Olympic Sports Science—Bibliometric Analysis of All Summer and Winter Olympic Sports Research

Grégoire P. Millet1,2*, Franck Brocherie3 and Johannes Burtscher1,2

1 Institute of Sport Sciences, University of Lausanne, Lausanne, Switzerland, 2 Department of Biomedical Sciences, University of Lausanne, Lausanne, Switzerland, 3 Laboratory Sport Expertise and Performance (EA 7370), French Institute of Sport, Paris, France

Introduction: The body of scientific literature on sports and exercise continues to expand. The summer and winter Olympic games will be held over a 7-month period in 2021–2022.

Objectives: We took this rare opportunity to quantify and analyze the main bibliometric parameters (i.e., the number of articles and citations) across all Olympic sports to weigh and compare their importance and to assess the structure of the “sport sciences” field. The present review aims to perform a bibliometric analysis of Olympic sports research. We quantified the following topics: (1) the most investigated sports; (2) the main journals in which the studies are published; (3) the main factors explaining sport-specific scientific attractiveness; (4) the influence of being in the Olympic programme, economic weight, and local influences on research output; and (5) which research topic is the most investigated across sports.

Methods: We searched 116 sport/exercise journals on PubMed for the 40 summer and 10 winter Olympic sports. A total of 34,038 articles were filtered for a final selection of 25,003 articles (23,334 articles on summer sports and 1,669 on winter sports) and a total of 599,820 citations.

Results and Discussion: Nine sports [football (soccer), cycling, athletics, swimming, distance & marathon running, basketball, baseball, tennis, and rowing] were involved in 69% of the articles and 75% of the citations. Football was the most cited sport, with 19.7 and 26.3% of the total number of articles and citations, respectively. All sports yielded some scientific output, but 11 sports (biathlon, mountain biking, archery, diving, trampoline, skateboarding, skeleton, modern pentathlon, luge, bobsleigh, and curling) accumulated a total of fewer than 50 publications. While ice hockey is the most prominently represented winter sport in the scientific literature, winter sports overall have produced minor scientific output. Further analyses show a large scientific literature on team sports, particularly American professional sports (i.e., baseball, basketball, and ice hockey) and the importance of inclusion in the Olympic programme to increasing scientific interest in “recent” sports (i.e., triathlon and rugby sevens). We also found local/cultural influence on the occurrence of a sport in a particular “sport sciences” journal. Finally, the...
relative distribution of six main research topics (i.e., physiology, performance, training and testing, injuries and medicine, biomechanics, and psychology) was large across sports and reflected the specific performance factors of each sport.

**Keywords:** citations, publication, sport sciences, summer Olympic sports, winter Olympic sports

**INTRODUCTION**

The Olympic sports (https://olympics.com/en/sports/) bring together a large and diverse range of human abilities that extend far beyond the Olympic motto, “Citius—Altius—Fortius” (i.e., Faster—Higher—Stronger”), and outstanding genetic, physical, technical and mental skills are required to reach an Olympic podium. It is therefore not surprising that behind each athlete is an interdisciplinary team of experts/scientists (Hodson, 2021). Elite sports performance has long been a fascinating field of research for scientists. The 1922 Nobel Prize in Physiology or Medicine, awarded to Sir A. V. Hill and his work on the best middle-distance runners of his time, provides a perfect example of ground-breaking research originating from related questions (Hill, 1925). Over the last two decades, the “sport sciences” field has massively expanded, as evidenced by the continuously growing number of journals (e.g., 85 journals in 2021 vs. 58 in 1998 in the “sport sciences” category of the Incites journal citations report—https://jcr.clarivate.com). The original definition of sport sciences as “the study and application of scientific principles and techniques to improve sporting performance” (Lippi et al., 2008) has become too narrow, and researchers in different scientific fields (e.g., antidoping sciences, biomechanics, physiology, nutrition, injury prevention and rehabilitation, psychology, pedagogy, management and marketing, history, sociology and many biomedical fields, including preventive medicine and oncology) (Millet and Giulianotti, 2019) are producing an enormous body of research related to exercise and sports. However, to our knowledge, there has been no comprehensive analysis of the “sport sciences” field and no comparison of the sport-specific scientific literature across all Olympic sports. Currently available bibliometric analyses are limited to the most cited articles in sport and exercise medicine (Knudson, 2011; Khatra et al., 2021) or specifically concern a single sport, such as football (soccer) (Brito et al., 2018), or a specific scientific field (e.g., sports economics, sports management or sociology) (Santos and Garcia, 2011; Shilbury, 2011; Gau, 2013).

In 1992, the summer (Barcelona) and winter (Albertville) Olympic games took place for the last time in the same year. Due to the COVID-19 pandemic, the two games (Tokyo 2020 Summer Olympic Games between 23 July and 8 August 2021 and Beijing 2022 Winter Olympics between 4 and 20 February 2022) will now be organized within a 7-month timeframe. This may be an occasion to review the science across all summer and winter Olympic sports.

The present review aims to perform a bibliometric analysis of Olympic sports research. We quantified the following topics: (1) the most investigated sports; (2) the main journals in which the studies are published; (3) the main factors explaining sport-specific scientific attractiveness; (4) the influence of being in the Olympic programme, economic weight, and local influences on research output; and (5) which research topic is the most investigated across sports.

**METHODS**

The data were obtained by a search in PubMed followed by a search conducted in Web of Science (Clarivate Analytics, USA). First, we selected 116 “sport sciences” journals (Table 1), including 85 journals of the “sport sciences” category in the Incites journal citations report (Clarivate Analytics, USA); then, we expanded the search to other journals with “exercise” or “sport” in the title. Second, we chose to limit the analysis to sports that are currently in the Olympic programme for Tokyo 2020 (Table 2A) and Beijing 2022 (Table 2B). This list of sports does not contain sports to be included in the Paris 2024 Olympic Games or sports eliminated from the Olympic programme. We split some sports into subdisciplines (e.g., athletics and distance running and marathon or walking; Alpine skiing and Nordic skiing; cycling and mountain biking) when their natures were too different and sufficient data were available.

The search was performed on 4–5 June 2021 on article titles, and the inclusion and exclusion items are displayed in Table 3. Searching for only the sports or athletes (e.g., judo and judoka) in all these “sport sciences” journals would have yielded 103,164 articles, with many of them irrelevant in terms of our goals. By selecting only articles related to the selected sports—e.g., excluding animal, paralympic, and ultra-sports and fulfilling the inclusion and exclusion (e.g., “American football” for “football” or “water skiing” for “alpine skiing” or “athletes”) criteria (see Tables 3A,B for the specific criteria of each sport), we reduced the final number of articles to 25,003 (23,334 articles on summer sports and 1,669 on winter sports). If two different sports were mentioned in the article title, the article was allocated to both. All articles were double-checked (GPM and FB) for conformity with the selection criteria. Auto citations were not removed from this analysis.

On 15 June, we performed a complete search for all these articles on Web of Science (Clarivate Analytics, USA). Basic information, including author(s), source journal, publication year, citations per year, and the total number of citations as well as keywords, was extracted. For each sport, the articles were listed based on citation frequency from highest to lowest, and the main metrics were averaged for the top 10 articles in each sport.

We compared the dates of the Olympic debut and the first publication for each sport (Figure 1) and for the “recent” Olympic sports (i.e., with an Olympic debut in 1998 or later)
TABLE 1 | List of the journals.

|   |   |
|---|---|
| 1. | ACSM Health & Fitness Journal |
| 2. | Adapted Physical Activity Quarterly |
| 3. | American Journal of Physical Medicine & Rehabilitation |
| 4. | American Journal of Sports Medicine |
| 5. | Applied Physiology Nutrition and Metabolism |
| 6. | Archives of Budo |
| 7. | Archives of Physical Medicine and Rehabilitation |
| 8. | Arthroscopy-The Journal of Arthroscopic and Related Surgery |
| 9. | Biology of Sport |
| 10. | BMC Sports Science Medicine and Rehabilitation |
| 11. | British Journal of Sports Medicine |
| 12. | British Medical Journal Open Sport Exercise |
| 13. | Canadian Journal of Applied Physiology |
| 14. | Clinical Biomechanics |
| 15. | Clinical Journal of Sport Medicine |
| 16. | Clinics in Sports Medicine |
| 17. | Current Sports Medicine Reports |
| 18. | Deutsche Zeitschrift fur Sportmedizin |
| 19. | European Journal of Applied Physiology |
| 20. | European Journal of Sport Science |
| 21. | European Sport Management Quarterly |
| 22. | Exercise and Sport Sciences Reviews |
| 23. | Exercise Immunology Review |
| 24. | Frontiers in Sports and Active Living |
| 25. | Gait & Posture |
| 26. | High Altitude Medicine & Biology |
| 27. | Human Movement Science |
| 28. | International Journal of Performance Analysis In Sport |
| 29. | International Journal of Sport Finance |
| 30. | International Journal of Sport Nutrition and Exercise Metabolism |
| 31. | International Journal of Sport Psychology |
| 32. | International Journal of Sports Marketing & Sponsorship |
| 33. | International Journal of Sports Medicine |
| 34. | International Journal of Sports Physiology and Performance |
| 35. | International Journal of Sports Science & Coaching |
| 36. | International Journal of the History of Sport |
| 37. | International Review for The Sociology of Sport |
| 38. | International Review of Sport and Exercise Psychology |
| 39. | Isokinetics and Exercise Science |
| 40. | Japanese Journal of Physical Fitness and Sports Medicine |
| 41. | Journal of Aging and Physical Activity |
| 42. | Journal of Applied Biomechanics |
| 43. | Journal of Applied Physiology |
| 44. | Journal of Applied Sport Psychology |
| 45. | Journal of Athletic Training |
| 46. | Journal of Clinical Sport Psychology |
| 47. | Journal of Electromyography and Kinesiology |
| 48. | Journal of Exercise Science & Fitness |
| 49. | Journal of Hospitality Leisure Sport & Tourism Education |
| 50. | Journal of Human Kinetics |
| 51. | Journal of Motor Behavior |
| 52. | Journal of Orthopaedic & Sports Physical Therapy |
| 53. | Journal of Orthopaedic Trauma |
| 54. | Journal of Rehabilitation Medicine |
| 55. | Journal of Science and Medicine in Sport |
| 56. | Journal of Shoulder and Elbow Surgery |
| 57. | Journal of Sport & Exercise Psychology |
| 58. | Journal of Sport & Social Issues |
| 59. | Journal of Sport and Health Science |
| 60. | Journal of Sport History |
| 61. | Journal of Sport Management |
| 62. | Journal of Sport Rehabilitation |
| 63. | Journal of Sports Chiropractic & Rehabilitation |
| 64. | Journal of Sports Economics |
| 65. | Journal of Sports Medicine and Physical Fitness |

TABLE 1 | Continued

|   |   |
|---|---|
| 66. | Journal of Sports Science and Medicine |
| 67. | Journal of Sports Sciences |
| 68. | Journal of Sports Traumatology and Related Research |
| 69. | Journal of Strength and Conditioning Research |
| 70. | Journal of Teaching in Physical Education |
| 71. | Journal of The International Society of Sports Nutrition |
| 72. | Journal of The Philosophy of Sport |
| 73. | Kinesiology |
| 74. | Knee |
| 75. | Knee Surgery Sports Traumatology Arthroscopy |
| 76. | Measurement in Physical Education and Exercise Science |
| 77. | Medicina Delo Sport |
| 78. | Medicine and Science in Sports and Exercise |
| 79. | Motor Control |
| 80. | Operative Techniques in Sports Medicine |
| 81. | Orthopaedic Journal of Sports Medicine |
| 82. | Pediatric Exercise Science |
| 83. | Physical Education and Sport Pedagogy |
| 84. | Physical Therapy in Sport |
| 85. | Physician and Sportsmedicine |
| 86. | Physikalisches Medizin Rehabilitationsmedizin Kurortmedizin |
| 87. | PM&R |
| 88. | Proceedings of The Institution of Mechanical Engineers Part P- Journal of Sports Engineering and Technology |
| 89. | Psychology of Sport and Exercise |
| 90. | Quest |
| 91. | Research in Sports Medicine |
| 92. | Research Quarterly for Exercise and Sport |
| 93. | Research Quarterly for Exercise and Sport |
| 94. | Revista Brasileira De Medicina Do Esporte |
| 95. | Revista Internacional De Medicina Y Ciencias De La Actividad Fisica Y Del Deporte |
| 96. | Scandinavian Journal of Medicine & Science in Sports |
| 97. | Science & Sports |
| 98. | Sociology of Sport Journal |
| 99. | South African Journal for Research in Sport Physical Education and Recreation |
| 100. | Sport Education and Society |
| 101. | Sport Exercise and Injury |
| 102. | Sport in Society |
| 103. | Sport Management Review |
| 104. | Sport Marketing Quarterly |
| 105. | Sport Psychologist |
| 106. | Sport Science Review |
| 107. | Sports (Basel) |
| 108. | Sports Biomechanics |
| 109. | Sports Exercise and Injury |
| 110. | Sports Health-A Multidisciplinary Approach |
| 111. | Sports Medicine |
| 112. | Sports Medicine and Arthroscopy Review |
| 113. | Sportverletzung-Sportschaden |
| 114. | Strength and Conditioning Journal |
| 115. | Wilderness & Environmental Medicine |
| 116. | Zeitschrift fur Sportpsychologie |

The 85 journals of the Clarivate Incites Journal Citation Reports "Sport Sciences" category are displayed in bold.
https://jcr.clarivate.com.

To display the potential influence of being in the Olympic programme on the scientific interest in a sport (Figure 2).

We also compiled the keywords related to six main research topics [1. Physiology; 2. Performance; 3. Training and testing (i.e., fitness, testing, training); 4. Injuries and medicine (i.e.,
TABLE 2 | Summer (A) and Winter (B) Olympic sports (https://olympics.com/en/sports).

A. SUMMER SPORTS
117. Archery
118. Athletics
119. Badminton
120. Baseball
121. Basketball
122. Boxing
123. Canoe-Kayak
124. Cycling
125. Diving
126. Equestrian
127. Fencing
128. Field Hockey
129. Football
130. Golf
131. Gymnastics
132. Handball
133. Judo
134. Karate
135. Marathon
136. Modern Pentathlon
137. Mountain Biking
138. Rowing
139. Rugby Sevens
140. Sailing
141. Shooting
142. Skateboarding
143. Softball
144. Sport Climbing
145. Surfing
146. Swimming
147. Table Tennis
148. Taekwondo
149. Tennis
150. Trampoline
151. Triathlon
152. Volleyball
153. Walking
154. Waterpolo
155. Weightlifting
156. Wrestling

B. WINTER SPORTS
157. Alpine—Freestyle Skiing
158. Biathlon
159. Bob sleigh
160. Curling
161. Ice Hockey
162. Luge
163. Nordic Skiing
164. Skating
165. Skeleton
166. Snowboarding

“Marathon” and “Walking” (Athletics) as well as “Mountain Biking” (Cycling) are displayed separately. Skiing is displayed in 2 separated categories: “Alpine and freestyle skiing” and “Nordic skiing.”

RESULTS

The bibliometric analysis was performed on 50 Olympic sports or disciplines in 116 “sport sciences” journals and led to the selection of 25,003 articles with a total number of ~600,000 citations.

There is a large range of articles and citations across sports (Figure 3). Nine sports (football, cycling, athletics, swimming, distance & marathon running, basketball, baseball, tennis, and rowing) were involved in 69% of the articles and 75% of the citations. Football (soccer) was the most cited sport, with 19.7 and 26.3% of the total numbers of articles and citations, respectively. Scientific research has been published on all sports, but 11 sports (biathlon, mountain biking, archery, diving, trampoline, skateboarding, skeleton, modern pentathlon, luge, bobsleigh, and curling) accumulated a total of fewer than 50 publications. While ice hockey is the most prominently represented winter sport in the scientific literature, winter sports overall have produced minor scientific output.

The analysis of the level and depth of the 10 most cited articles in every sports confirms this discrepancy across sports (Figure 4). This analysis confirms the results in terms of total publications across sports (Figure 3). Some sports (e.g., basketball and baseball) have highly cited articles (i.e., based on the average number of citations of the 10 most cited articles). This is also the case for handball, which has a relatively low number of citations (Figure 3) but a few highly cited articles (Figure 4).

Next, we analyzed the distribution of “Olympic sport sciences” publications across journals. This investigation revealed that only a small number of journals have published the greatest part of such articles. Merely six journals (J Strength Cond Res, 10.0%; J Sports Sci, 7.7%; J Sports Med Phys Fitness, 6.2%; Br J Sports Med, 5.5%; Int J Sports Med, 5.3%; and Med Sci Sports Excerc, 5.2%) of the 116 included in our search had published 40% of all publications (Figure 5). Some factors (including the nature of the sport as well as geographical and cultural factors and the composition of the editorial board), however, seem to have influenced the ratio of articles on specific sports appearing in different journals. For example, baseball articles have been published mainly in orthopedic or “sports medicine” journals (1. Am J Sports Med; 2. J Shoulder Elbow Surgery, and 3. Orthop J Sports Med) while basketball articles were published in conditioning or “sport sciences” journals (1. J Strength Cond Res; 2. J Sports Sci, and 3. J Sports Med Phys Fitness). Tennis articles are overrepresented in Br J Sports Med, and Nordic skiing articles in Scand J Med Sci Sports.

Finally, the distribution of different research topics (i.e., physiology, performance, training and testing, injuries and medicine, biomechanics, and psychology) varies largely among sports (Figure 6).

DISCUSSION

The present bibliometric analysis is the first to quantify the bibliometric across all summer and winter Olympic sports. This comprehensive review provides interesting outcomes that are summarized briefly here and discussed afterwards:

doping, injuries, medicine, rehabilitation); 5. Biomechanics (i.e., biomechanics, movement, motor control, equipment); 6. Psychology] for each sport. We display the top 5 most cited articles for every summer (Table 4) and winter (Table 5) Olympic sport.
### A. ALL SPORTS

| Exclusion topic | Exclusion items |
|-----------------|-----------------|
| Animal          | Rats, mice, mouse, dog, cat, horse, fish |
| Paralympic      | Disabl#, paral#, wheelchair |
| Ultra-sport     | Ultra |
| Retracted articles | Retract# |

### B. SUMMER SPORTS

| Sports                | Inclusion items | Nb articles | Exclusion                                      |
|-----------------------|-----------------|-------------|------------------------------------------------|
| Archery               | Archery, archer | 43          | Athlete, cycling, cyclist, swim, ski, skier, football, soccer, rugby, repeated-sprint |
| Athletics             | athletics, decathlon, heptathlon, track and field, track-and-field javelin, shot put, shot-put, shot putter, high jump, long jump, discus throw, triple jump, pole vault, pole-vault, pole-vaulter, hammer throw, steeple chase, hurdle, hurdle, sprint, sprinter, sprinting, relay | 8,492 | 1,586 |
| Badminton            | Badminton       | 143         | 143 |
| Baseball             | Baseball        | 953         | 949 |
| Basketball           | Basketball, basket player | 1,064 | 1,042 |
| Boxing               | Boxing, boxer   | 225         | 223 |
| Canoe-Kayak          | Canoe, kayak, canoeist, kayaker, kayakist, paddler | 184 | 180 |
| Cycling              | Cycling, cyclist, bike, bicycle, bicycling, BMX | 3,809 | 3,550 |
| Diving               | Diving, diver, springboard | 435 | 52 |
| Equestrian           | Equestrian, horseman, horsemen, horse rider, horse-rider, horse riding, horse-riding, equitation | 58 | 52 |
| Fencing              | Fencing, fencer | 90          | 90 |
| Field Hockey         | Field hockey, hockey | 166 | 167 |
| Football             | Football, soccer, foot player, footballer | 5,444 | 4,937 |
| Golf                 | Golf, golfer    | 491         | 491 |
| Gymnastics           | Gymnastics, gymnastic, gymnast, floor exercise, horizontal bar, parallel bars, pommel horse, uneven bars, balance beam | 429 | 428 |
| Handball             | Handball, handballer | 440 | 440 |
| Judo                 | Judo, judoka    | 262         | 261 |
| Karate               | Karate, karateka | 114 | 113 |
| Marathon—running     | Marathon, marathoner, running, runner, middle-distance, long-distance | 2,030 | 1,499 |
| Modern pentathlon    | Pentathlon, pentathlete | 12 | 12 |
| Mountain biking      | Mountain bike, mountainbike, mountain biker | 70 | 64 |
| Rowing               | Rowing, rower   | 678         | 673 |
| Rugby sevens         | Rugby sevens    | 89          | 89 |
| Sailing              | Sailing, sailor, sailer, windsurfing, windsurfer | 110 | 109 |
| Shooting             | Shooting, shooter, rifle | 135 | 55 |
| Skateboarding        | Skateboarding, skateboarder | 27 | 27 |
| Softball             | Softball        | 123         | 122 |
| Sport Climbing       | climbing, climber | 512 | 338 |
| Surfing              | Surfing, surf, surfer | 124 | 100 |
| Swimming             | Swimming, swimmer, butterfly, backstroke, freestyle, free style, breaststroke, front crawl, frontcrawl, front-crawl | 2,268 | 2,009 |
| Table Tennis         | Table tennis    | 90          | 90 |
| Taekwondo            | Taekwondo       | 159         | 159 |

(Continued)
TABLE 3 | Continued

| Sports            | Inclusion items                                                                 | Nb articles | Exclusion | Nb articles |
|-------------------|----------------------------------------------------------------------------------|-------------|-----------|-------------|
| Tennis            | Tennis                                                                           | 1,054       | Table tennis | 964         |
| Trampoline        | Trampoline                                                                       | 43          |           | 41          |
| Triathlon         | Triathlon, triathlete                                                             | 548         | Ironman    | 425         |
| Volleyball        | Volleyball, volley-ball, volley ball, beach volley, volley player                 | 606         |           | 602         |
| Walking           | Walking, walker                                                                   | 323         |           | 319         |
| Waterpolo         | Waterpolo, water polo, water-polo                                                 | 150         |           | 136         |
| Weightlifting     | Weightlifting, weightlifter                                                       | 264         |           | 264         |
| Wrestling         | Wrestling, wrestler                                                               | 405         |           | 400         |

C. WINTER SPORTS

| Sports                  | Inclusion items                                                                 | Nb articles | Exclusion | Nb articles |
|-------------------------|----------------------------------------------------------------------------------|-------------|-----------|-------------|
| Alpine—freestyle skiing | Alpine skiing, alpine ski, alpine skier, freestyle skiing, freestyle ski, freestyle skier, giant slalom, slalom | 300         | Canoe, kayak, water ski, water-ski | 294         |
| Biathlon                | Biathlon, biathlete                                                               | 47          |           | 47          |
| Bobsleigh               | Bobsleigh, bobsled                                                                | 7           |           | 7           |
| Curling                 | Curling, curler                                                                   | 8           |           | 8           |
| Ice Hockey              | Ice hockey, ice-hockey, NHL, National Hockey League                               | 540         |           | 540         |
| Luge                    | Luge                                                                              | 6           |           | 6           |
| Nordic skiing           | Cross-country ski, cross-country skier, cross-country skiing, Crosscountry ski, crosscountry skier, ski jumping, ski jumper, Nordic combined | 369         |           | 369         |
| Skating                 | Ice skating, ice skater, Ice-skating, ice-skater short track, skating, skate, figure skate, speed skating, speed skater | 380         | roller    | 334         |
| Skeleton                | Skeleton                                                                          | 17          |           | 12          |
| Snowboard               | Snowboard, snowboarding, snowboarder                                              | 152         |           | 152         |

The number of articles found with the inclusion criteria and with the subsequent exclusion criteria and "manual cleaning" of the database are displayed.

1. There is a large difference in scientific output among sports, with nine sports representing 75% of the citations and 11 having a total of fewer than 50 associated publications.

2. Football (soccer) is by far the leading Olympic sport in terms of bibliometrics.

3. Team sports, particularly American professional sports (i.e., baseball, basketball, ice hockey), generate high scientific interest.

4. Overall, winter sports generate minor scientific output.

5. Most articles have been published in a limited number of journals.

6. Whether the inclusion of a sport in the Olympic programme translates into an increase in scientific publications remains unclear.

7. We also report some influence of local/cultural factors and/or of editorial board composition on the importance of a given sport in a given journal.

8. Finally, the distribution of articles among six main research topics (i.e., physiology, performance, training and testing, injuries and medicine, biomechanics, and psychology) highlights the (scientific) performance determinants of each sport.

Large Differences Between Sports

To our knowledge, there has been no comprehensive analysis and comparison of the largely different physical demands across all Olympic sports since the multifactorial determinants of performance within and across all Olympic sports render such analysis difficult. For example, curling and shooting have little in common with boxing, triathlon, or freestyle skiing. A quantitative comparison of the "sport sciences" literature across all these sports, on the other hand, is feasible and provides information on the scientific importance of the various sports.

Our analysis revealed that only nine sports (football, cycling, athletics, swimming, distance & marathon running, basketball, baseball, tennis, and rowing) represented 69% of the articles and 75% of the citations, while 11 sports (biathlon, mountain biking, archery, diving, trampoline, skateboarding, skeleton, modern pentathlon, luge, bobsleigh, and curling) accumulated a total of fewer than 50 publications.

Why a given sport attracts many publications certainly depends on a number of variables. Unsurprisingly, the sports with the most published and cited articles are very popular, and most of them are long established in the Olympic programme, e.g., from the start in 1896–1900, with the exceptions of basketball (1936) and baseball (1992). While the time since inclusion in the Olympic programme seems to be a key criterion for the attraction of scientific interest for some sports, this appears not to be the case for other, even “traditional” Olympic sports, such as wrestling or fencing (both Olympic sports since 1896). Another criterion for scientific attractiveness may be individual vs. team
sports. Team sports are highly investigated, as is confirmed by our finding that five team sports (football, basketball, volleyball, handball, and ice hockey) rank among the top 12 most cited of the 50 sports analyzed. Conversely, the impact on the scientific literature is lower in other team sports, including field hockey, water polo and rugby sevens (a recent inclusion in the Olympic programme).

When analyzing the individual sports, it is noteworthy that the sports in which performance is determined mainly by energy (aerobic and anaerobic) production—as conceptually opposed to “motor control” or “technical” sports categories—have led to a larger scientific output. Sports belonging to the first category include cycling, athletics, swimming, distance running—marathon and rowing, all of which rank among the top 10 most cited sports. Baseball (see below) and tennis are the exceptions, representing technical sports in this top 10 ranking. Supporting this notion, the technical sports golf (despite its media prominence) and gymnastics (one of the most important Olympic sports) are less frequently cited than, for example, triathlon. One may speculate that more energy-reliant sports may benefit to a greater extent from general scientific support/knowledge (i.e., exercise physiology) than the more “technical” sports (i.e., motor control). This suggestion is corroborated by the importance of the “physiology” research topic (see chapter 8 and Figure 6) across most sports. However, the limitation of our search to PubMed and the biomedical literature may partially account for this result.

It is very challenging to clearly appreciate why a sport attracts the interest of sport scientists. We do not exclude the possibility that this effect can be explained by more general factors (e.g., a general increase in publication numbers in recent decades). Olympic sports may be of higher scientific interest to sport scientists than non-Olympic sports. This may be related to a trend of scientific support increasingly becoming a key component of elite performance. Many scientists of excellent scientific/academic background (i.e., Dupont et al., 2005; Bangsbo et al., 2008 in football, Mountjoy et al., 2016; Mujika et al., 2019 in swimming, Mujika et al., 2019 in athletics, Jones et al., 2021 in distance running, and Hebert-Losier et al., 2017; Solli et al., 2017 in Nordic skiing, to name only a few—we apologize to many other colleagues who deserve to be on this list) are indeed servicing and advising elite athletes or teams while in parallel producing outstanding scientific research that is sometimes relevant for coaches. Until recently, the translation of “sport sciences” research to practice was often poor (Bishop, 2008), and interdependence between the practical and scientific impacts of “sport sciences” research has frequently been advocated (Coutts, 2016; Brocherie and Beard, 2020). Elite sports organizations require embedded, fast-moving, service-providing applied research scientists as well as slow-thinking researchers (Sandbakk, 2018), who, working together, will carry on producing sport-specific research.

Most elite sports institutes (e.g., Insep in France https://labos-recherche.insep.fr/fr), the IOC (https://olympics.com/
IOC/medical-and-scientific-commission) and some National Olympic Committees and national and international governing bodies (e.g., World Athletics) have developed scientific committees to stimulate research on specific topics according to their needs. Examples are programmes with the aim of implementing new rules for the protection of athletes' health by limiting concussion (Stokes et al., 2021) or heat stress (Mountjoy et al., 2012). Although the scientific support and service sector has grown tremendously in the last two decades, the impact of scientific support on sports performance remains difficult to quantify.

However, while we believe that sport-specific attractiveness is due mainly to the importance of the sport itself, it is beyond the scope of the present review to relate the present bibliometric information to other sport characteristics, such as but not limited to the number of participants, economic weight and media exposure. These points are briefly discussed in the present review but certainly also contribute to the importance of a particular sport in the scientific literature. The quality of servicing scientists at the club, federation, or sport institute levels may be a factor of influence, but the vast majority of these sports publications seem to have come from academic (i.e., employed by universities or research organizations) researchers. With the evolution of the performance support model within the professional and elite sporting environment, deemed necessary to integrate an applied research process to bridge the gap between scientists and practitioners (Brocherie and Beard, 2020), the scientific publication landscape may change in the future, even for less attractive sports.

**Football (Soccer) Dominates the Scientific Literature**

The dominance of football in the “sport sciences” literature is impressive. Football represents 19.7 and 26.3% of the total number of articles and citations, respectively (Figure 3), despite its relatively low importance with regard to Olympic medal counts (i.e., 2 of 339 gold medals at Tokyo 2020 vs. 48 in athletics, 37 in swimming and 12 in Nordic skiing or skating at Beijing 2022, to cite only the main Olympic sports). The reasons, therefore, are unrelated to the Olympics and likely are attributable to its general popularity and associated economic characteristics. Football is the most popular sport worldwide (e.g., the global audience at the FIFA World Cup 2018 was estimated to be 3.57 billion people). Half of the total revenue of the sports industry is gained by competitive sports of the spectator sports sector, amounting to approximately US$250 billion in turnover each year. The share of football accounts for an estimated 43% of this revenue and thus is much larger than the shares of other Olympic sports or even of other US professional sports; it is almost equal to the combined revenue from all US sports, including American football (13%), baseball (12%), Formula 1 auto racing (7%), basketball (6%), ice hockey (4%) and tennis (4%) (https://www.researchandmarkets.com/reports/5022446/sports-global-market-report-2020-
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30-covid-19). While our findings are in line with previous results (Brito et al., 2018), the consequences and implications of the scientific dominance of football remain unclear. It is tempting to relate such scientific proliferation to the already well-organized performance support services within professional and elite football (Brocherie and Beard, 2020). However, to our knowledge, there has been no comprehensive analysis of the number of scientists working in professional football, even if it is obvious that this segment has grown considerably in the last decade, especially in the clubs of the five major football leagues in Europe (i.e., England, Spain, Germany, Italy, and France). This may have provided an edge over many other sports that are still in the process of establishing efficient structures (e.g., some leading US sports league franchises) (Brocherie and Beard, 2020).

**Importance of Team Sports, Particularly American Professional Sports**

Several North American professional sports are highly ranked in terms of bibliometrics. As for football, it is likely that the economic characteristics of the main North American national leagues (Major League Baseball, National Basketball Association, and National Hockey League (estimated at 5.5, 4.6, and 2.2 billion US dollars in 2015, respectively; https://www.ameriresearch.com/global-football-sports-market/) may be one reason for the scientific interest in these sports. Moreover, “sport sciences” is a well-established academic discipline, and the USA is a leading contributor in this field, as is exemplified by the largest “sport sciences” society worldwide, American College of Sports Medicine (ACSM) (www.acsm.org), with more than 50,000 members and certified professionals from 90 countries around the globe.

In line with other team sports (e.g., volleyball, handball, and field hockey), publications related to injuries (prevention and rehabilitation) are relatively more important in team sports (>20% of the total sport-specific articles; Figure 6) than in the main individual sports (cycling, athletics, swimming, distance running—marathon, etc.). This may stem from a higher degree of professionalization and therefore specialization of permanent full-time medical staff in team sports due to the economic power of these sports and the financial value of professional players.

**Winter Sports Generate Minor Scientific Production**

Despite some parts of the world being particularly passionate about winter sports (e.g., Sweden and Norway for Nordic skiing, Russia and Canada for ice hockey, and Austria and Switzerland for alpine skiing), the audience for winter sports and number of participants remain comparatively low worldwide. This is likely due primarily to geographical and climatic limitations (i.e., especially the lack of snow) for the development of winter...
sports. The lower importance of winter sports becomes clear when comparing the latest summer and winter Olympic games. A record number of 2,922 athletes from 92 countries participated in the Pyeongchang 2018 Winter Games, while 11,362 athletes from 204 countries participated in the Rio de Janeiro 2016 Summer Games. A similar discrepancy is observed with regard to the number of sports and disciplines, with 102 events in 7 sports (and 15 disciplines) at the 2018 winter Olympic games vs. 306 events in 28 sports and 43 disciplines at the 2016 summer games.

In the European Nordic countries, sport sciences have a long tradition of excellence, owing primarily to the work of famous pioneers in exercise physiology (e.g., Saltin and Astrand, 1967) who performed early studies, including some on Nordic skiers. This might partly explain why Nordic skiing is the second most cited winter sport (after ice hockey—see above).

**Most Articles are Published in a Limited Number of Journals**

Six journals of 116 included in our search (J Strength Cond Res, 10.0%; J Sports Sci, 7.7%; J Sports Med Phys Fitness, 6.2%; Br J Sports Med, 5.5%; Int J Sports Med, 5.3%; and Med Sci Sports Exerc, 5.2%) contained 40% of all analyzed publications. These leading journals publish articles predominantly on applied research as well as on conditioning or training and testing (e.g., J Strength Cond Res, J Sports Med Phys Fitness, and J Sports Sci). Some are tightly connected to powerful organizations (e.g., Br J Sports Med, which regularly publishes reports or statements of the IOC, or Med Sci Sports Exerc, which belongs to the ACSM).

Our search included 116 journals, but many of them do not publish “biomedical” articles (accessible in PubMed) specific to any of the Olympic sports. The scope of some journals is very broad (e.g., applied physiology in J Appl Physiol) or very narrow (e.g., High Alt Med Biol); articles focusing on one given sport in those journals are thus less frequent. Many journals are furthermore relatively new in PubMed (e.g., Int J Sports Physiol Perf and Front Sports Active Living). Finally, the fact that most articles are published in only a few journals may render questionable the profusion of (too?) many journals in the “sport sciences” field, which has been growing since the early 2000’s.
The Entry of a Sport Into the Olympic Programme Translates Into an Increase in Scientific Publications

We scrutinized whether the Olympic entrance of the “recent” Olympic sports (e.g., inserted in the Olympic programme in the last 25 years: snowboard in 1998; trampoline, triathlon, and taekwondo in 2000; rugby sevens in 2016; and surfing, karate, sport climbing, and skateboarding in 2020), might have impacted their specific scientific attractiveness. Figure 2 shows the evolution of yearly citation numbers between 1990 and 2020 with the date of the entrance into the Olympic programme for four “recent” sports (snowboard, triathlon taekwondo, and rugby sevens). Whether entrance into the programme has a positive effect remains unclear, even if an increase in the publication rate is observable 6–8 years after (for snowboard and taekwondo) or several years before (as is clearly shown for rugby sevens and triathlon) nomination as an Olympic sport. Overall, the “Olympic legacy” does not seem to stimulate a large increase in the volume of articles or citations (Thomas et al., 2016).

Of these “recent” Olympic sports, triathlon is by far the most productive of scientific output (Figure 2). As discussed in chapter 1, this may stem from the nature of the sport, which is highly energetic and of interest to physiologists, while other “recent” sports are less aerobic.

Local/Cultural Influence and/or Influence of Editorial Board Composition

Sports carry strong cultural and political meanings for their practitioners and spectators and powerfully symbolize identities and communities (Millet and Giulianotti, 2019). It is therefore not surprising—and in a sense reassuring in our globalized world—to find that a local sporting culture can impact the scientific output, as is testified by the overrepresentation of alpine and Nordic skiing in Scand J Med Sci Sport. “Sport sciences” (like most other scientific fields) are dominated by Anglo-Saxon countries (especially the USA, UK, Australia, and Canada). As has recently been observed (Pyne, 2021), research in several of the world's leading sporting nations (e.g., Russia, China, Japan, and South Korea; all top 8 nations at the 2016 Summer Olympic Games) is underrepresented in “sport sciences” journals that are published mostly in English. It is beyond the scope of this review to analyze all the other potential factors or barriers (economic, political, religious, gender based, etc.) that bias the over- vs. under-representation of a given sport in the “sport sciences” literature, but more cultural, geographical and gender diversity is needed. Another observation is the influence of the composition of the editorial boards of the journals on editorial policy as well as the published content. All the above-mentioned factors influence regular publications on certain sports in journals, such as rugby sevens in Int J Sports Physiol Perf or tennis in Br J...
Sports Med, while some sports that are extremely popular in Asia (taekwondo and table tennis) lack comparable platforms for scientific exchange.

**Relative Distribution of Six Main Research Topics Across Sports**

We analyzed the relative distribution of six research topics (i.e., physiology, performance, training and testing, injuries and medicine, biomechanics, and psychology) across all summer and winter Olympic sports publications since the analysis may provide informational particularities that are especially relevant for research on these sports or on the determinants of performance, which vary considerably among sports. For example, it has long been known that maximal aerobic power is paramount in cross-country skiing, cycling, distance running and rowing, as is evidenced by the high maximal oxygen consumption ($\text{VO}_2\max$) values in top performers in these sports (Haugen et al., 2018), who reach $\text{VO}_2\max$ values of $> 90 \text{ ml/kg/min}$ (Millet and Jornet, 2019). Although “physiology” covers other aspects than aerobic capacity, many publications (approximately two-thirds) on sports such as triathlon, swimming, and walking concern physiological aspects due to these sports’ high reliance on aerobic capacities.

Whereas, the scientific literature on many sports is dominated by physiological topics, research on other sports focuses on associated injuries-illnesses. The topic “injuries and medicine” is paramount (i.e., $> 40\%$ of related publications) in five summer (baseball, boxing, equestrian, skateboarding, and softball) and 4 winter (alpine freestyle skiing, curling, ice hockey, and snowboarding) sports. Of the publications, 65% of those on skateboarding and 82% of those on snowboarding concern injuries. Deeper analyses of these publications are required to differentiate the types and causes of injuries between contact sports (e.g., boxing and ice hockey), sports inducing falls (equestrian, alpine skiing, snowboarding, and skateboarding), and sports inducing overuse injuries (e.g., elbow injury in baseball and softball). The “injuries and illnesses prevention and incidence” topic is of the highest priority in elite sports; the IOC medical and scientific commission (https://olympics.com/ioc/medical-and-scientific-commission) publishes regular reports on injuries and illness incidences in the summer (Soligard et al., 2017) and winter (Soligard et al., 2019) Olympic games. During the last summer games in Rio de Janeiro in 2016, the injury incidence ranged from 38% in BMX cycling to 0–3% in canoeing, rowing, shooting, archery, swimming, golf, and table tennis, while the illness incidence was 10–12% in diving, swimming, sailing, canoeing-kayaking and equestrian (Soligard et al., 2017). During the last winter games in Pyeongchang in 2018, the injury incidence was highest (20–28%) in freestyle skiing and snowboarding and lowest (2–6%) in Nordic combined, biathlon, snowboard slalom, moguls, and cross-country skiing. The illness incidences ranged between 13 and 15% in biathlon, curling, bobsleigh, and snowboard slalom (Soligard et al., 2019).
Surprisingly, in every sport, the number of publications on psychology-related topics is quite low. Only for curling, shooting, and modern pentathlon are >10% of the sport-specific publications related to psychology, followed by table tennis. All these sports require extreme accuracy and self-control. The possibility that this low representation of psychological articles relates to the applied methodology (e.g., the database searched was PubMed) cannot be excluded, but most of the leading sport psychology journals (e.g., Journal of Sport & Exercise Psychology) were included in our search. These findings thus could also indicate that sport psychology is less represented than other scientific areas (physiology, medicine) in the literature. The potential underrepresentation of sport psychology should encourage sport psychologists or mental coaches to publish more of their research since there is no doubt that mental skills are an important aspect of performance in all sports.

**STRENGTH AND LIMITATIONS**

The main strength of this review is the exhaustive bibliometric analysis and review across all Olympic sports. To our knowledge, no similar work is available to date. The volume of extracted articles, the clear delimitation of journals and sports and the subsequent analysis permitted us to extract information on how the “sport sciences” field is structured and organized to characterize the research body on Olympic sports and highlight sports-related differential peculiarities, developments and limitations of the scientific literature.

Some limitations must be acknowledged. First, the search was performed only in the titles of the articles and did not include searching abstracts, keywords or text. Since our aim was to compare the literature on individual sports, this method may be better suited to extracting articles related primarily to one sport without risking the inclusion of false positives that refer to specific sports only marginally or incidentally. Not all physiology or medical articles on “athletes” were included since these articles can also refer to non-specific physiological responses or mechanisms. Instead, we targeted each sport or the athletes of that sport and applied clear exclusion criteria to enhance the specificity of the search strategy. However, minor categorization inaccuracies due to the high volume of articles analyzed, particularly in the “football” and “athletics” categories, cannot be ruled out. All American and Canadian publications on football in particular were checked individually to accurately distinguish between soccer and American football. If publications could not be unambiguously classified, they were excluded. For “athletics,” the single “athlete” item in the title would have led to 10,866 publications, most of which were not related to “athletics” (Table 3). In an alternative search, specific terms related to athletics (e.g., javelin and relay) were merged, yielding a sufficiently accurate outcome. Similarly, articles with the generic term “repeated sprints” were included only if one sport was clearly mentioned in the title. There is also potential for a biased bibliometric analysis because some articles published on topics other than “exercise and sport sciences” or general medical and basic science journals could not be excluded (e.g., Olympic sports-related sociology), possibly leaving out influential works. Therefore, the present bibliometric analysis should be interpreted in light of these limitations.

Using our approach, it was not possible to differentiate research on high-level exercise from (everyday) physical activities. This limitation applies in particular to sports that occur in parallel in common everyday activities, such as walking or cycling. These categories are therefore likely overrepresented in our analysis in comparison to sports that are practiced only for competitive purposes and therefore are less frequently treated in the scientific literature. It is noteworthy that despite this bias, football still dominates the “sport sciences” field.

The absolute bibliometric is by definition correct only at the date of the search. We decided to report these absolute metrics (and not only the relative percentage values) for clarity and because it might help the reader to search beyond the top 5 articles for each sport displayed in Tables 4, 5.

One additional limitation was the descriptive nature of the analysis and the lack of statistical treatment of the data. The descriptive nature of the present article was thought to be more appropriate for the 8 main outcomes presented in the discussion. The peculiarities in significant differences in the number of citations between sport A and sport B are of negligible importance and might distract the reader from the main points.

Finally, a more fundamental criticism of the applied approach concerns the importance attached to numbers of citations generated by peer-reviewed publications as a metric for assessing the research impact (Buttner et al., 2021). For the present review, general quantitative publication metrics were used to assess only the importance of the different sports in the scientific literature in this respect. Measuring and comparing the “quality” of science between sports is challenges for future research. We are aware that the use of the top 10 most cited articles (mean, max and min citations; Figure 4) in every sport as a metric of research quality is far from optimal. Our findings show that many factors are likely involved in determining the importance of a sport-specific scientific interest, and we do not intend to underestimate the importance of research that is impactful in terms of policy, economics and society. Finally, it would be interesting to relate the bibliometric data presented here to the economic weight and media exposure of these sports or the number of participants in them worldwide. Such analyses may provide further insights into why certain sports are more prominently represented in the scientific literature than others. The high scientific impact of publications, for example, on football (i.e., more articles and citations), likely does not reflect “better” scientific quality than that of publications on a less prominent sports.

**CONCLUSIONS**

The bibliometric analysis of all articles related to summer and winter Olympic sports published in the “sport sciences” literature provides novel insights into this research field, converging on eight key points: 1. nine sports (football, cycling, athletics, swimming, distance & marathon running, basketball, baseball, tennis, and rowing) were involved in 69% of the articles and 75% of the citations; 2. football (soccer) is the leading
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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author/s.
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