explore the correlations between individuals' various social, demographic, and personal characteristics, in addition to their abilities and skills. This approach will help establish connections between the advancements achieved in these abilities and skills in response to the month of birth. Likewise, it is necessary to recognize that there are sports on which most studies focus, and this same phenomenon replicates in studies that evaluate male athletes and men and women in the same research. By this, the possibility of expanding academic interests opens, seeking to respond to sports science needs by recognizing other sports such as baseball, swimming, taekwondo, tennis, cricket, and field hockey. At the same

time, it proliferates studies focused on evaluating female athletes. Finally, the academic community is invited to continue developing this type of study focused on recognizing the RAE in sports, seeking to relate it to other characteristics of the population samples and the needs of each context.

### Conflicts of interest

The authors have no conflict of interest

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