biomechanics

Review

Does Producing Scientific Articles Lead to Paralympic Podiums?

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Abstract: The Olympic/Paralympic Games are world events that promote countries and their participants, and more particularly, those winning medals. The potential link between a country's scientific productivity and its podium wins remains unknown for the Paralympic Games. This study aimed to (1) quantify the link between the production of Paralympic scientific articles and the medals won by countries during Summer/Winter Paralympic Games between 2012 and 2022, and (2) select the five most important articles published for all Paralympic sports. A bibliographic search of the Web of Science, PubMed, and Google Scholar databases was conducted. From the 1351 articles identified, 525 fulfilled the inclusion/exclusion criteria. The results showed a greater (7x) production of scientific articles relating to the Summer Paralympics compared to those relating to the Winter Paralympics. For the Summer Paralympics, there was a strong correlation (r = 0.79) between the number of medals and the number of scientific articles produced by a given country, while a low correlation (r = 0.12) was observed for the Winter Paralympics. Biomechanics-related articles represent almost 50% of the overall Paralympic publications. In conclusion, there is a strong link between scientific productivity and the number of medals won for the 2012–2022 Paralympic Games. Parasport Federations are strongly encouraged to promote the publication of more Paralympic research articles.

Keywords: biomechanics; Paralympics; sports; medals; publications

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1. Introduction

The Olympic and Paralympic Games are world events that promote countries and their participants, particularly those winning medals. The Olympic and Paralympic Games are also greatly publicized events and therefore an extraordinary showcase for the countries and sponsors. As a result, attention has been given to the policies adopted by countries to successfully identify talents, develop those talents, and provide coaches and athletes with the necessary scientific knowledge as well as the necessary funding to reach high-level performance. In 2006, Bosscher et al. [1] developed a framework for analyzing sport policy factors leading to international sporting success and compared elite sport systems and policies between nations. According to these researchers, one of the pillars of success is the production of scientific research. However, to date, most studies targeting major games have focused on the Olympic Games [2–4]. Although the Paralympic Games have been in existence since 1960, with many para-athletes standing out with extraordinary performances, much less attention has been given to the Paralympic Games [5,6]. A keen interest by researchers in Paralympic sports really began around the London Games of 2012 [6], unlike the Olympic Games, where research has been much more prolific since 1980 [2], with a significant uptake in 2008 [4]. With regard to the Paralympic Games, to date, much remains unknown about the best strategy to adopt to have a chance of winning medals. There is a possible knowledge transfer between Olympic scientific production and Paralympic performances [7], but the level and the nature of the para-athlete's impairment

should be considered. Research from able-bodied athletes may be more applicable to para-athletes with limb deficiency compared to spinal-cord-injured wheelchair racers exhibiting important physiological adaptations [8]. Thus, specific research is necessary to better understand the impact of physical, visual, and intellectual impairments on high-level performance in para-athletes.

The hypothesis of this study is that there is a positive and strong correlation between scientific production from a given country and their associated Paralympic podiums. This study aimed at (1) quantifying the link between the production of Paralympic scientific articles and the medals won by countries during Summer and Winter Paralympic Games between 2012 and 2022, (2) identify the scientific discipline that is most studied in Paralympic sports, and (3) select the five most important articles published for each Paralympic sport.

2. Materials and Methods

2.1. Literature Search

The data were obtained through a search in Web of Science (Clarivate™) followed by PubMed and then Google Scholar. The search terms were determined to align with the scope of the study. The search terms were as follows: Paralympic Sports, Classification, Exercise Physiology, Performance, Training, Testing, Injury, Biomechanics, Sports Medicine, Rehabilitation, Doping, Psychology, Thermoregulation, Prosthetics, Intellectual Disability, and Vision Impairment. Identifying articles in the literature targeting the improvement of performance in para-athletes who participated in the Summer and Winter Paralympics between 2012 and 2022 was conducted from the date of the database's inception to December 2022. Following retrieval, all citations were imported into EndNote V.20 (Clarivate™) where duplicate removal was performed. A total of 1351 articles published between 1989 and 2022 were identified, of which 525 articles fulfilled the inclusion and exclusion criteria (Figure 1). This narrative review was not registered.

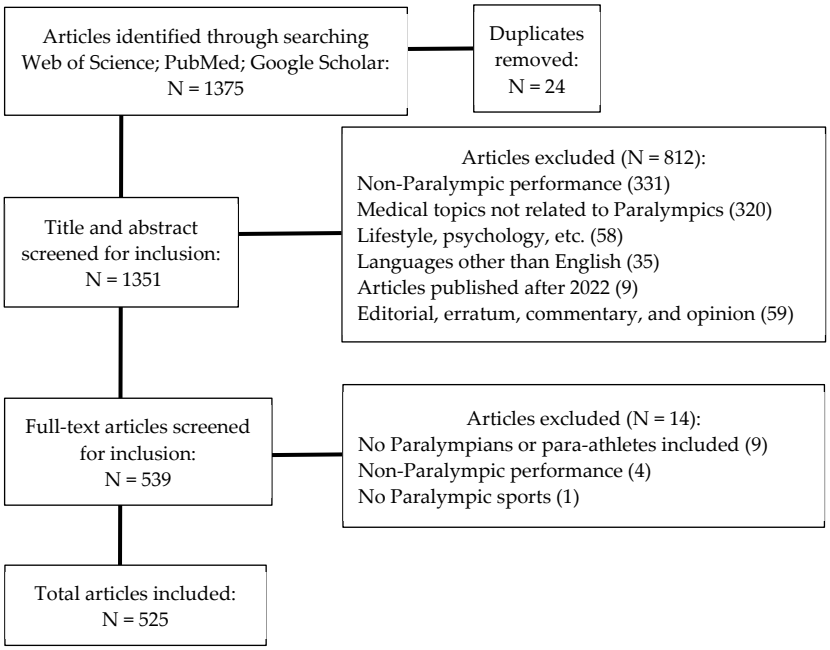

Figure 1. Flowchart of the literature search and review with inclusion/exclusion criteria.

2.2. Medal Counts

Statistics about countries' overall participation and medal counts as well as participation in each specific sport were extracted from the official International Paralympic Committee webpage for each of the Summer and Winter Paralympic Games under review. Medal counts for each Game and individual Summer and Winter sports were then tabulated. The total medal counts for London, Rio de Janeiro, and Tokyo (Summer Paralympics)

and Sochi, PyeongChang, and Beijing (Winter Paralympics) were then correlated to the article production per country.

2.3. Research Discipline

To establish the most important researched discipline, the title, abstract, and article content of all 525 articles were screened to establish a ranking. Included in the physiological discipline were performance, training, thermoregulation, and doping, while anthropometric, prosthetic/orthotics, and motor control were included in the biomechanical discipline.

2.4. Most Pertinent Articles

The most pertinent articles were selected through a three-step process. We first categorized the articles by sports; secondly, for each sport, we scored each article based on a Citation Index using the Web of Science Citation Report (Clarivate^{TM}). The Citation Index was calculated as follows:

$$\text{Citation Index} = \text{total citations} * 0.2 + \text{average citation per year} * 0.8 \quad (1)$$

where 0.2 and 0.8 are the associated weighting factors, respectively, for the total number of citations and the average number of citations per year. Finally, the pertinence of each article for a given sport was evaluated independently by two reviewers and a total of five articles per discipline were selected as the most important articles regarding Paralympic sports.

2.5. Data Analysis

The articles were separated between the Summer and Winter sports presented at all six Paralympic Games. All co-authors were identified and associated with their respective country. In the presence of co-authors from different countries, a given article could appear under several countries. For the Summer Paralympics, countries with at least 10 articles published over the period between 1989 and 2020 were considered in the final analysis. Due to the small number of articles pertaining to Winter Paralympics, countries with at least one article were considered over the period between 1989 and 2022. Countries who qualified based on their published articles but did not have participants in the Summer and Winter Paralympics under review were not included in the final analysis.

3. Results

The list of countries that contributed to the production of Paralympic scientific articles from 1989 to 2022 is detailed in Figure 2. Great Britain, Brazil, and Canada showed the greatest number of publications with 109, 92, and 68 articles, respectively, followed by the USA (61), Australia (54), and the Netherlands (52). The Summer Paralympics showed a much larger article production compared to the Winter Paralympics. As expected, countries without winter conditions offered little or no scientific contribution to the field of Winter sports (i.e., South Africa, Portugal, and Brazil). Surprisingly, Great Britain, who contributed largely to the Summer Paralympic sports with 112 articles, were not well represented, with only five articles dedicated to Winter Paralympic sports. On the other hand, Norway contributed almost equally in their production of Summer and Winter Paralympics articles.

For the Summer Paralympics, 20 sports were presented in London 2012, while 22 were presented in both Rio 2016 and Tokyo 2020. For the Winter Paralympics, five sports were presented in Sochi 2014 and six sports were presented in both PyeongChang 2018 and Beijing 2022 (Table 1). The Summer Paralympics attracts more than three times the number of para-athletes compared to the Winter Paralympics. During the Summer Paralympics, the total medal count reached 1509 in London and was up to 1617 medals in Tokyo, compared to 216 in Sochi and 240 in PyeongChang. This difference is mainly due to the limited number of disciplines presented during the Winter Paralympics.

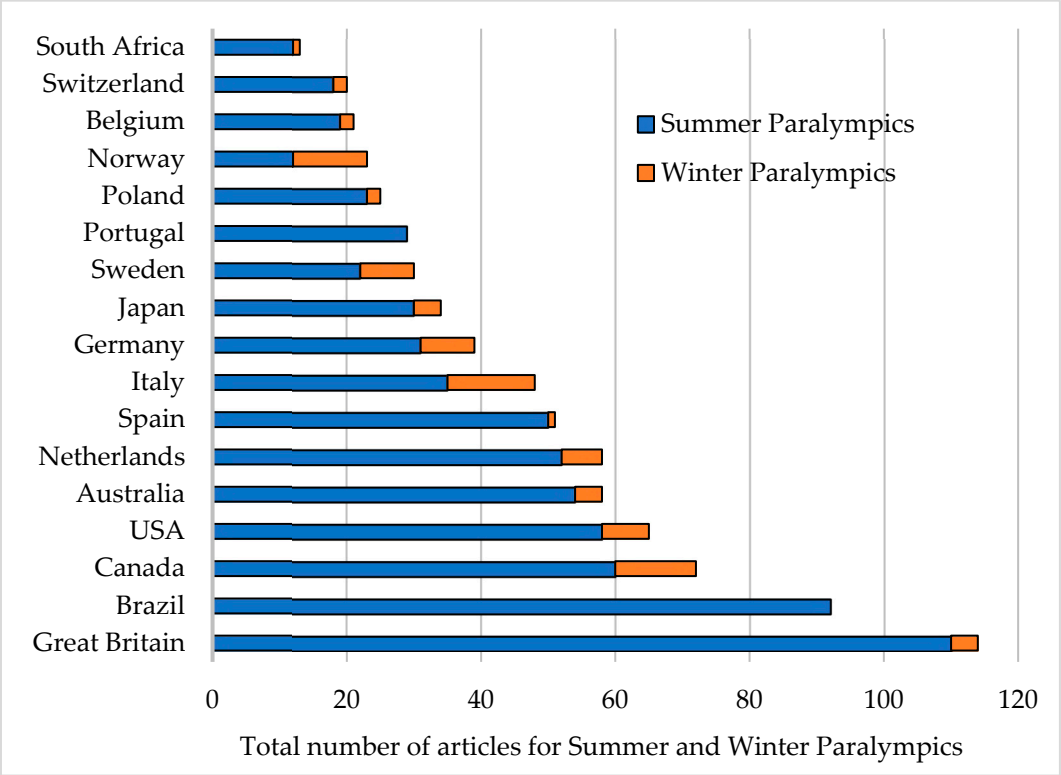

Figure 2. List of countries that contributed at least 10 articles on the Summer and Winter Paralympics between 1989 and 2022.

Table 1. Sports presented in Summer (2012–2020) and Winter (2014–2022) Paralympics.

Summer Paralympics			Winter Paralympics		
London 2012	**Rio 2016**	**Tokyo 2020**	**Sochi 2014**	**PyeongChang 2018**	**Beijing 2022**
Archery	Archery	Archery	Alpine Skiing	Alpine Skiing	Alpine Skiing
Athletics	Athletics	Athletics	Biathlon	Biathlon	Biathlon
		Badminton	Cross-Country Skiing	Cross-Country Skiing	Cross-Country Skiing
Blind Football	Blind Football	Blind Football	Ice Sledge Hockey	Ice Sledge Hockey	Ice Sledge Hockey
Boccia	Boccia	Boccia		Snowboarding	Snowboarding
	Canoeing	Canoeing	WC Curling	WC Curling	WC Curling
Cycling	Cycling	Cycling			
Equestrian	Equestrian	Equestrian			
Football (7-a-side)	Football (7-a-side)		Demonstration		
Goalball	Goalball	Goalball	Snowboarding		
Judo	Judo	Judo			
Powerlifting	Powerlifting	Powerlifting			
Rowing	Rowing	Rowing			
Sailing	Sailing				
Shooting	Shooting	Shooting			
Sitting Volleyball	Sitting Volleyball	Sitting Volleyball			
Swimming	Swimming	Swimming			
Table Tennis	Table Tennis	Table Tennis			
		Taekwondo			
	Triathlon	Triathlon			
WC Basketball	WC Basketball	WC Basketball			
WC Fencing	WC Fencing	WC Fencing			
WC Rugby	WC Rugby	WC Rugby			
WC Tennis	WC Tennis	WC Tennis			

3.1. Summer Paralympics

There was a total of 402 articles pertaining to the Summer Paralympics published between 1989 and 2021. The top five sports that were in the subjects of these articles were Athletics, Swimming, and Wheelchair (WC) Basketball, presented at the first Paralympics Games in Rome, 1960; Cycling, which was introduced in New York and Stoke Mandeville in 1984; and WC Rugby, which joined the Paralympics in Sydney, 2000. One year prior to the London 2012 Paralympic Games, we observed an important increase in scientific article production (Figure 3). Athletics and Swimming are the most studied, followed by Cycling, WC Basketball, and WC Rugby, which saw an important increase in scientific production starting in 2019.

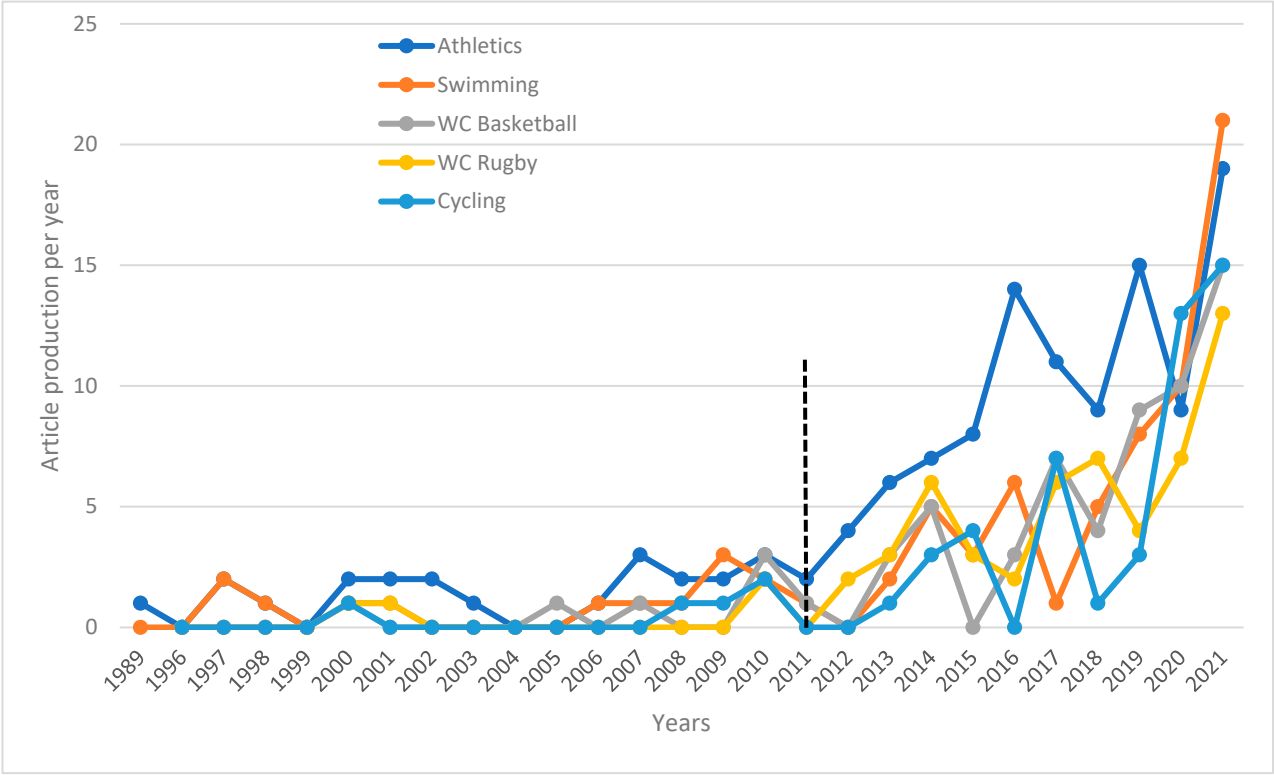

Figure 3. Progression of scientific article production for Athletics, Cycling, Swimming, WC Basketball, and WC Rugby. Article production increased strikingly after 2011.

The total number of podiums per country in relation to their scientific production is shown in Figure 4. Great Britain (391), the USA (317), and Australia (245) won the highest number of medals from the 2012 to the 2020 Summer Paralympics. Great Britain (112), Brazil (92), and Canada (60) showed the highest article production for Summer Paralympics. A strong correlation (r = 0.79) was established between the total number of medals and article production.

3.2. Winter Paralympics

For Winter Paralympics, there was a total of 64 articles published until 2022. The total number of podiums per country in relation to their scientific production is shown in Figure 5. Canada, Italy, and Norway showed the highest article production for Winter Paralympics with 14, 13, and 11 published articles, respectively, while Russia, the USA, Canada, China, and Germany dominated the number of podiums, with, respectively, 104, 74, 69, 62, and 53 medals each. Despite their low medal counts, Italy, Norway, and Sweden produced, respectively, 13, 11, and 8 articles. For the Winter Paralympics, the correlation between the number of articles and the total medal count is very low at r = 0.12 and can be explained by the fact that some countries (Russia and China) show a very high medal

count with a very low number of articles while others (Italy, Norway, and Sweden) show a high number of articles and a low number of medals.

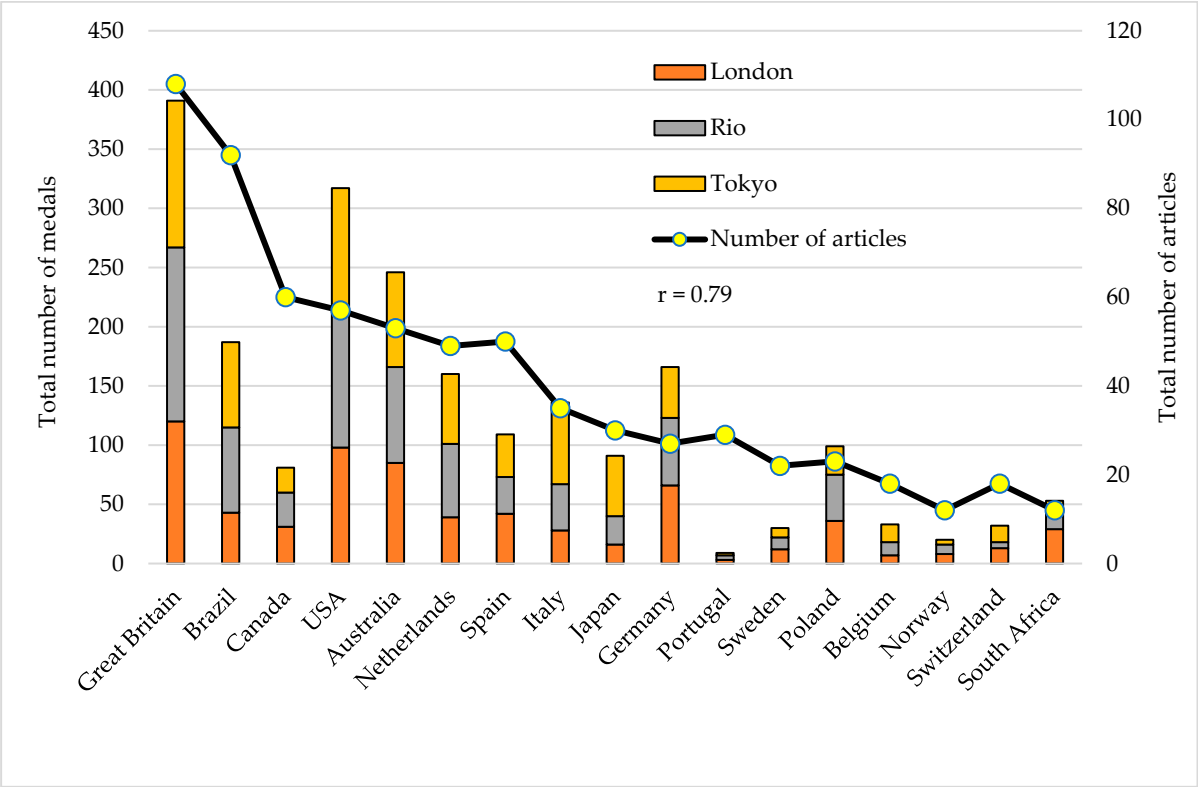

Figure 4. Total medal count and article production per country for three Summer Paralympic Games.

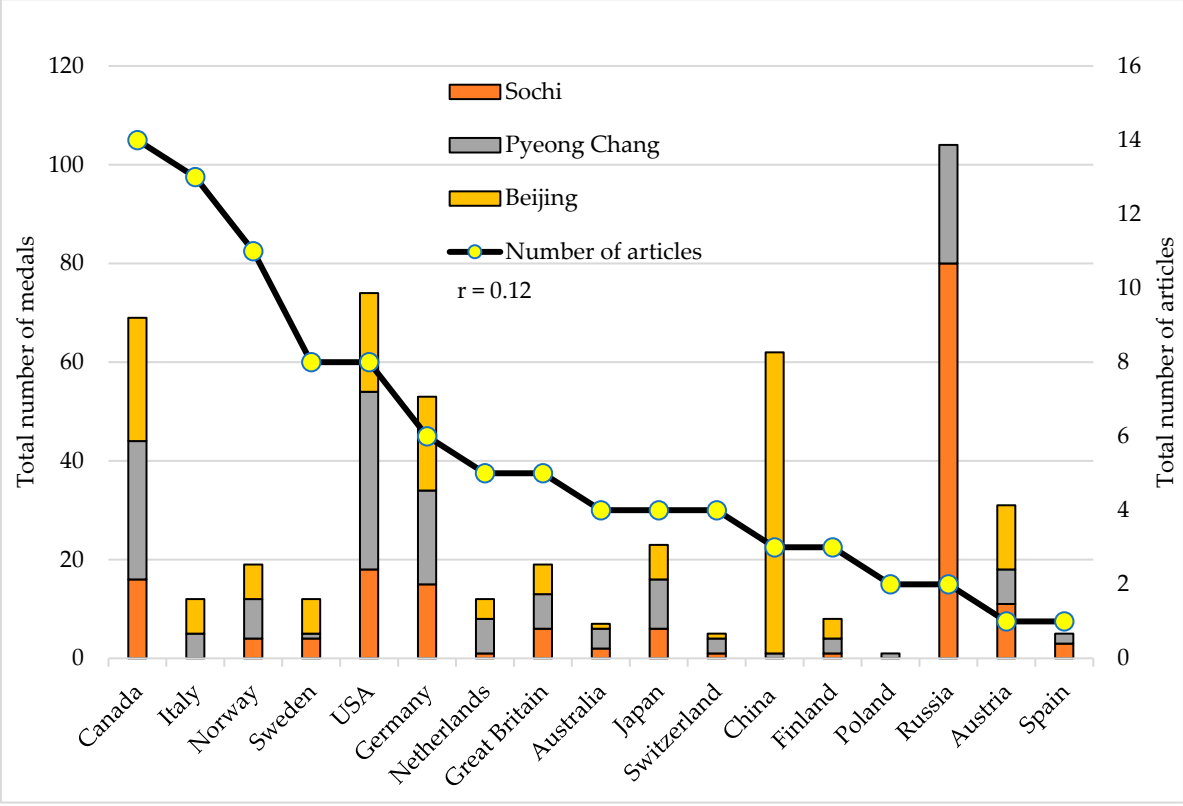

Figure 5. Total medal count and number of articles per country for three Winter Paralympic Games.

3.3. Main Research Disciplines

Among the 525 articles reviewed, as shown in Figure 6, the main research discipline was biomechanics, representing 49.1% (258 articles) of the total Paralympic scientific production. The second and third most important disciplines were physiology, 28.6% (150 articles), and psychology/social/impairment, 15.6% (82 articles). Finally, each of the following subgroups represented around 10% of the total Paralympic scientific production: (1) protocol, model, validity, and reliability; (2) classification, (3) injury, illness, medical, and rehabilitation.

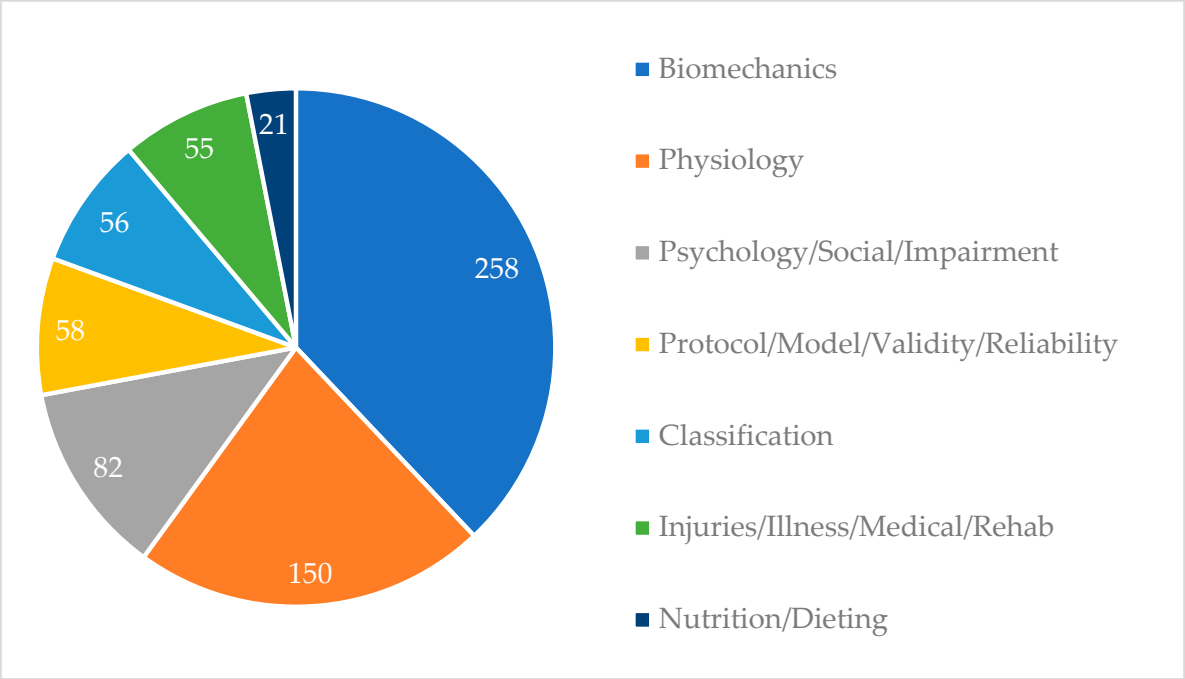

Figure 6. Number of Paralympic articles in main research categories.

Based on a modified approach from a previous study [2], a list of the top five articles per sport (with the exception of Snowboarding, with only two articles) are presented in Table 2 for Summer and Table 3 for Winter Paralympic sports. The current approach takes into consideration the fact that more recent publications are unlikely to show a high number of citations when compared to an article published 20 years ago. This list of articles provides scientific reading material for Paralympic sport organizations.

Table 2. Top five cited articles for each Summer Paralympic sport.

References	Title of the Article
1. Archery (total of 17 articles)	
Fagher and Lexell, 2014 [9]	Sports-related injuries in athletes with disabilities.
Ferrara et al., 2000 [10]	Injuries to athletes with disabilities—Identifying injury patterns.
Nakagawa et al., 2020 [11]	Cortical reorganization of lower-limb motor representations in an elite archery athlete with congenital amputation of both arms.
Kim et al., 2021 [12]	A feasibility study of kinematic characteristics on the upper body according to the shooting of elite disabled archery athletes.
Vendrame et al., 2021 [13]	Muscle synergies in archery: an explorative study on experienced athletes with and without physical disability.

Table 2. *Cont.*

References	Title of the Article
2. Athletics (140 articles)	
Bhambhani et al., 2002 [8]	Physiology of wheelchair racing in athletes with spinal cord injury.
Boninger et al., 1997 [14]	Three-dimensional pushrim forces during two speeds of wheelchair propulsion.
Silva et al., 2012 [15]	Sleep quality evaluation, chronotype, sleepiness and anxiety of Paralympic Brazilian athletes: Beijing 2008 Paralympic Games.
Bernardi et al., 2010 [16]	Field evaluation of Paralympic athletes in selected sports: Implications for training.
Ferrara et al., 2000 [10]	Injuries to athletes with disabilities—Identifying injury patterns.
3. Badminton (10 articles)	
Egger and Flueck, 2020 [17]	Energy availability in male and female elite wheelchair athletes over seven consecutive training days.
Alberca et al., 2022 [18]	Impact of Holding a Badminton Racket on Spatio-Temporal and Kinetic Parameters During Manual Wheelchair Propulsion.
Kim et al., 2019 [19]	Comparison of performance-related physical fitness and anaerobic power between Korean wheelchair badminton national and backup players.
Soares at al., 2022 [20]	Assistive technology for Para-badminton athletes: the application of the matching person and technology theoretical model in occupational therapy.
Oliveira et al., 2022 [21]	Heart rate, oxygen uptake, and energy expenditure response of an SL3 class parabadminton athlete to a progressive test and simulated training session: a case study.
4. Blind Football (5-a-side) (11 articles)	
Runswick et al., 2022 [22]	A valid and reliable test of technical skill for vision impaired football.
Magno e Silva et al., 2013 [23]	Sports injuries in Brazilian blind footballers.
Munoz-Jimenes et al., 2022 [24]	Analysis of Injuries and wellness in blind athletes during an International Football Competition.
Weiler et al., 2022 [25]	Monitoring the beautiful, adapted game: a 3-year prospective surveillance study of injuries in elite English Para football.
Fitzpatrick et al., 2021 [26]	Head impact forces in blind football are greater in competition than training and increased cervical strength may reduce impact magnitude.
5. Boccia (14 articles)	
Roldan et al., 2020 [27]	Inter-Rater Reliability, Concurrent Validity and Sensitivity of Current Methods to Assess Trunk Function in Boccia Players with Cerebral Palsy.
Roldan et al., 2017 [28]	Manual Dexterity and Intralimb Coordination Assessment to Distinguish Different Levels of Impairment in Boccia Players with Cerebral Palsy.
Sasaki and da Costa, 2021 [29]	Micronutrient deficiency in the diets of para-athletes participating in a sports scholarship program.
Marques and Alves, 2021 [30]	Investigating environmental factors and paralympic sports: an analytical study.
Rodriguez Macias et al., 2022 [31]	The sport training process of para-athletes: A systematic review.
6. Canoeing–Kayaking (17 articles)	
Ribeiro Neto et al., 2022 [32]	Internal and external training workload quantification in 4 experienced paracanoeing athletes.
Bjerkefors et al., 2019 [33]	Three-dimensional kinematics and power output in elite para-kayakers and elite able-bodied flat-water kayakers.
Heneghan et al., 2020 [34]	Lumbosacral injuries in elite Paralympic athletes with limb deficiency: a retrospective analysis of patient records.

Table 2. *Cont.*

References	Title of the Article
Rosen et al., 2019 [35]	Interrater reliability of the new sport-specific evidence-based classification system for para Va'a.
Ellis et al., 2018 [36]	The influence of lower-limb prostheses technology on paracanoeing time-trial performance.
7. Cycling (61 articles)	
Runciman et al., 2015 [37]	A descriptive comparison of sprint cycling performance and neuromuscular characteristics in able-bodied athletes and Paralympic athletes with cerebral palsy.
Stephenson et al., 2021 [38]	Physiology of handcycling: A current sports perspective.
Zeller et al., 2017 [39]	Monitoring training load in handcycling: A case study.
Groen et al., 2010 [40]	A power balance model for handcycling.
Zeller et al., 2015 [41]	Influence of noncircular chainring on male physiological parameters in hand cycling.
8. Equestrian (14 articles)	
Fagher and Lexell, 2014 [9]	Sports-related injuries in athletes with disabilities.
Ferrara and Peterson, 2000 [10]	Injuries to athletes with disabilities—Identifying injury patterns.
Jaarsma et al., 2014 [42]	Barriers and facilitators of sports in Dutch Paralympic athletes: An explorative study.
Sasaki and da Costa, 2021 [29]	Micronutrient deficiency in the diets of para-athletes participating in a sports scholarship program.
Fagher et al., 2020 [43]	Prevalence of sports-related injuries and illnesses in Paralympic athletes.
9. Football (7-a-side) (34 articles)	
Reina et al., 2019 [44]	Kinematic and kinetic analyses of the vertical jump with and without header as performed by para-footballers with cerebral palsy.
Reina et al., 2015 [45]	Change of direction ability performance in cerebral palsy football players according to functional profiles.
Reina et al., 2018 [46]	Vertical and horizontal jump capacity in international cerebral palsy football players.
Reina et al., 2020 [47]	Activity limitation and match load in para-footballers with cerebral palsy: An approach for evidence-based classification.
Yanci et al., 2018 [48]	External match loads of footballers with cerebral palsy: A comparison among sport classes.
10. Goalball (23 articles)	
Alves et al., 2018 [49]	Relationships between aerobic and anaerobic parameters with game technical performance in elite goalball athletes.
Petrigna et al., 2020 [50]	Physical fitness assessment in goalball: A scoping review of the literature.
Balci et al., 2021 [51]	The relationships between isometric muscle strength and respiratory functions of the Turkish National Paralympic goalball team.
Molik et al., 2015 [52]	Game performance evaluation in male goalball players.
Goulart-Siqueira, 2019 [53]	Relationships between different field test performance measures in elite goalball players.
11. Judo (30 articles)	
Kraben et al., 2019 [54]	The development of evidence-based classification of vision impairment in judo: A Delphi study.
Mashkovskiy et al., 2019 [55]	Degree of vision impairment influence the fight outcomes in the Paralympic judo: a 10-year retrospective analysis.

Table 2. *Cont.*

References	Title of the Article
Kons et al., 2019 [56]	The effect of vision impairment on competitive and technical-tactical performance in judo: Is the present system legitimate?
Krabben et al., 2021 [57]	May the best-sighted win? The relationship between visual function and performance in para judo.
Loturco et al., 2017 [58]	Performance changes of elite paralympic judo athletes during a Paralympic Games cycle: A case study with the Brazilian National team.
12. Powerlifting (50 articles)	
Fraga et al., 2020 [59]	Effects of ibuprofen intake in muscle damage, body temperature and muscle power in Paralympic powerlifting athletes.
Soares et al., 2020 [60]	Can creatine supplementation interfere with muscle strength and fatigue in Brazilian National level Paralympic powerlifting?
Teles et al., 2021 [61]	Static and dynamic strength indicators in Paralympic power lifters with and without spinal cord injury.
Loturco et al., 2019 [62]	Load-velocity relationship in National Paralympic powerlifters: A case study.
Paz et al., 2020 [63]	Comparison of post-exercise hypotension responses in Paralympic powerlifting athletes after completing two bench press training intensities.
13. Rowing (22 articles)	
Schaffert and Mattes, 2015 [64]	Effects of acoustic feedback training in elite-standard para-rowing.
Smoljanovic et al., 2011 [65]	Rib stress fracture in a male adaptive rower from the arms and shoulders sport class: A case report.
Porto et al., 2008 [66]	Anthropometric and physical characteristics of motor disability in paralympic rowers.
Nowak et al., 2017 [67]	The impact of the progressive efficiency test on a rowing ergometer on white blood cells distribution and clinical chemistry changes in Paralympic rowers during the preparatory stage.
Vieira et al., 2018 [68]	Design and test of a biomechanical model for the estimation of knee joint angle during indoor rowing: Implications for FES-rowing protocols in paraplegia.
14. Sailing (17 articles)	
Neville and Folland, 2009 [69]	The epidemiology and aetiology of injuries in sailing.
Ferrara and Peterson, 2000 [10]	Injuries to athletes with disabilities—Identifying injury patterns.
Gutierrez-Manzanedo et al., 2021 [70]	Sun-related behaviors, attitudes, and knowledge among paralympic sailors.
Caraballo et al., 2021 [71]	Performance analysis of Paralympic 2.4mR class sailing.
Fagher et al., 2022 [72]	Mental health, sleep, and pain in elite para-athletes and the association with injury and illness—A prospective study.
15. Shooting (19 articles)	
Allen et al., 2018 [73]	Contrast sensitivity is a significant predictor of performance in rifle shooting for athletes with vision impairment.
Allen et al., 2016 [74]	The level of vision necessary for competitive performance in rifle shooting: Setting the standards for Paralympic shooting with vision impairment.
Castle et al., 2013 [75]	Partial heat acclimation of athletes with spinal cord lesion.
Allen et al., 2021 [76]	Perspectives of a new sport-specific para-shooting classification system for athletes with vision impairment.
Myint et al., 2016 [77]	The relationship between visual function and performance in rifle shooting for athletes with vision impairment.

Table 2. *Cont.*

References	Title of the Article
16. Sitting Volleyball (15 articles)	
Gawel and Zwierzchowska, 2021 [78]	Effect of compensatory mechanisms on postural disturbances and musculoskeletal pain in elite sitting volleyball players: Preparation of a compensatory intervention.
Krzysztofik et al., 2021 [79]	The acute post-activation performance enhancement of the bench press throw in disabled sitting volleyball athletes.
Ahmadi et al., 2020 [80]	Asymmetry in glenohumeral muscle strength of sitting volleyball players: an isokinetic profile of shoulder rotations strength.
Petrigna et al., 2022 [81]	How physical fitness is evaluated in sitting volleyball players. A scoping review
Cavedon et al., 2022 [82]	Physique and performance in male sitting volleyball players: Implications for classification and training.
17. Swimming (89 articles)	
Edmonds et al., 2015 [83]	Effect of chronic training on heart rate variability, salivary IgA and salivary alpha-amylase in elite swimmers with a disability.
Burkett et al., 2010 [84]	The influence of swimming start components for selected Olympic and Paralympic swimmers.
Fulton et al., 2009 [85]	Variability and progression in competitive performance of Paralympic swimmers.
Burkett et al., 2018 [86]	Performance characteristics of para-swimmers. How effective is the swimming classification system?
Hogarth et al., 2021 [87]	Modelling the age-related trajectory of performance in para-swimmers with physical, vision and intellectual impairment.
18. Table Tennis (27 articles)	
Van Biesen et al., 2016 [88]	Cognitive predictors of performance in well-trained table tennis players with intellectual disability.
Lim et al., 2018 [89]	Applications of psychological skills training for Paralympic table tennis athletes.
Van Biesen et al., 2014 [90]	Comparing technical proficiency of elite table tennis players with intellectual disability: Simulation testing versus game play.
Duvall et al., 2021 [91]	Design of an adjustable wheelchair for table tennis participation.
Morrien et al., 2017 [6]	Biomechanics in Paralympics: Implications for Performance.
19. Taekwondo (5 articles)	
O'Sullivan et al., 2022 [92]	Functional reaction times of a simulated blocking yest among Para taekwondo athletes.
Davalli et al., 2021 [93]	Types and severity of physical impairments of para taekwondo athletes.
Wakefield-Scurr et al., 2022 [94]	A multi-phase intervention study of sports bra prescription for elite UK female athletes preparing for the Tokyo Olympics and Paralympics.
Fagher and Lexell, 2014 [9]	Sports-related injuries in athletes with disabilities.
McNamara et al., 2022 [95]	'That time of the month' horizontal ellipsis for the biggest event of your career! Perception of menstrual cycle on performance of Australian athletes training for the 2020 Olympic and Paralympic Games.
20. Triathlon (17 articles)	
Mujika et al., 2015 [96]	Physiology and training of a world-champion para triathlete.
Baumgart et al., 2018 [97]	Peak oxygen uptake in Paralympic sitting sports: A systematic literature review, meta- and pooled-data analysis.
Stephenson et al., 2020 [98]	High thermoregulatory strain during competitive paratriathlon racing in the heat.

Table 2. *Cont.*

References	Title of the Article
Stephenson et al., 2019 [99]	Mixed active and passive, heart rate-controlled heat acclimation is effective for Paralympic and able-bodied triathletes.
Stephenson et al., 2019 [100]	A multifactorial assessment of elite para triathletes' response to 2 weeks of intensified training.
21. WC Basketball (82 articles)	
Goosey-Tolfrey et al., 2013 [101]	Field-based physiological testing of wheelchair athletes.
Gomez et al., 2014 [102]	Performance analysis of elite men's and women's wheelchair basketball teams.
Vanlandewijck et al., 2011 [103]	Towards evidence-based classification in wheelchair sports: Impact of seating position on wheelchair acceleration.
De Lira et al., 2010 [104]	Relationship between aerobic and anaerobic parameters and functional classification in wheelchair basketball players.
Wang et al., 2005 [105]	Contributions of selected fundamental factors to wheelchair basketball performance.
22. WC Fencing (15 articles)	
Borysiuk et al., 2020 [106]	Neuromuscular, perceptual, and temporal determinants of movement patterns in wheelchair fencing: Preliminary study.
Borysiuk et al., 2022 [107]	Correlations between the EMG structure of movement patterns and activity of postural muscles in able-bodied and wheelchair fencers.
Blaszczyszyn et al., 2021 [108]	Wavelet coherence as a measure of trunk stabilizer muscle activation in wheelchair fencers.
Villiere et al., 2021 [109]	The physical characteristics underpinning performance of wheelchair fencing athletes: A Delphi study of Paralympic coaches.
Borysiuk et al., 2022 [110]	Movement patterns of Polish National Paralympic team wheelchair fencers with regard to muscle activity and co-activation time.
23. WC Rugby (71 articles)	
Altmann et al., 2018 [111]	Classifying trunk strength impairment according to the activity limitation caused in wheelchair rugby performance.
Paulson and Goosey-Tolfre, 2017 [112]	Current perspectives on profiling and enhancing wheelchair court sport performance.
Rhodes et al., 2015 [113]	Effect of team rank and player classification on activity profiles of elite wheelchair rugby players.
Paulson et al., 2015 [114]	Individualized internal and external training load relationships in elite wheelchair rugby players.
West et al., 2014 [115]	Effects of inspiratory muscle training on exercise responses in Paralympic athletes with cervical spinal cord injury.
24. WC Tennis (30 articles)	
Diaper and Goosey-Tolfrey, 2009 [116]	A physiological case study of a paralympic wheelchair tennis player: reflective practise.
Bernardi et al., 2010 [16]	Field evaluation of Paralympic athletes in selected sports: Implications for training.
Churton and Keogh 2013 [117]	Constraints influencing sports wheelchair propulsion performance and injury risk.
Stephenson et al., 2022 [118]	Ice slurry ingestion lowers thermoregulatory strain in wheelchair tennis players during repeated sprint intervals in the heat.
Vanlandewijck et al., 2011 [119]	Towards evidence-based classification in wheelchair sports: Impact of seating position on wheelchair acceleration.

Table 3. Top five cited articles for each Winter Paralympic sport.

References	Title of the Article
1. Alpine Skiing (29 articles)	
Bernardi et al., 2012 [120]	Physical fitness evaluation of Paralympic winter sports sitting athletes.
Blauwet et al., 2019 [121]	When van Mechelen's sequence of injury prevention model requires pragmatic and accelerated action: The case of para-alpine skiing in Pyeong Chang 2018.
Oh et al., 2019 [122]	Winter adaptive sports participation, injuries, and equipment.
Petrone et al., 2021 [123]	The effect of foot setting on kinematic and kinetic skiing parameters during giant slalom: A single subject study on a Paralympic gold medalist sit skier.
Stalin et al., 2021 [124]	Do impairments in visual functions affect skiing performance?
2. Biathlon (12 articles)	
Pernot et al., 2011 [125]	Validity of the test-table-test for Nordic skiing for classification of paralympic sit-ski sports participants.
Stalin and Dalton, 2021 [126]	Exploration of the minimum visual disability criteria for para-Nordic and para-alpine skiing using simulated vision impairments.
Stalin et al., 2021 [124]	Do impairments in visual functions affect skiing performance?
Bernardi et al., 2012 [120]	Physical fitness evaluation of Paralympic winter sports sitting athletes.
Song et al., 2020 [127]	Sports-related injuries sustained by disabled athletes in winter Paralympic games: A systematic review.
3. Cross-Country Skiing (31 articles)	
Gastaldi et al., 2016 [128]	Analysis of the pushing phase in Paralympic cross-country sit-skiers—Class LW10.
Gastaldi et al., 2012 [129]	A biomechanical approach to Paralympic cross-country sit-ski racing.
Pernot et al., 2011 [125]	Validity of the test-table-test for Nordic skiing for classification of paralympic sit-ski sports participants.
Bernardi et al., 2013 [130]	Kinematics of cross-country sit skiing during a Paralympic race.
Rosso et al., 2018 [131]	Balance perturbations as a measurement tool for trunk impairment in cross-country sit skiing.
4. Ice Sledge Hockey (20 articles)	
Molik et al., 2012 [132]	Game performance in ice sledge hockey: An exploratory examination into type of disability and anthropometric parameters.
Hawkeswood et al., 2011 [133]	A pilot survey on injury and safety concerns in international sledge hockey.
Sandbakk et al., 2014 [134]	The effects of heavy upper-body strength training on ice sledge hockey sprint abilities in world class players.
Skovereng et al., 2013 [135]	On the relationship between upper body strength, power, and sprint performance in ice sledge hockey.
Berthold et al., 2013 [136]	Pressure mapping to assess seated pressure distributions and the potential risk for skin ulceration in a population of sledge hockey players and control subjects.
5. Snowboarding (2 articles)	
Fagher and Lexell, 2014 [9]	Sports-related injuries in athletes with disabilities.
Song et al., 2020 [127]	Sports-related injuries sustained by disabled athletes in winter Paralympic games: A systematic review.
6. WC Curling (12 articles)	
Fairbairn and Huxel Bliven, 2019 [137]	Incidence of shoulder injury in elite wheelchair athletes differ between sports: A critically appraised topic.
Rum et al., 2021 [138]	Wearable sensors in sports for persons with disability: A systematic review.
Laschowski et al., 2017 [139]	Inverse dynamics modeling of Paralympic wheelchair curling.
Bernardi et al., 2012 [120]	Physical fitness evaluation of Paralympic winter sports sitting athletes.
Madden et al., 2017 [140]	Evaluation of dietary intakes and supplement use in Paralympic athletes.

4. Discussion

The present study shows a strong positive correlation between publishing sport related scientific articles and winning podiums at the Summer Paralympics, while a weaker link was established for the Winter Paralympics. This study also brings to light the much larger visibility of the Olympics and the associated scientific interest, with more than 34,000 related articles published [2] compared to 1351 for the Paralympics. This phenomenon can be attributed to the later entry of the Paralympic Games (1960) compared to the Olympic Games (1896) and the difference in the number of nations, athletes, and events. For example, in the Summer Paralympics of 2020, 162 nations sent a total of 4393 para-athletes to participate in 539 different events, while in the Summer Olympics of the same year, 11,420 athletes from 206 nations participated in 339 events. Two years later, for the 2022 Winter Paralympics, 46 nations sent a total of 564 para-athletes to participate in 78 different events. In the Beijing Winter Olympics, 2871 athletes from 91 nations participated in 109 events. Globally, over the last four decades, there has been a constant progression in the number of participating nations and para-athletes, while the number of sports and disciplines has remained relatively constant.

In a comprehensive bibliometric study of Olympic sports [2], the authors selected a total of 25,003 published articles, while the current study on Paralympic sports was based on 525 selected articles. In the present article, we compared countries' scientific productivity with their number of Paralympic podiums between 2012 and 2022. With this aim, countries without ample scientific production (less than ten articles for Summer Paralympics and less than one for Winter Paralympics) were excluded from the analysis. For example, France, who won 55 medals in the Summer and 44 medals in the Winter Paralympics, were excluded from the final analysis because they had a production of scientific papers below the established threshold. Between 2012 and 2020, Russia and China won 220 and 677 medals and produced only five and six articles, respectively, for the Summer Paralympics, and won 104 and 62 medals and produced two and three articles, respectively, for the Winter Paralympics. This statement brings to light the fact that some countries may be conducting a lot of research in parasports but choose not to publicly disseminate their results in English-speaking journals.

Notwithstanding the overall low production of scientific research in the field of Paralympics, the number of articles is increasing across many parasports, with the total production ranging from 40 to 54 articles in Cycling, Athletics, Swimming, WC Basketball, and WC Rugby. This increase in scientific production is most apparent following the London 2012 Paralympic Games.

While Millet et al., 2021 [2] selected their most important articles based on the number of citations, the current paper used a weighting factor by considering that a recently published paper will have less citations than a paper published several years ago. Our five most cited articles were based on a weighting factor between the average number of citations per year (80%) and the total number of citations (20%). This approach allowed us to consider more-recent articles, mainly from the last decade, while, for example, Millet et al. (2019) reported on articles as old as 1969 in Cycling. The sport scientific results from the late sixties are probably not as pertinent today and useful for coaching staff and the enhancement of athlete's performance. Furthermore, technology and protocols have also greatly evolved in sport sciences. Our research can provide coaches and sport scientists with the most relevant papers based on our selection criteria. As a global health initiative, reading these selected papers may encourage and improve coaches' perspectives to include para-athletes within their teams and clubs.

Surprisingly, this paper shows that the biomechanical discipline was the most important studied discipline in Paralympic literature, while Millet et al. 2021 [2] reported physiology as the most important studied discipline in Olympic sports. This can be explained by (1) the methodological approach used by Millet et al. (2021) [2], who chose 116 journals as a selecting criterion, (2) the fact that only three of the 116 selected journals were biomechanical journals, and (3) the fact that in many Paralympic sports, such as WC

Racing, biomechanical evaluation of the equipment and technique is the focus of many papers [5,6]. Furthermore, the current paper based its search on the title, abstract, keywords, and content of each article in order to categorize its discipline, as compared to Millet et al. (2021) [2], who used only the title of the article without considering the information included in the keywords and abstract in order to attribute a scientific discipline to a paper. The limitations of the present study include the fact that the word "Paralympic sport" was one of the keywords. As a result, some sport-specific articles might have been omitted if this word was not included in the title, abstract, or keywords.

Because the odds of making it to a Summer Paralympic podium is linked to the production of parasport-related scientific articles, it is highly recommended that coaches make use of this research-driven data to enhance the performance of their para-athletes. Coaches are invited to share their thoughts, needs, and ideas with researchers to create more research opportunities and publications for improving performance.

5. Conclusions

This article showed a strong link between scientific productivity and the number of medals won for countries during the 2012 to 2020 Summer Paralympic Games, while almost no link was shown for the Winter Paralympics during the 2014 to 2022 period. This paper also identified biomechanics as the most important discipline studied in Paralympics-related scientific production. This paper provides the five most pertinent scientific articles for each parasport that coaches should be aware of and use to enhance paralympic performances. To improve the chance of making it to a podium, national and international Sports Federations are strongly encouraged to promote and use Paralympic scientific publications.

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