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Biomechanical and psychophysiological features of qualified veteran boxers of various fighting styles

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Abstract

Purpose: to give a comparative description of the peculiarities of motor activity of boxers-veterans of different styles of fighting based on the analysis of psychophysiological and biomechanical parameters.
Material and Methods: The study involved 42 qualified veteran boxers (age 45-50 years, body length - 178.67±8.26 cm, body weight - 70.96±9.38 kg). The biomechanical indicators of a direct blow in boxing were recorded using the Kinovea program, version 0.8.15, and psychophysiological indicators using the Psychodiagnostics program. As biomechanical indicators, the speed of movement of various points of the limbs and the angles in the joints were determined. As psychophysiological indicators, the speed of a simple visual-motor reaction, a reaction of choice in various testing modes was recorded. Based on these indicators, the mobility and endurance of the nervous system were determined. The reliability of differences between groups of different fighting styles was determined.
Results. Tempo-style boxers differ from representatives of other fighting styles in their lower mobility of the nervous system and greater endurance for speedy and precise actions. Tempo-style boxers have the lowest values of the angle in the knee joint throughout the movement ($p<0.05$, $p<0.01$) and the highest speed of movement. Play style boxers are characterized by the greatest angle in the shoulder joint at the very beginning of the movement ($p<0.05$, $p<0.001$), the highest speed of fist and shoulder movement at the very beginning of the movement ($p<0.001$). Power style boxers develop maximum movement speed at the end of a straight punch compared to the beginning. Power style boxers are distinguished by the smallest values of the angle in the elbow joint, which is especially noticeable at the end of the movement ($p<0.001$).
Conclusions. Psychophysiological features of boxers of different styles of fighting are reflected in the features of the technique of a direct blow. The lack of speed when tempo-style boxers are engaged in movement is supplemented and compensated by the high speed of movement. Play style boxers are characterized by high speed of movement at the very beginning of punching. Power style boxers are distinguished by the gradual development of movement speed.
Key words: boxing, style, reaction speed, direct punch, movement speed, joint angle

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Анотація

Валентин Ю. Козін, Марина С. Омельченко, Ірина Х. Турчик, Ірина В. Єсьман. Біомеханічні та психофізіологічні особливості кваліфікованих боксерів-ветеранів різних стилів ведення поєдинку
Мета: дати порівняльну характеристику особливостям рухової діяльності боксерів-ветеранів різних стилів ведення поєдинку на основі аналізу психофізіологічних та біомеханічних показників.
Матеріал та методи: У дослідженні взяли участь 42 кваліфіковані боксери-ветерани (вік 45-50 років, довжина тіла – 178,67±8,26 см, маса тіла – 70,96±9,38 кг). Реєстрували біомеханічні показники прямого удару в боксі за допомогою програми Kinovea, версія 0.8.15, та психофізіологічні показники за допомогою програми «Психодіагностика». Як біомеханічні показники визначали швидкість руху різних точок кінцівок і величини кутів у суглобах. Як психофізіологічні показники реєстрували швидкість простої зорово-моторної реакції, реакції вибору в різних режимах тестування. На основі цих показників визначалися рухливість та витривалість нервової системи. Визначали достовірність різниці між групами різних стилів ведення поєдинку.
Результати. Боксери темпового стилю відрізняються від представників інших стилів ведення поєдинку меншою мобільністю нервової системи та більшою витривалістю до швидкісних та точних дій. У боксерів темпового стилю спостерігаються найменші значення кута в колінному суглобі протягом руху ($p<0,05$, $p<0,01$) і максимальна швидкість переміщень. Боксери ігрового стилю характеризуються найбільшим кутом у плечовому суглобі на початку руху ($p<0,05$, $p<0,001$), найбільшої швидкості руху кулака і плеча на самому початку руху ($p<0,001$). Боксери силового стилю розвивають максимальну швидкість руху наприкінці виконання прямого удару проти початком. Боксери силового стилю відрізняються найменшими значеннями кута в ліктьовому суглобі, що особливо помітно наприкінці руху ($p<0,001$).
Висновки. Психофізіологічні особливості боксерів різних стилів ведення поєдинку відбиваються на особливостях техніки прямого удару. Нестача швидкості при включенні в рух у боксерів темпового стилю доповнюється та компенсується високою швидкістю переміщень. Боксери ігрового стилю відрізняються високою швидкістю рухів на початку виконання ударів. Боксери силового стилю відрізняються поступовим розвитком швидкості руху.
Ключові слова: бокс, стиль, швидкість реакції, прямий удар, швидкість переміщень, кут у суглобі

Аннотация

Валентин Ю. Козин, Марина С. Омельченко, Ирина Х. Турчик, Ирина В. Есьман. Биомеханические и психофизиологические особенности квалифицированных боксеров-ветеранов различных стилей ведения поединка
Цель: дать сравнительную характеристику особенностям двигательной деятельности боксеров-ветеранов разных стилей ведения поединка на основе анализа психофизиологических и биомеханических показателей.
Материал и методы: В исследовании приняли участие 42 квалифицированных боксера-ветерана (возраст 45-50 лет, длина тела – 178,67±8,26 см, масса тела – 70,96±9,38 кг). Регистрировали биомеханические показатели прямого удара в боксе с помощью программы Kinovea, версия 0.8.15, и психофизиологичские показатели с помощью программы «Психодиагностика». В качестве биомеханических показателей определяли скорость движения различных точек конечностей и величины углов в суставах. В качестве психофизиологических показателей регистрировали скорость простой зрительно-моторной реакции, реакции выбора в различных режимах тестирования. На основе этих показателей определялись подвижность и выносливость нервной системы. Определяли достоверность различий между группами разных стилей ведения поединка.
Результаты. Боксеры темпового стиля отличаются от представителей других стилей ведения поединка меньшей мобильностью нервной системы и большей выносливостью к скоростным и точным действиям. У боксеров темпового стиля наблюдаются наименьшие значения угла в коленном суставе на всем протяжении движения ($p<0,05$, $p<0,01$) и наибольшая скорость перемещений. Боксеры игрового стиля характеризуются наибольшим углом в плечевом суставе в самом начале движения ($p<0,05$, $p<0,001$), наибольшей скорости движения кулака и плеча в самом начале движения ($p<0,001$). Боксеры силового стиля развивают максимальную скорость движения в конце выполнения прямого удара по сравнению с началом. Боксеры силового стиля отличаются наименьшими значениями угла в локтевом суставе, что особенно заметно в конце движения ($p<0,001$).
Выводы. Психофизиологические особенности боксеров различных стилей ведения поединка отражаются на особенностях техники прямого удара. Недостаток скорости при включении в движение у боксеров темпового стиля дополняется и компенсируется высокой скоростью перемещений. Боксеры игрового стиля отличаются высокой скоростью движений в самом начале выполнения ударов. Боксеры силового стиля отличаются постепенным развитием скорости движения.
Ключевые слова: бокс, стиль, скорость реакции, прямой удар, скорость перемещений, угол в суставе
Ключевые слова: коленный сустав, изокинетическое тестирование, крутящий момент, мышцы-разгибатели и сгибатели.

Introduction

Veteran boxers are a special category of people who do not just want to lead an active lifestyle and maintain their physical and psychological condition at an optimal level. These are athletes who continue to take risks [1, 2, 3]. At every training session and every competition, they seem to test themselves for courage, cleverness, courage, and the ability to withstand the dangerous circumstances of life at any moment and to protect themselves and their loved ones. They train almost all their lives, honing their skills [4, 5]. And each of them is more and more formalizing their own style of fighting. With increasing age with constant practice of any type of motor activity come to the fore movements that are most optimal in terms of anthropometric, physiological, psychological characteristics of each person. This is reflected in the clear manifestation of a certain style of movement, which with age becomes more noticeable [6]. That is why determining the characteristics of the style of fighting veteran boxers is relevant as a problem of determining the styles of people in general. In addition, this problem is relevant in terms of identifying the peculiarities of the fight of representatives of not only boxing but also other martial arts [7]. The issue of determining the indicators characteristic of a certain style of fighting is relevant for building the training process of boxers at all stages of the training process, in particular - for veteran boxers.

To date, the nature of the origin of different styles is not fully understood. There are hypotheses that suggest that the styles are the result of separate training of certain groups of people [1, 2, 8]. There are also historical facts that indicate the origin of the styles of dueling as imitation of the manners of movement and survival strategies of different animals [2, 8]. Thus copying was carried out both external movements, and internal states. Martial arts from the "crane style" have come down to our time, as well as different styles of fighting within one martial art - "style of image and form" or "style of imitation of form". They are based on imitating the movements and habits of animals. Man, mastering the "form and manner" of the tiger, snake, dragon, reached the natural freedom and natural potential of the animal in its "original state" [8, 9]. At the present stage, the vast majority of scientists in the field of martial arts, there are three options for tactical styles of fighting: game, power, tempo [1, 2].

What indicators to choose to compare boxers with different styles of fighting? First of all, these are indicators of movement technique, because it is the features of individual technical skills that are reflected in a certain style of movement. There are various research methods for this. Most researchers use observation of boxers during a fight with the fixation of applied technical and tactical elements [8, 9]. There is also a deeper analysis of the technical characteristics of each athlete on the basis of biomechanical indicators of individual movements [10, 11, 12]. But in modern boxing, this method is just beginning to be embodied in the practice of researching the movements of athletes of different styles. Biomechanical analysis allows to objectively determine the peculiarities of the development of the speed of the limbs and torso, changes in the angles in the joints and other indicators of movement of athletes [11, 12]. Therefore, this area of research has scientific prospects for both boxers and people in general to understand the peculiarities of the formation of individual manners and styles of motor activity. In addition, a promising area is also the definition of psychophysiological indicators, in particular - the speed of the pulse in different structures of the central nervous system [13]. The physiological basis of style formation is relatively constant genetically determined functions, such as neurodynamic processes and psychophysiological capabilities, and registration of these indicators in the training process will help determine the propensity of a boxer to a certain style of fighting. It was found that the level of development of psychomotor reactions and specific perception of athletes has certain relationships with typical styles of fighting [13, 14, 15].

For practical work it is necessary to use informative indicators, quite accessible in the definition, which do not require a long period of time for their development and relatively constant in ontogenesis [16, 17, 18]. Psychophysiological indicators can be used for this purpose [19–22]. Also, genetically determined psychophysiological indicators should be supplemented with indicators that are an external reflection of the internal state of man, ie indicators of motor activity [23, 24, 25]. From this point of view, it is advisable to use biomechanical indicators. Thus, the study hypothesized that veteran boxers with different styles of fighting differ in biomechanical and psychophysiological indicators.

Purpose of the work: to give a comparative description of the features of motor activity of boxers-veterans of different styles of fighting based on the analysis of psychophysiological and biomechanical parameters.

Material and methods

Participants

The study involved 42 qualified veteran boxers (age 45-50 years, body length - 178.67±8.26 cm, body weight - 70.96±9.38 kg). The total experience of boxing for the participants was 20-25 years. Athletes were selected as follows: a prerequisite for participation in the study was the presence of a sports qualification in the past not lower than a candidate for master of sports (winners of competitions not lower than the level of the city or region) and the regularity of training for the last 10 years 3-4 times a week. The study was conducted on the basis of sports clubs "KhTZ", "Vostok", "Metalist" in Kharkov, Ukraine.

All participants were aware of the aims of the study and agreed to participate. The study followed the principles of the Declaration of Helsinki and the World Association of Medical Editors.

Fighting styles were determined using a combination of factor and cluster analysis methods, the results of which are presented in our previous studies. [26].As a result of determining the styles of the fight, the boxers were distributed as follows: tempo style (n=11), game style (n=16), power style (n=15).

Procedure

The study was conducted from April 18 to May 25, 2021. At the beginning, video filming of athletes was carried out when performing a direct blow in boxing. Each athlete performed a series of blows alternately with his right and left hands in the mode of a training session against the background of a visible object for subsequent calibration with known dimensions. Video filming was carried out at training sessions from 18:00 after a short warm-up in the boxing gym of the KhTZ sports club. During one training session, 10-12 people were filmed. The next day after the video shooting, the athletes underwent psychophysiological testing also from 18:00. When conducting psychophysiological testing, athletes were first asked to pass the proposed tests in the training mode. Psychophysiological testing was carried out in the classroom for theoretical classes of the sports club "KhTZ".

Biomechanical analysis of direct punch technique in boxing

We have chosen direct hit as the main element for the analysis of sports equipment of qualified veteran boxers. The choice of direct hit was due to the fact that it is the main technical element in boxing. This stroke is the most standardized among all elements of boxing and provides the least variability of performance [26, 27, 28]. This element is perfectly mastered by all qualified boxers, in particular - veteran boxers. Also, the individual style of movement is most traced in those movements that are performed most automatically, ie with minimal control by the mind. This impact is most convenient for biomechanical analysis using video, as it is performed in almost the same plane.

Biomechanical analysis of direct hit technique in qualified veteran boxers was performed using the program "Kinovea", version 0.8.15. (Figs. 1, 2). Kinovea allows you to perform video analysis of movements. It is designed for athletes, coaches, health professionals, for research in the field of sports. Software can also be useful for professionals in the field of ergonomics or animation. The main function of Kinovea is to view and analyze sports videos. The main tools that involve users: "Line", "Chronometer", "Tracking", "Angles". The "Line" and "Chronometer" functions allow you to measure distance and time, and with the help of the tool "Semi-automatic tracking" you can track both the trajectory and time. When working with Kinovea, you can use video from external sources: camcorders, smartphones, and so on [11, 12].

For the analysis of biomechanical parameters of the direct hit technique, qualified veteran boxers were selected 6 frames at a speed of 26 frames per second. Thus, the time of one frame was 0.03-0.04 s (Fig. 1, 2). The total duration of the direct strike was 0.13-0.16 s, depending on the number of frames analyzed (5 or 6, respectively). Distance calibration was performed along the length of a special device, on the background of which video recording was performed (138 cm). The movement time was determined by the stopwatch in the program. The speed of movement of the fist, shoulder joint, elbow joint, knee joint (V, m • s-1) was determined (Fig. 2). The angles between the shoulder and the torso (angle in the shoulder joint), between the shoulder and the forearm (angle in the elbow joint), between the thigh and the shin (angle in the knee joint) (degrees) were also determined (Figs. 1, 2).

In total, 10 videos of direct hit for each athlete were analyzed. Of the 10 videos, the average data for each athlete was analyzed. The total number of videos was 420. The end of the impact was chosen as the point of greatest extension of the impact arm in the shoulder joint. In each video, 6 frames (duration of direct hit) were selected for analysis. If the stroke ended in the fifth frame, the sixth frame was excluded from the analysis. Before the fifth

frame, no athlete had a direct hit. Thus, the total duration of a direct hit in boxing in qualified veteran boxers was 0.13-0.16 s. The point of the minimum angle between the shoulder and the torso (shoulder joint), from which the movement of the striker's arm begins, was chosen as the beginning of the impact [26].

The Angles tool was chosen to analyze the angles in the joints on the Kinovea 0.8.15 toolbar. The point of the vertex of the angle was chosen, then the angle was determined for analysis. The angle selected for analysis was determined in each frame (Figs. 1, 2).

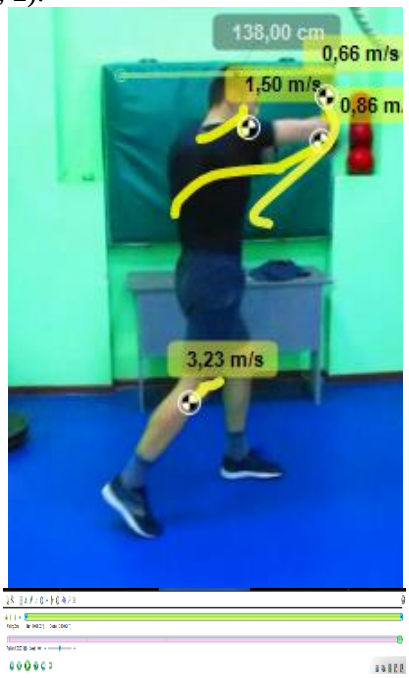


Fig. 1. Determining the speed of movement of various points of the body when performing a direct blow in boxing using the Kinovea 08.15 program



Fig. 2. Determining the angles in the joints when performing a direct blow in boxing using the Kinovea 08.15 program

We carried out the following trajectory tracking for subsequent analysis of the distance and speed of movement of each point (Fig. 1): 1 – we chose a point for analysis; 2 - chose the option "Track Path" ("Record the trajectory"); chose the "End Path Edition" function; 3 – the analyzed point was corrected for each frame; 4 - select the "Configuration" function and set the "Distance" function. The display showed the distance from the start of the movement to the selected section of the path. To measure the speed of the point, we selected the "Configuration" function, and then we selected the "Speed" function. We chose meters per second as the units of measurement. The measurement results were exported to the EXCEL program.

Psychophysiological methods

The following parameters characteristic of the psychophysiological state, typological features of the nervous system, indicators of the nervous system efficiency, and attention indicators [15] have been set using the computer program "Psychodiagnostics" (Kharkiv, Ukraine, KhNPU):

– A set of indices for the time of a simple visual-motor reaction (mean of 30 attempts (ms), standard deviation (ms), number of errors); duration of exposure (signal) – 900 ms.

– A set of indicators of a complex visual-motor reaction of selecting 2 element from 3 (mean value of 30 attempts (ms), standard deviation (ms), number of errors); duration of exposure (signal) – 900 ms.

– A set of indicators of a complex visual-motor reaction of selecting 2 elements out of 3 in the feedback mode, i.e. as the response time changes, the signal delivery time changes. The 'short version' is carried out in the feedback mode, when the duration of exposure changes automatically depending on the response of the subject: after a correct answer, the duration of the next signal is reduced by 20 ms, and after a wrong one, it increases by the same amount. The range of the signal exposure change during the test subject's operation is 20–900 ms, with a pause between exposures of 200 ms. The correct answer is to press the left (right) mouse button while displaying a certain exposure (image), or during a pause after the current exposure. In this test, the time to reach the minimum exposure of the signal and the time of the minimum exposure of the signal reflect the functional mobility (speed) of the nervous processes; the number of errors reflects the strength of the nervous processes (the lower these parameters, the higher the speed endurance of the nervous system). The duration of the initial exposure is 900 ms; the amount of change in the duration of the signals with correct or erroneous responses is 20 ms; pause between the presentation of signals – 200 ms; the number of signals is 50. The indicators are fixed: the average value of the latent period (ms); root mean square deviation (ms); number of mistakes; time of test execution (s); minimum exposure time (ms); time of exposure to the minimum exposure (s).

Statistical analysis

We used the following methods of statistical analysis using the SPSS-23.0 program.

1. Descriptive statistics (Analyze - Descriptive Statistics). We used this method to obtain a general idea of the analyzed sample of qualified veteran boxers. We calculated the following indicators: Minimum, Maximum, Mean value ((x)) , standard deviation (S). In total, 52 indicators were analyzed, including 42 indicators of the biomechanics of the technique of a direct blow in boxing and 10 indicators of the psychophysiological capabilities of athletes.

2. Determining the reliability of differences between groups of different fighting styles. To do this, a Chi-square test was first carried out to determine the normality of distribution for each group of athletes for each indicator. Since for all three groups of athletes the significance of the Chi-square test was greater than 0.05, it was concluded that there was a normal distribution for all analyzed indicators for all groups of athletes. Therefore, to determine the significance of differences between groups, we applied the Student's method. Differences were considered significant at a significance level of $p<0.05$.

Results

We determined the significance of differences between clusters (groups) of athletes. To do this, a Chi-square test was first carried out to determine the normality of distribution for each group of athletes for each indicator. Since for all three groups of athletes the significance of the Chi-square test was more than 0.05 (Tables 1–3), it was concluded that there was a normal distribution for all analyzed indicators for all groups of athletes. Therefore, to determine the significance of differences between groups, we applied the Student's method.

The analysis of differences between groups of boxers of different fighting styles showed significant differences between the time of simple visual-motor reaction in tempo style boxers and boxers of playing style ($p<0.01$), between the choice reaction time in tempo style boxers and boxers of other fighting styles ($p<0.05$; $p<0.001$), between the reaction time of choice in the test with feedback for tempo style boxers and boxers of the playing style ($p<0.001$), between the number of errors in the choice reaction test with feedback for tempo style boxers and boxers of the playing style ($p<0.001$), between the time of the minimum signal exposure in the choice reaction test with feedback for boxers of the tempo style and boxers of other fighting styles ($p<0.001$), between the time of reaching the minimum signal exposure in the reaction test selection with feedback among boxers of tempo style and boxers of other styles of fighting ($p<0.001$), between the total time of the reaction test choice with feedback among boxers of tempo style and boxers of playing style ($p<0.05$) (Table 4).

Table 1

The results of the Chi-square test of biomechanical and psychophysiological parameters of qualified boxers-veterans of the tempo style of fighting (n=11)

Indicators	Chi-Square	df	Asymp. Sig.	Monte Carlo Sig.	95% Confidence Interval	
					Lower bound	Upper bound
Simple visual-motor reaction time (ms)	4.28	10	0.5	0.49	0.48	0.5
Selection response time (ms)	2.57	10	0.46	0.27	0.27	0.28
Selection response time in feedback mode (ms)	5.14	10	0.27	0.99	0.99	0.99
Errors in the selection reaction test in the feedback mode (number)	0	10	0.99	0.27	0.27	0.28
The minimum exposure time of the signal to the test for the selection reaction in the feedback	5.14	10	0.27	0.9	0.97	0.99
Time to reach the minimum exposure of the signal in the test for the selection reaction in the	0	10	0.99	0.52	0.51	0.53
Total time to complete the test for the selection reaction in the feedback mode (s)	4.28	10	0.5	0.52	0.51	0.53
Shoulder angle at position 3 (degrees)	4.28	10	0.5	0.99	0.97	0.99
Shoulder angle at position 5 (degrees)	4.28	10	0.99	0.99	0.97	0.99
Elbow angle at position 3 (degrees)	4.28	10	0.99	0.99	0.97	0.99
Elbow angle at position 5 (degrees)	0.07	10	0.99	0.99	0.97	0.99
Knee angle in position 2 (degrees)	0.08	10	0.99	0.99	0.97	0.99

Knee angle at position 5 (degrees)	0.04	10	0.99	0.99	0.97	0.99
Fist movement speed in position 3 ($m \cdot s^{-1}$)	0.07	10	0.99	0.52	0.51	0.53
Fist movement speed in position 5 ($m \cdot s^{-1}$)	4.28	10	0.5	0.48	0.47	0.49
Shoulder speed in position 3 ($m \cdot s^{-1}$)	1.71	10	0.42	0	0	0.01
Shoulder speed in position 5 ($m \cdot s^{-1}$)	7.71	10	0	0.99	0.97	0.99
Elbow speed in position 3 ($m \cdot s^{-1}$)	0	10	0.99	0.52	0.51	0.53
Elbow speed in position 5 ($m \cdot s^{-1}$)	4.28	10	0.5	0.52	0.51	0.53
Knee speed in position 2 ($m \cdot s^{-1}$)	4.28	10	0.5	0.99	0.97	0.99
Knee speed in position 5 ($m \cdot s^{-1}$)	4.28	10	0.99	0.99	0.97	0.99

Table 2

The results of the Chi-square test of biomechanical and psycho-physiological parameters of qualified boxers-veterans of the game fighting style (n=16)

Indicators	Chi-Square	df	Asymp. Sig.	Monte Carlo Sig.	95% Confidence Interval	
					Lower bound	Upper bound
Simple visual-motor reaction time (ms)	4.28	15	0.99	0.52	0.51	0.53
Selection response time (ms)	2.57	15	0.5	0.52	0.51	0.53
Selection response time in feedback mode (ms)	5.14	15	0.5	0.99	0.97	0.99
Errors in the selection reaction test in the feedback mode (number)	5.14	15	0.99	0.99	0.97	0.99
The minimum exposure time of the signal to the test for the selection reaction in the feedback	0	15	0.99	0.99	0.97	0.99
Time to reach the minimum exposure of the signal in the test for the selection reaction in the	4.28	15	0.99	0.52	0.51	0.53
Total time to complete the test for the selection reaction in the feedback mode (s)	4.28	15	0.5	0.48	0.47	0.49
Shoulder angle at position 3 (degrees)	0.07	15	0.42	0	0	0.01
Shoulder angle at position 5 (degrees)	0.08	15	0	0.99	0.97	0.99
Elbow angle at position 3 (degrees)	0.04	15	0.99	0.52	0.51	0.53
Elbow angle at position 5 (degrees)	0.07	15	0.5	0.52	0.51	0.53
Knee angle in position 2 (degrees)	0.05	15	0.5	0.99	0.97	0.99
Knee angle at position 5 (degrees)	0.03	15	0.99	0.99	0.97	0.99
Fist movement speed in position 3 ($m \cdot s^{-1}$)	4.28	15	0.99	0.99	0.97	0.99
Fist movement speed in position 5 ($m \cdot s^{-1}$)	1.71	15	0.99	0.99	0.97	0.99
Shoulder speed in position 3 ($m \cdot s^{-1}$)	7.71	15	0.99	0.99	0.97	0.99
Shoulder speed in position 5 ($m \cdot s^{-1}$)	0.09	15	0.99	0.52	0.51	0.53
Elbow speed in position 3 ($m \cdot s^{-1}$)	4.28	15	0.5	0.52	0.51	0.53
Elbow speed in position 5 ($m \cdot s^{-1}$)	4.28	15	0.5	0.99	0.97	0.99
Knee speed in position 2 ($m \cdot s^{-1}$)	0.08	15	0.99	0.99	0.97	0.99
Knee speed in position 5 ($m \cdot s^{-1}$)	0.04	15	0.99	0.99	0.97	0.99

Table 3

The results of the Chi-square test of biomechanical and psychophysiological parameters of qualified boxers-veterans of the tempo fighting style (n=15)

Indicators	Chi-Square	df	Asymp. Sig.	Monte Carlo Sig.	95% Confidence Interval	
					Lower bound	Upper bound
Simple visual-motor reaction time (ms)	1.71	14	0.42	0	0	0.01
Selection response time (ms)	7.71	14	0	0.99	0.97	0.99
Selection response time in feedback mode (ms)	0	14	0.99	0.52	0.51	0.53
Errors in the selection reaction test in the feedback mode (number)	4.28	14	0.5	0.99	0.97	0.99
The minimum exposure time of the signal to the test for the selection reaction in the feedback	0	14	0.99	0.48	0.47	0.49
Time to reach the minimum exposure of the signal in the test for the selection reaction in the	1.71	14	0.42	0	0	0.01
Total time to complete the test for the selection reaction in the feedback mode (s)	7.71	14	0	0.99	0.97	0.99
Shoulder angle at position 3 (degrees)	0	14	0.99	0.52	0.51	0.53
Shoulder angle at position 5 (degrees)	4.28	14	0.5	0.52	0.51	0.53
Elbow angle at position 3 (degrees)	4.28	14	0.5	0.99	0.97	0.99
Elbow angle at position 5 (degrees)	0	14	0.99	0.99	0.97	0.99
Knee angle in position 2 (degrees)	0	14	0.99	0.99	0.97	0.99
Knee angle at position 5 (degrees)	0	14	0.99	0.99	0.97	0.99
Fist movement speed in position 3 ($m \cdot s^{-1}$)	0	14	0.99	0.48	0.47	0.49
Fist movement speed in position 5 ($m \cdot s^{-1}$)	1.71	14	0.42	0	0	0.01
Shoulder speed in position 3 ($m \cdot s^{-1}$)	7.71	14	0	0.99	0.97	0.99
Shoulder speed in position 5 ($m \cdot s^{-1}$)	0	14	0.99	0.52	0.51	0.53
Elbow speed in position 3 ($m \cdot s^{-1}$)	4.28	14	0.5	0.52	0.51	0.53
Elbow speed in position 5 ($m \cdot s^{-1}$)	4.28	14	0.5	0.99	0.97	0.99
Knee speed in position 2 ($m \cdot s^{-1}$)	0	14	0.99	0.99	0.97	0.99
Knee speed in position 5 ($m \cdot s^{-1}$)	0	14	0.99	0.99	0.97	0.99

Таблиця 4

Biomechanical and psychophysiological parameters of qualified boxers-veterans of different fighting styles

Indicators	Names of groups of athletes by fighting style						Reliability indicators of differences between groups of athletes					
	1 – tempo style, "Speed and coordination endurance" (n=11)		2 - play style, "Speed" (n-16)		3 - power style, "Strength and speed" (n=15)		t-1-2	p-1-2	t-1-3	p-1-3	t-2-3	p-2-3
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S						
Simple visual-motor reaction time (ms)	314	17.82	292	12.45	300	17.8	3.54	<0.01	1.98	>0.05	-1.44	>0.05

Selection response time (ms)	590.00	24.63	525.00	21.65	568.00	22.34	7.07	<0.001	2.34	<0.05	-5.44	<0.001
Selection response time in feedback mode (ms)	513.00	21.32	453.00	19.34	449.00	17.89	7.46	<0.001	8.09	<0.001	0.60	>0.05
Errors in the selection reaction test in the feedback mode (number)	17.00	2.03	20.00	2.13	19.00	2.11	-3.70	<0.01	-2.44	<0.05	1.31	>0.05
The minimum exposure time of the signal to the test for the selection reaction in the feedback mode (ms)	540.00	26.08	440.00	22.07	400.00	21.09	10.41	<0.001	14.64	<0.001	5.16	<0.001
Time to reach the minimum exposure of the signal in the test for the selection reaction in the feedback mode (s)связи (c)	73.00	8.09	43.00	5.68	50.00	4.62	10.63	<0.001	8.47	<0.001	-3.77	<0.01
Total time to complete the test for the selection reaction in the feedback mode (s)	107.00	14.82	94.00	12.67	97.00	12.48	2.37	<0.05	1.82	>0.05	-0.66	>0.05
Shoulder angle at position 3 (degrees)	77	9.12	55	6.71	69	4.76	6.83	<0.001	2.66	<0.05	-6.73	<0.001
Shoulder angle at position 5 (degrees)	86	9.67	83	9.25	78	7.56	0.81	>0.05	2.28	<0.05	1.65	>0.05
Elbow angle at position 3 (degrees)	58	5.14	91	9.63	63	6.72	-11.53	<0.001	-2.15	<0.05	9.44	<0.001
Elbow angle at position 5 (degrees)	177	14.16	151	14.46	122	12.43	4.65	<0.001	10.30	<0.001	6.00	<0.001
Knee angle in position 2 (degrees)	125	11.26	140	12.79	140	11.57	-3.22	<0.01	-3.32	<0.01	0.00	>0.05
Knee angle at position 5 (degrees)	143	15.72	163	14.65	149	14.57	-3.34	<0.01	-0.99	>0.05	2.67	<0.05
Fist movement speed in position 3 ($m \cdot s^{-1}$)	7.2	0.21	17.52	2.12	4.63	0.39	-19.33	<0.001	21.61	<0.001	23.89	<0.001
Fist movement speed in position 5 ($m \cdot s^{-1}$)	2.07	0.15	8.74	1.39	5.86	1.45	-19.03	<0.001	-10.05	<0.001	5.64	<0.001
Shoulder speed in position 3 ($m \cdot s^{-1}$)	2.56	0.18	5.71	0.92	1.74	0.08	-13.33	<0.001	14.12	<0.001	17.19	<0.001
Shoulder speed in position 5 ($m \cdot s^{-1}$)	2.41	0.17	1.06	0.01	1.9	19	26.31	<0.001	0.10	>0.05	-0.17	>0.05
Elbow speed in position 3 ($m \cdot s^{-1}$)	7.04	0.29	7.03	0.61	3.17	0.43	0.06	>0.05	27.38	<0.001	20.46	<0.001
Elbow speed in position 5 ($m \cdot s^{-1}$)	1.51	0.14	3.56	0.28	4.74	0.27	-25.08	<0.001	-39.63	<0.001	-11.94	<0.001

Knee speed in position 2 ($m \cdot s^{-1}$)	3.81	0.19	1.39	0.03	1.74	0.13	41.89	<0.001	31.18	<0.001	-10.18	<0.001
Knee speed in position 5 ($m \cdot s^{-1}$)	3.81	0.49	0.93	0.16	0.36	0.15	18.82	<0.001	22.59	<0.001	10.24	<0.001

All indicators reflecting the time are the highest among boxers of the tempo style ($p<0.05$; $p<0.01$; $p<0.001$), the indicator reflecting the number of errors when performing the choice reaction test in the feedback test, on the contrary, is the lowest among tempo style boxers ($p<0.05$; $p<0.01$). The greatest differences were revealed between these indicators in tempo style boxers and playing style boxers.

It follows from the obtained data that tempo-style boxers differ from representatives of other fighting styles in their lower mobility of the nervous system and greater endurance to speedy and precise actions. Accuracy is a manifestation of coordination abilities. In this regard, we can conclude that the boxers of the tempo style differ from the boxers of other fighting styles in greater coordination endurance, speed endurance and endurance in performing precise actions over time.

We also revealed that the psychophysiological features of boxers-veterans of different fighting styles determine the features of the direct punch technique. So, playing-style boxers, when performing a direct blow, sometimes first move their arm backwards, performing a small swing, then at high speed at the very beginning of the movement they perform a blow. This is reflected in the largest angle in the shoulder joint at the very beginning of the movement ($p<0.05$, $p<0.001$) (Table 4, Fig. 3), the greatest speed of movement of the fist and shoulder at the very beginning of the movement ($p<0.001$) (0 06 s from the start of movement) (Fig. 4, 5).

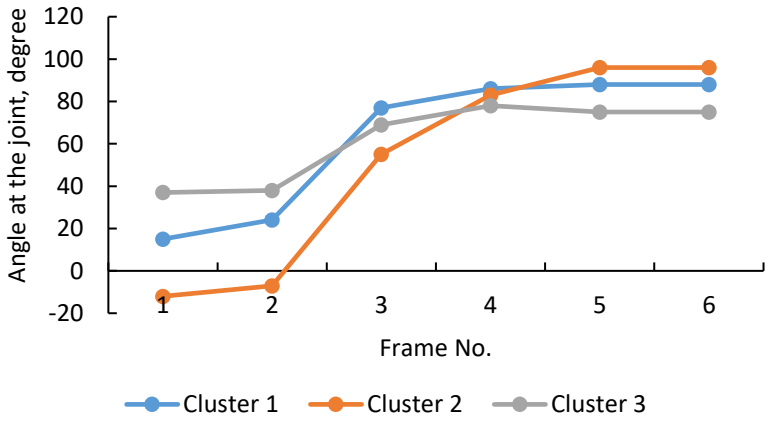


Fig. 3. The values of the angles between the shoulder and the torso of qualified veteran boxers of different fighting styles:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

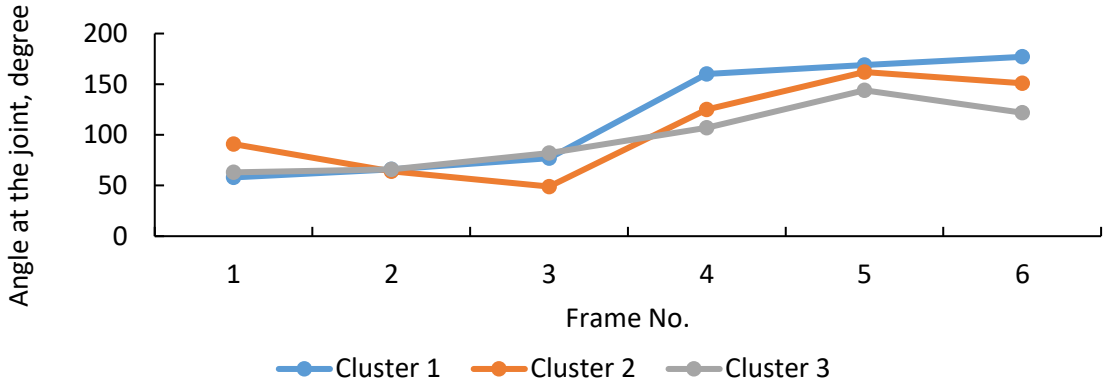


Fig. 4. Values of the angles between the shoulder and forearm of qualified boxers-veterans of different fighting styles:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

Such a quick start serves as a compensatory mechanism for the lack of speed and coordination endurance compared to tempo style boxers. To quickly achieve the result, boxers of the playing style develop maximum speed already in the first milliseconds of the execution of a direct blow. In addition, boxers of the playing style have the highest stance with the least bending of the knees (Table 4, Fig. 6). This is due to the fact that a high stance gives more opportunities for review and analysis of the situation and makes it possible to quickly vary actions. Boxers of the playing style also have the smallest angle in the elbow joint at the very beginning of the movement (0.06 s from the beginning of the movement) (Table 4, Fig. 6) and the lowest speed of movement of the knee joint (Table 4, Fig. 7) as at the beginning and at the end of the movement.

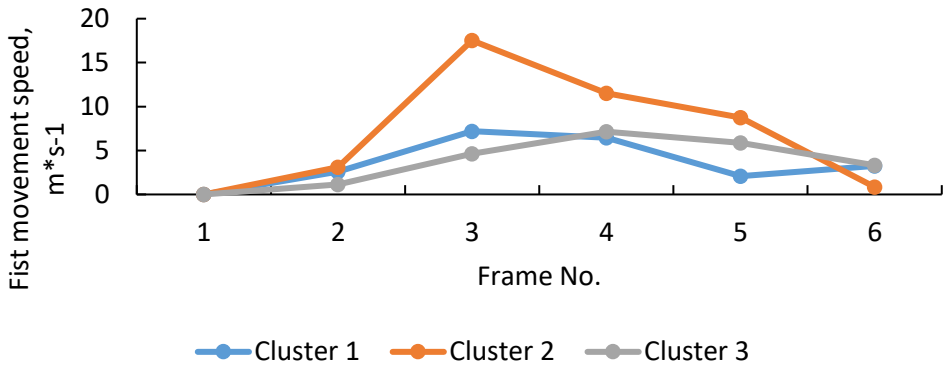


Fig. 5. Values of fist movement speed of qualified boxers-veterans of different fighting styles:
Cluster 1 - "Speed and coordination endurance", tempo style; Cluster 2 - "Speed", game style; Cluster 3 - "Strength and speed", power style; 1 – initial value of movement, 0.00 s; 2 - the second frame from the beginning of the movement, 0.03 s; 3 - the third frame from the beginning of the movement, 0.06 s; 4 - the fourth frame from the beginning of the movement, 0.10 s; 5 - the fifth frame from the beginning of the movement, 0.13 s; 6 - the sixth frame from the beginning of the movement, 0.16 s

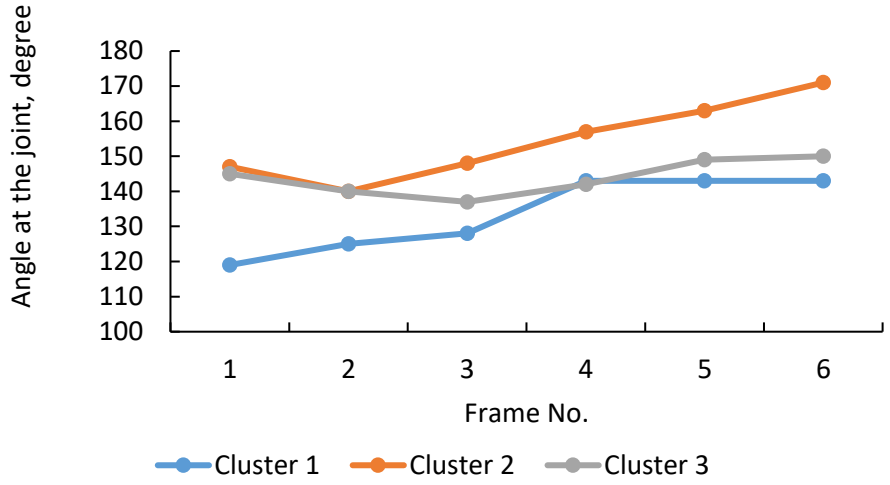


Fig. 6. The values of the angles between the thigh and lower leg in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

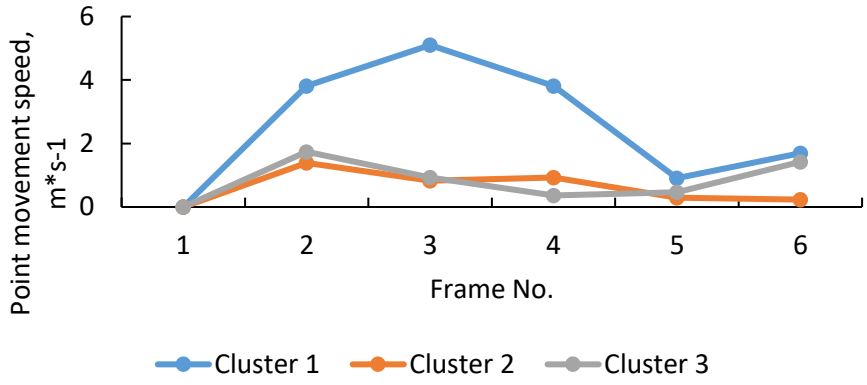


Fig. 7. Values of the speed of movement of the knee joint in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

We also revealed that the different fighting styles determine the features of the psychophysiological features of boxers-veterans of direct punch technique.

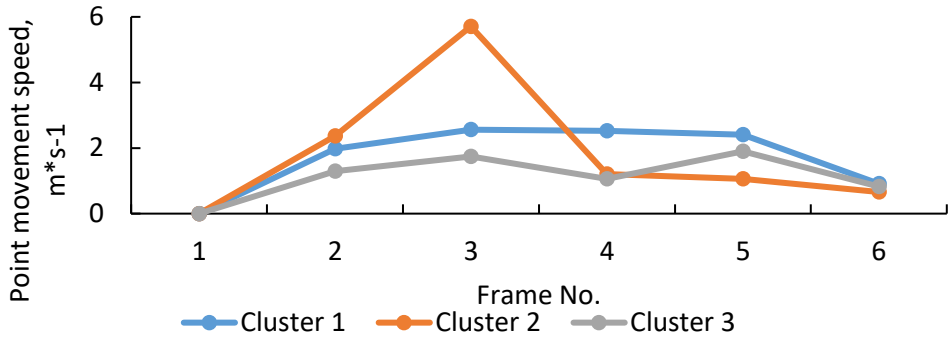


Fig. 8. Values of the speed of movement of the shoulder joint in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

Power-style boxers develop the maximum movement speed at the end of a direct punch compared to the beginning (Table 4, Fig. 5, 7, 8, 9), which is due to the gradual activation of myofilaments and motor units to achieve maximum strength. Also, power-style boxers are distinguished by the smallest values of the angle in the elbow joint, which is especially noticeable at the end of the movement (0.13-0.16 s from the beginning of the movement) ($p<0.001$) (Table 4, Fig. 3, 4).

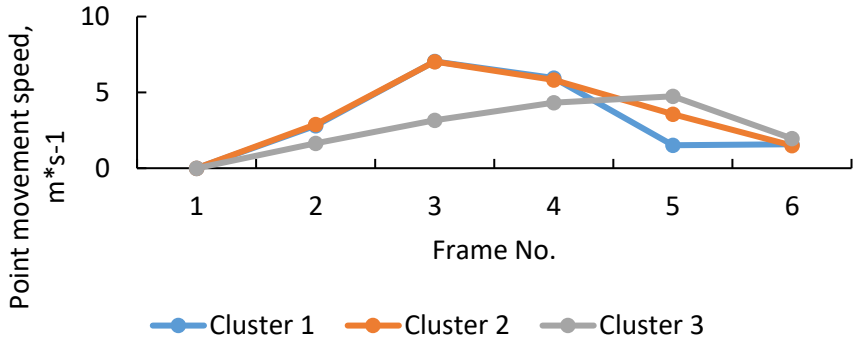


Fig. 9. Values of the speed of movement of the elbow joint in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style;
1 – initial value of movement, 0.00 s;
2 - the second frame from the beginning of the movement, 0.03 s;
3 - the third frame from the beginning of the movement, 0.06 s;
4 - the fourth frame from the beginning of the movement, 0.10 s;
5 - the fifth frame from the beginning of the movement, 0.13 s;
6 - the sixth frame from the beginning of the movement, 0.16 s

Tempo style boxers have the highest angle in the elbow joint at the end of the movement (0.13-0.16 s from the beginning of the movement) ($p<0.001$) (Table 4, Fig. 9), the smallest angle in the knee joint throughout the movement ($p<0.05$, $p<0.01$) (Table 4, Fig. 6) and the highest speed of movement, which is reflected in the highest speed of movement of the point of the knee joint throughout the movement ($p<0.001$) (Table 4, Fig. 7). This feature of the technique of tempo style boxers can be regarded as a compensatory mechanism for the lack of reaction speed and speed of inclusion in the movement at the very beginning of the action. The speed of movement of the points of the fist, elbow and shoulder in tempo style boxers is evenly distributed throughout the execution of a direct blow (Fig. 5, 8, 9). This fact characterizes the speed endurance of tempo style boxers. The revealed patterns of speed in the movement of the points of the fist, elbow, shoulder, knee and angles in the joints are also reflected in the trajectory of the movement of the points of the fist, elbow, shoulder, knee (Fig. 10–13).



Fig. 10. Values of the trajectory of the movement of the fist in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style

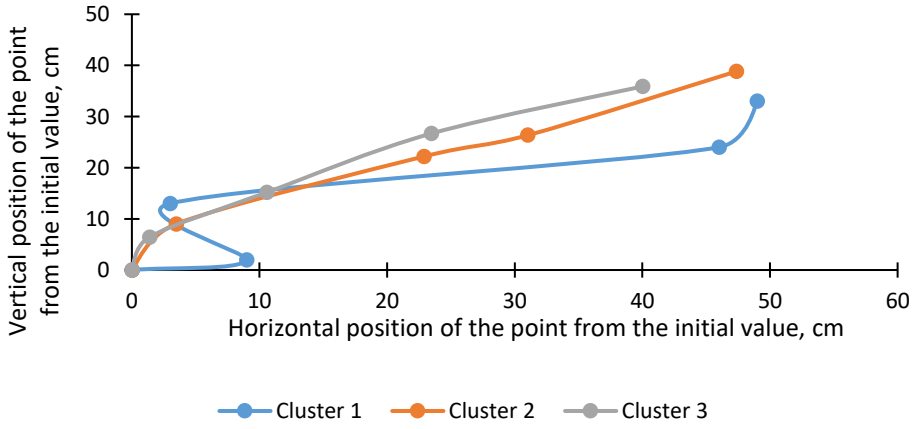


Fig. 11. Values of the trajectory of the elbow joint in qualified veteran boxers of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Power and speed", power style

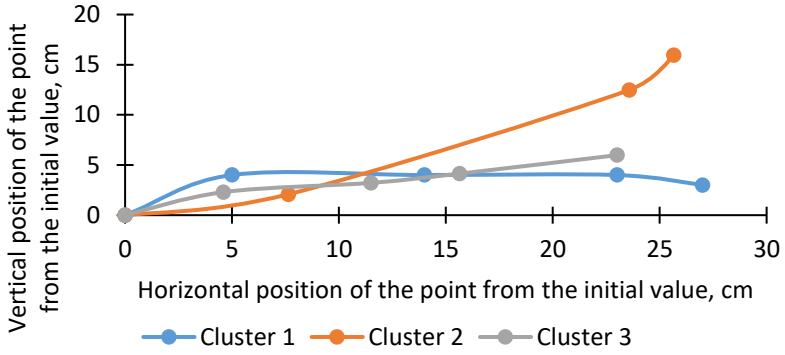


Fig. 12. Values of the trajectory of the shoulder joint movement in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style:
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style

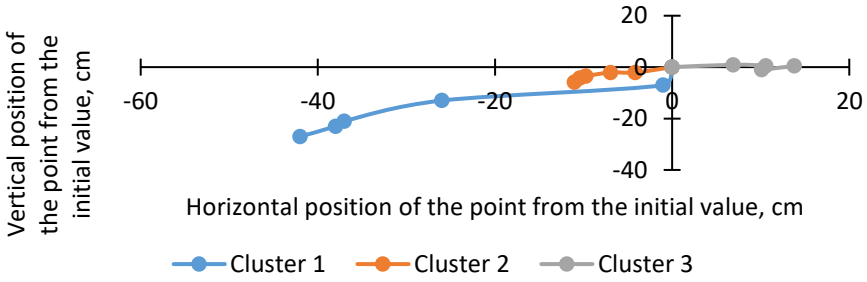


Fig. 13. The values of the trajectory of the knee joint movement in qualified boxers-veterans of different styles of fighting:
Cluster 1 - "Speed and coordination endurance", tempo style;
Cluster 2 - "Speed", game style;
Cluster 3 - "Strength and speed", power style

Thus, the psychophysiological features of boxers of different styles of fighting are reflected in the features of the direct punch technique. The lack of speed when tempo-style boxers are engaged in movement is supplemented and compensated by the high speed of movement. This ensures that speed is maintained throughout the fight and creates the conditions for victory by the fact that boxers of other fighting styles cannot maintain high endurance for accurate and fast actions for a long time, realizing their potential at the very beginning of the movement. Play style boxers are characterized by high speed of movement at the very beginning of punching. This provides the possibility of small rest breaks and thus creates the conditions for the variability of actions. Power style boxers are distinguished by the gradual development of movement speed, which creates conditions for the implementation of the impact force.

Discussion

In our study, the hypothesis was confirmed. It was found that veteran boxers with different fighting styles (tempo, game, power) significantly differ from each other in terms of psychophysiological and biomechanical indicators. The goal of the work was also achieved: a comparative description of veteran boxers of various styles of fighting was given. It was found that the psycho-physiological features of boxers of different styles of fighting are reflected in the features of the direct punch technique. The lack of speed when tempo-style boxers are engaged in movement is supplemented and compensated by the high speed of movement. This ensures that speed is maintained throughout the fight and creates the conditions for victory by the fact that boxers of other fighting styles cannot maintain high endurance for accurate and fast actions for a long time, realizing their potential at the very beginning of the movement. Play style boxers are characterized by high speed of movement at the

very beginning of punching. This provides the possibility of small rest breaks and thus creates the conditions for the variability of actions. Power style boxers are distinguished by the gradual development of movement speed, which creates conditions for the implementation of the impact force.

Analysis of the results of the study in terms of comparing them with the available literature data showed that this work is one of the first in terms of determining the influence of the athlete's psychophysiological indicators on the formation of the style of fighting in boxing. The authors who dealt with the problems of activity styles [1, 8, 9] do not consider the process of training athletes from the point of view of the system, the analysis of a wide range of readiness indicators, and also do not consider the possibility of using innate psychophysiological characteristics that are decisive in the formation of an individual style of activity. , one of the manifestations of which is the style of waging a fight in boxing.

Our study expands, confirms and supplements the data presented in [1, 7, 8] regarding the information content of psychophysiological indicators for the current and operational control of the functional state of athletes and determining their individual characteristics, which is most relevant for predicting the results of competitive activity.

It should be noted that the problem considered in our work closely intersects with the problem of individualization of the training process and is consistent with the concept of individualization presented in [29–32]. The concept of individualization of the training process developed using the deductive method lies in the fact that for an adequate construction of individual training programs, it is necessary, on the basis of an analysis of a wide range of indicators, including anthropometric, physiological, psychophysiological, psychological data, to identify the leading factors in the individual structure of the preparedness of athletes based on the complex related indicators.

In the theory and methodology of training boxers, attempts have already been made to link the type of temperament, which is based on the properties of the nervous system, and the style of activity, in particular, the style of fighting. The authors [1, 7, 8], dealing with this problem, focused on visual observation of the boxer's activity, without offering specific indicators for determining the style of the fight. In our study, the most informative psycho-physiological indicators have been identified that allow us to determine the boxer's inclination to a certain style of fighting, which is the data obtained for the first time.

This study confirmed the results of our previous studies [26, 33] on the informativeness of psychophysiological and biomechanical indicators to determine the propensity to a certain style of fighting in boxing. Confirmation of this position is due to the results of a comparative analysis of groups of athletes tested for psychophysiological and biomechanical indicators. The informativeness of biomechanical and psychophysiological indicators is also confirmed by the presence of significant differences between boxers with different styles of fighting on these indicators. From this point of view, our results complement the results of research presented in [1, 8]. It should be noted that differences in psychophysiological capabilities of boxers with different styles of fighting are the physiological basis for the formation and manifestation of individual style of activity. Thus, higher indicators of reaction speed determine the formation of the style of the fight, which requires a quick response to changing circumstances, quick decision-making. This is exactly what is observed in game style boxers. In addition, the game style involves performing precise actions in a rapidly changing environment. Physiological prerequisites for the formation and manifestation of this style of action are psychophysiological indicators such as speed, ie the number of correctly performed tasks per unit time in an unforeseen nature and time of the signal.

It should be noted that power style boxers compensate for the lack of reaction speed, speed and accuracy with higher stability with fewer errors, ie they are better than others in terms of identical actions. It follows that for such athletes the best option for the realization of their physiological talents is to achieve mastery in actions that do not require high variability of actions and which consist in the manifestation of a high level of strength in relatively similar actions. This is realized in boxers of power style of fighting. Thus, physiological talents are realized in specific abilities, which are manifested in the formation of a certain style of activity, in our case - the style of fighting in boxing. Similar provisions explain the higher mental and physical capacity of boxers of tempo style. From this point of view, the results are new.

It is known that each person has different "sets" of abilities. An individual combination of abilities is formed throughout life and determines the uniqueness of the individual. Success is also ensured by the presence of a combination of abilities that work for the result. In activity, some abilities can be replaced by others - similar in manifestations, but differ in their origin. The success of the same activity can be ensured by different abilities, so the lack of one ability can be compensated by the presence of

another or even a whole complex. Therefore, the individual uniqueness of a set of individual abilities that ensure the successful implementation of activities, it is common to call "individual style of activity". Psychophysiological differences of boxers with different styles of fighting are the basis for differences in the special performance of boxers.

Prospects for further research

Further research suggests development and substantiation of recommendations regarding the construction of the training process of qualified veteran boxers of different styles of fighting.

Limitations

The study was conducted on qualified veteran boxers, therefore, the data obtained apply only to the studied contingent. Additional research is needed to disseminate the obtained data to boxers of other age and social groups, as well as to representatives of other sports.

Conclusions

1. Boxers of the tempo style of fighting differ from representatives of other styles of fighting by less mobility of the nervous system and greater endurance to speedy and precise actions. Tempo style boxers differ from boxers of other fighting styles in greater coordination endurance, speed endurance and endurance in performing precise actions over time.

2. Psychophysiological features of boxers of different styles of fighting are reflected in the features of the technique of a direct blow. The lack of speed when tempo-style boxers are engaged in movement is supplemented and compensated by the high speed of movement. This ensures that speed is maintained throughout the fight and creates the conditions for victory by the fact that boxers of other fighting styles cannot maintain high endurance for accurate and fast actions for a long time, realizing their potential at the very beginning of the movement.

3. Play style boxers are characterized by high speed of movement at the very beginning of punches. This provides the possibility of small rest breaks and thus creates the conditions for the variability of actions. Power style boxers are distinguished by the gradual development of movement speed, which creates conditions for the implementation of the impact force.

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Conflict of interest

The authors declare that there is no conflict of interest.

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