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

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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 für 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**

(Continued)

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 Dello 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. **Physikalische 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 Performance Psychology**
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 für 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. Bobsleigh	
160. Curling	
161. Ice Hockey	
162. Luge	
163. Nordic Skiing	
164. Skating	
165. Skeleton	
166. Snowboard	

"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."

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.

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 Exerc*, 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:

TABLE 3 | Inclusion and exclusion criteria in the search for **(A)** all sports, **(B)** the summer, and **(C)** winter Olympic sports.

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#			
Sports	Inclusion items	Nb articles	Exclusion	Nb articles
B. SUMMER SPORTS				
Archery	Archery, archer	43		43
Athletics	athletics, decathlon, decathlete, heptathlon, heptathlete, 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, hurdler, sprint, sprinter, sprinting, relay	8,492	Athlete, cycling, cyclist, swim, ski, skier, football, soccer, rugby, repeated-sprint	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	Triathlon, triathlete, mountain bike	3,550
Diving	Diving, diver, springboard	435	Breath-hold, scuba, apnea, football, pearl diver, decompression	52
Equestrian	Equestrian, horseman, horse, horse rider, horse-rider, horse riding, horse-riding, equitation	58		52
Fencing	Fencing, fencer	90		90
Field Hockey	Field hockey, hockey	166	ice	167
Football	Football, soccer, foot player, footballer	5,444	American football, league football, NFL, Gaelic football, Australian rules football, rugby football, quarterback	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	all sports but running	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, sailer, sailor, windsurfing, windsurfer	110		109
Shooting	Shooting, shooter, rifle	135	football, soccer, handball, basketball	55
Skateboarding	Skateboarding, skateboarder	27		27
Softball	Softball	123		122
Sport Climbing	climbing, climber	512	step, stair, ladder, altitude, cyclist, cycling, mountaineer, mountaineering	338
Surfing	Surfing, surf, surfer	124	windsurf	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	954
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				
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

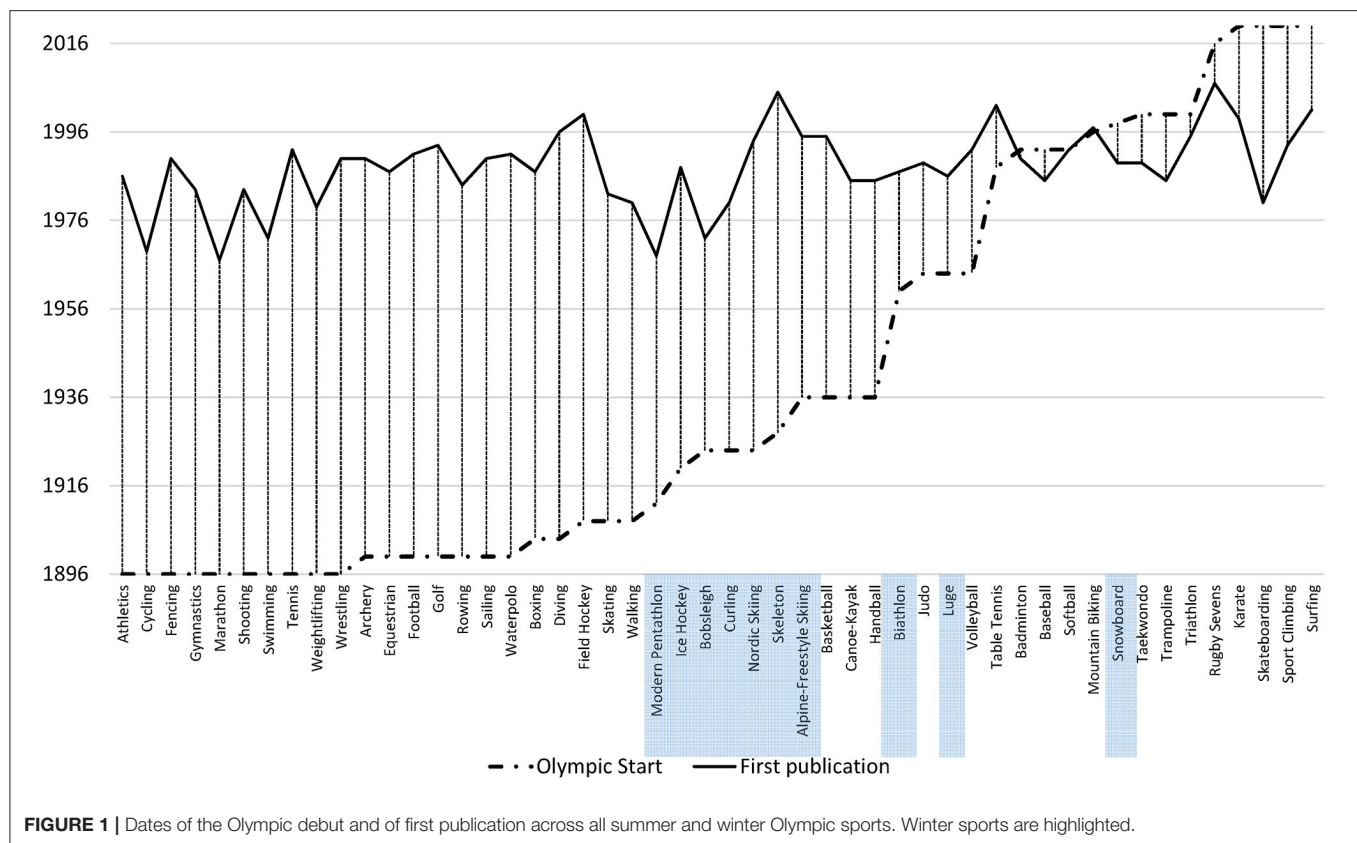


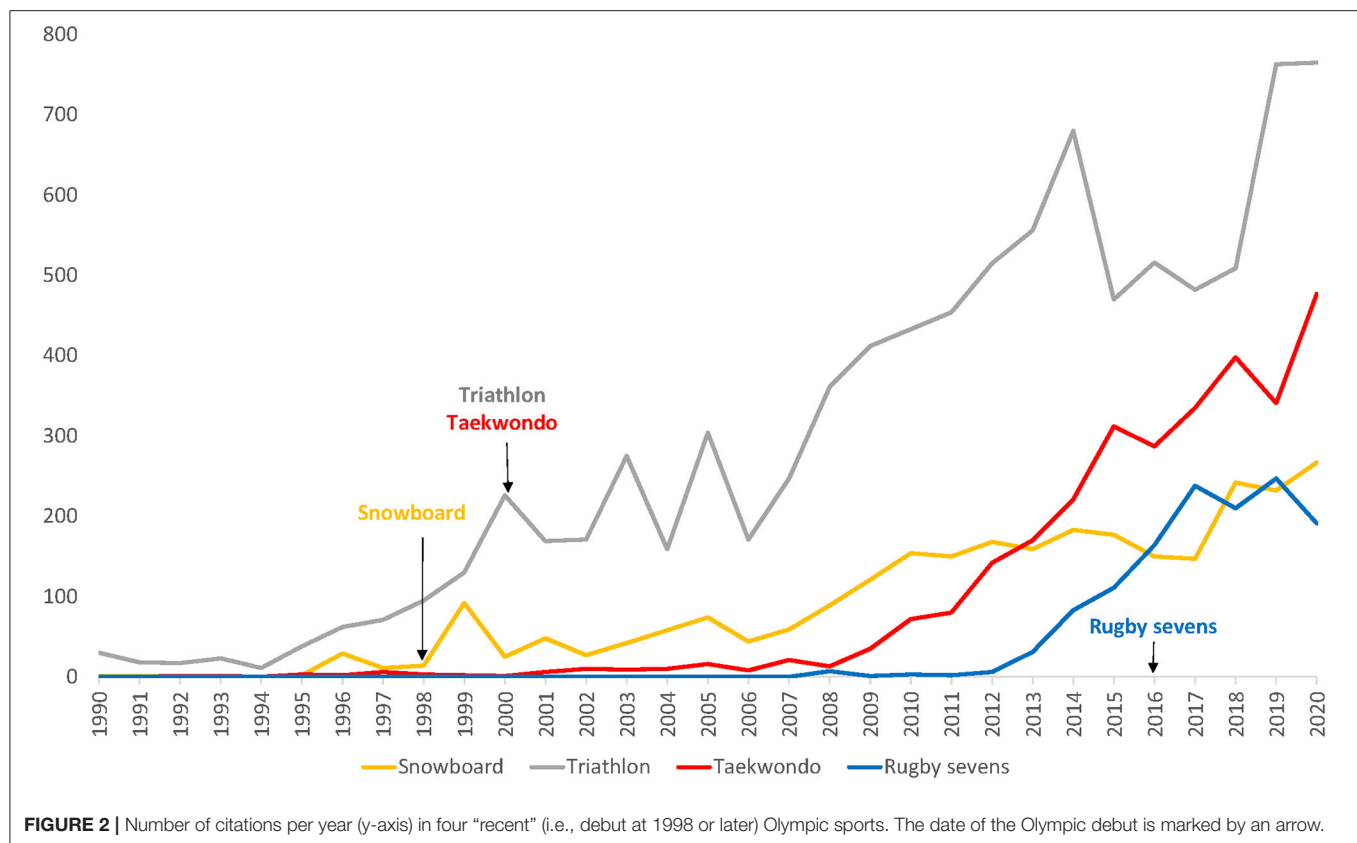
FIGURE 1 | Dates of the Olympic debut and of first publication across all summer and winter Olympic sports. Winter sports are highlighted.

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 <https://www.worldathletics.org/about-iaaf/health-science>) 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->

TABLE 4 | Top-5 articles on summer sports.

References	Articles	Number citations
1. ARCHERY		
Salazar et al. (1990)	Salazar W, Landers DM, Petruzzello SJ, Han M, Crews DJ, Kubitz KA. Hemispheric asymmetry, cardiac response, and performance in elite archers. <i>Res Q Exerc Sport</i> . 1990 Dec;61(4):351-9.	99
Landers et al. (1991)	Landers DM, Petruzzello SJ, Salazar W, Crews DJ, Kubitz KA, Gannon TL, et al. The influence of electrocortical biofeedback on performance in pre-elite archers. <i>Med Sci Sports Exerc</i> . 1991 Jan;23(1):123-9.	85
Ertan et al. (2003)	Ertan H, Kentel B, Tümer ST, Korkusuz F. Activation patterns in forearm muscles during archery shooting. <i>Hum Mov Sci</i> . 2003 Feb;22(1):37-45.	40
Leroyer et al. (1993)	Leroyer P, Van Hoecke J, Helal JN. Biomechanical study of the final push-pull in archery. <i>J Sports Sci</i> . 1993 Feb;11(1):63-9.	35
Mann and Littke (1989)	Mann DL, Littke N. Shoulder injuries in archery. <i>Can J Sport Sci</i> . 1989 Jun;14(2):85-92.	29
2. ATHLETICS		
Mero et al. (1992)	Mero A, Komi PV, Gregor RJ. Biomechanics of sprint running. A review. <i>Sports Med</i> . 1992 Jun;13(6):376-92.	363
Young et al. (1995)	Young W, McLean B, Ardagna J. Relationship between strength qualities and sprinting performance. <i>J Sports Med Phys Fitness</i> . 1995 Mar;35(1):13-9.	237
Hunter et al. (2005)	Hunter JP, Marshall RN, McNair PJ. Relationships between ground reaction force impulse and kinematics of sprint-running acceleration. <i>J Appl Biomech</i> . 2005 Feb;21(1):31-43.	217
Chelly and Denis (2001)	Chelly SM, Denis C. Leg power and hopping stiffness: relationship with sprint running performance. <i>Med Sci Sports Exerc</i> . 2001 Feb;33(2):326-33.	216
Kuitunen et al. (2002)	Kuitunen S, Komi PV, Kyrolainen H. Knee and ankle joint stiffness in sprint running. <i>Med Sci Sports Exerc</i> . 2002 Jan;34(1):166-73.	214
3. BADMINTON		
Cabello Manrique and Gonzalez-Badillo (2003)	Cabello Manrique D, Gonzalez-Badillo JJ. Analysis of the characteristics of competitive badminton. <i>Br J Sports Med</i> . 2003 Feb;37(1):62-6.	121
Phomsoupha and Laffaye (2015)	Phomsoupha M, Laffaye G. The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. <i>Sports Med</i> . 2015 Apr;45(4):473-95.	83
Callow et al. (2001)	Callow N, Hardy L, Hall C. The effects of a motivational general-mastery imagery intervention on the sport confidence of high-level badminton players. <i>Res Q Exerc Sport</i> . 2001 Dec;72(4):389-400.	81
Faude et al. (2007)	Faude O, Meyer T, Rosenberger F, Fries M, Huber G, Kindermann W. Physiological characteristics of badminton match play. <i>Eur J Appl Physiol</i> . 2007 Jul;100(4):479-85.	71
Kuntze et al. (2010)	Kuntze G, Mansfield N, Sellers W. A biomechanical analysis of common lunge tasks in badminton. <i>J Sports Sci</i> . 2010 Jan;28(2):183-91.	59
4. BASEBALL		
Fleisig et al. (1995)	Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. <i>Am J Sports Med</i> . 1995 Mar-Apr;23(2):233-9.	776
Lyman et al. (2002)	Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. <i>Am J Sports Med</i> . 2002 Jul-Aug;30(4):463-8.	391
Crockett et al. (2002)	Crockett HC, Gross LB, Wilk KE, Schwartz ML, Reed J, O'Mara J, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. <i>Am J Sports Med</i> . 2002 Jan-Feb;30(1):20-6.	373
Olsen et al. (2006)	Olsen SJ, 2nd, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. <i>Am J Sports Med</i> . 2006 Jun;34(6):905-12.	359
Fleisig et al. (1999)	Fleisig GS, Barrentine SW, Zheng N, Escamilla RF, Andrews JR. Kinematic and kinetic comparison of baseball pitching among various levels of development. <i>J Biomech</i> . 1999 Dec;32(12):1371-5.	336
5. BASKETBALL		
Arendt and Dick (1995)	Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. <i>Am J Sports Med</i> . 1995 Nov-Dec;23(6):694-701.	1012
Plisky et al. (2006)	Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. <i>J Orthop Sports Phys Ther</i> . 2006 Dec;36(12):911-9.	591
Krosshaug et al. (2007)	Krosshaug T, Nakamae A, Boden BP, Engebretsen L, Smith G, Slauterbeck JR, et al. Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. <i>Am J Sports Med</i> . 2007 Mar;35(3):359-67.	587
Ford et al. (2003)	Ford KR, Myer GD, Hewett TE. Valgus knee motion during landing in high school female and male basketball players. <i>Med Sci Sports Exerc</i> . 2003 Oct;35(10):1745-50.	557
Agel et al. (2005)	Agel J, Arendt EA, Bershadsky B. Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review. <i>Am J Sports Med</i> . 2005 Apr;33(4):524-30.	491

(Continued)

TABLE 4 | Continued

References	Articles	Number citations
6. BOXING		
Walilko et al. (2005)	Walilko TJ, Viano DC, Bir CA. Biomechanics of the head for Olympic boxer punches to the face. <i>Br J Sports Med.</i> 2005 Oct;39(10):710-9.	158
Hall and Lane (2001)	Hall CJ, Lane AM. Effects of rapid weight loss on mood and performance among amateur boxers. <i>Br J Sports Med.</i> 2001 Dec;35(6):390-5.	99
Otto et al. (2000)	Otto M, Holthusen S, Bahn E, Sohnchen N, Wiltfang J, Geese R, et al. Boxing and running lead to a rise in serum levels of S-100B protein. <i>Int J Sports Med.</i> 2000 Nov;21(8):551-5.	95
Smith et al. (2000)	Smith MS, Dyson RJ, Hale T, Janaway L. Development of a boxing dynamometer and its punch force discrimination efficacy. <i>J Sports Sci.</i> 2000 Jun;18(6):445-50.	95
Hristovski et al. (2006)	Hristovski R, Davids K, Araujo D, Button C. How boxers decide to punch a target: emergent behaviour in nonlinear dynamical movement systems. <i>J Sports Sci Med.</i> 2006; 5(CSSI):60-73.	82
7. CANOE-KAYAK		
Bishop et al. (2002)	Bishop D, Bonetti D, Dawson B. The influence of pacing strategy on VO2 and supramaximal kayak performance. <i>Med Sci Sports Exerc.</i> 2002 Jun;34(6):1041-7.	145
Mackinnon et al. (1993)	Mackinnon LT, Ginn E, Seymour GJ. Decreased salivary immunoglobulin A secretion rate after intense interval exercise in elite kayakers. <i>Eur J Appl Physiol Occup Physiol.</i> 1993;67(2):180-4.	113
Liow and Hopkins (2003)	Liow DK, Hopkins WG. Velocity specificity of weight training for kayak sprint performance. <i>Med Sci Sports Exerc.</i> 2003 Jul;35(7):1232-7.	90
Garcia-Pallares et al. (2009)	Garcia-Pallares J, Sanchez-Medina L, Carrasco L, Diaz A, Izquierdo M. Endurance and neuromuscular changes in world-class level kayakers during a periodized training cycle. <i>Eur J Appl Physiol.</i> 2009 Jul;106(4):629-38.	79
Ackland et al. (2003)	Ackland TR, Ong KB, Kerr DA, Ridge B. Morphological characteristics of Olympic sprint canoe and kayak paddlers. <i>J Sci Med Sport.</i> 2003 Sep;6(3):285-94.	75
8. CYCLING		
Coyle et al. (1992)	Coyle EF, Sidossis LS, Horowitz JF, Beltz JD. Cycling efficiency is related to the percentage of type I muscle fibers. <i>Med Sci Sports Exerc.</i> 1992 Jul;24(7):782-8.	418
Oja et al. (2011)	Oja P, Titze S, Bauman A, de Geus B, Krenn P, Reger-Nash B, et al. Health benefits of cycling: a systematic review. <i>Scand J Med Sci Sports.</i> 2011 Aug;21(4):496-509.	412
Coyle et al. (1991)	Coyle EF, Feltner ME, Kautz SA, Hamilton MT, Montain SJ, Baylor AM, et al. Physiological and biomechanical factors associated with elite endurance cycling performance. <i>Med Sci Sports Exerc.</i> 1991 Jan;23(1):93-107.	380
Bassett et al. (2008)	Bassett DR, Jr., Pucher J, Buehler R, Thompson DL, Crouter SE. Walking, cycling, and obesity rates in Europe, North America, and Australia. <i>J Phys Act Health.</i> 2008 Nov;5(6):795-814.	362
Hermansen and Saltin (1969)	Hermansen L, Saltin B. Oxygen uptake during maximal treadmill and bicycle exercise. <i>J Appl Physiol.</i> 1969 Jan;26(1):31-7.	354
9. DIVING		
Baranto et al. (2006)	Baranto A, Hellstrom M, Nyman R, Lundin O, Sward L. Back pain and degenerative abnormalities in the spine of young elite divers: a 5-year follow-up magnetic resonance imaging study. <i>Knee Surg Sports Traumatol Arthrosc.</i> 2006 Sep;14(9):907-14.	43
Blanksby et al. (1997)	Blanksby BA, Wearne FK, Elliott BC, Blitvich JD. Aetiology and occurrence of diving injuries. A review of diving safety. <i>Sports Med.</i> 1997 Apr;23(4):228-46.	39
Schmitt and Gerner (2001)	Schmitt H, Gerner HJ. Paralysis from sport and diving accidents. <i>Clin J Sport Med.</i> 2001 Jan;11(1):17-22.	37
Lewis et al. (2013)	Lewis RM, Redzic M, Thomas DT. The effects of season-long vitamin D supplementation on collegiate swimmers and divers. <i>Int J Sport Nutr Exerc Metab.</i> 2013 Oct;23(5):431-40.	35
Barris et al. (2014)	Barris S, Farrow D, Davids K. Increasing functional variability in the preparatory phase of the takeoff improves elite springboard diving performance. <i>Res Q Exerc Sport.</i> 2014 Mar;85(1):97-106.	32
10. EQUESTRIAN		
Paix (1999)	Paix BR. Rider injury rates and emergency medical services at equestrian events. <i>Br J Sports Med.</i> 1999 Feb;33(1):46-8.	59
Devienne and Guezennec (2000)	Devienne MF, Guezennec CY. Energy expenditure of horse riding. <i>Eur J Appl Physiol.</i> 2000 Aug;82(5-6):499-503.	51
Lloyd (1987)	Lloyd RG. Riding and other equestrian injuries: considerable severity. <i>Br J Sports Med.</i> 1987 Mar;21(1):22-4.	51
McCrory and Turner (2005)	McCrory P, Turner M. Equestrian injuries. <i>Med Sport Sci.</i> 2005;48:8-17.	45
Kusma et al. (2004)	Kusma M, Jung J, Dienst M, Goedde S, Kohn D, Seil R. Arthroscopic treatment of an avulsion fracture of the ligamentum teres of the hip in an 18-year-old horse rider. <i>Arthroscopy.</i> 2004 Jul;20 Suppl 2:64-6.	37

(Continued)

TABLE 4 | Continued

References	Articles	Number citations
11. FENCING		
Roi and Bianchedi (2008)	Roi GS, Bianchedi D. The science of fencing: implications for performance and injury prevention. <i>Sports Med.</i> 2008;38(6):465-81.	107
Giombini et al. (2013)	Giombini A, Dragoni S, Di Cesare A, Di Cesare M, Del Buono A, Maffulli N. Asymptomatic Achilles, patellar, and quadriceps tendinopathy: a longitudinal clinical and ultrasonographic study in elite fencers. <i>Scand J Med Sci Sports.</i> 2013 Jun;23(3):311-6.	48
Hosseini and Lifshitz (2009)	Hosseini AH, Lifshitz J. Brain injury forces of moderate magnitude elicit the fencing response. <i>Med Sci Sports Exerc.</i> 2009 Sep;41(9):1687-97.	48
Taddei et al. (2012)	Taddei F, Bultrini A, Spinelli D, Di Russo F. Neural correlates of attentional and executive processing in middle-age fencers. <i>Med Sci Sports Exerc.</i> 2012 Jun;44(6):1057-66.	46
Williams and Walmsley (2000)	Williams LR, Walmsley A. Response timing and muscular coordination in fencing: a comparison of elite and novice fencers. <i>J Sci Med Sport.</i> 2000 Dec;3(4):460-75.	41
12. FIELD HOCKEY		
Spencer et al. (2004)	Spencer M, Lawrence S, Rechichi C, Bishop D, Dawson B, Goodman C. Time-motion analysis of elite field hockey, with special reference to repeated-sprint activity. <i>J Sports Sci.</i> 2004 Sep;22(9):843-50.	275
Cochrane and Stannard (2005)	Cochrane DJ, Stannard SR. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. <i>Br J Sports Med.</i> 2005 Nov;39(11):860-5.	254
MacLeod et al. (2009)	MacLeod H, Morris J, Nevill A, Sunderland C. The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. <i>J Sports Sci.</i> 2009 Jan 15;27(2):121-8.	133
Aziz et al. (2000)	Aziz AR, Chia M, Teh KC. The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. <i>J Sports Med Phys Fitness.</i> 2000 Sep;40(3):195-200.	111
Elferink-Gemser et al. (2004)	Elferink-Gemser MT, Visscher C, Lemmink KA, Mulder TW. Relation between multidimensional performance characteristics and level of performance in talented youth field hockey players. <i>J Sports Sci.</i> 2004 Nov-Dec;22(11-12):1053-63.	103
13. FOOTBALL		
Stolen et al. (2005)	Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. <i>Sports Med.</i> 2005;35(6):501-36.	1150
Mohr et al. (2003)	Mohr M, Krstrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. <i>J Sports Sci.</i> 2003 Jul;21(7):519-28.	1120
Arendt and Dick (1995)	Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. <i>Am J Sports Med.</i> 1995 Nov-Dec;23(6):694-701.	1013
Reilly et al. (2000)	Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. <i>J Sports Sci.</i> 2000 Sep;18(9):669-83.	781
Impellizzeri et al. (2004)	Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. <i>Med Sci Sports Exerc.</i> 2004 Jun;36(6):1042-7.	635
14. GOLF		
Wulf et al. (1999)	Wulf G, Lauterbach B, Toole T. The learning advantages of an external focus of attention in golf. <i>Res Q Exerc Sport.</i> 1999 Jun;70(2):120-6.	258
Wulf and Su (2007)	Wulf G, Su J. An external focus of attention enhances golf shot accuracy in beginners and experts. <i>Res Q Exerc Sport.</i> 2007 Sep;78(4):384-9.	233
Hume et al. (2005)	Hume PA, Keogh J, Reid D. The role of biomechanics in maximising distance and accuracy of golf shots. <i>Sports Med.</i> 2005;35(5):429-49.	163
Perkins-Ceccato et al. (2003)	Perkins-Ceccato N, Passmore SR, Lee TD. Effects of focus of attention depend on golfers' skill. <i>J Sports Sci.</i> 2003 Aug;21(8):593-600.	138
Vad et al. (2004)	Vad VB, Bhat AL, Basrai D, Gebeh A, Aspergren DD, Andrews JR. Low back pain in professional golfers: the role of associated hip and low back range-of-motion deficits. <i>Am J Sports Med.</i> 2004 Mar;32(2):494-7.	124
15. GYMNASTICS		
Bressel et al. (2007)	Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. <i>J Athl Train.</i> 2007 Jan-Mar;42(1):42-6.	221
Kolt and Kirkby (1999)	Kolt GS, Kirkby RJ. Epidemiology of injury in elite and subelite female gymnasts: a comparison of retrospective and prospective findings. <i>Br J Sports Med.</i> 1999 Oct;33(5):312-8.	140
Bencke et al. (2002)	Bencke J, Damsgaard R, Saekmose A, Jorgensen P, Jorgensen K, Klausen K. Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming. <i>Scand J Med Sci Sports.</i> 2002 Jun;12(3):171-8.	137
Cassell et al. (1996)	Cassell C, Benedict M, Specker B. Bone mineral density in elite 7- to 9-yr-old female gymnasts and swimmers. <i>Med Sci Sports Exerc.</i> 1996 Oct;28(10):1243-6.	134

(Continued)

TABLE 4 | Continued

References	Articles	Number citations
Caine et al. (1989)	Caine D, Cochrane B, Caine C, Zemper E. An epidemiologic investigation of injuries affecting young competitive female gymnasts. <i>Am J Sports Med.</i> 1989 Nov-Dec;17(6):811-20.	132
16. HANDBALL		
Olsen et al. (2004)	Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. <i>Am J Sports Med.</i> 2004 Jun;32(4):1002-12.	711
Myklebust et al. (2003)	Myklebust G, Engebretsen L, Braekken IH, Skjølberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. <i>Clin J Sport Med.</i> 2003 Mar;13(2):71-8.	504
Koga et al. (2010)	Koga H, Nakamae A, Shima Y, Iwasa J, Myklebust G, Engebretsen L, et al. Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. <i>Am J Sports Med.</i> 2010 Nov;38(11):2218-25.	368
Myklebust et al. (1998)	Myklebust G, Maehlum S, Holm I, Bahr R. A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. <i>Scand J Med Sci Sports.</i> 1998 Jun;8(3):149-53.	283
Gorostiaga et al. (2005)	Gorostiaga EM, Granados C, Ibanez J, Izquierdo M. Differences in physical fitness and throwing velocity among elite and amateur male handball players. <i>Int J Sports Med.</i> 2005 Apr;26(3):225-32.	231
17. JUDO		
Franchini et al. (2011)	Franchini E, Del Vecchio FB, Matsushige KA, Artioli GG. Physiological profiles of elite judo athletes. <i>Sports Med.</i> 2011 Feb 1;41(2):147-66.	291
Perrin et al. (2002)	Perrin P, Deviterne D, Hugel F, Perrot C. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. <i>Gait Posture.</i> 2002 Apr;15(2):187-94.	235
Degoutte et al. (2003)	Degoutte F, Jouanel P, Filaire E. Energy demands during a judo match and recovery. <i>Br J Sports Med.</i> 2003 Jun;37(3):245-9.	133
Artioli et al. (2010)	Artioli GG, Franchini E, Nicasio H, Sterkowicz S, Solis MY, Lancha AH, Jr. The need of a weight management control program in judo: a proposal based on the successful case of wrestling. <i>J Int Soc Sports Nutr.</i> 2010 May 4;7:15.	129
Degoutte et al. (2006)	Degoutte F, Jouanel P, Begue RJ, Colombier M, Lac G, Pequignot JM, et al. Food restriction, performance, biochemical, psychological, and endocrine changes in judo athletes. <i>Int J Sports Med.</i> 2006 Jan;27(1):9-18.	121
18. KARATE		
Mori et al. (2002)	Mori S, Ohtani Y, Imanaka K. Reaction times and anticipatory skills of karate athletes. <i>Hum Mov Sci.</i> 2002 Jul;21(2):213-30.	170
Beneke et al. (2004)	Beneke R, Beyer T, Jachner C, Erasmus J, Hutler M. Energetics of karate kumite. <i>Eur J Appl Physiol.</i> 2004 Aug;92(4-5):518-23.	127
Chaabene et al. (2012)	Chaabene H, Hachana Y, Franchini E, Mkaouer B, Chamari K. Physical and physiological profile of elite karate athletes. <i>Sports Med.</i> 2012 Oct 1;42(10):829-43.	118
Doria et al. (2009)	Doria C, Veicsteinas A, Limonta E, Maggioni MA, Aschieri P, Eusebi F, et al. Energetics of karate (kata and kumite techniques) in top-level athletes. <i>Eur J Appl Physiol.</i> 2009 Nov;107(5):603-10.	81
Wong del et al. (2010)	Wong del P, Tan EC, Chaouachi A, Carling C, Castagna C, Bloomfield J, et al. Using squat testing to predict training loads for lower-body exercises in elite karate athletes. <i>J Strength Cond Res.</i> 2010 Nov;24(11):3075-80.	76
19. MARATHON - LONG DISTANCE RUNNING		
van Gent et al. (2007)	van Gent RN, Siem D, van Middelkoop M, van Os AG, Bierma-Zeinstra SM, Koes BW. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. <i>Br J Sports Med.</i> 2007 Aug;41(8):469-80; discussion 80.	700
Conley and Krahenbuhl (1980)	Conley DL, Krahenbuhl GS. Running economy and distance running performance of highly trained athletes. <i>Med Sci Sports Exerc.</i> 1980;12(5):357-60.	455
Sjodin and Jacobs (1981)	Sjodin B, Jacobs I. Onset of blood lactate accumulation and marathon running performance. <i>Int J Sports Med.</i> 1981 Feb;2(1):23-6.	395
Nieman et al. (1990)	Nieman DC, Johanssen LM, Lee JW, Arabatzis K. Infectious episodes in runners before and after the Los Angeles Marathon. <i>J Sports Med Phys Fitness.</i> 1990 Sep;30(3):316-28.	373
Billat (2001)	Billat LV. Interval training for performance: a scientific and empirical practice. Special recommendations for middle- and long-distance running. Part I: aerobic interval training. <i>Sports Med.</i> 2001;31(1):13-31.	285
20. MODERN PENTATHLON		
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Lee et al. (2002)	Lee H, Martin DT, Anson JM, Grundy D, Hahn AG. Physiological characteristics of successful mountain bikers and professional road cyclists. <i>J Sports Sci.</i> 2002 Dec;20(12):1001-8.	70
Stapelheldt et al. (2004)	Stapelheldt B, Schwirtz A, Schumacher YO, Hillebrecht M. Workload demands in mountain bike racing. <i>Int J Sports Med.</i> 2004 May;25(4):294-300.	64
Gregory et al. (2007)	Gregory J, Johns DP, Walls JT. Relative vs. absolute physiological measures as predictors of mountain bike cross-country race performance. <i>J Strength Cond Res.</i> 2007 Feb;21(1):17-22.	49
MacRae et al. (2000)	MacRae H-H, Hise KJ, Allen PJ. Effects of front and dual suspension mountain bike systems on uphill cycling performance. <i>Med Sci Sports Exerc.</i> 2000 Jul;32(7):1276-80.	30
Seifert et al. (1997)	Seifert JG, Luetkemeier MJ, Spencer MK, Miller D, Burke ER. The effects of mountain bike suspension systems on energy expenditure, physical exertion, and time trial performance during mountain bicycling. <i>Int J Sports Med.</i> 1997 Apr;18(3):197-200.	26
22. ROWING		
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23. RUGBY SEVENS		
Higham et al. (2012)	Higham DG, Pyne DB, Anson JM, Eddy A. Movement patterns in rugby sevens: effects of tournament level, fatigue and substitute players. <i>J Sci Med Sport.</i> 2012 May;15(3):277-82.	106
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Suarez-Arrones et al. (2013)	Suarez-Arrones L, Calvo-Liuch A, Portillo J, Sanchez F, Mendez-Villanueva A. Running demands and heart rate response in rugby sevens referees. <i>J Strength Cond Res.</i> 2013 Jun;27(6):1618-22.	52
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24. SAILING		
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Mononen et al. (2007)	Mononen K, Konttinen N, Viitasalo J, Era P. Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. <i>Scand J Med Sci Sports.</i> 2007 Apr;17(2):180-5.	90
Causer et al. (2010)	Causer J, Bennett SJ, Holmes PS, Janelle CM, Williams AM. Quiet eye duration and gun motion in elite shotgun shooting. <i>Med Sci Sports Exerc.</i> 2010 Aug;42(8):1599-608.	74

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Kroncke et al. (2008)	Kroncke EL, Niedfeldt MW, Young CC. Use of protective equipment by adolescents in inline skating, skateboarding, and snowboarding. <i>Clin J Sport Med.</i> 2008 Jan;18(1):38-43.	
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Werner et al. (2006)	Werner SL, Jones DG, Guido JA, Jr., Brunet ME. Kinematics and kinetics of elite windmill softball pitching. <i>Am J Sports Med.</i> 2006 Apr;34(4):597-603.	62
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Watts (2004)	Watts PB. Physiology of difficult rock climbing. <i>Eur J Appl Physiol.</i> 2004 Apr;91(4):361-72.	135
Mermier et al. (2000)	Mermier CM, Janot JM, Parker DL, Swan JG. Physiological and anthropometric determinants of sport climbing performance. <i>Br J Sports Med.</i> 2000 Oct;34(5):359-65; discussion 66.	113
Grant et al. (1996)	Grant S, Hynes V, Whittaker A, Aitchison T. Anthropometric, strength, endurance and flexibility characteristics of elite and recreational climbers. <i>J Sports Sci.</i> 1996 Aug;14(4):301-9.	107
Watts et al. (1993)	Watts PB, Martin DT, Durtschi S. Anthropometric profiles of elite male and female competitive sport rock climbers. <i>J Sports Sci.</i> 1993 Apr;11(2):113-7.	103
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29. SURFING		
Mendez-Villanueva et al. (2006)	Mendez-Villanueva A, Bishop D, Hamer P. Activity profile of world-class professional surfers during competition: a case study. <i>J Strength Cond Res.</i> 2006 Aug;20(3):477-82.	66
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Craig and Pendergast (1979)	Craig AB, Jr., Pendergast DR. Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. <i>Med Sci Sports.</i> 1979 Fall;11(3):278-83.	230
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31. TABLE TENNIS		
Rodrigues et al. (2002)	Rodrigues ST, Vickers JN, Williams AM. Head, eye and arm coordination in table tennis. <i>J Sports Sci.</i> 2002 Mar;20(3):187-200.	85
Raab et al. (2005)	Raab M, Masters RS, Maxwell JP. Improving the 'how' and 'what' decisions of elite table tennis players. <i>Hum Mov Sci.</i> 2005 Jun;24(3):326-44.	64
Kondric et al. (2013)	Kondric M, Zagatto AM, Sekulic D. The physiological demands of table tennis: a review. <i>J Sports Sci Med.</i> 2013;12(3):362-70.	44
Martinet and Ferrand (2009)	Martinet G, Ferrand C. A naturalistic study of the directional interpretation process of discrete emotions during high-stakes table tennis matches. <i>J Sport Exerc Psychol.</i> 2009 Jun;31(3):318-36.	42
Iino and Kojima (2009)	Iino Y, Kojima T. Kinematics of table tennis topspin forehands: effects of performance level and ball spin. <i>J Sports Sci.</i> 2009 Oct;27(12):1311-21.	40
32. TAEKWONDO		
Bridge et al. (2014)	Bridge CA, Ferreira da Silva Santos J, Chaabene H, Pieter W, Franchini E. Physical and physiological profiles of taekwondo athletes. <i>Sports Med.</i> 2014 Jun;44(6):713-33.	123
Campos et al. (2012)	Campos FA, Bertuzzi R, Dourado AC, Santos VG, Franchini E. Energy demands in taekwondo athletes during combat simulation. <i>Eur J Appl Physiol.</i> 2012 Apr;112(4):1221-8.	109
Matsushigue et al. (2009)	Matsushigue KA, Hartmann K, Franchini E. Taekwondo: Physiological responses and match analysis. <i>J Strength Cond Res.</i> 2009 Jul;23(4):1112-7.	106
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Falco et al. (2009)	Falco C, Alvarez O, Castillo I, Estevan I, Martos J, Mugarra F, et al. Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. <i>J Biomech.</i> 2009 Feb 9;42(3):242-8.	95
33. TENNIS		
Nirschl (1992)	Nirschl RP. Elbow tendinitis/tennis elbow. <i>Clin Sports Med.</i> 1992 Oct;11(4):851-70.	295
Fernandez et al. (2006)	Fernandez J, Mendez-Villanueva A, Pluim BM. Intensity of tennis match play. <i>Br J Sports Med.</i> 2006 May;40(5):387-91; discussion 91.	201
Ellenbecker et al. (2002)	Ellenbecker TS, Roetert EP, Bailie DS, Davies GJ, Brown SW. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. <i>Med Sci Sports Exerc.</i> 2002 Dec;34(12):2052-6.	188
O' Donoghue and Ingram (2001)	O' Donoghue P, Ingram B. A notational analysis of elite tennis strategy. <i>J Sports Sci.</i> 2001 Feb;19(2):107-15.	179
Mishra et al. (2014)	Mishra AK, Skrepnik NV, Edwards SG, Jones GL, Sampson S, Vermillion DA, et al. Efficacy of platelet-rich plasma for chronic tennis elbow: a double-blind, prospective, multicenter, randomized controlled trial of 230 patients. <i>Am J Sports Med.</i> 2014 Feb;42(2):463-71.	179
34. TRAMPOLINE		
Eliasson et al. (2002)	Eliasson K, Larsson T, Mattsson E. Prevalence of stress incontinence in nulliparous elite trampolinists. <i>Scand J Med Sci Sports.</i> 2002 Apr;12(2):106-10.	99
Nysted and Drogset (2006)	Nysted M, Drogset JO. Trampoline injuries. <i>Br J Sports Med.</i> 2006 Dec;40(12):984-7.	42
Da Roza et al. (2015)	Da Roza T, Brandao S, Mascarenhas T, Jorge RN, Duarte JA. Volume of training and the ranking level are associated with the leakage of urine in young female trampolinists. <i>Clin J Sport Med.</i> 2015 May;25(3):270-5.	34
Blajer and Czaplicki (2001)	Blajer W, Czaplicki A. Modeling and inverse simulation of somersaults on the trampoline. <i>J Biomech.</i> 2001 Dec;34(12):1619-29.	31
Hume et al. (1996)	Hume PA, Chalmers DJ, Wilson BD. Trampoline injury in New Zealand: emergency care. <i>Br J Sports Med.</i> 1996 Dec;30(4):327-30.	30
35. TRIATHLON		
Jeukendrup (2011)	Jeukendrup AE. Nutrition for endurance sports: marathon, triathlon, and road cycling. <i>J Sports Sci.</i> 2011;29 Suppl 1:S91-9.	168
Plews et al. (2012)	Plews DJ, Laursen PB, Kilding AE, Buchheit M. Heart rate variability in elite triathletes, is variation in variability the key to effective training? A case comparison. <i>Eur J Appl Physiol.</i> 2012 Nov;112(11):3729-41.	139
Coutts et al. (2007)	Coutts AJ, Wallace LK, Slaterry KM. Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. <i>Int J Sports Med.</i> 2007 Feb;28(2):125-34.	139
Millet et al. (2009)	Millet GP, Vleck VE, Bentley DJ. Physiological differences between cycling and running: lessons from triathletes. <i>Sports Med.</i> 2009;39(3):179-206.	128
Bentley et al. (2002)	Bentley DJ, Millet GP, Vleck VE, McNaughton LR. Specific aspects of contemporary triathlon: implications for physiological analysis and performance. <i>Sports Med.</i> 2002;32(6):345-59.	109

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Newton et al. (1999)	Newton RU, Kraemer WJ, Hakkinen K. Effects of ballistic training on preseason preparation of elite volleyball players. <i>Med Sci Sports Exerc.</i> 1999 Feb;31(2):323-30.	221
Ferretti et al. (1992)	Ferretti A, Papandrea P, Conteduca F, Mariani PP. Knee ligament injuries in volleyball players. <i>Am J Sports Med.</i> 1992 Mar-Apr;20(2):203-7.	208
Bahr and Bahr (1997)	Bahr R, Bahr IA. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. <i>Scand J Med Sci Sports.</i> 1997 Jun;7(3):166-71.	206
Bahr et al. (1997)	Bahr R, Lian O, Bahr IA. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. <i>Scand J Med Sci Sports.</i> 1997 Jun;7(3):172-7.	179
Verhagen et al. (2004)	Verhagen EA, Van der Beek AJ, Bouter LM, Bahr RM, Van Mechelen W. A one season prospective cohort study of volleyball injuries. <i>Br J Sports Med.</i> 2004 Aug;38(4):477-81.	178
37. WALKING		
Bassett et al. (2008)	Bassett DR, Jr., Pucher J, Buehler R, Thompson DL, Crouter SE. Walking, cycling, and obesity rates in Europe, North America, and Australia. <i>J Phys Act Health.</i> 2008 Nov;5(6):795-814.	362
Heller et al. (2001)	Heller MO, Bergmann G, Deuretzbacher G, Durselen L, Pohl M, Claes L, et al. Musculo-skeletal loading conditions at the hip during walking and stair climbing. <i>J Biomech.</i> 2001 Jul;34(7):883-93.	316
Ryan et al. (2006)	Ryan CG, Grant PM, Tigbe WW, Granat MH. The validity and reliability of a novel activity monitor as a measure of walking. <i>Br J Sports Med.</i> 2006 Sep;40(9):779-84.	272
Lee and Buchner (2008)	Lee IM, Buchner DM. The importance of walking to public health. <i>Med Sci Sports Exerc.</i> 2008 Jul;40(7 Suppl):S512-8.	254
Kelly et al. (2014)	Kelly P, Kahlmeier S, Gotschi T, Orsini N, Richards J, Roberts N, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. <i>Int J Behav Nutr Phys Act.</i> 2014 Oct 24;11:132.	224
38. WATERPOLO		
Royal et al. (2006)	Royal KA, Farrow D, Mujika I, Halson SL, Pyne D, Abernethy B. The effects of fatigue on decision making and shooting skill performance in water polo players. <i>J Sports Sci.</i> 2006 Aug;24(8):807-15.	140
Smith (1998)	Smith HK. Applied physiology of water polo. <i>Sports Med.</i> 1998 Nov;26(5):317-34.	124
McMaster et al. (1991)	McMaster WC, Long SC, Caiozzo VJ. Isokinetic torque imbalances in the rotator cuff of the elite water polo player. <i>Am J Sports Med.</i> 1991 Jan-Feb;19(1):72-5.	107
Lupo et al. (2010)	Lupo C, Tessitore A, Minganti C, Capranica L. Notational analysis of elite and sub-elite water polo matches. <i>J Strength Cond Res.</i> 2010 Jan;24(1):223-9.	75
Tsekouras et al. (2005)	Tsekouras YE, Kavouras SA, Campagna A, Kotsis YP, Syntosi SS, Papazoglou K, et al. The anthropometrical and physiological characteristics of elite water polo players. <i>Eur J Appl Physiol.</i> 2005 Sep;95(1):35-41.	73
39. WEIGHTLIFTING		
Tricoli et al. (2005)	Tricoli V, Lamas L, Carnevale R, Ugrasowitsch C. Short-term effects on lower-body functional power development: weightlifting vs. vertical jump training programs. <i>J Strength Cond Res.</i> 2005 May;19(2):433-7.	169
Haff et al. (2005)	Haff GG, Carlock JM, Hartman MJ, Kilgore JL, Kawamori N, Jackson JR, et al. Force-time curve characteristics of dynamic and isometric muscle actions of elite women olympic weightlifters. <i>J Strength Cond Res.</i> 2005 Nov;19(4):741-8.	119
Hori et al. (2008)	Hori N, Newton RU, Andrews WA, Kawamori N, McGuigan MR, Nosaka K. Does performance of hang power clean differentiate performance of jumping, sprinting, and changing of direction? <i>J Strength Cond Res.</i> 2008 Mar;22(2):412-8.	115
Pearson et al. (2002)	Pearson SJ, Young A, Macaluso A, Devito G, Nimmo MA, Cobbold M, et al. Muscle function in elite master weightlifters. <i>Med Sci Sports Exerc.</i> 2002 Jul;34(7):1199-206.	113
Garhammer, 1980)	Garhammer J. Power production by Olympic weightlifters. <i>Med Sci Sports Exerc.</i> 1980 Spring;12(1):54-60.	111
40. WRESTLING		
Gould et al. (1993b)	Gould D, Eklund RC, Jackson SA. Coping strategies used by U.S. Olympic wrestlers. <i>Res Q Exerc Sport.</i> 1993 Mar;64(1):83-93.	203
Steen and Brownell (1990)	Steen SN, Brownell KD. Patterns of weight loss and regain in wrestlers: has the tradition changed? <i>Med Sci Sports Exerc.</i> 1990 Dec;22(6):762-8.	176
Kraemer et al. (2001)	Kraemer WJ, Fry AC, Rubin MR, Triplett-McBride T, Gordon SE, Koziris LP, et al. Physiological and performance responses to tournament wrestling. <i>Med Sci Sports Exerc.</i> 2001 Aug;33(8):1367-78.	168
Oppliger et al. (1996)	Oppliger RA, Case HS, Horswill CA, Landry GL, Shelter AC. American College of Sports Medicine position stand. Weight loss in wrestlers. <i>Med Sci Sports Exerc.</i> 1996 Jun;28(6):ix-xii.	141
Webster et al. (1990)	Webster S, Rutt R, Weltman A. Physiological effects of a weight loss regimen practiced by college wrestlers. <i>Med Sci Sports Exerc.</i> 1990 Apr;22(2):229-34.	135

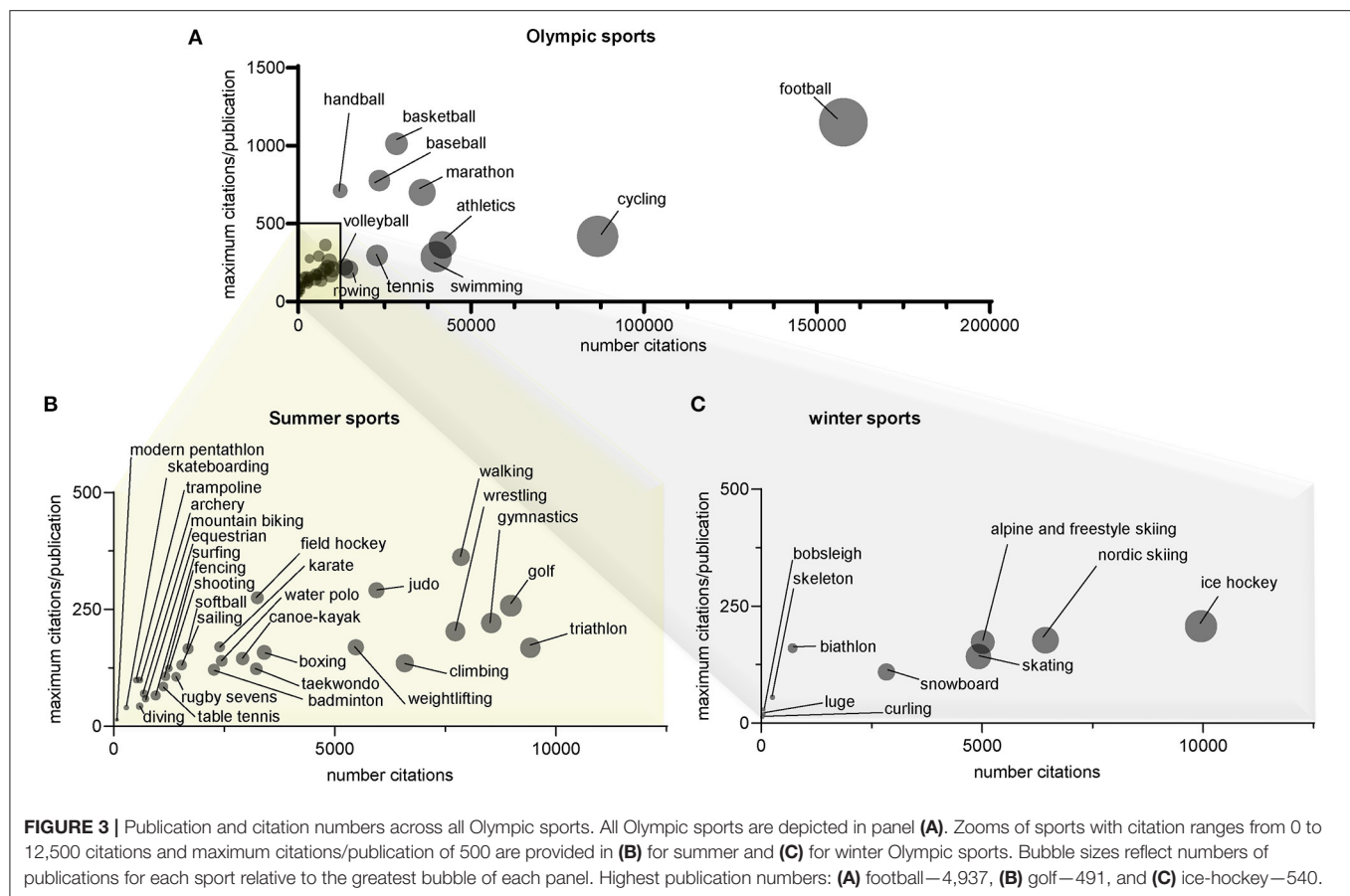
TABLE 5 | Top-5 articles on winter sports.

References	Articles	Number citations
1. ALPINE SKIING		
Ettlinger et al. (1995)	Ettlinger CF, Johnson RJ, Shealy JE. A method to help reduce the risk of serious knee sprains incurred in alpine skiing. <i>Am J Sports Med.</i> 1995 Sep-Oct;23(5):531-7.	173
Florenes et al. (2009)	Florenes TW, Bere T, Nordsletten L, Heir S, Bahr R. Injuries among male and female World Cup alpine skiers. <i>Br J Sports Med.</i> 2009 Dec;43(13):973-8.	104
Burtscher et al. (2008)	Burtscher M, Gatterer H, Flatz M, Sommersacher R, Woldrich T, Ruedl G, et al. Effects of modern ski equipment on the overall injury rate and the pattern of injury location in Alpine skiing. <i>Clin J Sport Med.</i> 2008 Jul;18(4):355-7.	95
Bere et al. (2011)	Bere T, Florenes TW, Krosshaug T, Koga H, Nordsletten L, Irving C, et al. Mechanisms of anterior cruciate ligament injury in World Cup alpine skiing: a systematic video analysis of 20 cases. <i>Am J Sports Med.</i> 2011 Jul;39(7):1421-9.	90
Pujol et al. (2007)	Pujol N, Blanchi MP, Chablat P. The incidence of anterior cruciate ligament injuries among competitive Alpine skiers: a 25-year investigation. <i>Am J Sports Med.</i> 2007 Jul;35(7):1070-4.	89
2. BIATHLON		
Vickers and Williams (2007)	1. Vickers JN, Williams AM. Performing under pressure: the effects of physiological arousal, cognitive anxiety, and gaze control in biathlon. <i>J Mot Behav.</i> 2007 Sep;39(5):381-94.	160
Heinicke et al. (2005)	1. Heinicke K, Heinicke I, Schmidt W, Wolfarth B. A three-week traditional altitude training increases hemoglobin mass and red cell volume in elite biathlon athletes. <i>Int J Sports Med.</i> 2005 Jun;26(5):350-5.	81
Hoffman et al. (1992)	1. Hoffman MD, Gilson PM, Westenburg TM, Spencer WA. Biathlon shooting performance after exercise of different intensities. <i>Int J Sports Med.</i> 1992 Apr;13(3):270-3.	64
Rundell and Bacharach (1995)	1. Rundell KW, Bacharach DW. Physiological characteristics and performance of top U.S. biathletes. <i>Med Sci Sports Exerc.</i> 1995 Sep;27(9):1302-10.	38
Rundell (1995)	1. Rundell KW. Treadmill roller ski test predicts biathlon roller ski race results of elite U.S. biathlon women. <i>Med Sci Sports Exerc.</i> 1995 Dec;27(12):1677-85.	35
3. BOBSLEIGH		
Dabnichki and Avital (2006)	Dabnichki P, Avital E. Influence of the position of crew members on aerodynamics performance of two-man bobsleigh. <i>J Biomech.</i> 2006;39(15):2733-42.	29
Haralambie et al. (1976)	Haralambie G, Cerny FJ, Huber G. Serum enzyme levels after bobsled racing. <i>J Sports Med Phys Fitness.</i> 1976 Mar;16(1):54-6.	11
Reid (2003)	Reid SA. Stress fracture of the ulna in an elite bobsled brakeman. <i>Clin J Sport Med.</i> 2003 Sep;13(5):306-8.	4
Lopes and Alouche (2016)	Lopes AD, Alouche SR. Two-Man Bobsled Push Start Analysis. <i>J Hum Kinet.</i> 2016 Apr 1;50:63-70.	4
Okada et al. (1972)	Okada A, Miyake H, Takizawa A, Minami M. A study on the excreted catecholamines in the urine of Bobsleigh-tobogganing contestants. <i>J Sports Med Phys Fitness.</i> 1972 Jun;12(2):71-5.	3
4. CURLING		
Bradley (2009)	Bradley JL. The sports science of curling: a practical review. <i>J Sports Sci Med.</i> 2009;8(4):495-500.	13
Robertson et al. (2017)	Reeser JC, Berg RL. Self-reported injury patterns among competitive curlers in the United States: a preliminary investigation into the epidemiology of curling injuries. <i>Br J Sports Med.</i> 2004 Oct;38(5):E29.	5
Berry et al. (2013)	Berry JW, Romanick MA, Koerber SM. Injury type and incidence among elite level curlers during world championship competition. <i>Res Sports Med.</i> 2013;21(2):159-63.	4
Stone et al. (2018)	Stone RC, Rakhilova Z, Gage WH, Baker J. Curling for Confidence: Psychophysical Benefits of Curling for Older Adults. <i>J Aging Phys Act.</i> 2018 Apr 1;26(2):267-75.	2
Pojksic et al. (2020)	Pojksic H, McGawley K, Gustafsson A, Behm DG. The Reliability and Validity of a Novel Sport-Specific Balance Test to Differentiate Performance Levels in Elite Curling Players. <i>J Sports Sci Med.</i> 2020 Jun;19(2):337-46.	1
5. ICE HOCKEY		
Philippon et al. (2010)	Philippon MJ, Weiss DR, Kuppersmith DA, Briggs KK, Hay CJ. Arthroscopic labral repair and treatment of femoroacetabular impingement in professional hockey players. <i>Am J Sports Med.</i> 2010 Jan;38(1):99-104.	207
Tyler et al. (2001)	Tyler TF, Nicholas SJ, Campbell RJ, McHugh MP. The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. <i>Am J Sports Med.</i> 2001 Mar-Apr;29(2):124-8.	205
Sherar et al. (2007)	Sherar LB, Baxter-Jones AD, Faulkner RA, Russell KW. Do physical maturity and birth date predict talent in male youth ice hockey players? <i>J Sports Sci.</i> 2007 Jun;25(8):879-86.	195
Williamson and Goodman (2006)	Williamson IJ, Goodman D. Converging evidence for the under-reporting of concussions in youth ice hockey. <i>Br J Sports Med.</i> 2006 Feb;40(2):128-32; discussion-32.	189
Flik et al. (2005)	Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. <i>Am J Sports Med.</i> 2005 Feb;33(2):183-7.	165

(Continued)

TABLE 5 | Continued

References	Articles	Number citations
6. LUGE		
Platzer et al. (2009)	Platzer HP, Raschner C, Patterson C. Performance-determining physiological factors in the luge start. <i>J Sports Sci.</i> 2009 Feb 1;27(3):221-6.	20
Cummings et al. (1997)	Cummings RS, Jr., Shurland AT, Prodoehl JA, Moody K, Sherk HH. Injuries in the sport of luge. <i>Epidemiology and analysis. Am J Sports Med.</i> 1997 Jul-Aug;25(4):508-13.	17
Crossland et al. (2011)	Crossland BW, Hartman JE, Kilgore JL, Hartman MJ, Kaus JM. Upper-body anthropometric and strength measures and their relationship to start time in elite luge athletes. <i>J Strength Cond Res.</i> 2011 Oct;25(10):2639-44.	10
Mossner et al. (2011)	Mossner M, Hasler M, Schindelwig K, Kaps P, Nachbauer W. An approximate simulation model for initial luge track design. <i>J Biomech.</i> 2011 Mar 15;44(5):892-6.	6
Lembert et al. (2011)	Lembert S, Schachner O, Raschner C. Development of a measurement and feedback training tool for the arm strokes of high-performance luge athletes. <i>J Sports Sci.</i> 2011 Dec;29(15):1593-601.	4
7. NORDIC SKIING		
Millet and Lepers (2004)	Millet GY, Lepers R. Alterations of neuromuscular function after prolonged running, cycling and skiing exercises. <i>Sports Med.</i> 2004;34(2):105-16.	239
Holmberg et al. (2005)	Holmberg HC, Lindinger S, Stoggl T, Eitzlmair E, Muller E. Biomechanical analysis of double poling in elite cross-country skiers. <i>Med Sci Sports Exerc.</i> 2005 May;37(5):807-18.	177
Hoff et al. (1999)	Hoff J, Helgerud J, Wisloff U. Maximal strength training improves work economy in trained female cross-country skiers. <i>Med Sci Sports Exerc.</i> 1999 Jun;31(6):870-7.	121
Grimsmo et al. (2010)	Grimsmo J, Grundvold I, Maehlum S, Arnesen H. High prevalence of atrial fibrillation in long-term endurance cross-country skiers: echocardiographic findings and possible predictors—a 28-30 years follow-up study. <i>Eur J Cardiovasc Prev Rehabil.</i> 2010 Feb;17(1):100-5.	118
Andersson et al. (2010)	Andersson E, Supej M, Sandbakk O, Sperlich B, Stoggl T, Holmberg HC. Analysis of sprint cross-country skiing using a differential global navigation satellite system. <i>Eur J Appl Physiol.</i> 2010 Oct;110(3):585-95.	87
8. SKATING		
Gould et al. (1993a)	Gould D, Finch LM, Jackson SA. Coping strategies used by national champion figure skaters. <i>Res Q Exerc Sport.</i> 1993 Dec;64(4):453-68.	142
Herzog et al. (1991)	Herzog W, Guimaraes AC, Anton MG, Carter-Erdman KA. Moment-length relations of rectus femoris muscles of speed skaters/cyclists and runners. <i>Med Sci Sports Exerc.</i> 1991 Nov;23(11):1289-96.	121
van Ingen Schenau et al. (1994)	van Ingen Schenau GJ, de Koning JJ, de Groot G. Optimisation of sprinting performance in running, cycling and speed skating. <i>Sports Med.</i> 1994 Apr;17(4):259-75.	90
van Ingen Schenau (1982)	van Ingen Schenau GJ. The influence of air friction in speed skating. <i>J Biomech.</i> 1982;15(6):449-58.	90
Foster et al. (1999)	Foster C, Rundell KW, Snyder AC, Stray-Gundersen J, Kemkers G, Thometz N, et al. Evidence for restricted muscle blood flow during speed skating. <i>Med Sci Sports Exerc.</i> 1999 Oct;31(10):1433-40.	70
9. SKELETON		
Bullock et al. (2008)	Bullock N, Martin DT, Ross A, Rosemond CD, Jordan MJ, Marino FE. Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. <i>J Strength Cond Res.</i> 2008 Jul;22(4):1371-4.	55
Bullock et al. (2009)	Bullock N, Gulbin JP, Martin DT, Ross A, Holland T, Marino F. Talent identification and deliberate programming in skeleton: ice novice to Winter Olympian in 14 months. <i>J Sports Sci.</i> 2009 Feb 15;27(4):397-404.	51
Sands et al. (2005)	Sands WA, Smith LS, Kivi DM, McNeal JR, Dorman JC, Stone MH, et al. Anthropometric and physical abilities profiles: US National Skeleton Team. <i>Sports Biomech.</i> 2005 Jul;4(2):197-214.	31
Zanoletti et al. (2006)	Zanoletti C, La Torre A, Merati G, Rampinini E, Impellizzeri FM. Relationship between push phase and final race time in skeleton performance. <i>J Strength Cond Res.</i> 2006 Aug;20(3):579-83.	26
Bullock et al. (2007)	Bullock N, Martin DT, Ross A, Rosemond D, Marino FE. Effect of long haul travel on maximal sprint performance and diurnal variations in elite skeleton athletes. <i>Br J Sports Med.</i> 2007 Sep;41(9):569-73; discussion 73.	25
10. SNOWBOARD		
Bladin et al. (1993)	Bladin C, Giddings P, Robinson M. Australian snowboard injury data base study. A four-year prospective study. <i>Am J Sports Med.</i> 1993 Sep-Oct;21(5):701-4.	109
Kim et al. (2012)	Kim S, Endres NK, Johnson RJ, Ettlinger CF, Shealy JE. Snowboarding injuries: trends over time and comparisons with alpine skiing injuries. <i>Am J Sports Med.</i> 2012 Apr;40(4):770-6.	86
Pino and Colville (1989)	Pino EC, Colville MR. Snowboard injuries. <i>Am J Sports Med.</i> 1989 Nov-Dec;17(6):778-81.	85
Tarazi et al. (1999)	Tarazi F, Dvorak MF, Wing PC. Spinal injuries in skiers and snowboarders. <i>Am J Sports Med.</i> 1999 Mar-Apr;27(2):177-80.	83
Ronning et al. (2001)	Ronning R, Ronning I, Gerner T, Engebretsen L. The efficacy of wrist protectors in preventing snowboarding injuries. <i>Am J Sports Med.</i> 2001 Sep-Oct;29(5):581-5.	77



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

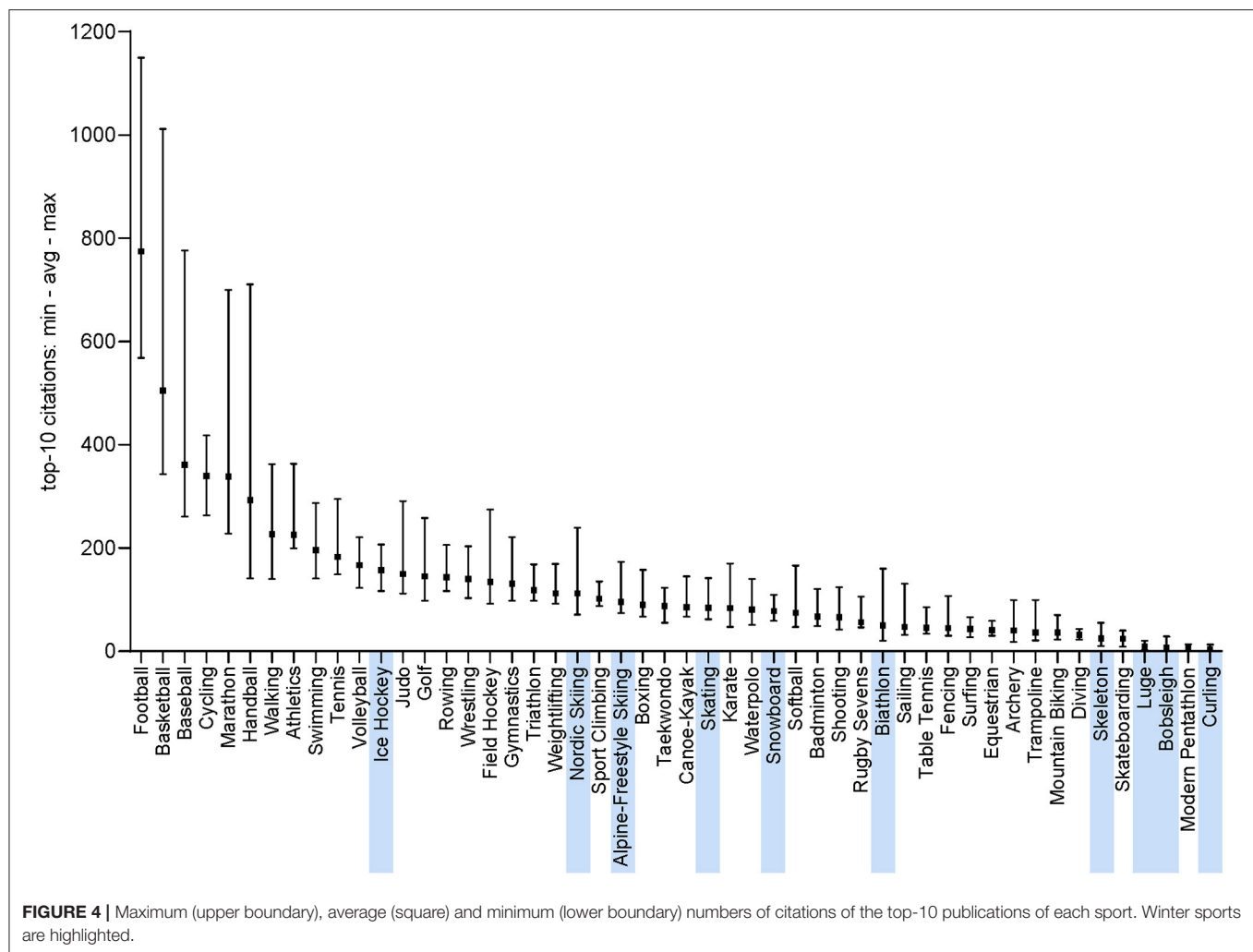


FIGURE 4 | Maximum (upper boundary), average (square) and minimum (lower boundary) numbers of citations of the top-10 publications of each sport. Winter sports are highlighted.

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.

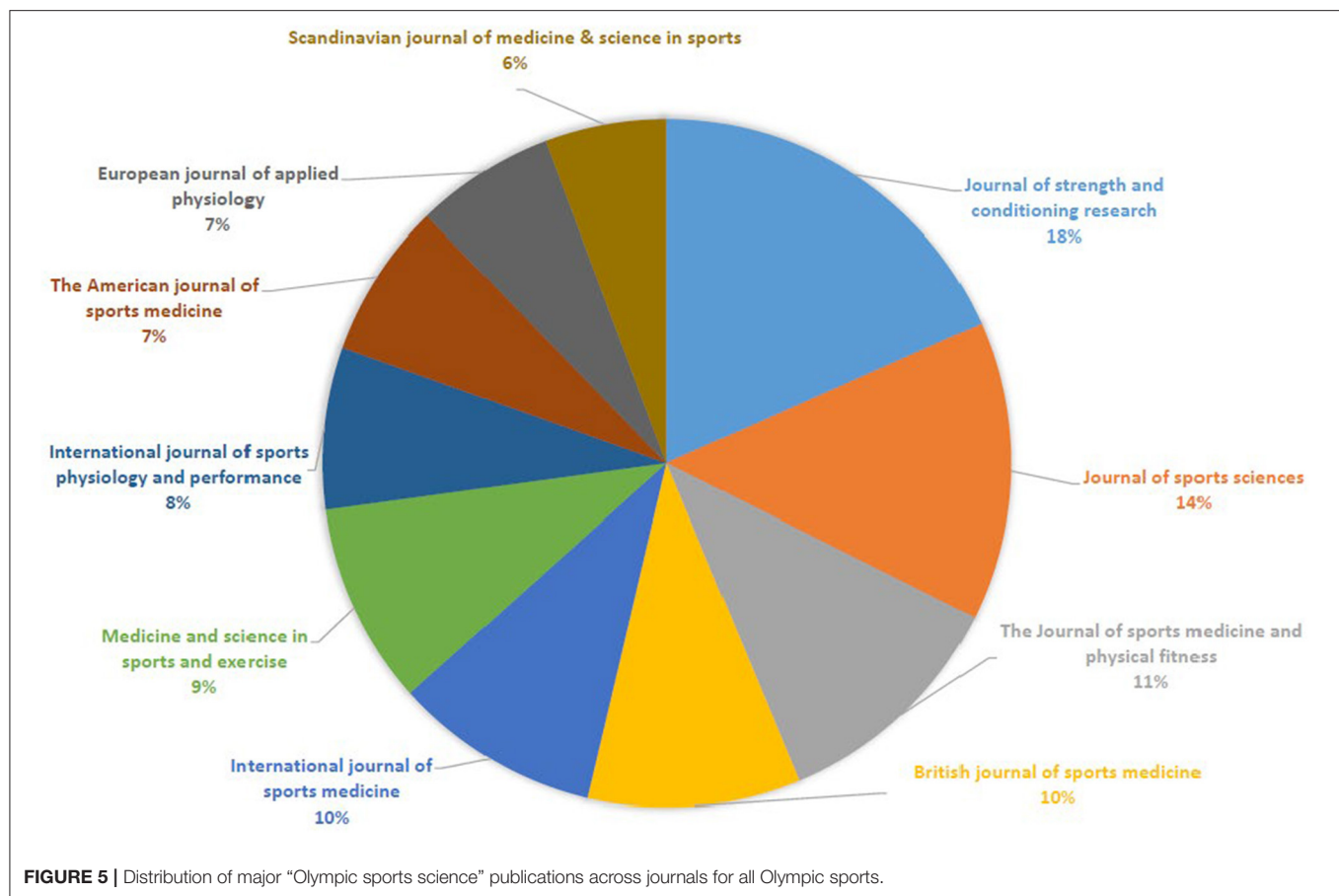
In the European Nordic countries, sport sciences have a long tradition of excellence, owing primarily to the work of famous pioneers in exercise physiology (e.g., Saltin and Astrand, 1967) who performed early studies, including some on Nordic skiers. This might partly explain why Nordic skiing is the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



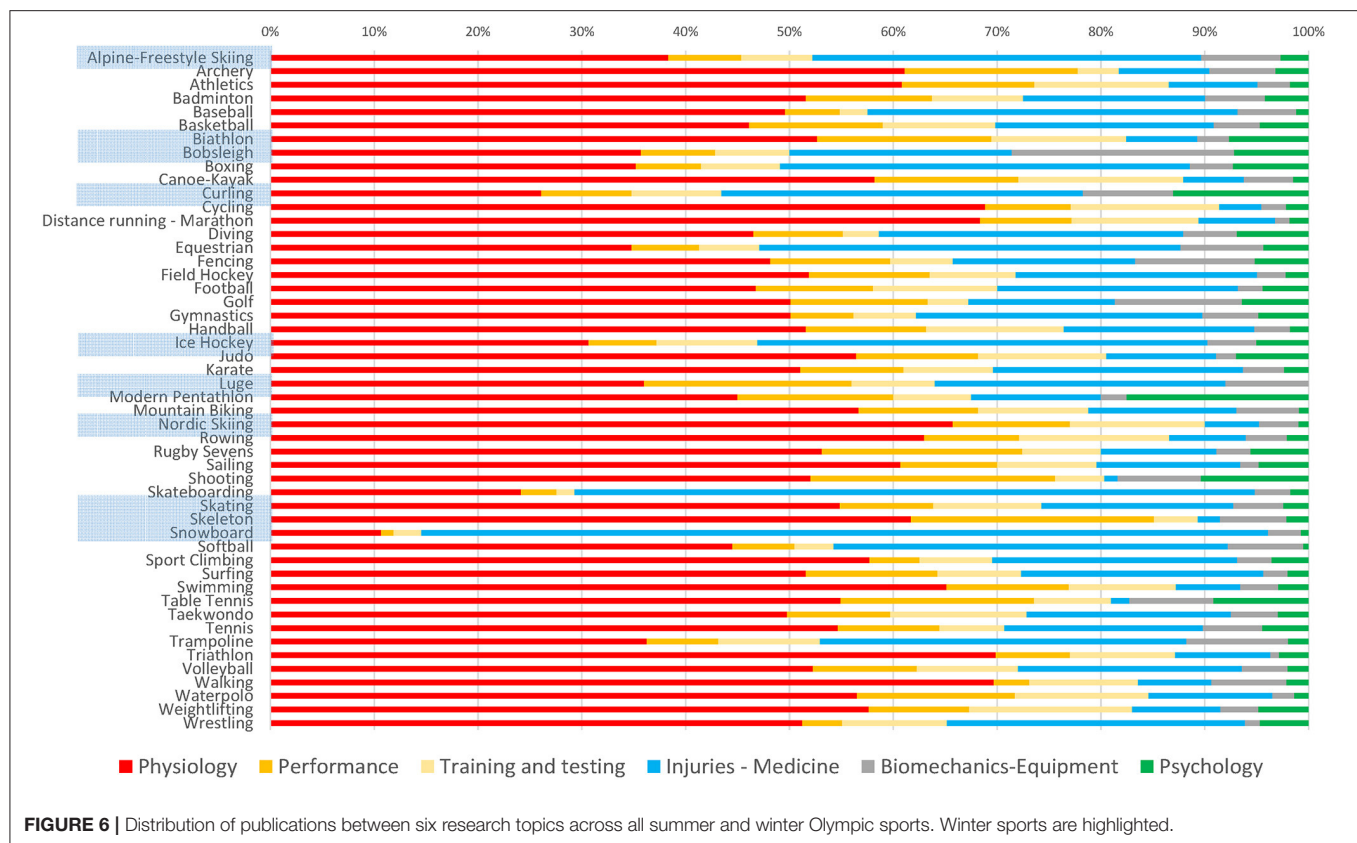
The Entry of a Sport Into the Olympic Programme Translates Into an Increase in Scientific Publications

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 (VO_{2max}) values in top performers in these sports (Haugen et al., 2018), who reach VO_{2max} values of >90 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 are 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 understate 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

sport, with 19.7 and 26.3% of the total number of articles and citations, respectively; 3. team sports, especially American professional sports (i.e., baseball, basketball, and ice hockey), are the focus of prominent scientific output; 4. overall, winter sports generate comparatively minor scientific interest; 5. the greatest number of studies in the field are published in a relatively small number of “sport sciences” journals; 6. entrance into the Olympic programme may increase the scientific output of “recent” sports, although this hypothesis requires further substantiation; 7. local/cultural influences contribute to the representation of different sports in a journal’s portfolio; and 8. finally, the relative distribution of six main research topics (i.e., physiology, performance, training and testing, injuries and medicine, biomechanics, and psychology) is extremely diverse across sports and provides information on the performance determinants of each sport. Overall, within the rapidly growing

interdisciplinary “sport sciences” field, this bibliometric analysis provides valuable and helpful information for researchers, practitioners, and funding stakeholders to achieve future progress in the Olympic-based research agenda.

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.

AUTHOR CONTRIBUTIONS

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

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