

Main research areas in kickboxing investigations: an analysis of the scientific articles of the Web of Science Core Collection

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Abstract

Background and Study Aim Combat sports are among the most popular sports nowadays. Scientific support of combat sports is one of the urgent tasks of modern sports science. The purpose of this article is an analytical analysis of studies devoted to kickboxing.

Material and Methods The bibliometric database Web of Science Core Collection (WoS) is analyzed. 194 articles that met the search criteria were selected for the primary analysis. We used bibliometric methods for processing the information received in the context of kickboxing. The VOSviewer 1.6.18 software was used: keyword analysis method and direct citation analysis with the construction of bibliometric maps, visualization of cluster density, and citation weights.

Results The constructed bibliometric maps made it possible to identify the leading thematic areas of research, the most popular areas of research in this area. They can be divided into sports and rehabilitation and recreational areas. In a sports context, these include the performance of technical and tactical elements of kickboxing, the study of the physiological characteristics of combat sports athletes; assessment of the main physical qualities and analysis of the adaptive potential of athletes; the study of biochemical and features of homeostasis, the state of the cardiorespiratory system; highlighting factors important for winning competitions. In the rehabilitation context, kickboxing is used to optimize the functional state, recover from injuries, and improve the quality of life of patients with chronic diseases. The use of the VOSviewer software, version 1.6.18, made it possible to conduct a comprehensive analysis of the problem, to determine the priority scientific directions in this area. In sports, this is an analysis of the technical and tactical indicators of athletes, the time spent on their implementation, the study of the metabolic characteristics of combat sports athletes, and the assessment of their physical qualities.

Conclusions The conducted bibliometric analysis of publications on the problem of kickboxing confirms the relevance of this area of sports science. There is a lack of research on a comprehensive study of success, monitoring the state of kickboxing athletes. These directions should be recognized as the most relevant in this area.

Keywords: kickboxing, combat sports, bibliometric mapping, VOSviewer

Introduction

Modern sports activities significantly demand the level of functional fitness of combat sports athletes. For a qualitative assessment of the state of combatants, it is necessary to use informative and objective methods. No unified position on determining the most effective methods for monitoring the state of combat sports athletes has yet been developed. An analysis of scientific research in this area was carried out in the study [1]. Domestic and foreign experts widely use biochemical, physiological methods, and special fitness tests to control the functional state of combatants. The limitations of some biochemical methods, and indicators of the reaction of the body

of athletes to the load, were revealed. Relevant is the analysis of data that evaluates the response of athletes to stress. A lack of research on certain groups of athletes has been revealed. These include young athletes, athletes over 30 years old, and girls and women involved in combat sports.

The most relevant in the scientific support of sports should be the justification for monitoring the health of athletes, the study of the effects of sports stress and adaptation, the identification of selection criteria, and the establishment of integral indicators of training. A complex of works [2, 3] was devoted to this. Informative coefficients of statokinetic stability, resistance to hypoxia, and an integral rating indicator of the success of the competitive activity were obtained. An analysis of effective adaptation, readiness variability, normal limits, stable and premorbid health conditions,

overtaining, and overwork are proposed. The search and substantiation of evaluation and diagnostic technologies in the monitoring of physical fitness and the development of training programs were carried out. The functional and metabolic stability of a single special functional system of motor activity was confirmed during long-term adaptation.

Several factors determine success in sports. These include specific sports skills, the level of development of physical qualities, features of the functional state of the central body systems, and anthropometric characteristics. It has been repeatedly pointed out that athletes have different physical characteristics depending on the sport. The study of these features is an important task in sports science. The development of an anthropometric profile for a particular sport is important for optimizing training and identifying specific markers. Such a profile can serve as a diagnostic criterion for predicting the results of an athlete [4].

The problem of factors determining success in combat sports has not yet been resolved [5]. There is no consensus on a fully comprehensive assessment of these factors. The specificity of most combat sports makes it difficult to single out one or more factors leading to victory. Strength has been identified as a predictor of success in mixed martial arts (MMA), wrestling, and Brazilian jiu-jitsu. The aerobic and anaerobic potential has been studied in Brazilian Jiu-Jitsu, Judo, Boxing, Kickboxing (KB), and MMA. Its various contributions to success at various levels are confirmed. Endurance, flexibility, and body composition have also been investigated, but this issue has not been finally resolved. The authors conclude that it is necessary to comprehensively study the physical and physiological characteristics of kickboxing athletes.

Kickboxing is one of the most popular modern combat sports. This is a complex type of combat sports in terms of technique, tactics, and structure of movements. It requires an adequate level of motor skills as the basis for successful competitive activity [6, 7].

Combat sports training is complex in terms of the intensity of training, the development of various physical qualities, and the study of many technical skills. This is due to the specific of combat sports. The effects of kickboxing training on cardiorespiratory endurance, muscular endurance, single leg balance, trunk flexibility, trunk strength, static arm strength, speed agility, and explosive leg strength have been studied [8]. A positive effect on improving well-being, balance, aerobic endurance, flexibility, static arm strength, and the development of speed and agility has been confirmed.

One of the important areas of sports science is the directed influence on the functional state of athletes. A promising method of its implementation is the use of the alimentary factor. The importance

of informing kickboxers about food ergogenic products and the level of special training of athletes on these issues has been confirmed [9].

In the context under consideration, it was of interest to conduct a bibliometric analysis of scientific publications devoted to kickboxing in the journals of the international database Web of Science Core Collection.

The purpose of the study is an analytical analysis of publications devoted to kickboxing and the establishment of priority scientific directions in this area.

Methodology

Data sources

The Web of Science Core Collection (WoS) bibliometric database has been selected for the research sampling process as at 06/01/2022.

The quality of the information sources was the main criterion for choosing the databases. The sample is 194 records (Web of Science Core Collection). The articles matched the search term “kickbox*” in the topic. This made it possible to combine publications according to the criteria “kickboxing”, “kickboxer”, etc. The search period was 1970–2022. The period of actual publications was 1991–2022. Most publications – 165 (85.05%) – appeared in the period 2008–2022. 83 articles (42.78%) were published in the period 2018–2022.

Table 1 presents TOP-10 different categories. These WoS subject areas are of the greatest interest in the context of the topic of the article: Sport Science, Physiology, Rehabilitation, Anthropology.

TOP-10 journals which contain articles on the research topic are the following: Journal of Strength and Conditioning Research -10, Medicine and Science in Sports and Exercise – 8, Archives of Budo – 6, International Journal of Environmental Research and Public Health – 6, Archives of Budo Science of Martial Arts and Extreme Sports – 5, Human Sport Medicine – 4, Ido Movement for Culture. Journal of Martial Arts Anthropology – 4, International Journal of Performance Analysis in Sport – 4, Journal of Sport Medicine and Physical Fitness – 4, Physical education of students – 4.

Method of Study

The Web of Science Core Collection database was used to clarify world trends in kickboxing research: the publication period 1991–2022 was considered. The search results are presented in Table 1. According to the information on the most significant categories (table 1, 100 sources), we analyzed the most priority scientific studies in the field of kickboxing.

Data analysis

We used bibliometric methods [10, 11] to identify the leading researchers on the problems of our

Table 1. Results analysis table for web of science categories field (Web of Science Core Collection)

Category	Items (N; %)
	All subject areas, n=194
Subject area (top 10 items)	Sport Science (85; (43.81 %), Education Educational Research (11; (5.57 %), Hospitality Leisure Tourism (10; (5.15 %), Medicine General Internal (9; (4.63 %), Public Environmental Occupational Health (8; (4.12 %), Clinical Neurology (7; (3.61 %), Endocrinology Metabolism (6; (3.09 %), Environmental Science (6; (3.09 %), Orthopedics (6; (3.09 %), Physiology (6; (3.09 %).
	Subject areas, in the context of the topic of the article, n=100
Subject area	Sport Science (85; (43.81 %), Physiology (6; (3.09 %), Rehabilitation (5; (2.58 %), Anthropology (4; (2.06 %).

NOTE: the source of information is the authors' own research (06/01/2022).

study in processing the information received in the context of kickboxing. To do this, we used VOSviewer 1.6.18, a software tool for creating and visualizing bibliometric networks [12]. The most important for the study was the implementation of the keyword analysis method [10] and direct citation analysis [11]. The methodology for calculating the main indicators for the analysis and identification of the most significant research categories is described in detail in the work of van Eck and Waltman [13]. 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 connection between the elements. A smaller distance usually means a stronger connection.

Results

The analysis carried out made it possible to create the corresponding visualization maps.

Network visualization is presented in Figure 1.

The network is created based on 24 elements – keywords. They are grouped into 5 clusters. The size of the keywords corresponds to the number of links received, and the spatial proximity reflects the strength of the connection between subjects. Fig. 1 allows highlights the most popular research. They are focused on the keywords “combat sports”, “performance”, “sport”, “kickboxing”, “exercise”.

The first cluster includes 6 keywords. It is marked red on the map. The cluster received the code title «Rehabilitation». The most significant keyword is “exercise”. This keyword is characterized by having 18 links to other map keywords. Keywords and publications of the cluster confirm the possibility of using kickboxing for rehabilitation and recreational purposes. It has been proven to optimize health, improve the quality of life, and recovery from traumatic brain injuries.

The second cluster is marked green on the map. It received the title “Combat sports”. This keyword

is part of it. It was characterized by the presence of 21 links. The keywords of this cluster are as follows: In descending order of the number of connections: “performance” – 20, “time-motion analysis” – 14, “physiological-responses” – 13, “adolescents” – 8, “taekwondo” – 6. Keywords of this cluster determine the focus of publications on the assessment of the time spent on the implementation of technical and tactical elements of kickboxing, the study of the physiological characteristics of athletes, and the study of the connection between them and performance.

The third cluster is marked blue on the map. It received the code title “Sport”. This is the most significant of the five words in this cluster. It has 20 links. The keywords of this cluster are arranged as follows in decreasing order of the number of links: “kickboxing” – 18, “power” – 16, “strength” – 11, and “reliability” – 8. The keywords reflect the focus of research on the assessment of basic physical qualities, such as strength and endurance, and analysis of the adaptive potential of athletes.

The fourth cluster is marked yellow on the map. It includes four keywords: “lactate” – 15 links, “health rate” – 13, “recovery” – 12, “time” – 12. We titled it “Recovery”. The keywords illustrate the study of the recovery features of athletes, the study of the biochemical features of homeostasis, and the state of the cardiorespiratory system.

The fifth cluster is marked in purple on the map. It consists of three keywords: “competition” – 15 links, “profile” – 13, “velocity” – 10. We titled it “Success”. This research is focused on studying the important factors for winning competitions.

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

Keywords are analyzed by frequency of citation and differ in color. Blue corresponds to the lowest average number of citations, yellow corresponds to the highest.

In the first cluster, this indicator is the highest for “quality-of-life” – 30.20. In the second cluster for

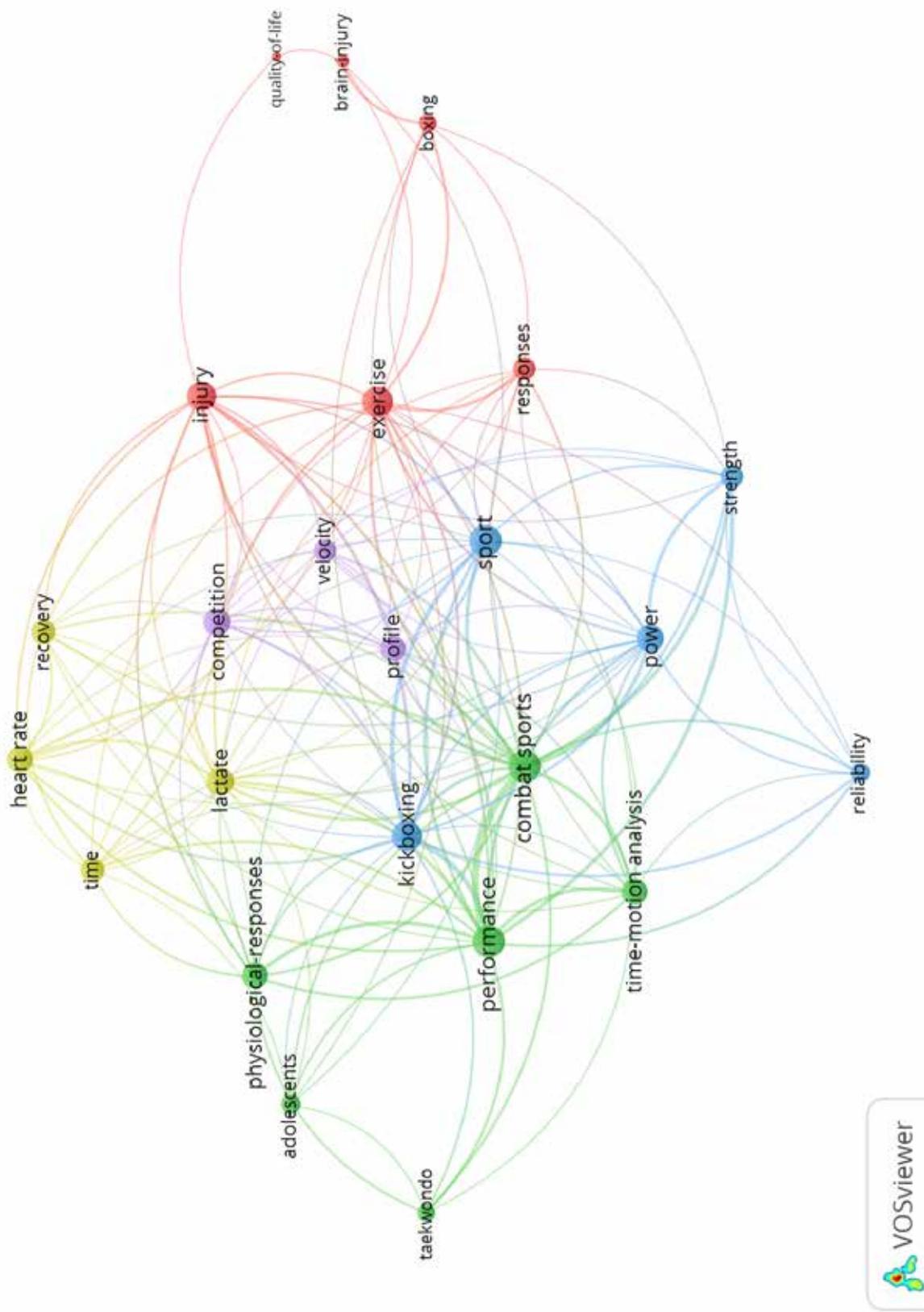


Figure 1. The main keywords in kickboxing publications, network visualization. Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

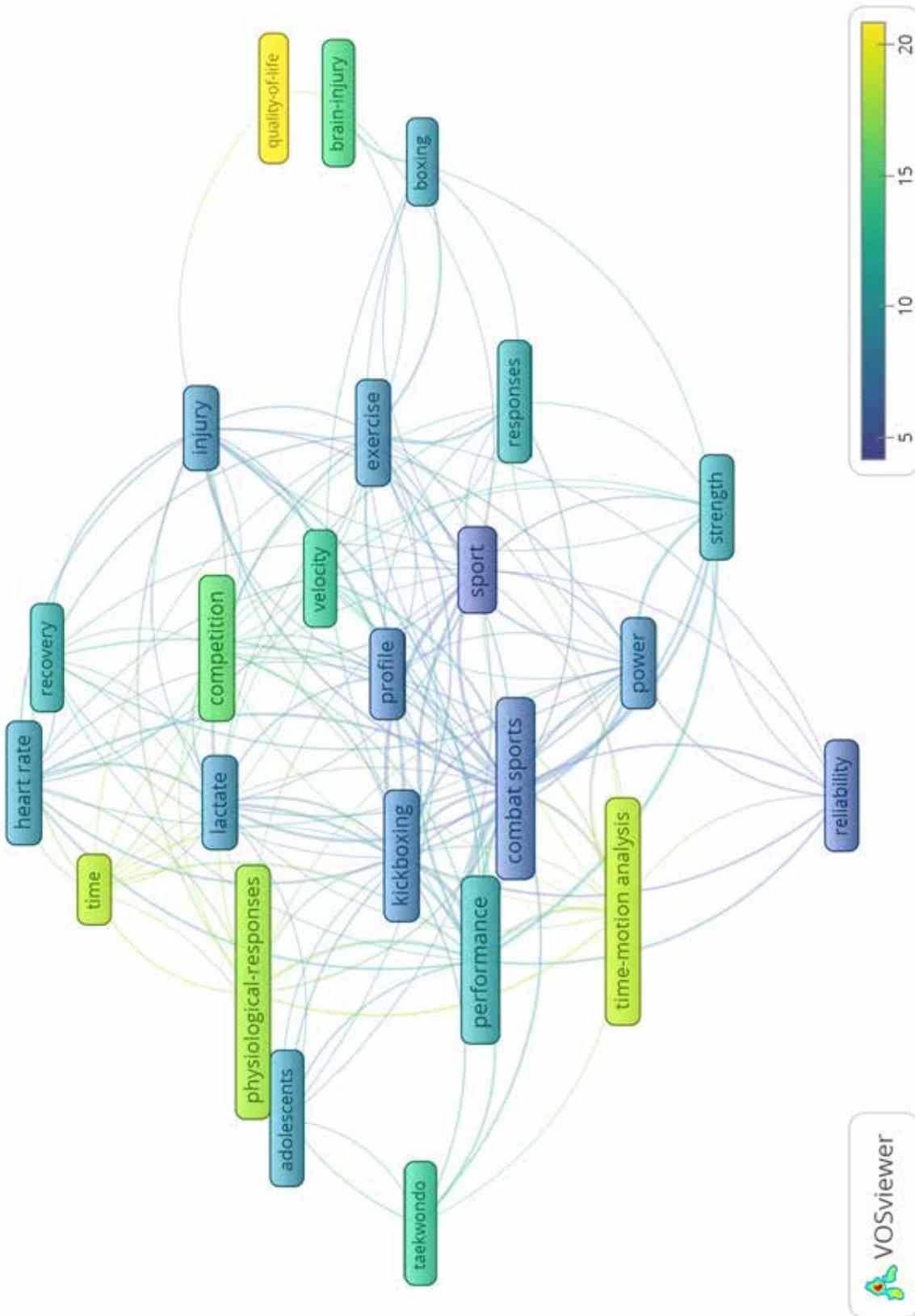


Figure 2. Average number of keyword citations in kickboxing publications, overlay visualization. Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

“time-motion analysis” – 17.89 and “physiological-responses” – 17.25. In the third cluster for “strength” – 10.09. In the fourth cluster for “time” – 17.80. In the fifth cluster for “competition” – 15.14.

The results of density visualization are shown in Fig.3. Data interpretation on Fig. 3 is similar to Fig. 1: the more important the subject is, the larger is its circle and font size. Fig. 3 allows identifying the studies that can be categorized as the most popular. These include studies on the topic (in order of importance): “combat sports”, “performance”, “kickboxing”.

The total strength of the simultaneous connection with other keywords was determined for each of the 24 keywords

The maximum value of the strength of the simultaneous connection with other keywords is set for “combat sports” – 94. In decreasing order, they are as follows: “performance” – 89, “kickboxing” – 58, “sport” – 41, “power” – 40, “exercise” – 35, “lactate” – 33, “injury” – 33, “strength” – 28, “heart rate” – 27, “physiological-responses” – 27, “time-motion analysis” – 27, “competition” – 24, “profile” – 20, “recovery” – 18, “time” – 17, “velocity” – 16, “reliability” – 15, “responses” – 15, “taekwondo” – 12, “boxing” – 11, “adolescents” – 10, “brain-injury” – 6, “quality-of-life” – 2.

A bibliometric citation map (Fig. 4) was created based on the sample (n=146). To determine the main references, the sample was limited to the following indicators: the maximum number of co-authors – 25, the minimum number of author’s documents – 2; the minimum number of author citations is 0. Out of 486 authors, 65 reached the indicated limits. 21 authors with the highest total link strength were selected among them. Analysis of Fig. 4 illustrates the work fields of these authors. Most authors belonged to the green and red clusters. The blue cluster is represented by only two authors. The authors of the yellow and purple clusters are absent from the map. The results allow us to conclude about the most popular authors focused on the problems of kickboxing. Among them are the follows: Francini Emerson, Ouergui Ibrahim, Ambrozy Tadeusz, Rydzik Łukasz.

Discussion

The analysis made it possible to identify the most priority areas in the scientific support of kickboxing. They can be divided into sports and rehabilitation and recreational areas.

In a sports context, priority is given to the implementation of technical and tactical elements of kickboxing, the study of the physiological characteristics of combat sports athletes; assessment of the main physical qualities and analysis of the adaptive potential of athletes; the study of biochemicals and features of homeostasis, the state of the cardiorespiratory system; highlighting factors

important for winning competitions.

Kickboxing training is used in rehabilitation and recreation to optimize the functional state, recovery from injuries, and improve the quality of life of patients with chronic diseases. In the context under consideration, we were interested in the first direction.

An analysis of network visualization (see Fig. 1) allows us to draw the following conclusions. The study of combat sports is the most sought-after. It is interesting to highlight the general term “combat sports” and the separate term “kickboxing”. This reflects the studies in which these sports were compared. Such a comparison allows us to highlight the specific features of kickboxing, and to assess the impact of the sport on the body of athletes. The overwhelming majority of works are aimed at studying sports kickboxing. This explains the widespread use of this keyword. The keyword “exercise” implies an analysis of the characteristics of the training. Simultaneously, this word is common to both selected areas. Exercises are used in both sports for rehabilitation and recreation. This issue was confirmed in the analysis of the first cluster.

Overlay visualization analysis data illustrate the relevance of kickboxing to improve the quality of life of various ages’ people and health conditions. In the sports context, the significance of the study of technical and tactical actions in kickboxing, psychophysiological, physical, and physiological characteristics of athletes has been confirmed. A sufficiently high citation level confirms the relevance of research on the functional state in various stages of preparation and competition periods. The importance of studying competitive features in kickboxing is also confirmed.

The density visualization analysis also makes it possible to highlight the most important directions in the studied problem. These include general problems of combat sports, comparison of kickboxing with other types of combat sports, and analysis of the athletes’ potential. The analysis of Fig. 3 confirms the conclusions made in the analysis of Figs. 1. Density imaging analysis data confirm that publications are predominantly devoted to sport. Studies devoted to the recreational and rehabilitation issues are practically unconnected with other publications.

Performing technical and tactical elements of kickboxing, studying the physiological characteristics of combat sports athletes.

The most sought-after authors in the field of kickboxing work in this direction. The results of the study [14] confirmed the effectiveness of using video recordings of fights with special software for calculating and analyzing special indicators of technical and tactical training.

The analysis of video recordings in combat

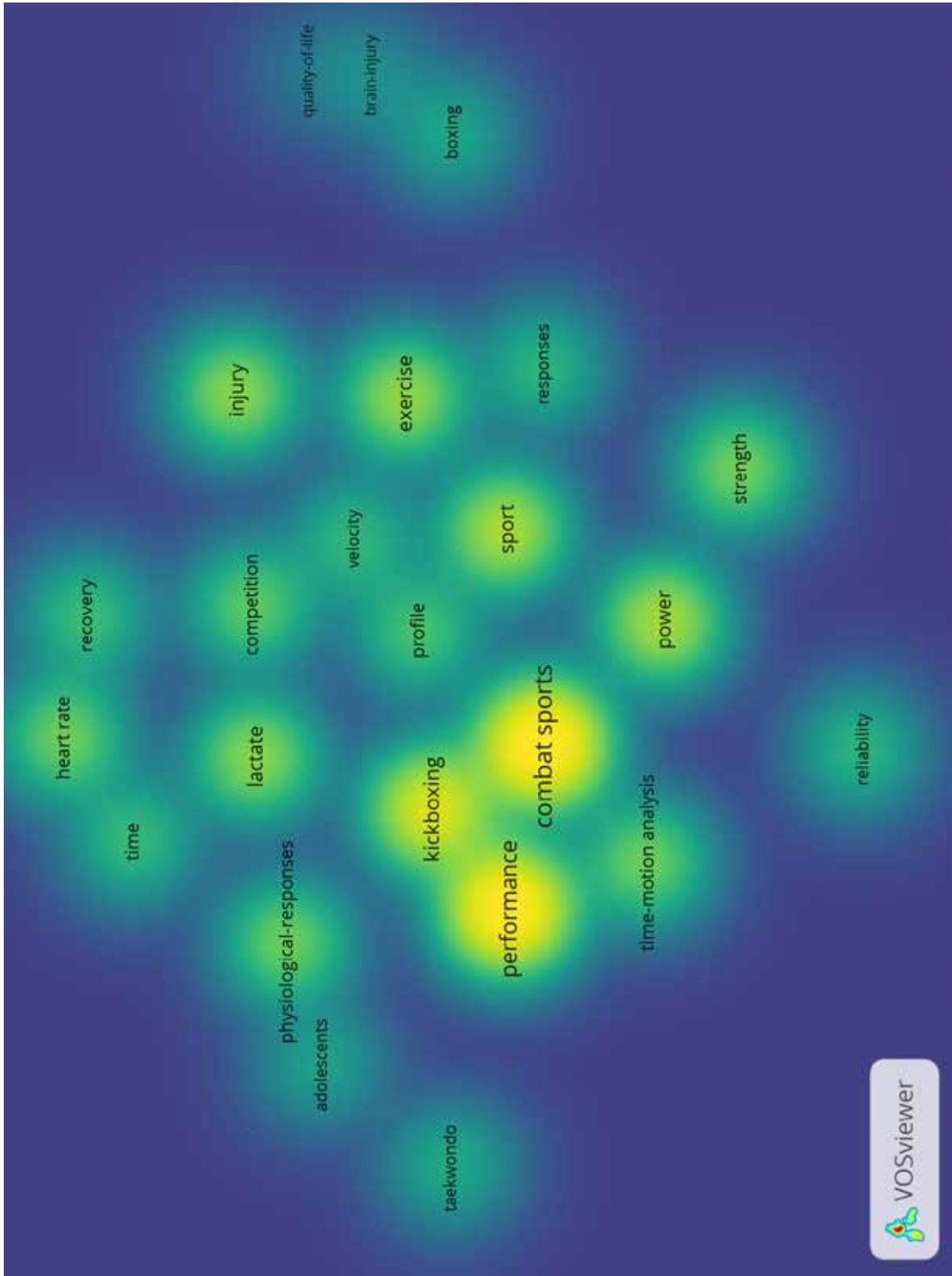


Figure 3. Directions of research in publications devoted to kickboxing (direct citation analysis, visualization of cluster density, weights - citations). Source: Own research based on data sourced from WoS and analyzed with VOSviewer (06/01/2022).

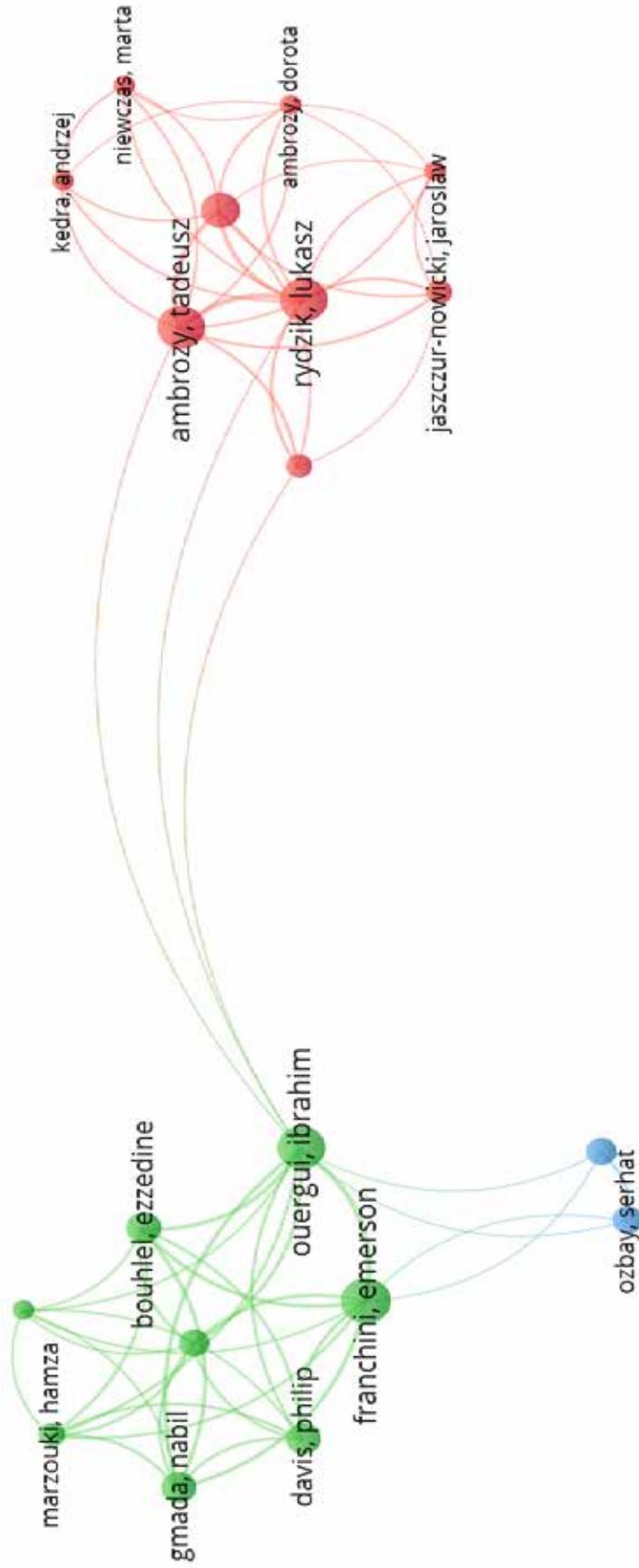


Figure 4. Main authors studied kickboxing problems, direct citation analysis, element density visualization, weights – citations): Source: own study based on data from WoS and analyzed using VOSviewer (06/01/2022).

sports is a simple and effective method of research. It was used to assess the frequency of rule violations and the possible impact on performance [15]. Performance indicators were calculated: activity, overall performance, and attack performance. The connection between the number of rule violations and indicators of technical and tactical training was determined. It was found that the calculated indicators had no connection with the number of rule violations.

Using the most effective techniques in kickboxing allows increases the likelihood of success. Ambrozy et al. [16] analyzed the connection between wins and the use of various techniques. The head hook and roundhouse kick were the most effective kickboxing techniques to win by knockout. Particular attention to the fighters during training should be given to the combinations of punches and kicks using these techniques.

Belosevic et al. [17] identified the most significant technical indicators for achieving success in kickboxing. An analysis was made of a sample of 8 final matches of the K1 tournament and the frequency of components of 280 matches. Reducing the distance is an important condition for a successful attack. The front hook can be used to thwart an opponent's attack and successfully defend.

An analysis of the time spent on the implementation of various technical and tactical elements for elite kickboxing athletes was carried out [18]. Male athletes performed more jab crosses and fewer low kicks than females. They punched more often than kicked, to the head more often than to the body and legs. It is concluded that the training programs must be adapted to the specific requirements of the weight categories and gender of kickboxing athletes to develop technical and tactical abilities that increase the chances of athletes to win.

Another popular trick in kickboxing is the double side kick. The determination of the main parameters of this kick was the purpose of this study [19]. Analysis of video recordings of kicks by elite athletes made it possible to identify the elements most important for the successful implementation of this technique.

The series of studies by Ouergui et al. [14,20,21] was devoted to the analysis of the time structure of fights in kickboxing. The results confirm the intermittent nature of kickboxing competition. This information is important for planning training sessions, simulating physical activity at competitions, and maintaining a high level of technique during a fight. An analysis of video recordings of fights showed that kickboxing athletes were more engaged in offensive actions than defensive ones. The most commonly used moves were straight punches, roundhouse kicks, blocking/parrying, and kicking. The winners used more

attacking (i.e., hook strikes), defensive techniques (i.e., kicking and clinching), and punch combinations than the losers. To win, athletes must develop the most commonly used offensive techniques.

Mala et al. [22] studied the features of body composition and the asymmetry in combat sports athletes. It was determined the differences in body composition between groups in terms of the absolute values of free fat mass (FFM), bone mass, protein mass, basal metabolic rate, absolute value of total body water (TBW). A significantly larger volume of water was found in the dominant hand compared with the non-dominant hand in karate and fencing athletes.

Similar results were obtained when studying the body composition of elite combat sports athletes [23]. Judo and sambo athletes have a larger relative amount of fat tissue (about 12%). The values of fat tissue for kickboxing and taekwondo athletes were in the range of 7%-9%. The resulting models of body composition of wrestlers, kickboxing and taekwondo athletes make it possible to individualize the training process and predict sports results.

The availability and information content of heart rate predetermined the interest in using this indicator in the state monitoring of kickboxing athletes. The review summarizes the data devoted to heart rate (HR) to combat sports matches and determines the load on the cardiovascular system and the intensity of combat sports matches [24]. Optimal HR intensity as a percentage of HRmax ranged from 90-94% in judo, 86-100% in taekwondo, 83-94% in karate, and approximately 95% during Muay Thai matches. It is recommended to use HR to assess the potential of the cardiovascular system and control the intensity of exercises during combat sports competitions.

Gavrilošević et al. [25] studied the dynamics of heart rate in kickboxing athletes during various training and competitive loads. During a match, kickboxing athletes achieve higher peak heart rates compared to punching and kicking the punch bag and sparring.

Another review was devoted to the analysis of data on methods for rating of perceived exertion (RPE) during competition and training in combat arts [26]. The rating of perceived exertion is a powerful tool for assessing training and competitive loads in beginner and elite combat athletes. RPE methods make it possible to assess the activation of the anaerobic and aerobic systems.

Evaluation of the main physical qualities and analysis of the adaptive potential of athletes.

The conducted bibliographic analysis confirmed that Ambrozy Tadeusz, Rydzik Łukasz are among the most effective authors in the field of kickboxing. In the article [27], they studied the effect of modified training based on the principles of crossfit on the

development of general physical fitness in a group of kickboxing athletes compared to the control group. An experimental training program based on the principles of crossfit training demonstrated a positive effect on the general and special physical fitness of kickboxing athletes.

Ambrozy et al. [28] confirmed that individuals with higher physical fitness were more active and effective in attack. Indicators of special effectiveness correlated significantly with technical and tactical parameters. Improvements in performance depended on punching speed, kicking distance, and special fitness test scores.

Strength, power and flexibility are some characteristics that give kickboxing athletes an edge over their opponents [29]. Increasing the level of these qualities with the help of special exercises allows increase the success of athletes. The importance of increasing flexibility in the preparation of kickboxing athletes has been confirmed. Simultaneously, the strength of compression is recognized as an uninformative quality for this sport.

Catikkas et al. [30] assessed the anthropometric characteristics of combat sports athletes such as karate, taekwondo, judo, and kickboxing. It was established that the mesomorphic somatotype dominates. Although the BMI was considered normal, the percentage of body fat was low. The athletes had broad shoulders, narrow hips and average body sizes.

The state monitoring of kickboxing athletes requires informative, valid and accessible and functional tests. The urgency of monitoring especially increases when regular observations by the coach are impossible. The physical fitness of athletes was studied during the SARS-CoV-2 pandemic [31]. A test developed by the International Committee for the Standardization of Physical Fitness Tests (ICSPFT) was used. The Tanita BC601 Body Constitution Monitor assessed the body constitution. The effectiveness of these methods has been confirmed. An increase in the body weight of athletes and deterioration in their physical fitness have been determined.

An important aspect of monitoring is the substantiation and development of screening tests to predict the growth of athletes' sportsmanship. It is proposed to use for the ratio of the second and fourth fingers of the hand (2D:4D) [32]. In judoists, wrestlers and kickboxing athletes, the 2D:4D ratio was significantly lower (on average by 0.035) than in other athletes, and in karate and taekwondo athletes it was significantly higher (on average by 0.014) than in other athletes. This index can be a useful criterion in the selection of athletes. The definition of 2D:4D reference values for specific sports is recommended.

The tensiomiography method can be used as a screening test for the kickboxing athletes' state

[33]. This method allows determining local muscle fatigue, assessing the marker level of exercise-induced muscle damage (EIMD).

The specific kickboxing circuit training protocol (SKCTP) can be used for a similar purpose [7]. The effectiveness of SKCTP as a special tool for quantitative assessment of the level of physical fitness of kickboxers has been confirmed. This is because SKCTP adequately reproduces the hormonal, physiological and physical aspects of competition.

Combat sports can lead to specific morphofunctional changes in the body. Domaradzki et al. [34] conducted a comparative analysis of the posture of kickboxing and crossfit athletes. The presence of specific postural disorders in kickboxing athletes has been confirmed. It is concluded that it is necessary to include special corrective exercises in training. Postural indicators should be used for monitoring the condition of kickboxing athletes.

A comparative analysis of the strength of the leg muscles of elite kickboxing athletes was carried out in this study [35]. The presence of pronounced asymmetry was confirmed. The non-dominant leg had lower strength indicators. It is proposed to consider the results in athletes training organization.

The actual scientific direction in kickboxing is the search for adequate methods for analyzing the state of athletes. The specificity of this sport determines the interest in the study of maintaining balance. Korobeynikov et al. [36] studied the correlation between neurodynamic function and postural stability in highly skilled kickboxing athletes. Kickboxing athletes with a higher level of stability have a smaller area of fluctuations in the total center of body mass during visual deprivation. Such a higher level of resistance in kickboxing athletes is associated with an increase in accuracy and attention under conditions of differentiated information processing, while reducing muscle strength and reducing the speed of the sensory-motor response to a complex stimulus.

Similar results were obtained in a study [37]. The authors note that it is difficult for athletes to maintain balance in the third phase of the strike when performing strikes. Special balance exercises were used to improve balance, and their effectiveness was confirmed.

Flexibility refers to the physical qualities important for striking. An analysis of the goniometric parameters of the joints of the extremities of combat sports athletes was carried out in this study [38]. The influence of the level of skill on the amplitude of movements in kickboxing athletes was confirmed. The established differences reflect the specifics of the sports. The wrestlers had a higher range of motion of the wrist joint. This determines the quality of the grip in the fight. The amplitude of flexion of the right elbow joint and movements

in the shoulder joints in kickboxing athletes were increased. This allows for achieving a high-quality and strong strike. The constancy of maintaining the combat stance decreases the amplitude of adduction in the right wrist joint and abduction in the left shoulder joint in experienced athletes. An increase in training experience leads to the development of working asymmetry of movements in the joints.

Biochemical, physiological, and psychophysiological indicators of athletes reflect their functional state. Heart rate, lactate level, the speed of perceived reaction to load, the number of attacks, and leg strength in kickboxing competitions were determined in the study [39]. The metabolic requirements of athletes gradually increase from the first to the third round. This is manifested by cardiovascular responses, lactate levels, and the level of perceived load. The strength of the leg muscles and the number of punches and kicks decreased significantly during the fight. Thus, physiological stress increased, and technical and tactical indicators decreased during the three rounds.

The analysis of the adaptive potential of kickboxing athletes is one of the priority areas of research. Podrigalo et al. [40] studied the adaptive capabilities of the cardiovascular system of kickboxing athletes during standard physical activity and the recovery period. Sufficient adaptive potential of athletes, high power of the myocardium, and the possibility of more economical adaptation to the loads performed have been confirmed. The peculiarities of the reaction of participants to the loads performed reflect the specifics of combat sports.

The specificity of combat sports necessitates the control of body weight and its changes. The aim of this study [41] was to determine the rapid weight loss (RWL) in elite kickboxing athletes. Most athletes typically lose 2–5% of their body weight, while 30% lose 6–8%. It is alarming that almost 30% reported a 10% or more weight loss during sports performance. Almost half of the athletes always practice a gradual diet and increase physical activity to reduce body weight. Kickboxing athletes typically lose weight three to four times a year, usually 7–15 days before a competition. The practice of RWL in kickboxing athletes is somewhat specific and different from those of other combat sports. This can be explained by a large number of weight categories and a specific weighing protocol.

Choosing the optimal nutrition strategy is essential for success in sports. The popularity of the Mediterranean diet and the pronounced health character determined the interest in its use in sports. The influence of the Mediterranean diet on the physical performance of kickboxing athletes and runners was studied in this study [42]. Maintaining this diet for three months, along with training,

improved functional test scores and reduced body fat percentage.

Analysis of the physical development of combat sports athletes is an important element in predicting the growth of sportsmanship. The physique features of elite combat sports athletes were studied using special indices [43]. A higher body mass index in wrestlers reflects the predominance of the muscular component of the somatotype. The Erisman and Pignier indices, the shoulder width index illustrate better muscle development in wrestlers and kickboxing athletes compared to karate and taekwondo athletes. The increase in the relative body surface of wrestlers reflects the growth of their aerobic capacity. An increase in the strength index confirms the importance of grip strength for success in wrestling. Limb segment ratio indices reflect the peculiarities of combat sports techniques. The conclusion is made about the presence of features due to the specifics of the types of combat sports. The validity of the use of special indices, especially those illustrating the ratio of limb segments, in monitoring the functional state of athletes, has been proven.

Slimani et al. [44] studied the effect of mental training on the development of muscle strength, hormonal changes, and physiological adaptation in trained male kickboxing athletes. The inclusion of mental training in the training of athletes contributed to the reduction of stress levels. The athletes' characterized features were the following: a decrease in the concentration cortisol, normalization of the parameters of the cardiovascular system, and improvement in strength indicators.

The study of the biochemical features of homeostasis, the state of the cardiorespiratory system

Kickboxing fights are performed under conditions of anaerobic metabolism. Athletes must have a good tolerance for metabolic acidosis and the ability to fight effectively despite acid imbalances. Indicators of homeostasis determine the possibility of success. An analysis of the level of acid balance and technical and tactical indicators of kickboxing athletes in the dynamics of the fight was carried out in the study [45]. Elite athletes demonstrated a change in blood oxygen and carbon dioxide saturation immediately after the fight. 20 min after the fight, all indicators tended to normalize and did not differ significantly from the initial values. It is concluded that anaerobic training should be included in the training programs for kickboxing athletes. This will prepare the athletes for the stress during a fight.

Kickboxing is a type of combat sports that requires high physical fitness and coordination of movements. A kickboxing fight causes significant physiological stress. Therefore, it is important to determine the body composition of athletes before the competition and analyze their skin temperature

and skin pH during the fight [46]. Changes in skin temperature and pH were demonstrated after each round of the fight. The level of fat and muscle tissue significantly correlates with the technical and tactical skills of the K1 athletes under study.

The high loads in kickboxing require athletes to achieve high results in various aspects of fitness. This review was devoted to the analysis of the anthropometric, physiological, physical, and psychological characteristics of kickboxing athletes, considering their activity profile [6]. Male kickboxing athletes, both amateur and elite, demonstrated a higher proportion of mesomorphy with well-developed muscle mass and a low percentage of body fat. The potential of the cardiorespiratory system in these athletes varies from moderate to high. Regardless of the level of kickboxing athletes, high peak and average anaerobic power outputs have been reported. High-level kickboxing also requires sufficient limb muscle strength. Confirmed characteristics affect success and should be considered in training.

The presence of different styles in kickboxing determines the specifics of the physiological reactions of athletes and the peculiarities of conducting fights. Ouergui et al. [47] studied these indicators in full contact, light contact, and point fighting. The results are the basis for improving training. Trainers should pay special attention to the development of anaerobic and muscular strength in all disciplines, especially for full contact, light contact, and maximizing aerobic power. The training regimen may include high-intensity interval training to mimic the specifics of these sports.

Monitoring the functional state of athletes is one of the leading problems in sports science. The biochemical and physiological reactions of kickboxing athletes during fights have been studied [48]. Blood lactate level and heart rate were used as monitoring indicators. It has been determined that a fight in kickboxing causes severe physiological stress in participants. The load in the fight was close to the maximum, and anaerobic metabolism played an important role in ensuring performance.

An adequate tool for monitoring the state of athletes is to control the reaction to training loads. Biochemical methods are adequate tools for monitoring the state of athletes [49]. The stress of adaptive mechanisms leads to an imbalance in the POL system – antioxidant defense. Information on the assessment of the activity of POL processes and the state of the antioxidant system and the degree of balance shift between prooxidants and antioxidants are indicators of the general state of the body, the activity, and perfection of the functioning of regulation systems, and the maintenance of a stable state of homeostasis. The informational significance of indices reflecting the ratio of various biochemical

indicators, as well as the study of the dynamics of correlation structures for assessing the sufficiency of loads, was confirmed. The painlessness and information content of saliva studies is the basis for the use of such studies in monitoring the functional state of athletes.

The possibility of using psychophysiological and functional tests, biochemical analysis, and technical and tactical indicators in monitoring was studied in this study [50]. The informativeness of the study of blood lactate was confirmed. It was concluded that it is necessary to increase tolerance to lactate accumulation to perform more strokes.

Analysis and prediction of success in kickboxing.

This direction should be recognized as the most relevant in the context under consideration. The issues of predicting success, improving performance, and increasing sportsmanship are most often indicated in publications when substantiating the relevance of research. The solution to this problem requires the selection and application of adequate tools.

The importance of using informative tests to assess the state of kickboxing athletes is emphasized in the study [51]. The authors examined the validity and reliability of the Kickboxing Anaerobic Speed Test (KAST) and compared it with the Maximum Cyclic Sprint Test (MCST). The first test involved performing various striking techniques with the arms and legs. The second test was performed on a bicycle ergometer with repeated cyclic efforts of 5 x 6 sec with 10-sec rest intervals. The reliability and validity of the tests used were confirmed. The use of these tests allows for dividing athletes into elite and sub-elite.

Study [52] has a similar focus. The authors used the 10-second frequency speed of kick test (FSKT) and counter movement jump (CMJ) test to differentiate the skill level of kickboxing athletes. It has been shown that FSKT can be used to identify successful and unsuccessful kickboxing athletes, as it is more effective in distinguishing groups than the CMJ test.

Olmez et al. [53] studied the effect of sprint and calisthenics training methods on improving athletic performance in kickboxing. Anthropometric indicators (body length and weight, body composition) and functional indicators (aerobic endurance VO_{2max}), peak anaerobic power, and isometric leg strength) were used to evaluate the effectiveness. Repetitive sprint training and calisthenics methods are effective in regulating athletes' body composition and accelerating the development of aerobic endurance, power, and strength.

The prediction of sportsmanship's growth can be based on the study of the connection between the technical-tactical and physical training of athletes.

Rydzik et al. [54] determined a significant correlation between the indicators of technical and tactical training and the results of fitness tests. There is a connection between the effectiveness, activity, and effectiveness of attacks and upper limb movement speed, explosive strength, static hand strength, agility, VO(2)max, and abdominal muscle strength.

An important point in the prediction of combat sports is the determination of the sportsmanship level of athletes. Various indicators and criteria can be used for this. The review [55] is devoted to determining the optimal physiological profile for differentiating combat sports athletes of different levels. Wrestling is characterized by the development of maximum strength and a lower level of speed qualities. Combat sports require the predominant development of speed. The sportsmanship level directly depends on the anaerobic capabilities of the athletes. The ability to maintain long-term anaerobic efforts determines success in wrestling, and short-term – in combat sports.

The success of athletes is determined by the level of general and special performance. Romanov et al. [56] studied these indicators at the stages of pre-competitive training. An assessment of the overall performance of kickboxing athletes revealed significant reserves of the anaerobic threshold, lung volume, respiratory rate, and pulmonary ventilation. The values of systolic pressure testified to the high cardiovascular potential of the athletes during the functional test. A higher rate of lactic acid neutralization in working muscles was observed, which indicated a higher rate of adaptation to the applied loads.

A promising method for predicting success in kickboxing is the development of special prognostic methods. The use of sequential analysis according to Wald made it possible to develop such

a technique [57]. The prognostic table includes morphofunctional, physiological, biomechanical, and psychophysiological indicators, the information content of which varied within 115.45 – 2.23. The content of the prediction consists of evaluating the results, determining the appropriate predictive coefficient, and summing these coefficients to achieve one of the prognostic thresholds. Following generally accepted approaches, the threshold value was set at ± 13 , which corresponds to a probability of 95% ($p < 0.05$). Exceeding the positive threshold means a high level of success for the athlete. When the negative threshold is reached, the probability of success is low.

Conclusions

The conducted bibliometric analysis of publications devoted to kickboxing in the WoS database confirms the relevance of this area of sports science. The use of the VOSviewer program, version 1.6.18, made it possible to conduct a comprehensive analysis of the problem, to determine the priority scientific directions in this area. Publications belong to two main areas: sports and rehabilitation and recreation. These areas are practically unrelated.

In sports, the most popular direction is the analysis of the technical and tactical indicators of athletes, and the time spent on their implementation. Research has a pronounced practical orientation. The study of the metabolic characteristics of combat sports athletes and the assessment of their physical qualities are quite relevant. There is a lack of research on the comprehensive study of success. This direction is declared in many works but is practically unimplemented. The situation is similar in studies of monitoring the condition of kickboxing athletes. These areas should be recognized as the most relevant in this area.

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