REVIEW ARTICLE

Scientific support for strength sports: analysis of scientific resources from the Web of Science Core Collection

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Abstract

Background and Study Aim Strength is a key physical attribute that contributes to success in sports. Strength training plays a crucial role in enhancing athletes' physical condition, improving skill levels, and achieving competitive success. This study aims to analyze publications on strength sports using bibliometric methods to identify priority research areas in this field.

Material and Methods The Web of Science Core Collection (WoS) bibliometric database was analyzed. A total of 589 sources published between 2021 and 2025 that met the search criteria were selected for primary analysis. Bibliometric methods were applied to process the data. VOSviewer 1.6.18 software was used for keyword analysis and direct citation analysis, including the construction of bibliometric maps, cluster density visualization, and weighted citation analysis.

Results The leading publication categories in WoS were Sports Sciences, Physiology, Orthopedics, Hospitality, Leisure, Sport, Tourism, and Rehabilitation. The highest number of publications appeared in 2022 and 2024. The top five countries in terms of publication output were Spain, Brazil, England, the USA, and Australia. The top five universities with the highest publication activity were identified. The most cited authors were also determined. The constructed bibliometric maps helped identify the main research themes and current directions in strength sports. Six research clusters were identified, covering the following topics: strength training in sports, rehabilitation and return to sport after injuries, athlete performance dynamics under strength training, strength training in fitness, strength development across different sports, and the impact of nutrition on training effectiveness. The keywords associated with each cluster were analyzed.

Conclusions A bibliometric analysis of the WoS database on strength sports has been conducted. The priority research directions in this field have been identified. These include sports-related topics, such as strength training methods, testing, and evaluation of athletes' strength, as well as rehabilitation and recreational aspects, including strength training for recovery, rehabilitation after injuries, and injury prevention. Various tests and assessment methods are used to evaluate athletes' strength. These methods must meet the principles of specificity, simplicity, reliability, and practicality. The most commonly used assessments include body composition indices, anthropometric criteria, and strength performance measures. Among strength exercises, the most frequently analyzed are the bench press, grip strength, squats, and jumps. The effectiveness of these tests for athlete monitoring, selection, and performance prediction has been confirmed.

Keywords: strength sports, bibliometric mapping, VOSviewer.

Introduction

Strength training plays a fundamental role in sports performance, influencing athletes' physical capabilities, endurance, and overall success. Over the past decades, research on strength sports has expanded significantly, covering various aspects such as training methodologies, physiological adaptations, injury prevention, and rehabilitation. The increasing scientific interest in this field is reflected in a growing number of publications exploring the optimization of strength training programs and their effects on athletic performance. Given the diverse applications of strength training across competitive sports, fitness, and rehabilitation, a systematic analysis of existing scientific literature indicates the need to search for key research trends and priority areas for future investigations.

In this context, many studies provide detailed results on the physiological effects of strength training, including its role in sports performance, rehabilitation after injuries, injury prevention, fitness applications, and strength development across various sports. Strength is a fundamental physical quality that determines success in sports, and strength training serves as a key tool for enhancing athletes' physical condition, improving

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skill levels, and achieving competitive success [1, 2]. It is widely applied across different sports disciplines [3, 4, 5, 6, 7], with strength indices commonly used to assess training effectiveness. Strength analysis plays a crucial role in monitoring athletes' condition in team sports [4, 6, 8, 9], swimming [10], martial arts [11, 12, 13, 14], and rock climbing [15, 16, 17]. These indicators serve as predictors of success and contribute to forecasting performance progression. Effective athlete training requires continuous monitoring of key physical attributes [18, 19, 20], with strength being one of the most significant. The selection of appropriate tests for strength assessment is essential for optimizing the training process, yet this task is complicated by the vast array of available tests and measurement methods.

Strength exercises have been known to humanity since ancient times, with the origins of weightlifting and strength feats traced back to ancient Egypt, China, and Greece. However, it was not until the 1950s that strength training began to be incorporated into team sports and athletics, while research on weightlifting in peer-reviewed journals became prominent in the 1970s [21]. Strength sports (SS) are distinguished by their primary focus on strength training and encompass a broad range of disciplines, including weightlifting, kettlebell lifting, powerlifting, bodybuilding, and arm wrestling. These sports enjoy high popularity among both young people and adults [22, 23, 24, 25], and their accessibility makes them suitable for fitness recommendations [22, 24, 26]. Although most SS are not part of the Olympic program, this does not diminish their popularity or the high level and spectacle of competitions. This growing interest underscores the need for scientific support in SS, with key objectives including enhancing athletic performance and skill development. Achieving these goals requires the optimization of athlete monitoring and the implementation of reliable, informative tests and functional assessments.

The results of the study [27] confirmed the possibility of using the index method to assess the condition of armwrestling athletes of different skill levels. Experienced lifters were characterized by high values of indices reflecting muscle development. These include body mass, shoulder width, the Erisman index, Livi index, Vervek index, body surface and relative body surface indices, and the strength index. The indices of massiveness and conditional moments of strength of limb segments were highly informative and served as predictors of success in armwrestling.

A study [28] analyzed the influence of kettlebell lifting exercises on the development of strength qualities in military school cadets. A set of test exercises assessing the strength of individual muscle groups was used as an evaluation tool. The effectiveness of kettlebell exercises in improving the physical fitness of future officers was confirmed.

A comparative analysis of the effect of kettlebell exercises and rowing machine exercises on adaptation status was conducted [29]. An increase in oxygen consumption and heart rate was observed, leading to the conclusion that kettlebell exercises provide an adequate aerobic stimulus for improving the cardiorespiratory system.

The growing popularity of powerlifting has led to a significant amount of research aimed at evaluating competitive performance and identifying predictors of success [30, 31, 32]. A study [30] analyzed competitive performance strategy in powerlifting, assessing key factors through regression analysis and reporting them as odds ratios. The likelihood of victory increased when lifters selected a higher weight for their initial squat attempt compared to their competitors and successfully completed the lift. The initial squat attempt is considered one of the most critical exercises during competition.

In another study [32], the effect of competition frequency on the strength of powerlifting athletes (both relative and absolute) was examined. Strength performance was assessed based on competition scores, confirming that an increase in the success rate was associated with the number of competitions. An upper limit of four competitions per year was identified as the threshold affecting success.

An analysis of para powerlifting athletes' performances [31] identified absolute and relative load, chronological age, and the nature of health disorders (congenital or acquired) as key evaluation criteria. Correlations between performance and these factors were confirmed, leading to the recommendation that they should be considered when designing training programs.

Similar results were obtained, as shown in the study [33], where the authors examined the influence of relative age on athletes' success in top-level modern wrestling competitions. Age as a predictor was most evident at the cadet level.

An analysis of grip strength indicators in armwrestling athletes was conducted, as described in the study [34]. The specificity of the sport necessitates studying grip strength in both static and impulse modes. Additionally, somatotype characteristics play a crucial role in armwrestling success. These indicators serve as predictors of performance in the sport.

The condition of kettlebell lifting athletes was analyzed using anthropometric, physiological, and electromyographic methods, as reported in the study [35]. Training in an aerobic mode induces high physiological stress and requires significant energy expenditure. Optimal exercise technique enables athletes to maximize their potential and helps prevent injuries.

In another study [36], the influence of kettlebell lifting on endurance development and adaptive capabilities was examined. The findings indicated an increase in endurance and an expansion of adaptive potential due to the optimization of cardiovascular system indices (pulse, blood pressure), improved physiological parameters derived from these indices, and enhanced tolerance to physical loads.

A comparative analysis of morphological and functional indices in armwrestling and street wrestling athletes was conducted, as shown in the study [37]. The findings confirmed the specific influence of these sports on athletes' physical characteristics. Grip strength was identified as one of the key predictors of success in both disciplines. The informativeness of grip strength indices in pulse mode for monitoring the functional state of athletes was also established.

The trajectory of kettlebell lifting was analyzed, as shown in the study [23]. The results enabled researchers to estimate strength indices across different phases of the jerk exercise. Additionally, the data allowed for predictions regarding the dynamics of athletes' condition and contributed to optimizing their training.

Similar results were obtained, as shown in the study [38]. The authors evaluated the biomechanical characteristics of strongmen when lifting the Atlas stone, dividing the process into five phases. Each phase was characterized by specific joint movements. Differences in movement execution based on gender and performance level were identified. The findings were proposed to inform training adaptations and enhance performance in weightlifting.

Training with kettlebells has been proposed as an alternative to weightlifting [24, 26]. It contributes to increased strength, power, and endurance in traditional weightlifting exercises. One of its key advantages is its applicability beyond professional and elite lifters.

The existing research confirms the relevance and significance of scientific support for strength sports. A bibliometric analysis of available studies will provide a comprehensive examination of the issue and identify leading research directions.

This study aims to analyze publications on strength sports using the bibliometric method and establish priority scientific directions in this field.

Methodology

Data sources

The Web of Science Core Collection (WoS) bibliometric database was selected for analysis as of November 6, 2024. The research sample was formed using the keywords "strength sports" and "strength sport" for the period 2021–2025. A total of 589 publications were included in the sample. The highest number of publications appeared in 2022 (138, 23.4%) and 2024 (133, 22.6%).

The WoS database enables an initial analysis of the top five main categories and indicators within the sample. The results of this analysis are presented in Table 1.

Method of Study

The WoS database was used to identify priority trends in strength sports (SS) research. The review period covered 2021–2025. The primary search results are presented in Table 1.

The data in Table 1 confirm the strong sports orientation of the publications, as reflected in the structure of the publication categories. The majority of publications in the sample (over 70%) align with this focus. In this context, studies categorized under *Sport Sciences, Physiology,* and *Rehabilitation* are of particular interest. An analysis of publication frequency by country, journal, and institution indicates no pronounced dominance by any single entity.

Data analysis

Bibliometric methods were applied to identify priority research areas in strength sports (SS). VOSviewer 1.6.18 [39] was used as the primary tool, enabling the construction and visualization of bibliometric networks for further analysis. Keyword analysis [40] and direct citation analysis [41] were employed. The methodology for calculating

Table 1. Results of the analysis of Web of Science category fields

Analysis Indicator	Items (N; %)
Subject area (top 5 items)	Sport Sciences (351; 59.6%), Physiology (62; 10.5%), Orthopedics (49; 8.3%), Hospitality, Leisure, Sport, Tourism (45; 7.6%), Rehabilitation (38; 6.5%)
Country (top 5 items)	Spain (109; 18.5%), Brazil (94; 15.6%), England (88; 14.9%), USA (83; 14.1%), Australia (73; 12.4%)
Journals (top 5 items)	Journal of Strength and Conditioning Research (32; 5.4%), Sports (25; 4.2%), International Journal of Environmental Research and Public Health (21; 3.6%), International Journal of Sports Physiology and Performance (19; 3.2%), Frontiers in Physiology (18; 3.1%)
Institutions (top 5 items)	Universidad Andres Bello (26; 4.4%), Edith Cowan University (22; 3.7%), Auckland University of Technology (19; 3.2%), University of the Basque Country (16; 2.7%), Universidade de São Paulo (15; 2.5%)

Note: The source of information is the authors› research (November 6, 2024).

key indicators to analyze and identify the most significant research categories was outlined by van Eck and Waltman [42].

Priority research areas were determined based on the most cited references. The results were graphically represented as bibliometric maps and summarized in tables containing bibliometric characteristics of keywords. The fundamental principle of these maps is that the distance between items reflects the strength of the link between them, with smaller distances indicating stronger relationships.

To enhance the depth of the study and strengthen scientific argumentation, the methodological technique of double citation was applied in the analysis [43].

Results

The sample was analyzed based on the authors' keywords, totaling 1,430 unique terms. To enhance the quality of the analysis, only keywords that appeared at least 10 times were selected, resulting in a final set of 37 keywords. The analysis enabled the creation of corresponding visualization maps. The network visualization is presented in Figure 1.

The VOSviewer program divided the keywords into 6 clusters and assessed the number and strength of links. The total number of links was 238 and the total strength of these links was 1103. The size of the keywords corresponds to the number of links obtained. Spatial proximity depicts the strength of links between topics. Keywords were analyzed number of links, total link strength, occurrences, and avq. citations. The cluster composition and characteristics of each keyword are summarised in Table 2.

The second cluster, displayed in green, consists of 9 keywords. "Athletes" and "Reliability" had the highest number of links and the strongest link

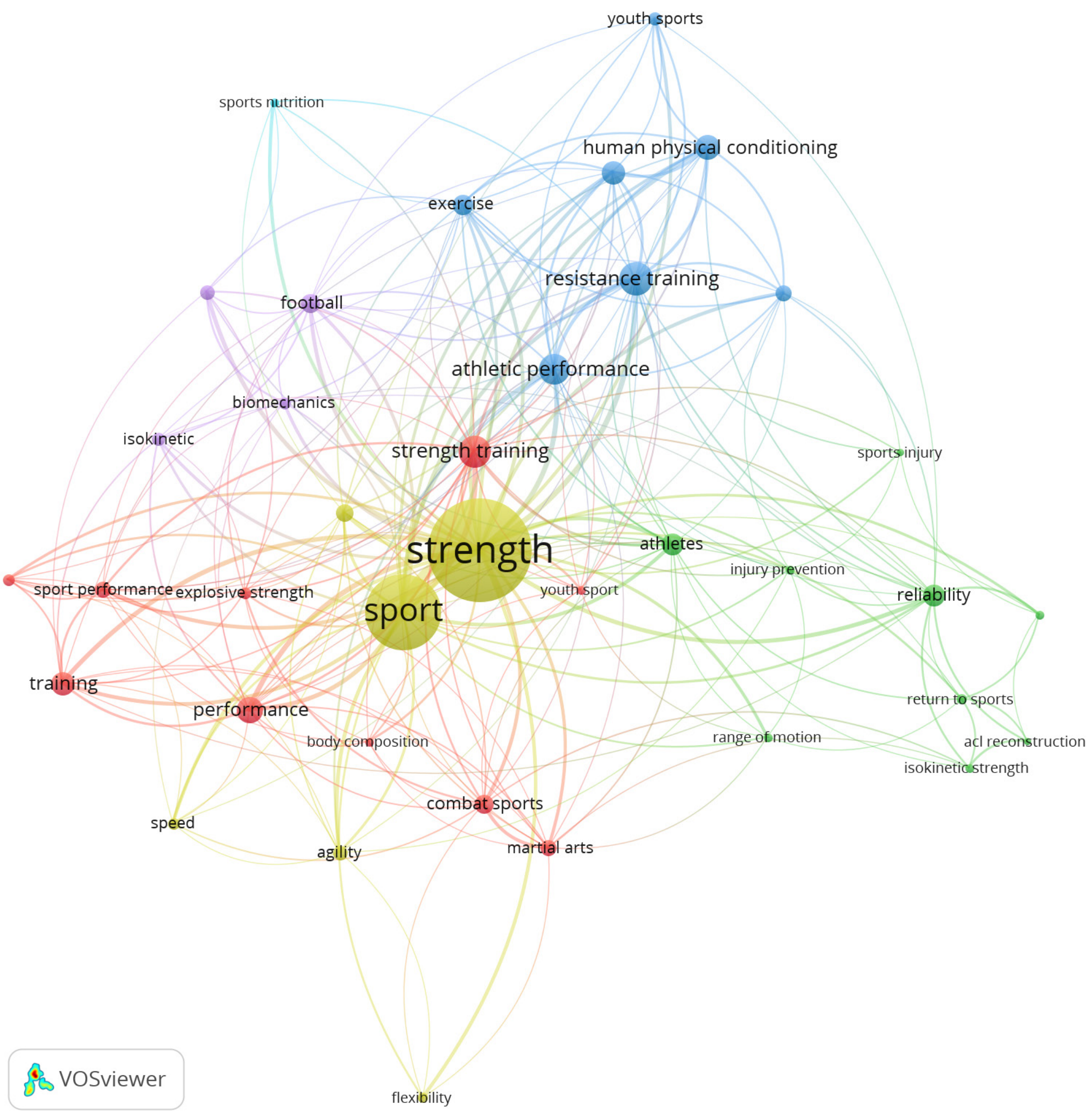

Figure 1. Main keywords in strength sports publications: network visualization. The source of information is the authors' research based on data obtained from WoS and analyzed using VOSviewer (November 6, 2024).

Table 2. Characteristics of keywords

Keyword	Link	Total link strength	Occurrences	Avq. citations
Cluster 1				
Body composition	9	16	14	6.86
Combat sports	14	45	31	4.52
Explosive strength	13	25	13	7.77
Fatigue	10	25	10	8.80
Martial arts	14	37	16	3.38
Performance	17	73	32	6.00
Sport performance	11	35	24	5.71
Strength training	24	96	75	5.64
Training	14	60	25	4.36
Youth sport	11	18	12	4.00
Cluster 2				
Act reconstruction	4	13	10	11.90
Anterior cruciate ligament	6	18	12	2.92
Athletes	17	57	23	2.30
Injury prevention	10	17	10	4.10
Isokinetic strength	6	16	12	7.58
Range of motion	7	17	10	12.00
Reliability	17	55	44	7.07
Return to sports	8	19	12	7.42
Sports injury	6	10	10	4.30
Cluster 3				
Athletic performance	20	93	32	5.09
Exercise	17	53	19	5.11
Human physical conditioning	14	66	15	8.87
Plyometric exercise	14	65	16	6.00
Resistance training	20	106	36	7.78
Sports medicine	13	38	17	3.76
Youth sports	9	28	12	4.25
Cluster 4				
Agility	5	19	16	5.81
Flexibility	5	19	13	3.69
Physical fitness	15	42	16	5.19
Speed	9	25	14	6.07
Sport	28	324	186	6.26
Strength	34	510	308	5.35
Cluster 5				
Biomechanics	9	25	15	6.00
Football	17	48	17	7.82
Isokinetic	9	27	10	4.80
Sports performance	9	34	31	5.61
Cluster 6				
Sports nutrition	6	18	15	5.33

The first cluster, shown in Figure 1 in red, includes 10 keywords. The term “Strength training” appeared most frequently and had the highest association strength. This cluster represents research on strength training in sports.

strength within the cluster. The keyword analysis highlights the specificity of these studies, which focus on the organization of athlete rehabilitation and their return to sport after injury.

The third cluster, shown in blue, includes seven keywords. The most frequent terms, "Athletic performance" and "Resistance training," have the highest association strength. This cluster represents research on the dynamics of athletes under the influence of strength training and its application in fitness.

The fourth cluster, marked in yellow, consists of six keywords. The most significant terms in this cluster are "Strength" and "Sport." The keywords indicate that strength is considered the primary physical quality in sports, suggesting that research in this cluster focuses on strength development across various sports disciplines.

The fifth cluster, marked in purple, includes four keywords. The most frequent term is "Football." This cluster appears to be focused on performance analysis and the role of strength training in enhancing athletic performance in this sport.

The sixth cluster is the smallest, consisting of a single keyword, "Sports nutrition," and is marked in blue. This cluster represents studies incorporating the nutritional factor. The links associated with this keyword reflect the influence of nutrition on athletes' training performance.

An analysis of the keyword clusters based on Table 1 confirms the overlap of research areas. This observation is supported by the similarity of research focus across different clusters and the recurrence of keywords among them. Another notable aspect is the minimal representation of strength sports topics in the keywords. On the one hand, this significantly broadens the scope of analysis. On the other hand, it slightly shifts the focus away from the study's stated objective.

The results of the overlay visualization are shown in Figure 2.

Keywords in Figure 2 are analyzed based on

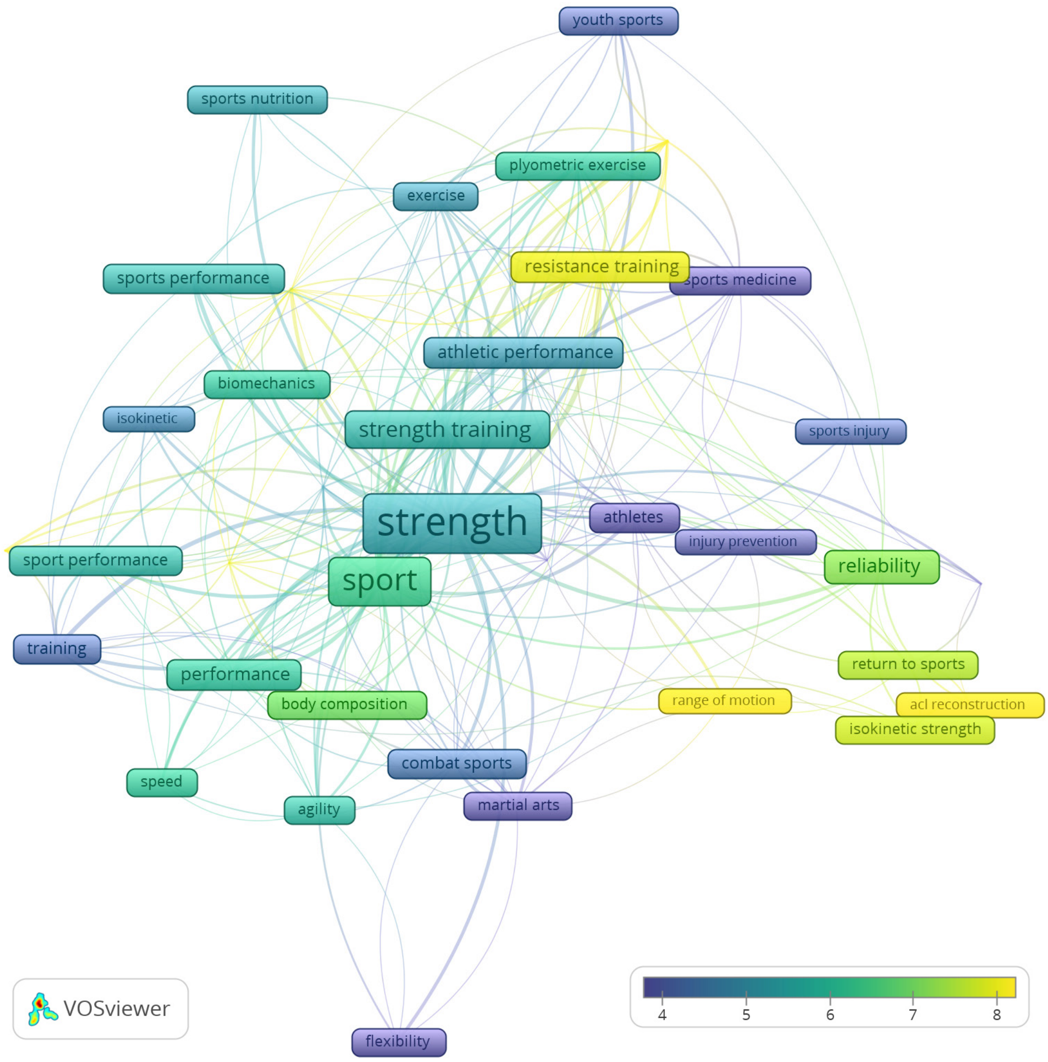

Figure 2. Average number of keyword citations in publications on power sports and overlay visualization. The source of information is the authors' research based on WoS data and analyzed using VOSviewer (November 6, 2024).

citation frequency and are color-coded accordingly. Purple represents the lowest average number of citations, while yellow indicates the highest. Analyzing the map and the data in Table 2 reveals that the keywords with the highest citation numbers are: "Range of motion" (12.00), "Act reconstruction" (11.90), "Human physical conditioning" (8.87), "Fatigue" (8.80), "Football" (7.82), "Resistance training" (7.78), and "Explosive strength" (7.77). Overlay visualization suggests that studies with a rehabilitation or recreational focus, as well as those investigating the use of strength training for recovery in other sports, can be considered promising for citation.

VOSviewer software also enables the analysis of publication datasets by author. The results of this analysis are presented in Figure 3. This map highlights the most influential authors in this research area. The total number of authors in the sample publications was 2,619. For the analysis, authors with a minimum of five publications and at least five citations were selected, narrowing the sample to 24 authors and allowing for the construction of the corresponding map.

An analysis of Figure 3 shows that the authors were divided into five clusters. The largest is the red cluster, which includes seven authors, with Rodrigo Ramirez-Campillo (22 publications) and Urs Granacher (10 publications) being the most active. The green cluster consists of six authors, with Irineu Loturco (14 publications) as the most active. The blue cluster includes four authors, with Marco Beato (8 publications) as the most active. The yellow cluster comprises three authors, with Chris Bishop (9 publications) leading in activity. The purple cluster also includes three authors, with Tomas Herrera-Valenzuela (10 publications) as the most active.

The bibliometric characteristics of the authors were taken as before to improve the quality of the analysis (Table 3).

According to the data in Table 3, the most cited authors on the studied topic are Jason Moran in cluster 1, Tomas T. Freitas and Irineu Loturco in cluster 2, Antonio Dello Iacono in cluster 3, Chris Bishop in cluster 4, and Alex Ojeda-Aravena in cluster 5.

The bibliometric analysis confirms and expands the results of the primary sample analysis, helping to establish priority research directions and identify the most influential specialists in this field.

Discussion

Literature analysis is a fundamental component of scientific research, enabling researchers to assess the current state of the problem, identify key objectives, and determine priority research areas. It also provides a basis for selecting appropriate approaches to address the issue under study. Therefore, the purpose of this study is of significant importance for the advancement of sports science. Additionally, the high popularity of strength sports among the general population further underscores the relevance of the chosen research direction.

The bibliometric method can significantly enhance the quality of analysis. VOSviewer is one of the widely used and publicly available tools for bibliometric analysis in scientific research. It is frequently applied in sports science, enabling researchers to examine publications on various topics. For instance, it has been used to analyze studies on the rehabilitation of patients with Alzheimer's disease through physical activity [44], as well as publications on kickboxing [45] and esports [46], helping to establish priority research areas in these fields.

Most publications in the sample were related to the research and evaluation of strength in sport, as confirmed by the keyword analysis (Fig. 1, Table 1).

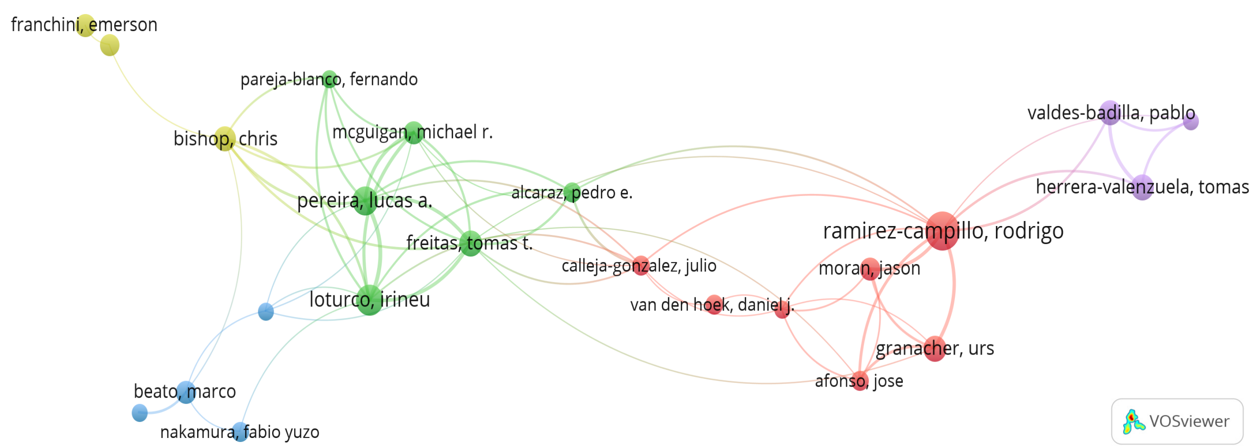

Figure 3. Main authors in strength sports research (direct citation analysis, visualization of item density, weights – citations). The source of information is the authors' research based on data retrieved from WoS and analyzed using VOSviewer (November 6, 2024).

Table 3. Bibliometric characteristics of the authors of the publications

Keyword	Link	Total link strength	Occurrences	Avq. citations
Cluster 1				
Afonso, Jose	5	16	6	3.33
Calleja-Gonzaltz, Julio	8	15	6	7.67
Clemente, Filipe Manuel	6	9	5	5.60
Granacher, Urs	5	20	10	8.50
Moran, Jason	4	16	8	10.88
Ramirez-Campillo, Rodrigo	10	39	22	8.00
Van den Hoek, Daniel	2	2	6	6.33
Cluster 2				
Alcaraz, Pedro E.	6	17	6	8.33
Freitas, Tomas T.	11	37	10	`12.00
Loturco, Irineu	9	44	14	12.00
Mcguigan, Michel R.	8	29	8	6.50
Pareja-Blanco, Fernando	5	17	5	9.60
Pereira, Lucas A.	8	43	12	11.08
Cluster 3				
Beato, Marco	4	7	8	8.50
Dello Iacono, Antonio	5	5	5	9.60
Nakamura, Fabio Yuzo	2	2	6	1.33
Raya-Gonzalez, Javier	1	4	5	5.00
Cluster 4				
Bishop, Chris	7	22	9	10.89
Detanico, Daniele	2	2	7	8.71
Franchini, Emerson	1	1	8	4.50
Cluster 5				
Herrera-Valenzuela, Tomas	3	18	10	4.50
Ojeda-Aravena, Alex	3	10	5	5.20
Valdes-Badilla, Pablo	3	17	9	4.78

However, these publications cover not only strength sports but also other sports that incorporate strength-based training. This distinction is likely due to terminological differences between English-language scientific literature and national sources on strength sports.

Most of the keywords (Table 1) reflect research methods applied to athletes, their physical condition, various training approaches, and preparation specifics. This suggests that the issue of strength training in sports is closely linked to sports monitoring. The main stages of this process include collecting and analyzing data on athletes' condition and training specifics, predicting success and skill development, and implementing corrective and optimization measures. Publications assessing training effectiveness illustrate the application of the feedback principle.

The analysis of publications in the WoS database identified the most prioritized research directions related to the studied problem. These directions can be categorized into sports-related (strength training in sports, tests, and methods for assessing and evaluating athletes' strength) and rehabilitation and recreational (the use of strength training for recovery, rehabilitation after injuries, and injury prevention in strength training).

Use of strength training in sports

Strength training enhances not only strength but also other physical qualities of athletes. A review [47] assessed the effects of weightlifting training on jumping ability, short-distance running, and change-of-direction performance. The results confirmed that such training significantly improves athletic performance.

The monitoring and diagnostics of functional parameters in strength sports athletes are described in the study [20]. Morphological parameter monitoring provides insights into adaptive potential, forming the basis for training program adjustments. The dynamics of the fat component of the somatotype allow coaches to determine optimal body composition parameters. Key risk factors have been identified, including excessive body weight and the risk of cardiovascular diseases, necessitating adjustments in athlete training.

The use of speed training in strength training is discussed in the study [48]. Interviews with high-performance coaches confirmed the importance of monitoring athletes' condition and implementing the feedback principle. A promising approach to improving training is the use of gamification. Specialized applications enhance planning, provide objective guidelines for training adjustments, monitor athletes' readiness, and assess training quality.

A review [2] discusses and summarizes the evidence on optimal strength loading, defined as the load that maximizes power output in a given exercise. This value can be determined through testing based on relative percentages of body mass. The testing protocol is characterized by its adequacy and simplicity, making it a viable alternative to traditional strength training strategies. This method can be applied across various sports and for assessing the physical health of the population.

Another review [49] investigated the effectiveness of strength training in young athletes, with the vast majority of studies supporting its benefits. Strength training enhances muscle development in young athletes. However, difficulties in formulating recommendations arise due to variations in training programs and techniques. The authors suggest guidelines on training frequency, rest intervals, intensity, and volume.

Similar results are reported in the review [25], which analyzes the potential of strength training and weight-bearing exercises for young athletes. Various performance, physical, and physiological variables, such as body composition, strength, and power, have been shown to improve with training. Designing an effective and appropriate training program requires an understanding of the sport, the scientific principles of training, and musculoskeletal development.

Another study [21] highlights the importance of strength training in non-power sports, attributing this to the biomechanical similarities between weightlifting, jumping, and sprinting movements. Incorporating weight-bearing exercises into training has been found to be more effective than general or plyometric training, as confirmed by numerous studies and meta-analyses.

In the study [1], the relative weight of physical strength factors across different sports was evaluated. Participants were classified into four types based on their dominant physical qualities: Type A – short-term muscular strength and short-term muscular endurance, Type B – medium-term muscular strength, Type C – long-term cardiorespiratory endurance, and Type D – coordination ability, agility, flexibility, and balance.

The relative weights of physical factors in Type A were: power 30%, muscular strength 18%, coordination 16%, agility 11%, flexibility 10%, cardiorespiratory endurance 1%, and balance 0%. In Type B, the relative weights were: muscular endurance 43%, muscular strength 25%, balance 9%, cardiorespiratory endurance 2%, flexibility 1%, agility 0%, and coordination 0%.

The specificity of many sports necessitates the development of strength qualities, which is particularly relevant in martial arts [14]. Strength is a key factor determining the effectiveness of techniques and strikes, as well as offensive and defensive actions. The study [3] examines the peculiarities of strength manifestation and the monitoring of strength qualities. The authors provide recommendations for their application in training wrestling techniques and strikes in mixed martial arts.

The review [50] examines strategies for optimizing training effectiveness to enhance motor skills, support long-term athletic development, and prevent injuries in young athletes. Training should follow a structured approach that ensures a gradual increase in load. A variety of equipment and implements should be incorporated to achieve a comprehensive impact on the body. When designing and monitoring strength and conditioning programs, factors such as the athlete's age, maturity level, cognitive ability, stage of puberty, training volume, and readiness level should be taken into account.

Another review [7] investigated the effects of strength, power, and speed training on change-of-direction ability. The PRISMA protocol was used as a meta-analysis tool. Strength, speed, power, and agility training were found to be effective in improving change-of-direction performance, with each quality influenced by one or more variables.

Another review [51] examined the effects of resistance training (RT) on the performance of elite athletes. A comprehensive search was conducted following the PRISMA protocol in the PubMed, Scopus, SPORTDiscus, and Web of Science databases. Studies were categorized based on competition level among elite athletes, athlete gender, performance outcomes, and training focus. The results of the meta-analyses revealed a significant overall effect of RT on sport-specific outcomes. Weight training was shown to be effective in enhancing performance in elite athletes. The findings emphasize the need for personalized RT regimens and the implementation of advanced RT techniques.

Strength is a key predictor of success in American football, making strength training a central component of athletic preparation in this sport. The study [4] examined the effectiveness of strength training with varying loads on the performance of professional football players. A six-week strength training program was implemented, with anthropometric indices and motor test results used as criteria for training effectiveness. The findings confirmed an increase in hip circumference and maximum sprint speed following the program.

Success in throwing is largely dependent on strength levels. The study [5] highlights the importance of upper body strength training for throwing performance. The aerobic intervention method has been identified as an effective approach to enhancing upper body strength in athletes involved in this sport. It is recommended that athletes incorporate upper extremity strength training into their daily workouts.

Volleyball requires high levels of maximal strength, reactive strength, and power at the elite level. The study [8] evaluated the effects of a six-week strength training program on professional athletes. A three-phase training method was implemented to enhance muscle actions by integrating eccentric, isometric, and concentric phases. The effectiveness of the program was confirmed.

Success in basketball is also influenced by strength, speed, and agility [52]. The study presents a comparative analysis of the relationships between anthropometric and physical measures in elite young athletes, identifying key predictors of speed and agility. Body fat percentage was found to be a significant predictor for speed and agility tests across all age groups but a negative predictor of muscle strength. It is recommended that this indicator be taken into account when designing individual training programs for players and in talent identification processes.

A review [10] examined the influence of physiological, biomechanical, and anthropometric characteristics on swimming performance. The findings indicate that higher levels of muscle strength, muscle power, and lean body mass contribute positively to swimming performance. Muscle strength and power are particularly crucial for starts and turns. Additionally, anaerobic and aerobic metabolic rates were identified as important performance determinants, with aerobic capacity being especially significant in middle- and long-distance events.

Lifting in kettlebell sport is performed through pushing and jerking movements. However, the specific mechanics of these movements remain insufficiently studied. It has been suggested that findings from other sports can be used as reference points. For instance, the kinematics of unilateral and bilateral overhead jerks were analyzed in the study [53]. The range of motion in the shoulder joint and the strength of rotator muscles during these movements were examined and compared. The study involved athletes from sports requiring unilateral (badminton) and bilateral (swimming) jerks. The results indicated that athletes performing unilateral jerks exhibited greater shoulder motion asymmetry and rotational strength than those engaged in bilateral jerks.

A study [9] examined the relationships between strength, speed, and performance in ice hockey, considering participants' age and training level. The findings indicated that maximal strength influences sprinting performance on ice, as well as performance differences between age groups and professional players. It was suggested that strength and jump performance assessments be incorporated into regular ice hockey testing protocols.

A review [11] examined the role of strength development in successful punching in boxing. The study identified key factors influencing punching power, including body mass, gender, technique, and punching characteristics. A direct correlation between strength development and punching power was confirmed. The findings highlight the need for further research in this area.

The use of tests and samples to assess and analyze strength in sports

The importance of using tests for monitoring athletes is undisputed. These tests must be adequate, informative, and valid. A study [54] assessed the reliability of the squat test, suggesting that reliability should be evaluated using correlation values and the coefficient of variation. The findings confirmed that the squat test is a valid and reliable measure of lower limb performance.

The study [18] proposed a method for selecting measurement tests to assess athletes' physical fitness. This method incorporates multiple levels of validity by linking test measurements with competition results. Test selection is based on factors influencing athletic performance, ensuring that the most appropriate and informative assessments are chosen.

The correct selection of a battery of tests for analysis significantly enhances its effectiveness. The study [55] applied a set of anthropometric indicators and physical fitness tests to assess the condition of young handball players. Evaluations were conducted at the beginning and end of the season to monitor athletes' physical status. The observed increase in body weight and decrease in fat percentage were interpreted as indicators of muscle mass gain. Physical fitness parameters were shown to improve over the course of the season.

Similar findings were reported in the study [56], where a set of indicators and tests was used to assess the condition of elite basketball players based on their playing positions. The study confirmed the informativeness of assessing strength development, body composition, and the cardiorespiratory system.

A similar study design was used in the study [57], where the authors evaluated the physical profile of sub-elite female cricket players across different playing roles. The assessment included body composition analysis, muscle strength testing using dynamometry, a 2 km run, countermovement jump (CMJ), single-leg jump (SLJ), isometric mid-thigh pull, push-up, and jumping jacks on weight plates. Body composition and musculoskeletal profiles were identified as baseline markers for determining playing roles in sub-elite women's cricket. This information can be utilized to enhance fitness, support player selection, and predict skill development.

The relevance of tests to the specificity of the sport is the primary criterion for their selection. The study [15] applied a battery of strength tests for a comparative analysis of climbing athletes. General muscular strength was assessed using arm dynamometry, the bent-arm hang, and the bar hang. Specific muscular strength was evaluated through the maximal finger flexor strength test, the finger hang on bent arms on the fingerboard, and the finger hang. The results suggest that assessing both specific and general muscular strength can serve as a useful tool for sport-specific selection.

The specificity of climbing necessitates the analysis of strength not only in the hand and forearm but also in individual fingers. The study [17] proposed and tested tests to assess these parameters, concluding that intermittent muscular endurance is a key predictor of success in difficult climbing.

A similar research focus was observed in the study [16], where the authors compared forearm muscle and grip strength in climbers performing different types of finger hangs. Maximum loads of individual muscles, as well as flexors and extensors of the fingers and hands, were recorded. The study identified the grip type that allows for the most efficient load execution.

A similar approach was used in the study [58], where the authors assessed the reliability of a battery of handball strength tests using a functional electromechanical dynamometer (FEMD) and examined the relationship between these tests and performance metrics. The findings confirmed high reliability across all exercises and significant correlations with sprint time and throwing speed. It was recommended that these tests be used to evaluate training effectiveness in handball teams.

A review [13] analyzed the performance of Greco-Roman and freestyle wrestlers, with strength indices serving as key comparison criteria. These included grip strength, isometric back and leg strength, power endurance, and anaerobic power indices. The findings indicated that Greco-Roman wrestlers exhibited greater isometric strength, muscle power, and speed indices, whereas freestyle wrestlers demonstrated higher flexibility. The results were interpreted in the context of the specific demands of each wrestling style.

The study [19] presents the results of monitoring the anthropometric and physical characteristics of international women's rugby union players over five seasons. Body weight, skinfold thickness, and fat deposits were analyzed, while physical fitness was assessed using the bench press, single-leg squats, and sprint time. The findings confirmed the applicability of these criteria for evaluating the dynamics of athletes' fitness.

The importance of strength development in rugby is highlighted in the study [6]. The authors examined the strength-velocity profile of young rugby players in strength exercises and compared gender differences. The squat and bench press were used as test exercises, confirming the relationship between strength and speed performance. The findings are suggested for improving the quality of rugby training.

Another informative test for assessing strength capabilities was proposed in the study [59]. The authors applied the isometric pull-to-mid-thigh test to examine the relationship between strength and momentum. The findings confirmed correlations between the results of this test, jumping tests, and sprint performance. It was concluded that the isometric mid-thigh pull test can be used to assess maximal and rapid force expression.

Similar results were reported in the study [60], where the authors used an isometric hip stability test to evaluate the strength of the posterolateral thigh muscle. The study confirmed that this field test serves as a quick and convenient screening tool for monitoring muscle strength in an athletic setting.

Grip performance, including strength and endurance, is a key predictor of success in martial arts. The study [61] conducted a comparative analysis of these parameters in judo athletes and non-athletes. The assessment included the maximum isometric grip test (three repetitions of 5 seconds each with 90-second intervals) and the isometric grip strength and endurance test (ten repetitions of an isometric grip for 10 seconds each with 20-second intervals) performed with both the dominant and non-dominant hands. The grip strength-to-body weight ratio was used as an evaluation metric, while the strength ratio at the beginning and end of the test served as an index of fatigue. The results indicated that most indices were significantly higher in athletes.

Similar results were reported in the study [34], which examined grip strength in static and impulse modes among armwrestlers with different training backgrounds. The study proposed the use of multiple indices linking grip strength to body weight. Higher indices were observed in more experienced lifters, confirming the importance of grip strength in various modes as a predictor of success in armwrestling.

A similar analysis was conducted in the study [62], where the authors investigated grip strength characteristics in judo athletes and correlated these parameters with the performance of sport-specific tasks. Grip strength was assessed in standing and sitting positions, using one hand and both hands simultaneously, as well as in dynamic and isometric modes. Special indices were calculated based on the obtained results.

The study [63] examined possible relationships between hand grip strength and anthropometric characteristics, body composition, and sport-related parameters. The findings confirmed that gender, dominant hand, fat mass, and muscle mass are significant predictors of grip strength.

The development of specific research protocols is essential for assessing athletes' grip strength. This objective was addressed in the study [64], which evaluated the functional status of female pole dancers. Maximum voluntary isometric contractions were measured in three sport-specific positions on the pole (shoulder extension and adduction, hip adduction). The study concluded that the strength assessment protocol is a reliable and functional analysis tool, suitable for objective strength testing.

The study [65] applied the Delphi method to develop an index system for assessing the specific physical fitness of Chinese wheelchair badminton players. The authors established a hierarchical structure of key indices based on their weighting: sport-specific skills (0.4406), athletic qualities (0.2928), cardiorespiratory system status (0.1828), and body proportions (0.0838). The index system demonstrated high reliability and specificity for evaluating wheelchair badminton players.

The study [12] examined limb strength in kickboxers by measuring the isometric strength of the extensors and flexors of the upper and lower limbs. The BTE PrimusRS system (BTE USA, New Hampshire) was used as a dynamometer. The findings confirmed upper extremity strength symmetry, while the lead leg exhibited a higher level of muscle strength. A comparison of strength test results with technical and tactical training indicators highlighted the necessity of developing extensor and flexor strength in the lower limbs.

Another study [66] compared the maximal isometric and dynamic strength of MMA athletes, considering their competitive level and weight category. Isometric strength was assessed using grip strength and isometric lumbar strength tests, while dynamic strength was evaluated through a single maximal bench press and leg press. A one-way analysis of variance revealed differences between groups in absolute and relative bench press performance, as well as in absolute isometric lumbar strength. The study suggested that these tests could be used to differentiate MMA athletes based on strength characteristics.

A set of tests and assessments was applied in the study [67] to examine the relationship between performance, anthropometric indices, somatotype characteristics, and strength performance in swimmers. Anthropometric data were collected using the ISAK protocol with a Tanita HD 357 digital scale and a Rosscraft Centurion kit. Jump height was measured using a DmJump® contact platform. Strength was assessed through a maximal bench press and pull-ups, while hand grip strength was evaluated with a digital dynamometer. The findings confirmed an inverse correlation between swimming performance and the studied indices.

A promising test for talent identification and success prediction in sports is the ratio of the lengths of the second and fourth fingers of the right hand (2D:4D). The study [68] analyzed this index in martial arts athletes and non-athletes, revealing that athletes had a lower 2D:4D ratio compared to the control group. A negative correlation between this index, grip strength, and the muscular component of somatotype was confirmed. The findings suggest that 2D:4D could be included as one of the indices for assessing strength potential.

A review [69] presents data on the assessment of isokinetic torso strength in athletes of different ages. Muscle assessment methods using an isokinetic dynamometer are considered reliable, demonstrating a strong correlation with peak strength values and flexor/extensor ratios across various age groups. Isokinetic performance data for torso muscles also correlate with anthropometric parameters, sport type, and training volume. The impact of sports training on muscle strength is evaluated both as a positive factor and as a potential risk factor for back injuries.

Another review [70] examined evidence on improving motor competence in young athletes. Functional movement screening was the most commonly used assessment method, with squats being the most frequent test. The squat load varied from bodyweight to barbells of different weights.

The use of strength training for wellness, recovery, and rehabilitation after injury, and injury prevention.

A review [71] analyzed the occurrence of overexertion (OR) and overtraining syndrome (OTS) in strength sports and resistance training (RT). The findings confirm that short periods of OR caused by high-volume or high-intensity RT can lead to functional overexertion (FOR). Additionally, evidence suggests that chronic high-volume and/or high-intensity RT can result in non-functional overexertion (NFOR). The development of practical tools for detecting and diagnosing the transition from FOR to NFOR, and subsequently to OTS, in strength sport athletes is recognized as a promising research direction.

The high incidence of injuries in sports necessitates the search for effective rehabilitation methods, with strength training playing a key role. The study [72] examined the effect of a nine-week strength training protocol on the prevalence and incidence of overexertion injuries in young tennis players. However, the small sample size prevented confirmation of the study's hypothesis.

A review [73] discussed the significance of methods for testing the strength and stability of major muscle groups in both sports and rehabilitation. The review emphasized the importance of exercises that assess muscle strength, speed, and power, highlighting their relevance for designing rehabilitation and training programs aimed at enhancing athletic performance and reducing the risk of back pain.

Hamstring injuries are among the most common muscle injuries in sports, often resulting from excessive strain and insufficient hamstring strength. The study [74] investigated the relationship between hamstring flexibility and the concentric and eccentric strength of the hamstring and quadriceps muscles in athletes. Flexibility of the posterior thigh muscles was assessed by measuring the active knee extension angle using a goniometer, while muscle strength was evaluated with an isokinetic dynamometer. The findings suggest that flexibility may negatively affect concentric muscle strength in female athletes, as they tend to be more flexible and have lower muscle strength compared to male athletes. Based on these results, it is recommended that concentric and eccentric strength exercises be incorporated into female athletes' training programs, while flexibility-enhancing exercises should be prioritized for male athletes.

A similar research focus was observed in the study [75], which examined the effects of training on the hamstrings and investigated risk factors for hamstring injuries. The findings indicate that increased hamstring strength can reduce the risk of injury.

The study [76] compared functional test results and injury rates in relation to different strength measures of the thigh muscles. Strength-to-weight ratio indices were used for assessment, revealing that participants with lower strength scores exhibited poorer hamstring functional status.

Assessing rehabilitation effectiveness also necessitates the development of specialized tests. The study [77] validated a shoulder strength test to evaluate an athlete's readiness to return to sport after injury. This test measures strength in three shoulder extension positions (90, 135, and 180 degrees) using weight plates. The authors compared its effectiveness with dynamometer-based force testing, confirming the test's reliability and validity.

Another study [78] compared the lower limb muscle strength of the intact limb in individuals with a history of hamstring injury to the dominant limb in those without such an injury. Maximal isometric strength was assessed in six muscle groups using a hand-held dynamometer. Separate two-factor analyses of variance were conducted for each muscle group, considering limb and sex as factors. The study design can be applied to assess the effectiveness of rehabilitation programs.

The study [79] analyzed the preventive and therapeutic effects of functional strength training on calisthenics injuries. Training outcomes were evaluated using a functional motor test scale. The findings confirmed that functional strength training enhances overall strength development, improves movement coordination, control, and stability, and increases athletes' overall strength. Additionally, it was shown to be an effective method for preventing sports injuries.

Another study [80] examined differences in maximal strength, flexibility, and body composition among CrossFit® participants based on their competition category. Strength was assessed using the maximal bench press and bodyweight squats, flexibility was measured with the Flexitest, and body composition was analyzed using bioimpedance. The results revealed statistically significant differences in maximal strength between competition categories, while no significant differences were observed in body mass, fat mass, or muscle mass.

Conclusions

An analytical review of publications in the WoS database on power sports was conducted using the bibliometric method. The priority research directions in this field were identified, including sports-related aspects (strength training in sports, tests, and methods for assessing and evaluating athletes' strength) as well as rehabilitation and recreational aspects (the use of strength training for recovery, rehabilitation after injuries, and injury prevention).

A wide range of tests and measurements are employed to assess athletes' strength, which must meet the principles of specificity, simplicity, reliability, and practicality. The most commonly used assessments include body composition indices, anthropometric criteria, and strength performance indicators. Among strength exercises, the most frequently applied are the bench press, grip strength tests, squats, and jumps. The effectiveness of these tests for monitoring athletes' condition, selection, and performance prediction has been confirmed.

Conflict of interests

The authors declare that there is no conflict of interests.

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