COMPARATIVE ANALYSIS OF THE KINEMATIC STRUCTURE OF RIGHT-HAND AND LEFT- HAND HOOKS TECHNIQUES FROM THE FRONT GUARD OF HIGH QUALIFIED ATHLETES SPECIALIZING IN HAND-TO-HAND COMBAT

ПОРІВНЯЛЬНИЙ АНАЛІЗ КІНЕМАТИЧНОЇ СТРУКТУРИ ТЕХНІКИ БОКОВИХ УДАРІВ ПРАВОЮ ТА ЛІВОЮ РУКОЮ З ФРОНТАЛЬНОЇ СТІЙКИ ВИСОКОКВАЛІФІКОВАНИХ СПОРТСМЕНІВ, ЯКІ СПЕЦІАЛІЗУЮТЬСЯ В РУКОПАШНОМУ БОЮ

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Abstracts

The purpose of the study is to fulfill a comparative analysis of the kinematic structure of the technique of right- and left-hand hooks from the frontal guard of high qualified athletes specializing in hand-to-hand combat. **Material & methods.** Theoretical methods are to determine the topicality of the problem of forming the technique of motor actions in hand-to-hand combat; empirical methods: pedagogical observation as a method of empirical level of research – to familiarize the process of organizing educational and training classes; registration of the kinematic characteristics of the technique of the right-hand hook from the frontal guard was carried out using the marker system of registration and analysis of motions Qualysis, which allowed to record the data in three-dimensional space. The shooting frequency was 100 frames per second. The measurement error in determining spatial indicators was 1 millimeter per 1 meter of cubic space, the measurement error in time indicators was 0.01 seconds, ensuring high accuracy of registration of kinematic characteristics of athletes' motor actions. Methods of mathematical statistics were used. The technique of performing the studied motor action of twelve high qualified athletes was registered within the research. **Research results.** It was established that the total duration of a right-hand blow is 0.13 s longer than the duration of a left-hand blow (although the difference is not statistically significant). However, the phase-rhythmic structure of both blows should be considered in more detail. The duration of the active period (which consists of the phases: preparation for blow, swing, impact motion and contact) of a right-hand blow is 0.49 s (S= 0.051 s), and a left-hand blow is 0.64 s (S= 0.054 s), the difference between the indicators of the duration of the active period is statistically significant at a value of $p<0.05$. At the same time, the duration of the swing, impact motion, and contact phases of right and left hook practically do not differ, and are 0.21 s, 0,1 s, and 0.05 s for the right hook, and 0.21 s, 0.09 s and 0.04 s for the left hook respectively. **Conclusions.** It has been determined that right-hand and left-handed hooks from the front guard are performed by right-handed athletes have significant differences of the kinematic structure of the performing motions technique. The differences in the time structure of both hooks relate to the duration of the phases of preparing for the blow and returning to the starting position, that is, those phases that do not have a significant impact on the effectiveness of the execution of blows. Statistically significant differences ($p<0,01$) of the indicators of the maximum speed of the impact biokinematic link were revealed.

***Key words*:** combat, hand-to-hand combat, sport training, comparative analysis, technique, kinematic structure, high qualified athletes.

Мета – провести порівняльний аналіз кінематичної структури техніки бокових ударів правою та лівою рукою з фронтальної стійки висококваліфікованих спортсменів, які спеціалізуються в рукопашному бою. **Методи.** Теоретичні – для визначення актуальності проблеми формування техніки рухових дій у рукопашному бою; емпіричні: педагогічне спостереження як метод емпіричного рівня досліджень – для ознайомлення із процесом організації навчально-тренувальних занять; реєстрація

кінематичних характеристик техніки бокового удару правою рукою з фронтальної стійки відбувалася за допомогою маркерної системи реєстрації та аналізу рухів Qualisis, що дозволило зафіксувати дані в тримірному просторі. Частота зйомки становила 100 кадрів за секунду. Похибка під час визначення просторових показників становила 1 міліметр на 1 метр кубічного простору, похибка за часовими показниками становила 0,01 секунди, що забезпечує високу точність реєстрації кінематичних характеристик рухових дій спортсменів. Методи математичної статистики. Нами було зареєстровано техніку виконання досліджуваної рухової дії у 12 спортсменів високої кваліфікації. **Результати.** Встановлено, що загальна тривалість удару правою рукою на 0,13 с більша за тривалість удару лівою рукою (хоча різниця статистично не достовірна). Проте розглянемо фазово-ритмову структуру обох ударів більш детально. Тривалість активного періоду (який складається з фаз: підготовки до удару, замаху, ударного руху та контакту) удару правою рукою – 0,49 с (S= 0,051 с), а лівою рукою – 0,64 с (S= 0,054 с), відмінність між показниками тривалості активного періоду статистично достовірна за значення $p<0,05$. Разом із тим тривалість фаз замаху, ударного руху та контакту практично не відрізняється під час удару правою та лівою рукою та становлять у правому боковому ударі 0,21 с, 0,1 с та 0,05 с, а в лівому 0,21 с, 0,09 с та 0,04 с відповідно. **Висновки.** Встановлено, що бокові удари правою та лівою рукою з фронтальної стійки у виконанні спортсменів правшів мають суттєві відмінності кінематичної структури техніки виконання рухів. Відмінності часової структури обох ударів стосуються тривалості фаз підготовки до удару та повернення у вихідне положення, тобто тих фаз, що не мають значного впливу на ефективність виконання ударів. Виявлено статистично достовірні відмінності ($p<0,01$) показників максимальної швидкості ударної біоланки.

***Ключові слова*:** єдиноборства, рукопашний бій, спортивна підготовка, порівняльний аналіз, техніка, кінематична структура, висококваліфіковані спортсмени.

Introduction. Hand-to-hand combat is a unique modern sport that combines sports and applied directions. The high level of development of hand-to-hand combat and unbridled competition in competitive activities require specialists to constantly search for effective means and methods of training, develop new theoretical and practical provisions to optimize the educational and training process and build an effective system of athletes training [9; 12; 15].

Currently, it is an indisputable fact that the long-term process of sports training from a beginner to the high sport mastery can be represented in the form of large stages that alternate in sequence, including separate stages of long-term training related to the age and qualification conditions of athletes [1; 3; 6].

The system of hand-to-hand combat involves the correct organization of the training process, during which the motor skills of hand-to-hand combat are formed and the necessary physical and psychological qualities, as well as special tactical skills are developed [7; 8]. The basic technique of hand-to-hand combat consists of basic guards, displacements and blows and defensive actions with hands and feet as well [4; 5; 14]. Additional techniques characterize the individual characteristics of athletes and include complex techniques that require long-term training [2; 13].

In the special scientific and methodical literature it is stated [10; 11] that the main tasks that are solved in the process of technical training of an athlete include: achieving high stability and rational variability of specialized actions that are the basis of hand-to-hand combat techniques, sequential transition of learned technical motion to expedient and effective competitive actions, improving the structure of motor actions, their dynamics and kinematics, taking into account the special athletes conditions. **The purpose of the study** was to fulfill the comparative analysis of the kinematic structure of the technique of the right- and left-hand hooks from the frontal guard of high qualified athletes, specializing in hand-to-hand combat.

Material & methods. Twelve high qualified athletes specializing in hand-to-hand combat took part in the study. Seven Masters of Sports of Ukraine and five Masters of Sports of Ukraine of International Class were among them. The study was fulfilled in compliance with the requirements of the World Medical Association Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects. Such *methods of research* as analysis of methodological literature, biomechanical analysis of actions kinematic structure were used in the research. Registration of the kinematic char-

acteristics of the technique was carried out using the marker system of registration and analysis of motions Qualysis, which allowed to record the data in three-dimensional space. The shooting frequency was 100 frames per second. The measurement error in determining spatial indicators was 1 millimeter per 1 meter of cubic space, the measurement error in time indicators was 0.01 seconds, ensuring high accuracy of registration of kinematic characteristics of athletes' motor actions.

Study organization. Twelve high qualified athletes specializing in hand-to-hand combat performed right and left-hand hooks from the frontal guard. All athletes who participated in the research are right-handed and fight in the left-hand guard. *Statistical analysis.* Since the sample size is only 12, we used Pearson's chi-squared (χ^2) test to check of the hypothesis that the input data obey the normal distribution law. All indicators of the kinematic structure of motion technique were subject to normal distribution. Therefore, the following statistical characteristics were determined: the average ($\bar{x}$) standard deviation (S). The Student's t-test was used to determine the difference between the kinematic characteristics of right and left hooks. Statistical reliability of P = 95% was assumed (probability of error 5%, i.e. significance level $p = 0.05$). Some results were obtained at a higher significance level of p = 0.01.

Statistical processing of the research results was carried out using the Statistica 21 software.

Research results. The time characteristics of right and left hooks from the front guard by right-handed athletes are presented in the Table 1.

In martial arts, it is believed that the shorter the duration of the action, the more effective its execution. As we can see from the data presented in Table 1, the total duration of a right-hand hook is 0.13 s longer than the duration of a left-hand hook (although the difference is not statistically significant). However, the phase-rhythmic structure of both hooks should be considered in more detail. The duration of the active period (which consists of the phases: preparation for blow, swing, impact motion and contact) of a right-hand blow is 0.49 s (S= 0.051 s), and a left-hand blow is 0.64 s (S= 0.054 s), the difference between the indicators of the duration of the active period is statistically significant at a value of $p<0.05$. At the same time, the duration of the swing, impact motion, and contact phases of right and left hook practically do not differ, and are 0.21 s, 0.1 s, and 0.05 s for the right hook, and 0.21 s, 0.09 s and 0.04 s for the left hook respectively. There are no statistically significant differences between mentioned indicators. The phases of preparing for the blow and returning to the starting position when executing right and left hooks from the front guard differ statistically significantly. Thus, the phase of preparation for a blow lasts 0,13 s, and 0,3 s, when executing the right-hand and left-hand hook respectively, that is, it differs by more than 2 times. Although the athlete's motor actions in this phase have a rather low informativeness for the opponent (due to inessential motions of biokinematic links of the athlete's body during this phase), the shorter the duration of the phase, the more effective is the execution of the blow. That is, precisely because of the short duration of this phase, the

Table 1

Duration of different phases of right and left hooks from front guard (n=12)

№	Name of phase	Duration of a phase, s				significance level p
		right hook		left hook		
		$\bar{x}$	S	$\bar{x}$	S	
1	Preparation for the blow	0.13	0.021	0.3	0.029	p<0.05
2	Swing	0.21	0,.029	0.21	0.022	p>0.05
3	Impact motion	0.1	0.016	0.09	0.008	p>0.05
4	Contact	0.05	0.007	0.04	0.003	p>0.05
5	Return to the starting position	0.62	0.07	0.34	0.038	p<0.05
	The total duration of the hook	1.11	0.14	0.98	0.093	p>0.05

whole duration of the right-hand hook active period decreases.

We will also compare the dynamics of the velocity of impact biolinks during performing right and left hooks from the front guard, the data are presented at figure 1.

We can see at the Figure 1 that the maximum values of the instantaneous velocity are observed at the moment of the end of the impact phase and the beginning of the contact phase during the both right and left hooks. However, the ratio of the maximum instantaneous velocity is 13.38 $m \cdot s^{-1}$, during executing the right hook and 10,91 $m \cdot s^{-1}$ when executing the left hook respectively. It should also be noted that the beginning of the impact action occurs at the moment of time 0.36 s (the speed of the impact biolink at this moment is 3.73 $m \cdot s^{-1}$) when executing the right hand hook, and the beginning of the impact action phase occurs at the moment of time 0.51 s (the speed of the impact biolink is 3.46 $m \cdot s^{-1}$) during the left hand hook. That is, the velocity of the impact biolink, registered at the end of the swing phase during the executing right hand hook is only 0.27 $m \cdot s^{-1}$ (7.2%) higher than such indicator during the executing left hand hook. During the contact phase, the velocity of the impact biolink when executing the right hand hook decreases from 13.38 $m \cdot s^{-1}$ to 3.91 $m \cdot s^{-1}$ (the difference is 9.47 $m \cdot s^{-1}$), and such parameter of the right hand hook decreases from 10.91 $m \cdot s^{-1}$ to 1.49 $m \cdot s^{-1}$ (the difference is 9.42 $m \cdot s^{-1}$) respectively. That is, the of the amount of motion transferred to the body that is being hit is approximately the same when executing the right- and left-hand hooks from the front guard (regardless of the lower velocity ratio of the impact biolink executing the left hook).

At the same time, the velocity of all points of the athlete's body also affects the effectiveness of the blow. In particular, it is necessary to analyze the velocities of various biolinks of the athletes' body directly in the impact phase. Therefore, we considered the indicators of the average velocity of different points of the athletes' body during the executing the right and left hooks from the front guard. The comparative analysis data are presented in the figure 2. As we can see at figure 2, all indicators of average velocity are higher when executing the right hook from the front guard, than during executing the left hook. It should also be noted that the velocity of such points of the athlete's body as the ankle joint, hip joint, and shoulder joint is higher when executing the right hook, than the speed of similar points on the left side of the body, what indicates a more effective performance of the hook. Then, the velocities of the left and right ankle, hip, and shoulder joints practically do not differ when executing a left hook.

The values of the angles in the joints at the moments of the beginning of the impact motion phase and at the end of the impact motion phase during the executing right-hand and left-hand hooks from the front guard were also analyzed. The postures of the athlete at the beginning and

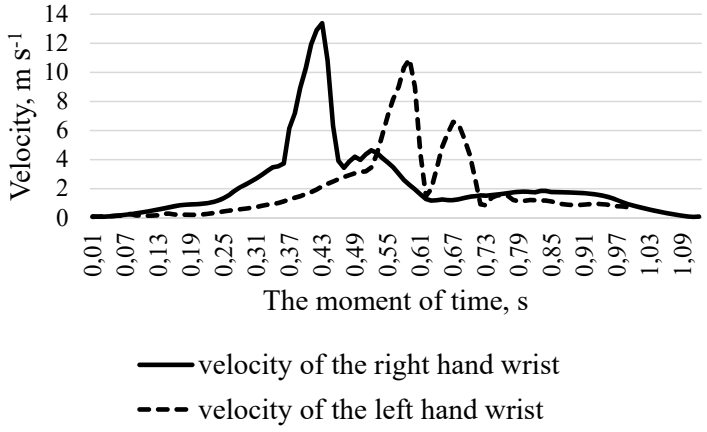

Fig. 1. Dynamics of the velocity of the wrists of the right and left hands when executing right hand and left-hand hooks from the front guard

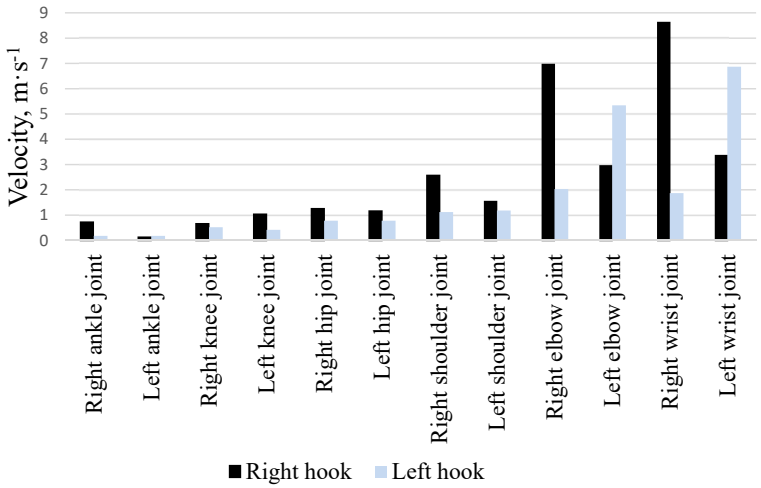

Fig. 2. Indicators of the average velocity of different points of the athletes' body during the impact phase during the executing right and left hooks from the front guard

end of the impact motion phase when performing right and left hooks from the front guard were illustrated at figure 3.

Thus, the values of the angles in the athletes' joints in the impact motion phase during the executing right and left hooks from the frontal guard are statistically significantly different.

Namely, at the moment of the start of the impact motion phase when the executing a right-hand hook, the angles in the right and left knee joints were 136.5° and 126°, respectively, while the same indicators are 147° and 136,3° for the left-hand hook. The angle in the knee joint of the right leg at the end of the impact motion phase during the executing right hook was 152.3°, that is, it increased by 15.8° per the phase.

Then, as at the same moment of time the angle in the left leg knee joint was 144.6° and

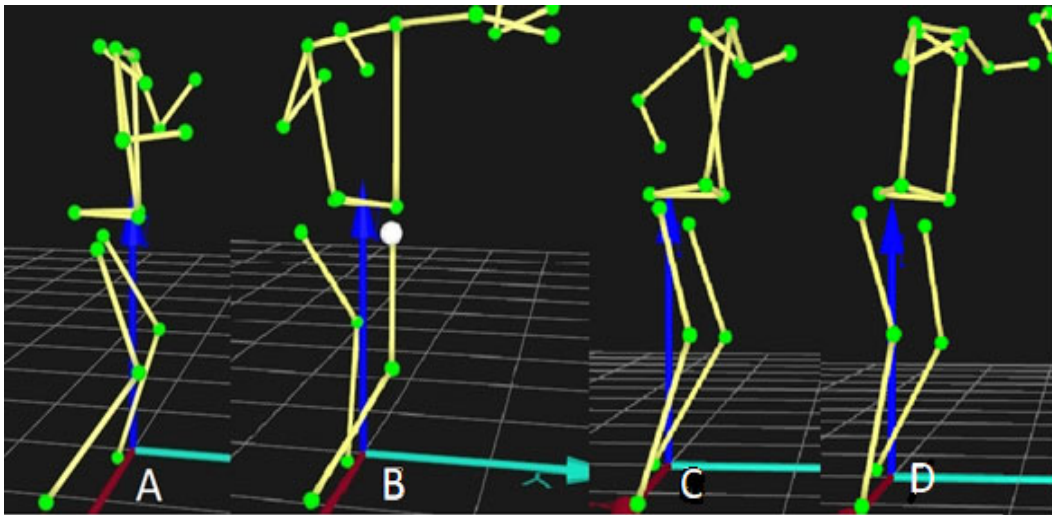

Fig. 3. Postures of the athlete's body at the beginning and end of the impact motion phase during the executing right and left hooks from the front guard: A) – the moment of the start of the impact motion during the executing the right hook; B) – the moment of the end of the impact motion during the executing the right hook; C) – the moment of the start of the impact motion during the executing the left hook; D) – the moment of the end of the impact motion during the executing the left hook

the amplitude per phase was 8.3° during the executing left hand hook. The difference in amplitudes in the knee joint from the impact side during the executing the right and left hooks was statistically significant at p<0,05. From the given data, it can be concluded that the athlete used the strength of the leg muscles more effectively during the executing the right-hand hook, than during the executing the left-hand hook. The position of the athlete's body and its impact phase are also important. At a Figure 3A, it can be observed that the axis that passes through the iliac crest points and the axis that passes through the acromial points (that is, the axes that characterize the pelvis and the shoulders and the torso in general) at the moment of the beginning of the impact phase of the movement had a very small reversal in the opposite direction to the direction of impact, and the same axes had a significant reversal in the direction of impact at Figure 3B. The amplitude of turning the torso during the executing the right-hand hook is 76,8°, which allows you to use the muscles of the torso and use body weight to increase the effectiveness of the blow. Then, as in Figure 3C, we can see that the axis that passes through the iliac crest points and the axis that passes through the acromial points are turned in the direction opposite to the stroke slightly more than in the right-hand hook. But at Figure 3D the turning in the direction of the blow is less than during the executing the right-hand hook. The amplitude of the torso turn during the executing the left hand hook was 55.9°, i.e. 20.9° less than during the executing the right hook. This indicates a lower contribution of the strength of the torso muscles to the execution of the blow and the lower efficiency of using body weight in the execution of the left hook compared to the right-hand hook. The longer duration of the phase of returning to the starting position (0.62 s) during the executing the right hand hook compared to the similar phase during the executing the left hand hook (0.36 s) is also explained by the fact that the position of the athletes' torso at the end of the impact motion phase is different during the executing the right and left hooks (torso turn in the direction of the kick was much wider during the executing the right hook), the difference of the duration of motion was 0.26 s. Also, in the comparative analysis of the angles in the joints, the difference between the position of the striking hand at the moment of the beginning of the impact motion phase during the executing the right- and lef- hand hooks should be considered. The angle in the right shoulder joint at the moment of the beginning of the impact phase during the executing the right hook was 94.5°, the athlete practically did not move his hand back, but raised it up (Fig. 3A). The angle in the left shoulder joint at the same moment of time during the executing the left-hand hook was 71.8°, but the athletes moved their hand back and lowered it to the bottom (Fig. 3C).

Discussion. Taking into account the physical conditions for the implementation of the required motor task, which directly affect and impose requirements on the level of technical, physical, and theoretical preparedness of the athlete, our research also showed that a deep understanding of the importance of the relationship between the selected technical method of the executing the sports exercise with the biomechanical parameters of the performer's movement as factors of the effectiveness of the implementation of this method of action needed for achievement of the desired final result of the athlete's mechanical actions [2; 4]. This statement supplements these works [6; 8]. Its creation as a result of psychomotor activity of a person is based on the presence of an athlete's mode of action, the formation of which is inextricably related to with motor instruction [3; 9]. In general, the obtained results complement the data of the special literature on the control of the athlete's motions, convincingly indicating the high degree of importance not only of the leading level in the control of motions, but also of the so-called background levels responsible for the control of involuntary movements, which is evidenced by the introduction of effective corrections in one's own actions of highly qualified athletes a fraction of a second before the decisive moments of the technical performance of one or another sports exercise [1].

Conclusions. It was established that the right- and left-hand hooks from the front

guard performed by right-handed athletes have significant differences in the kinematic structure of the motion technique. The differences in the time structure of both hooks relate to the duration of the phases of preparing for the blow and returning to the starting position, that is, those phases that do not have a significant impact on the effectiveness of the execution of hooks. Statistically significant differences ($p<0.01$) in the indicators of the maximum speed of the impact biolink were revealed, namely: 13.38 $m \cdot s^{-1}$ during the executing the right hook and 10,91 $m \cdot s^{-1}$ during the execution the left hook. Also, the execution the right-hand hook from the front guard, the value of the average velocities during the phase of the impact motion of the impact arm of the torso and pelvis are statistically significantly higher when compared with the left-hand hook. Also, due to the greater amplitude of turning the torso and pelvis, and the greater amplitude of extension of the leg of the same as the blow arm in the knee joint during the executing the right hand hook, it is more effective to include the muscles of the torso and legs of athletes in the work and use body weight to increase the force of the blow compared to the left hand hook.

Thus, the technique of the executing the right-hand hook from the front guard of high qualified hand-to-hand fighters whose leading hand is right is much more effective than the technique of the executing the left-hand hook from the front guard.

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