Analyzing predictive approaches in martial arts research

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Abstract

Background and Study Aim	Predicting the results of martial arts competitions is an important task that attracts the attention of both sports analysts and fans of these sports. The objective of this study is to perform an analytical examination of publications on martial arts prediction, with the aim of identifying the primary research directions in this field.
Material and Methods	The bibliometric analysis of PubMed database data was used to create a sample of studies at 18.05.2023. The keywords "prediction", "martial arts" were used for the search. A total of 151 publications were found. The first publication was dated 1983. VOSviewer 1.6.19 program was used: keyword analysis method and direct citation analysis with the construction of bibliometric maps, the visualization of cluster density, weights – citations.
Results	51 journals from 21 countries were identified. The unconditional leader among the countries is the United States (16 journals). Between 1983 and May 18, 2023, 741 scientific works were found. The analysis involved 67 authors whose link strength was more than 0. Eight clusters were identified. They were characterized by the presence of 271 links with total link strength of 276. The number of items in the clusters did not have a significant difference; this can be explained by the popularity of all directions in the research. The authors of the seventh and eighth clusters had the most publications. To visualize the network 63 items (keywords) were selected. They were grouped into 4 clusters. The network includes 951 links; the total link strength is 4027. The most popular studies are highlighted. These studies include the following keywords: "humans", "martial arts", "female", "male", "athletes", "young adult", "middle aged".
Conclusions	The analysis of the bibliometric maps revealed the tendencies of scientific research and highlighted the priority areas. The relevance of the problem of prediction in martial arts is confirmed. An increase in the number of publications in PubMed database over the past decade has been observed. The main areas of research include martial arts, health, sports training, and humans. Most publications focus on utilizing artificial intelligence and machine learning techniques for predicting competition outcomes. Additionally, they explore the application of analytical tools to uncover patterns in data and identify critical factors that impact competition results. Modern technologies and the availability of big data open up new possibilities for predicting competitive success in martial arts.
Keywords:	prediction, martial arts, VOSviewer, bibliometric mapping.

Introduction

Nowadays, martial arts are a popular sport worldwide. Every year the level of professionalism and technical skills of athletes is growing, which makes competitions more and more intense and spectacular [1, 2, 3]. Also, there is an increase in competition in the international arena, which leads to the need for further search for new pedagogical tools and methods in the system of preparation of highly qualified athletes [4, 5, 6].

One of the ways to achieve high results in sport is clear management, planning, and use of advanced training methods in the training process [7]. The successful and effective management of sports training is impossible without a reasonable prediction. Predicting creates the prerequisites for making qualified decisions in sport [8]. Setting prospective goals always involves predicting sport performance [9].

The main primary goal of training elite athletes is successful performance at major competitions [10]. The identification of talented athletes and ways of their development is one of the most discussed and popular directions in sports science [11, 12]. Health prediction is an effective tool to determine the level of physical fitness and risk of injury in athletes and amateurs [13, 14].

Predicting the result in martial arts attracts the attention of both sports analysts and fans of these sports [15, 16]. It can have an important practical value by helping athletes and coaches. Performance

prediction allows us to determine the optimal strategy of preparation for competitions to improve the tactics of a fight (fight, battle) [17, 18]. Such prediction can be used as a tool for sports betting [19, 20].

The above data allow us to consider the chosen direction of research relevant. Several sources, constant updating of information in this area significantly complicate the analysis. The bibliometric method and in particular VOSviewer software tool can be used to analyze the literature. VOSviewer is a tool that helps create visual maps and visualize bibliographic data. Such maps can contain journal titles, authors' names, names of organizations where research was conducted, and keywords. This program is capable of systematizing and grouping key terms into specific semantic clusters reflecting interest in a particular problem over a certain period of time [21, 22].

Purpose of the Study. To analyze publications devoted to prediction in martial arts using VOSviewer software tool in PubMed database and to determine the priority scientific directions in this area.

Materials and Methods

Methodology

We used the bibliometric method to achieve the goal of the study [23]. The research tool was VOSviewer 1.6.19. VOSviewer is a software used to build and visualize bibliometric networks. These networks include journals, researchers, and individual publications. They are built on the basis of citations, bibliographic links, joint citations, or co-authorship [24].

The main method of data analysis using the VOSviewer software tool was "co-occurrence", which clusters keywords according to how often they occur together in the same paper. The keywords form thematic clusters. The clusters are marked with different colors, the size of each keyword is determined by the "total link strength" index, i.e., the link strength of a given keyword with all others, and the lines reflect the links between two individual keywords [25].

Data Extraction

When the article selection was completed, the following data were extracted for visual and bibliometric analysis: author name, article title, publication journal, keywords, organization, publication country, and citation amount.

Research Design

The bibliometric analysis of PubMed database data was used to create a sample of studies at 18.05.2023. The phrase "prediction in martial arts" was used for the search. A total of 151 publications for the period 1983-2023 were extracted. The study period was divided into four decades (Figure 1). The number of publications by decade was as follows: 1983-1993 – 4 (2.7%), 1994-2003 – 5 (3.3%), 2004-2013 – 36 (23.8%), 2014-2023 – 106 (70.2%). It is observed a large increase in publications after 2004. This is due to the popularization of many types of martial arts in the world. All publications were published in English.

Based on the most cited references, we identified promising areas of research in this category. Distance-based bibliometric maps have been used – these are maps where the distance between two elements reflects the strength of the correlation between the elements. A smaller distance usually means a stronger connection [21].

Statistical Data

The study identified 51 journals from 21 countries. The United States stood out as the leading country with 16 journals. Between 1983 and May 18, 2023, 741 scientific works were found. The analysis involved 67 authors whose link strength was more than 0. Eight clusters were identified. They were characterized by the presence of 271 links with total link strength of 276. To visualize the network 63 items (keywords) were selected. They were grouped into 4 clusters. The network includes 951 links; the total link strength is 4027.

Results

51 journals from 21 countries were identified according to the keywords "prediction" and "martial arts". The unquestionable leader among the most productive countries is the USA (16 journals). The other major contributors are China (7 journals) and the United Kingdom (4 journals).

Bibliometric maps were created using VOSviewer 1.6.19 software tool. The analysis of these maps was aimed at identifying trends in scientific research in the field, highlighting priority areas. The results for the leading authors in this field are presented in Figure 2. 741 scientific studies were extracted between 1983 and May 18, 2023. 67 authors whose link strength was more than 0 participated in the analysis. A feature of Fig. 2 is its division into 8 clusters. They are characterized by 271 links and their total strength is 276. The first cluster includes 12 authors, the second has 11 authors, the third and fourth have 10 authors each, the fifth has 9 authors, the sixth has 6 authors, the seventh has 5 authors, and the eighth has 4 authors. Note that the authors of the seventh and eighth clusters have the most publications: Franchini Emerson (6) and Capranica Laaura (3). These clusters include the smallest number of authors. The link between seventh and eighth clusters is formed by these authors. However, this link is formed by only one document.

63 items (keywords) were selected to visualize the network (Fig. 3). They were grouped into 4
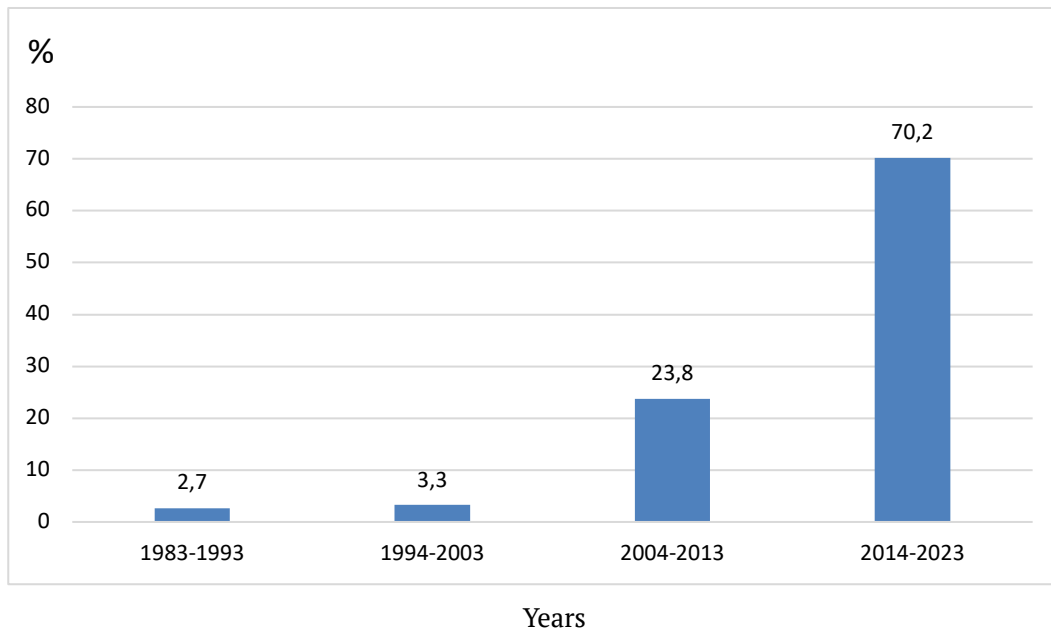
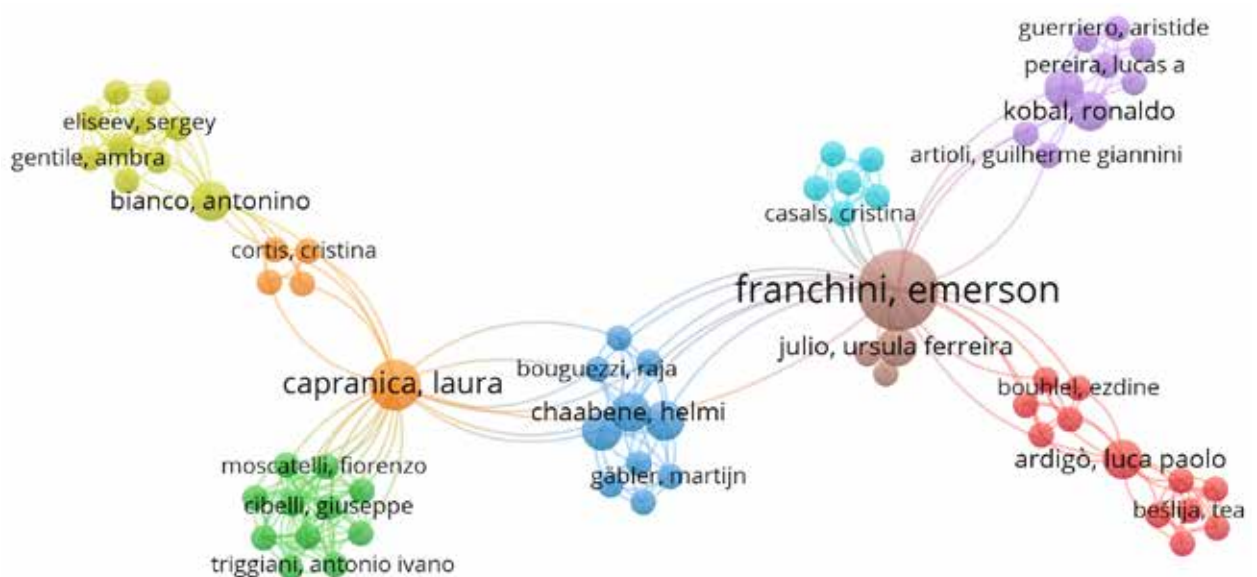**Figure 1.** Dynamics of publications in the research period

Figure 2. Bibliometric map of the top authors of publications that have studied the prediction in martial arts. Source: own study based on data obtained from PubMed and analyzed with VOSviewer (18.05.2023)

clusters. The network includes 951 links, the total link strength is 4027. Each keyword is in a circle. The larger the size of the circle, the more links have that keyword. The proximity of these circles on the map reflects the strength of the correlation between objects.

An analysis of Figure 3 makes it possible to highlight the most popular studies. These studies include the following keywords: "humans", "martial arts", "female", "male", "athletes", "young adult", "middle aged". The first cluster on the map is highlighted in red. It includes 19 keywords. The cluster is conventionally called "martial arts". It is the most significant keyword in this cluster. It occurs 97 times, has 54 links to other keywords on the map, and the total link strength (TLS) is 576.

Further, the occurrences and number of links in decreasing order are as follows: Male – occurrences 96, links 62, TLS 737; Young adult – occurrences 34, links 53, TLS 287; Adolescent – occurrences 31, links 52, TLS 256; Athletes – occurrences 31, links 47, TLS 221; Body composition – occurrences 12, links 32, TLS 92; Body weight – occurrences 9, links 32, TLS 83; Cross-sectional studies – occurrences 7, links 29, TLS 59; Combat sports – occurrences 9, links 27, TLS 68; Competitive behavior – occurrences 8, links 26, TLS 60; Mixed martial arts – occurrences 6, links 26, TLS 52; Wrestling – occurrences 6, links 26, TLS 59; Anthropometry – occurrences 8, links 25, TLS 62; Boxing – occurrences 7, links 25, TLS 64; Retrospective studies – occurrences 5, links 18, TLS 42; Absorptiometry – occurrences 5, links 16, TLS
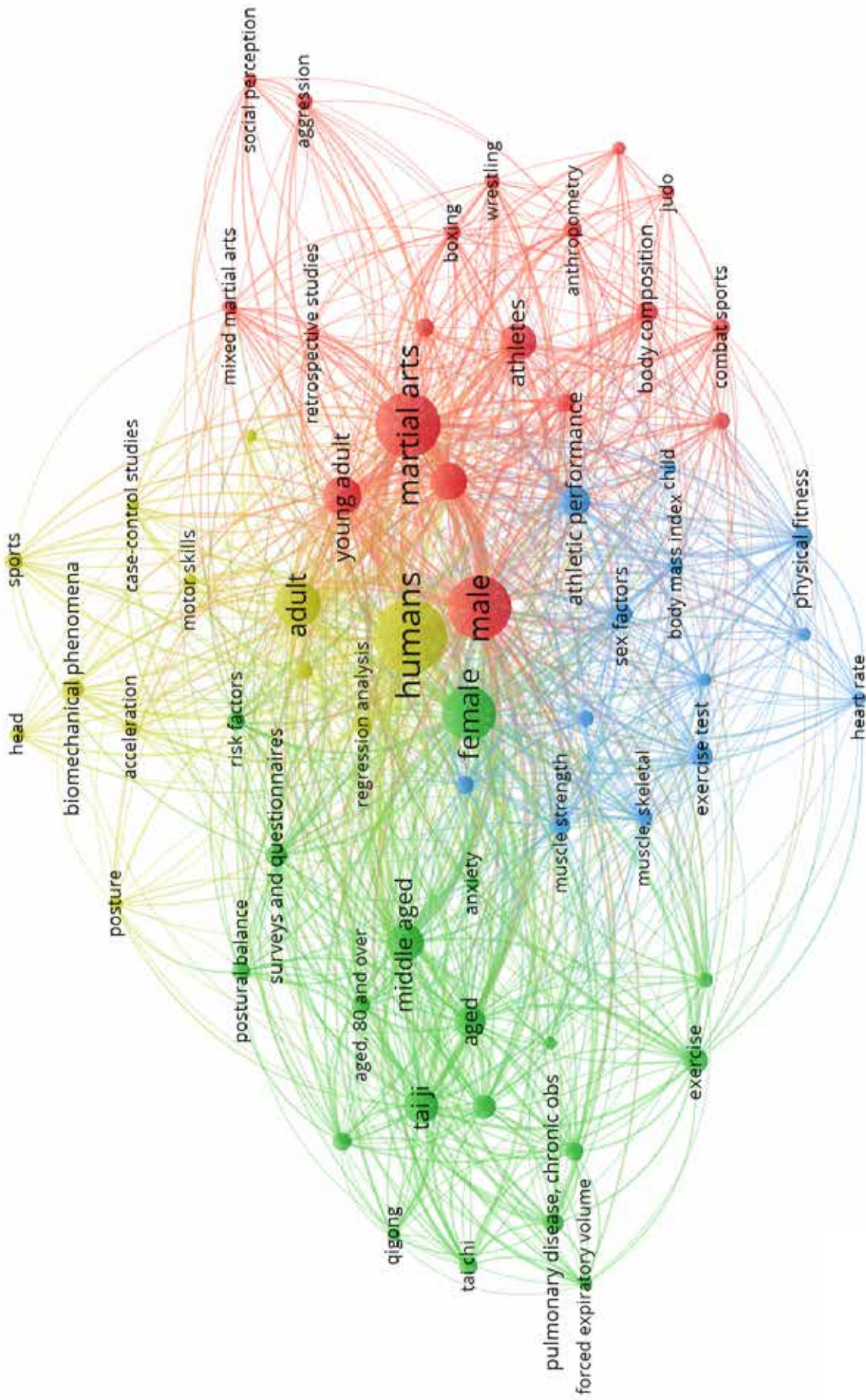
Figure 3. Bibliometric map of keywords in martial arts prediction publications, network visualization. Source: own study based on data obtained from PubMed and analyzed with VOSviewer (18.05.2023)

37; Aggression – occurrences 7, links 15, TLS 41; Social perception – occurrences 5, links 14, TLS 33; Judo – occurrences 5, links 13, TLS 20. The keywords of this cluster characterize martial arts types, age groups, anthropometric and morphofunctional features, and psychological preparedness.

The second cluster also includes 19 keywords. It is marked in green on the map. Conventionally, this cluster can be called "health preservation". The keywords of this cluster characterize physical exercise, disease prevention, recovery from injuries, and old age. The occurrence and number of links in the order of decreasing are as follows: Female – occurrences 68, links 62, TLS 564; Middle aged – occurrences 32, links 50, TLS 289; Aged – occurrences 25, links 43, TLS 236; Tai ji – occurrences 30, links 38, TLS 250; Surveys and questionnaires – occurrences 12, links 37, TLS 118; Aged, 80 and over – occurrences 8, links 32, TLS 88; Exercise – occurrences 15, links 31, TLS 116; Treatment outcome – occurrences 13, links 31, TLS 119; Risk factors – occurrences 8, links 27, TLS 71; Postural balance – occurrences 8, links 27, TLS 70; Exercise therapy – occurrences 8, links 26, TLS 7; Quality of life – occurrences 8, links 25, TLS 81; Anxiety – occurrences 5, links 24, TLS 45; Oxygen consumption – occurrences 6, links 24, TLS 48; Pulmonary disease, chronic obstructive – occurrences 10, links 22, TLS 92; Tai chi – occurrences 9, links 21, TLS 78; Pilot projects – occurrences 5, links 21, TLS 37; Forced expiratory volume – occurrences 5, links 19, TLS 47; Qigong – occurrences 5, links 18, TLS 43.

The third cluster includes 13 keywords. It is shown in blue on the map. The conditional name of this cluster is "Athletic performance". This is the most significant keyword in this cluster. It occurs 23 times, has 43 links with other keywords in the map, and the total link strength is 182. Further, the occurrence and number of links in decreasing order is as follows: Muscle strength – occurrences 9, links 38, TLS 88; Muscle, skeletal – occurrences 7, links 35, TLS 74; Exercise test – occurrences 11, links 34, TLS 95; Sex factors – occurrences 10, links 34, TLS 96; Physical fitness – occurrences 10, links 34, TLS 93; Time factors – occurrences 8, links 33, TLS 70; Predictive value of tests – occurrences 7, links 29, TLS 59; Age factors – occurrences 5, links 28, TLS 54; Body mass index – occurrences 6, links 27, TLS 49; Heart rate – occurrences 5, links 23, TLS 45; Reproducibility of results – occurrences 5, links 20, TLS 42; Child – occurrences 5, links 20, TLS 38. The keywords of this cluster characterize sports training, the control of fitness, and factors that affect the results.

The fourth cluster is marked in yellow on the map and includes 12 keywords. The most significant keyword is "humans". It occurs 128 times, has 62 links with other keywords in the map, and the total link strength is 879. The occurrence of other keywords and the number of links to them in descending order is as follows: Adult – occurrences 52, links 59, TLS 396; Movement – occurrences 8, links 33, TLS 68; Regression analysis – occurrences 8, links 29, TLS 67; Biomechanical phenomena – occurrences 12, links 21, TLS 56; Case–control studies – occurrences 5, links 21, TLS 47; Analysis of variance – occurrences 5, links 20, TLS 39; Acceleration – occurrences 6, links 20, TLS 37; Motor skills – occurrences 6, links 19, TLS 44; Posture – occurrences 5, links 19, TLS 34; Sports – occurrences 8, links 18, TLS 46; Head – occurrences 6, links 13, TLS 30. The keywords of this cluster characterize research methods, techniques, and athletes.

The overlay visualization shows that most of the keywords with the most recent publication dates describe general concepts: martial arts types, athletes, and their activities. Earlier publications reflect more specific studies: anxiety, muscle, skeleton, and regression analysis.

Fig. 3 shows the visualization of density. The interpretation of the results in this figure: the more important is the topic, the larger and brighter is the circle, and the larger is the font size. According to Figure 3 the most popular research topics can be identified. These include studies by topic (in descending order of importance): "humans", "martial arts", "male", "female".

Discussion

VOSviewer was used to perform bibliometric analysis of PubMed database. A similar design was used to analyze Web of Science Core Collection (WoS) [21], Scopus [22], PubMed [26], and Google Scholar [29].

The design of systematic reviews of various databases and meta-analyses also uses other representations of the results. Krzysztofik et al. [28] conducted a literature review in accordance with the recommendations on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The authors searched the MEDLINE, SPORTDiscus, Scopus and Google Scholar databases for all studies examining the effect of unilateral conditioning on the effect of PAPE until February 2022. Similar studies using PRISMA were performed by Makaruk et al. [29]. The research sought to review methodological procedures in the current literature that analyzed the effects of weight training on strength, speed, and endurance in athletes. Computer-based literature searches of SPORTDiscus, Scopus, Medline, and Web of Science were conducted. The internal validity of individual studies was assessed using the PEDro scale.

Other studies [30] conducted a computerized literature search in PubMed, ISI Web of Knowledge, SPORTDiscus, and Scopus databases (until January 2016) to study the physical and physiological profiles of Brazilian jiu-jitsu athletes. This systematic review

was compiled according to MOOSE (Meta-analysis Of Observational Studies in Epidemiology). A database study resulted in 205 articles. After applying the inclusion and exclusion criteria, 58 studies were included in this systematic review. A total of 1,496 participants were included in all selected studies.

Kwok et al. [31] conducted a systematic review and meta-analysis of the biomechanical evaluation of the effectiveness of strength and conditioning training programs in front crawl sprint swimming performance. Four online databases, including PubMed, EBSCOhost, Web of Science, and SPORTDiscus, were searched according to different combinations of keywords. 954 articles were extracted from the databases, and 15 articles were included in this study after removal of duplicates and articles screening according to inclusion and exclusion criteria. Meta-analyses were adopted when appropriate and Egger's regression symmetry was adopted to assess the publication bias and the results were presented with forest plots and funnel plots, respectively. Fifteen articles studied the effects of strength and resistance, core, and plyometric training. The quality of the investigation was assessed using the checklist developed by Downs and Black. Most investigations found that training programs were beneficial to front crawl sprint swimming performance, stroke biomechanics, force, and muscle strength.

The study [32] performed a systematic literature search in EBSCOhost, MEDLINE, PubMed, Web of Science, and SPORTDiscus with dates ranging from the earliest record to October 2018.

The purpose of this review was to determine the magnitude of changes in muscle strength and power at different stages of an elite rugby league season. The search identified 668 potentially relevant studies that were extracted into a spreadsheet. Following the removal of duplicates, the total remaining was 442. Titles and abstracts were reviewed for inclusion against eligibility criteria by one of the authors. Any doubts on a study meeting the inclusion criteria resulted in two authors reviewing the full text. Disagreements were resolved by discussion between the authorship team. Of these articles, twelve met the selection criteria. The methodological quality of each study was appraised using the Newcastle–Ottawa scale adapted for cross-sectional studies.

A bibliometric review of the literature on prediction in martial arts contributes to the mapping of the field of study and indicates key areas of research. Four thematic clusters were identified using VOSviewer 1.6.19. The first cluster is focused on martial arts. Among the topics of research interest are worth mentioning: the study of different types of martial arts [2], age groups [33], anthropometric and morphofunctional features [34], and psychological preparedness [35].

The second cluster is devoted to the health preservation by martial arts. Its main research topics are as follows: the use of physical exercises [36], disease prevention [37], recovery from trauma [38], and old age [39].

The third cluster is characterized by more professional sports activities, focusing on athletic training [40], fitness control [41], and factors that influence the results [9].

The fourth cluster concentrates around the keyword "humans". The authors of this cluster studied: research methods [42], technical skills [43], and athletes [44].

The analysis of Figure 1 makes it possible to assert that prediction in martial arts is a relevant and popular topic for research. Studies on this topic have been conducted in many types of martial arts. Latyshev et al. [1] determined the influence of relative age on the achievement of success by elite athletes in wrestling. The data obtained show that the relative age effect does not affect the achievement of success in wrestling and is levelled at the adult stage. However, the analysis has shown that the greatest influence of the relative age effect on athletes was revealed at the cadet level.

Li et al. [13] developed several inertial MEMS sensors to improve the accuracy of training injury risk prediction and reduce physical injuries. By analyzing the data, a martial arts training model and injury risk prediction models were developed that can provide recommendations and suggestions for martial arts training tasks. Similar studies have been conducted before [45].

Ćenanović & Kevrić [19] used machine learning (ML) algorithm and classifier to predict the winners of MMA. The results are presented in percent accuracy for two different types of samples. The percentage of successful fight predictions ranged from 80% to 92% across all subsets. This model can be further extended and modified to predict the winner of future fights.

Holmes et al. [20] presented Markov chain models for predicting MMA mixed martial art competition results. The developed models generate transition probabilities that are used to simulate realistic MMA. Also, a model was developed for predicting judges' decisions based on the bout statistics of opposing fighters. The models presented can be used by fighters when preparing for a particular opponent and when using them as a basis for betting strategies.

Podrigalo et al. [46] analyzed the bodybuild features of elite athletes of combat sports with the application of special indexes. It was determined that a higher body mass index in athletes demonstrates the prevalence of muscular component of somatotype. The Erismann and Pignier indexes, shoulders width index illustrate the best development of muscles in athletes and kickboxing athletes in comparison with karate athletes, and taekwondo. Increase in a

relative body surface of athletes demonstrates the growth of their aerobic opportunities. Increase in the power index confirms the importance of grip strength for success in combat. Indexes of a ratio of segments of extremities reflect features of the technique of combat sports.

Ota and Kimura [14] proposed a statistical model of injuries based on the analysis of performances of professional sumo wrestlers in the highest division. The proposed model provides the estimated probability of the next potential injury occurrence for a sumo wrestler. In addition, it can support making a risk-based injury prevention scenario for sumo wrestlers. The proposed model can also be applied to injury prediction for athletes in other sports.

Latyshev et al. [8] conducted a retrospective analysis of 41 wrestling careers of the six Olympic Games winners in freestyle wrestling from 1996 to 2016. The obtained data can be used for: identifying the main tendencies and regularities specific for each stage of athletic performance; choosing informative predictive indicators, and developing a model of a successful wrestler. A similar analysis was used by Norjali et al. [18]. This study aimed to predict the performance of young judo athletes using linear and nonlinear predictive statistical models. In this retrospective cross-sectional study, a common battery of tests was used, which consisted of five anthropometrical, seven physical performance, and three motor coordination tests. Generic talent characteristics (anthropometry) included in this study allow for successful discrimination between dropout, subelite, and elite judo athletes. In addition to the trainer's opinion and the individual screening of judo-specific performance characteristics, this generic test battery provides opportunities for predicting the judo performance of young athletes.

There are differences in success prediction factors in different types of martial arts: head punches maintaining distance and takedowns landed are the most significant variables that affect the probability of predicting winning fights in MMA [47]; the ranking scores and the CPS of the competitors are important variables in predicting winners in high-level taekwondo competition [15]; the Random Forests classifier identified seven key success factors in wrestling: anaerobic power, strength endurance, reaction time, special endurance, wrestling-specific fitness and technical wrestling skills performed in a horizontal position.

Analysis of the visualization of Figure 3 allows us to conclude that more studies predicting success are conducted in popular martial arts: boxing, wrestling, judo, taekwondo, karate, and MMA. The popularity of these sports is growing every year, which significantly affects the number of publications. These data are confirmed with earlier results [48, 49, 50].

The results of density visualization actually repeat the results of network visualization. This should be taken as a confirmation of the correctness of the assumptions made.

Conclusions

The conducted bibliometric analysis and analysis of bibliometric maps made it possible to identify trends in scientific research and highlight priority areas. The urgency of the problem of prediction in martial arts is confirmed. An increase in publications in the PubMed database over the past decade has been observed. The main areas of research include martial arts, health, sports training, and humans. Most publications use artificial intelligence and machine learning to predict the results of competitions. Also on the use of analytical tools for revealing regularities in data and determination of key factors influencing results of competitions. Modern technology and the availability of large amounts of data open up new opportunities for predicting success in martial arts.

Acknowledgement

Conflict of interest

The authors declare no conflicts of interest.

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