

ФІЗИЧНА КУЛЬТУРА І СПОРТ

KINEMATIC STRUCTURE OF SIDE KICK TECHNIQUE BY RIGHT LEG STARTING FROM FRONT STANCE PERFORMED BY HIGHLY QUALIFIED ATHLETES SPECIALIZING IN HAND-TO-HAND COMBAT

ОСОБЛИВОСТІ КІНЕМАТИЧНОЇ СТРУКТУРИ ТЕХНІКИ БОКОВОГО УДАРУ ПРАВОЮ НОГОЮ З ФРОНТАЛЬНОЇ СТІЙКИ У СПОРТСМЕНІВ ВИСОКОЇ КВАЛІФІКАЦІЇ, ЯКІ СПЕЦІАЛІЗУЮТЬСЯ НА РУКОПАШНОМУ БОЮ

Vako I. I.¹, Zhyrnov O. V.¹, Levandovska L. Yu.²¹National University of Physical Education and Sports of Ukraine,
Kyiv, Ukraine²Taras Shevchenko Kremenets Regional Humanitarian and Pedagogical Academy,
Kremenets, UkraineDOI <https://doi.org/10.32782/2522-1795.2023.17.24>**Abstracts**

The **aim** is to analyze the kinematic structure of side kick technique by the right leg starting from the front stance by highly qualified athletes specializing in hand-to-hand combat. **Research methods.** To fulfil the set tasks, particular research methods were used, namely, analysis of scientific and methodological literature sources and documentary materials, methods of registration and analysis of athlete movements ("Qualisys Motion Capture", a system of video recording and analysis of athlete's movements and 3D registration of human movements). The research findings were processed using the methods of mathematical statistics. We registered the technique of performing the studied motor action by 12 highly qualified athletes. **Results.** The analysis of the kinematic structure of side kick technique by the right leg starting from the front stance (like most kicks) consists of 7 phases: the phase of preparation for the kick, the phase of encroachment, the double-support phase, the phase of the striking/kicking movement, contact phase, the phase of returning of the kicking leg to the support, and phases of returning to fighting stance. All the studied phases of the kick can be generally divided into two periods, i.e., the period of active actions, which consists of the following phases: preparation for the kick, encroachment, the double-support phase, kicking movement, contact; and the period of return to the initial position (fighting stance). The total duration of technique performance is 1.83 s, the duration of the active period is 0.84 s, and the period of return to the initial position is 0.99 s, respectively. Thus, the duration of the active period is 45.9% of the total duration of technique performance, and the period of return to the original position comprises 54.1%, respectively. That is, the duration of the period of return to the original position is almost 10% longer within the total duration of technique performance. Sufficiently long duration of the kick execution, 1.83 s, and the return to the initial position of 0.99 s determine the specificity of this action application during the match. The movement indicators of the kicking biolink (the one of right tibial joint) were analyzed. It was established that the shape of the trajectory has only a slight curvature, especially when viewed from the side, and the shape of the trajectory when viewed from above is S-shaped, with a slight curvature. **Conclusions.** It was determined that the side kick by the left leg starting from the front stance is performed by highly qualified athletes specializing in hand-to-hand combat with high efficiency.

Key words: martial arts, hand-to-hand combat, analysis of movements performed by highly qualified athletes, technique, kinematic structure.

Мета – аналіз кінематичної структури техніки бокового удару правою ногою з фронтальної стійки висококваліфікованих спортсменів, які спеціалізуються на рукопашному бою. **Методи дослідження.** Для виконання поставлених завдань використано такі методи дослідження, як аналіз науково-методичної літератури й документальних матеріалів, методи реєстрації

та аналізу рухів спортсмена (система відеореєстрації та аналізу рухів спортсмена 3D реєстрації рухів людини «Qualisys Motion Capture»). Результати, отримані в процесі дослідження, було оброблено з використанням методів математичної статистики. Нами було зареєстровано техніку виконання досліджуваної рухової дії у 12 спортсменів високої кваліфікації. **Результати.** Аналіз кінематичної структури техніки бокового удару правою ногою з фронтальної стійки (як і більшість ударів ногами) складається з 7 фаз, а саме: фази підготовки до удару, фази нашагування, двохопорної фази, фази ударного руху, фази контакту, фази повернення ударної ноги на опору та фази повернення в бойову стійку. Всі досліджені фази удару можна умовно поділити на два періоди: період активних дій, що складається з фаз: підготовки до удару, нашагування, двохопорної фази, ударного руху, контакту; та період повернення у вихідне положення (бойову стійку). Загальна тривалість прийому становить 1,83 с, тривалість активного періоду 0,84 с, а періоду повернення у вихідне положення 0,99 с відповідно. Таким чином, тривалість активного періоду становить 45,9% від загальної тривалості прийому, а періоду повернення у вихідне положення 54,1% відповідно. Тобто тривалість періоду повернення у вихідне становище майже на 10% більша в загальній тривалості прийому. Досить велика тривалість самого виконання удару 1,83 с та повернення у вихідне положення 0,99 с зумовлюють специфіку застосування такої дії в поєдинку. Проаналізовано показники руху ударної біоланки (правого гомілкового суглобу). Встановлено, що форма траєкторії має лише незначну кривизну, особливо у виді збоку, а форма траєкторії у виді згори є S-образною знову ж з незначною кривизною. **Висновки.** Встановлено, що боковий удар лівою ногою з фронтальної стійки висококваліфіковані спортсмени, що спеціалізуються на рукопашному бою, виконують досліджену ударну дію на досить високому рівні ефективності.

Ключові слова: єдиноборства, рукопашний бій, аналіз рухів висококваліфікованих спортсменів, техніка, кінематична структура.

Introduction. The current level of sports development requires further scientific substantiation of ways to shape the technical skills of athletes, the search for which has recently intensified given the observed rapid scientific and technological progress [2; 8; 11]. The late 20th – early 21st centuries were marked by the introduction of information technologies into didactic biomechanics [6; 7]. Software and hardware complexes that allow real-time processing of data entering the computer became widespread [5]. The use of video analysis systems in sports makes it possible to determine the biomechanical indicators of sports skills of athletes of various qualifications and automate information collecting and processing [3; 4; 6].

Methods. Theoretical – to determine the relevance of the formation of the technique of motor actions in hand-to-hand combat; empirical: pedagogical observation as a method of empirical research – to become familiar with the process of organizing training sessions; registration of kinematic characteristics of the technique of a right-side kick from the front stance was performed via Qualisys, the marker system of registration and analysis of movements, which assisted in recording the data in three-dimensional space. The shooting frequency was 100 frames per second.

The error in determining the spatial indicators was 1 millimeter per 1 meter of cubic space, and the error in time indicators was 0.01 seconds. The above ensures high accuracy of recording the kinematic characteristics of athletes' motor actions.

The methods of mathematical statistics [9]: we registered the technique of performing the motor action under study by 12 highly qualified athletes.

Research results. We begin the analysis of the kinematic structure of the technique of a right-side kick from front stance with studying the time and phase composition of the specific motor action. Such a kick (like most kicks) consists of 7 phases, namely: the preparation phase, encroachment, the double-support phase, the phase of the striking/kicking movement, contact phase, the phase of returning of the kicking leg to the starting point, and phases of returning to fighting stance. The data on the total duration of a right leg kick from front stance and its individual phases are presented in Table 1.

All the studied phases of a kick can be divided into two periods: the period of active actions, consisting of the phases: preparation, encroachment, double-support phase, kicking movement, contact; and return to the starting position (combat rack).

Table 1

Duration of different phases of a right-side kick from front stance (n=12)

№	Phase Name	Phase duration, s		
		x	S	V.
1	Preparation for a kick	0.14	0.01	7.1
2	Encroachment	0.15	0.02	13.3
3	Double-support phase	0.06	0.01	16.7
4	Kicking movement	0.38	0.04	10.5
5	Contact	0.11	0.01	9.1
6	Return of the kicking leg to the support	0.72	0.09	12.5
7	Return to battle stance	0.27	0.03	11.1
	Total kick duration	1.83	0.14	7.7

The total duration of technique performance is 1.83 s, active period is 0.84 s, and the period of return to the initial position is 0.99 s, respectively. Thus, the duration of active period is 45.9% of total technique performance, and the period of return to the initial position is 54.1%, respectively. It means that the duration of return to the initial position is almost 10% longer within the total duration of technique performance. Sufficiently long duration of kick performance – 1.83 s – and the return to the initial position – 0.99 s – determine the specifics of resorting to such action during the match. Such kicks are usually performed when an athlete is confident that the opponent will not be able to take effective action in response.

Let us consider the time characteristics of active period's phases (the phase of preparation for a kick, encroachment, the two-support phase, the phase of a kicking movement, and the phase of contact) in more detail. The pre-kick phase lasts 0.14 s and aims to bring all biological links of the body to the most convenient position for delivering a kick. Since the movements and average speeds of all the biolinks of the athlete's body in this phase are insignificant, the movements in this phase have low information value for the opponent. The encroachment phase lasts 0.15 s: in this part of the motor action, the athlete takes a step to take a more advantageous position for a kick, giving an additional acceleration and shifting their body weight to the supporting leg. The performance of such a movement also regards force and the distance at which the athlete can reach the opponent. The opponent can notice such a movement when the kick is deliv-

ered from any stance, but during the match, the performance of the action is disguised by the athlete's movements across the ring.

In the double-support phase, the athlete keeps the body in equilibrium with the shift of most weight on the supporting leg. In order not to lose the body's acceleration acquired during encroachment, the two-support phase should be as short as possible – in our case the duration is 0.06 s.

The direct phase of a kicking movement lasts 0.38 s: such a duration is explained by the long trajectory of a kicking biolink throughout the phase. The contact phase (by a kicked object) lasts 0.11 s.

We do not analyze the phases of returning the leg to the support and bringing it to the initial position since, in the context under study (exercise of a single kick), duration will differ considerably from the exercise of a kick in sparring or at competitions.

For further analysis, we consider the athlete's performance of motor actions in the kicking phase, which is the most crucial phase of the kick. The indicators of movement of the kicking biolink (right ankle joint) are analyzed. The trajectory of the right ankle joint in the kicking phase is shown in Figure 1.

It can be observed that the trajectory's shape has insignificant curvature, particularly when viewed from the side, and it is S-shaped with insignificant curvature when viewed from the top. The trajectory's length of the right ankle joint during the kicking phase is 2.39 m, and moving is 2.17 m. It means that the difference between the path and moving is only 0.21 m.



Fig. 1. The trajectory of the kicking biolink when performing a right-side kick from front stance in the kicking phase (a – side view, b – top view)

The average speed of the right ankle joint during the kicking phase is $5.72 \text{ m}\cdot\text{s}^{-1}$.

We will also consider the characteristics of kicking techniques, which is integral and can be a criterion for the effectiveness of all kicking techniques, namely the dynamics of the instantaneous velocity of the kicking biolink. The dynamics of the velocity of the ankle joint is shown in Figure 2.

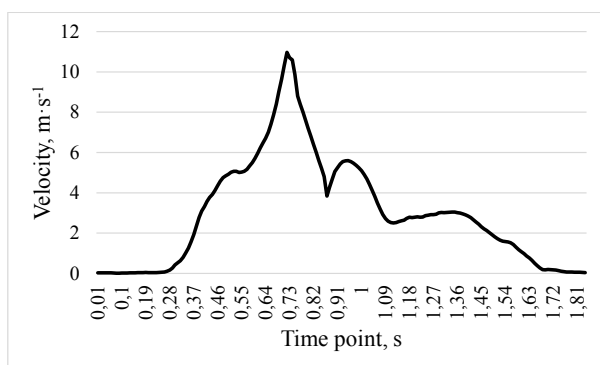


Fig. 2. Dynamics of the right ankle joint's velocity when exercising a right-side kick from front stance

As we can see, in the preparation phase (this is the period from the movement's beginning the time point of 0.14 s), the velocity of the studied point scarcely changes and varies from $0.3 \text{ m}\cdot\text{s}^{-1}$ at the phase's commencement to $0.27 \text{ m}\cdot\text{s}^{-1}$ at the time of its end, that is, the kicking biolink almost the same. The encroachment phase lasts from a time point of 0.14 s to a time point of 0.29 s; only in the last 0.02 s, velocity begins increasing slightly to $0.41 \text{ m}\cdot\text{s}^{-1}$. In the double-support phase, by the time point of 0.35 s, the velocity of the right tibial joint increases to $1.26 \text{ m}\cdot\text{s}^{-1}$. In the phase of kicking movement, which lasts from the

time of 0.35 s to the time of 0.73 s, there is the greatest increase in the velocity of the kicking biolink from $1.26 \text{ m}\cdot\text{s}^{-1}$ to $10.97 \text{ m}\cdot\text{s}^{-1}$, which is undeniable, since this phase is the kick's main part in which the athlete performs the key task of the kick. Therefore, the higher the instantaneous velocity of the kicking biolink at the phase end, the more effective kick is. However, it is necessary to consider the dynamics of increasing the velocity of the kick biolink in this phase of movement in more detail. The increase in velocity occurs from the phase's beginning to the first "peak" at a time point of 0.53 s reaches a value of $5.06 \text{ m}\cdot\text{s}^{-1}$ and then decreases to $5.02 \text{ m}\cdot\text{s}^{-1}$ within 0.02 s and, in the second part of the kicking phase, it continuously increases until the end of the phase. In the phase of contact with the target, velocity decreases from $10.97 \text{ m}\cdot\text{s}^{-1}$ to $5.6 \text{ m}\cdot\text{s}^{-1}$, which indicates the transfer of kinematic kicking energy to the kicked body.

Discussion. Video analysis in sports consists of three main stages: the organization of filming, processing, and analysis of video materials [1; 7; 8; 12]. Video analysis is a trend in modern and actively developing sports and one of the tools for implementing scientific research in sports biomechanics [2; 7; 8; 11]. The elaboration and study of biomechanical models of motor action techniques of athletes based on video analysis is currently used by many specialists in sports training [4; 5; 6]. Our research was an extension of developments by the above authors.

Conclusions. It has been established that highly qualified athletes specializing in hand-to-hand combat exercise a left-side kick from front stance with high efficiency.

Bibliography

1. Вако І.І. Визначення помилок, що допускають юні спортсмени, які спеціалізуються в рукопашному бою, при освоєнні бокових ударів руками. *Реабілітаційні та фізкультурно-рекреаційні аспекти розвитку людини (Rehabilitation & recreation)*. 2021. № 9. С. 23–28. DOI: <https://doi.org/10.32782/2522-1795.2021.9.3>.

2. Вако І.І., Радченко Ю.А. Структура успішності змагальної діяльності в змішаних єдиноборствах (на прикладі рукопашного бою). *Спортивний вісник Придніпров'я*. 2022. № 2. С. 111–122. DOI: [10.32540/2071-1476-2022-2-111](https://doi.org/10.32540/2071-1476-2022-2-111).

3. Вако І. Характерні помилки, що допускають юні спортсмени, які спеціалізуються в рукопашному бою, при освоєнні ударів ногами. *Фізична культура, спорт та здоров'я нації*. 2022. № 13 (32). С. 134–42. DOI: [10.31652/2071-5285-2022-13\(32\)-134-142](https://doi.org/10.31652/2071-5285-2022-13(32)-134-142).

4. Кашуба В., Литвиненко Ю., Вако І. Особливості техніки бокового удару рукою на ближній дистанції висококваліфікованих спортсменів, які спеціалізуються в рукопашному бою. *Науковий часопис НПУ імені М.П. Драгоманова*. 2020. № 8. (128)2. С. 83–87. DOI: [https://doi.org/10.31392/NPU-nc.series15.2020.8\(128\).19](https://doi.org/10.31392/NPU-nc.series15.2020.8(128).19).

5. Кашуба В., Литвиненко Ю., Вако І. Відмінні риси техніки бокового удару рукою на ближній дистанції спортсменів різної кваліфікації, які спеціалізуються в рукопашному бою. *Молодіжний науковий вісник Східноєвропейського національного університету імені Лесі Українки*. 2020. 37. С. 131–37.

6. Радченко Ю.А., Вако І.І. Модельні характеристики техніко-тактичної підготовленості найсильніших спортсменів у змішаних єдиноборствах (на прикладі рукопашного бою). *Фізична культура, спорт та здоров'я нації*. 2022. 14 (33). С. 74–83. DOI: [https://doi.org/10.31652/2071-5285-2022-14\(33\)-74-83](https://doi.org/10.31652/2071-5285-2022-14(33)-74-83).

7. Gamalii V., Potop V., Lytvynenko Y., Shevchuk O. Practical use of biomechanical principles of movement organization in the analysis of human motor action. *Journal of Physical Education and Sport*. 2018. 18(2). 874–877.

8. Kashuba V., Khmel'nitska I., Krupenya S. Biomechanical analysis of skilled female gymnasts' technique in "round-off, flic-flac" type on the vault table. *Journal of Physical Education and Sport*, 2012. (4), 431–435.

References

1. Vako, I.I. (2021). Vyznachennya pomylk, shcho dopuskayut' yuni sportsmeny, yaki spetsializuyut'sya v rukopashnomu boyu, pry osvoyenni bokovykh udariv rukamy [Determination of mistakes made by young athletes who specialize in hand-to-hand combat when mastering side blows with the hands]. *Rehabilitation and physical culture and recreational aspects of human development – Reabilitatsiyni ta fizkul'turno-rekreatsiyni aspekty rozvytku lyudyny (Rehabilitation & recreation)*. 9. 23–28. DOI: <https://doi.org/10.32782/2522-1795.2021.9.3> [in Ukrainian].

2. Vako, I. (2022). Kharakterni pomylky, shcho dopuskayut' yuni sportsmeny, yaki spetsializuyut'sya v rukopashnomu boyu, pry osvoyenni udariv nohamy [Typical mistakes made by young athletes who specialize in hand-to-hand combat when mastering kicks]. *Fizychna kul'tura, sport ta zdorov'ya natsiyi*. 13 (32). 134–142. DOI: [10.31652/2071-5285-2022-13\(32\)-134-142](https://doi.org/10.31652/2071-5285-2022-13(32)-134-142) [in Ukrainian].

3. Vako, I.I., Radchenko, Yu.A. (2022). The structure of the success of competitive activities in mixed martial arts (on the example of hand-to-hand combat) [The structure of the success of competitive activities in mixed martial arts (on the example of hand-to-hand combat)]. *Sportivnyi visnyk Prydniprovyi*. 2. 111–122. DOI: [10.32540/2071-1476-2022-2-111](https://doi.org/10.32540/2071-1476-2022-2-111) [in Ukrainian].

4. Kashuba, V., Lytvynenko, Yu., Vako, I. (2020). Osoblyvosti tekhniky bokovoho udaru rukoyu na blyzhniy dystantsiyi vysokokvalifikovanykh sportsmeniv, yaki spetsializuyut'sya v rukopashnomu boyu [Peculiarities of the short-range side kick technique of highly qualified athletes who specialize in hand-to-hand combat]. *Naukovyy chasopys NPU imeni M.P. Dragomanova*. 8. (128)2. 83–87. DOI: [https://doi.org/10.31392/NPU-nc.series15.2020.8\(128\).19](https://doi.org/10.31392/NPU-nc.series15.2020.8(128).19) [in Ukrainian].

5. Kashuba, V., Lytvynenko, Yu., Vako, I. (2020). Vidminni rysy tekhniky bokovoho udaru rukoyu na blyzhniy dystantsiyi sportsmeniv riznoyi kvalifikatsiyi, yaki spetsializuyut'sya v rukopashnomu boyu [Distinctive features of the side kick technique at close range of athletes of various qualifications who specialize in hand-to-hand combat]. *Molodizhnyy naukovyy visnyk Skhidnoyevropeys'koho natsional'noho universytetu imeni Lesi Ukrayinky*. 37. 131–137 [in Ukrainian].

9. Kashuba V., Stepanenko O., Byshevets N., Kharchuk O., Savliuk S., Bukhovets B., Grygus I., Napierała M., Skaliy T., Hagner-Derengowska M., Zukow W. Formation of Human Movement and Sports Skills in Processing Sports-pedagogical and Biomedical Data in Masters of Sports. *International Journal of Human Movement and Sports Sciences*, 2020. 8(5), 249–257. DOI: 10.13189/saj.2020.080513.

10. Kindzer B., Danylevych M., Ivanochko V., Hrybovska I., Kashuba Y., Grygus I., Napierała M., Smolenska O., Ostrowska M., Hagner-Derengowska M., Muszkieta R., Zukow W. Improvement of special training of karatists for kumite competitions using Kata. *Journal of Physical Education and Sport*, 2021. Vol. 21 (5), 2466–2472.

11. Vako I., Kashuba V., Litvinenko Y., Goncharova N., Samolenko T., Tarasyuk V., Nikitenko O., Kovalchuk L. Identification of distinctive biomechanical features of the technique of side hand strike at close range of athletes of different qualifications specializing in hand-to-hand combat. 2021. *Journal of Physical Education and Sport*. 2835–2841. DOI: 10.7752/jpes.2021.s5377.

12. Vako I.I., Grygus I.M., Nikitenko O.V. The use of modern multimedia resources practice of sports and physical education. *Rehabilitation & Recreation*. 2023. 14. 258–268. DOI: <https://doi.org/10.32782/2522-1795.2023.14.31>.

Отримано: 27.10.2023

Прийнято: 16.11.2023

Опубліковано: 28.12.2023

6. Radchenko, Yu.A., Vako, I.I. (2022). Model'ni kharakterystyky tekhniko-taktychnoyi pidhotovlenosti naysyl'niyshykh sportsmeniv u zmishenykh yedynoborstvakh (na prykladi rukopashnoho boyu) [Model characteristics of technical and tactical preparation of the strongest athletes in mixed martial arts (on the example of hand-to-hand combat)]. *Fizychna kul'tura, sport ta zdorov'ya natsiyi*. 14 (33). 74–83. DOI: [https://doi.org/10.31652/2071-5285-2022-14\(33\)-74-83](https://doi.org/10.31652/2071-5285-2022-14(33)-74-83) [in Ukrainian].

7. Gamalii, V., Potop, V., Lytvynenko, Y., Shevchuk, O. (2018). Practical use of biomechanical principles of movement organization in the analysis of human motor action. *Journal of Physical Education and Sport*. 18(2). 874–877.

8. Kashuba, V., Khmel'nitska, I., Krupenya, S. (2012). Biomechanical analysis of skilled female gymnasts' technique in “round-off, flic-flac” type on the vault table. *Journal of Physical Education and Sport*. (4), 431–435.

9. Kashuba, V., Stepanenko, O., Byshevets, N., Kharchuk, O., Savliuk, S., Bukhovets, B., Grygus, I., Napierała, M., Skaliy, T., Hagner-Derengowska, M., Zukow W. (2020). Formation of Human Movement and Sports Skills in Processing Sports-pedagogical and Biomedical Data in Masters of Sports. *International Journal of Human Movement and Sports Sciences*, 8(5), 249–257. DOI: 10.13189/saj.2020.080513.

10. Kindzer, B., Danylevych, M., Ivanochko, V., Hrybovska, I., Kashuba, Y., Grygus, I., Napierała, M., Smolenska, O., Ostrowska, M., Hagner-Derengowska, M., Muszkieta, R., Zukow, W. (2021). Improvement of special training of karatists for kumite competitions using Kata. *Journal of Physical Education and Sport*, Vol. 21 (5), 2466–2472.

11. Vako, I., Kashuba, V., Litvinenko, Y., Goncharova, N., Samolenko, T., Tarasyuk, V., Nikitenko, O., Kovalchuk, L. (2021). Identification of distinctive biomechanical features of the technique of side hand strike at close range of athletes of different qualifications specializing in hand-to-hand combat. *Journal of Physical Education and Sport*. 2835–2841. DOI: 10.7752/jpes.2021.s5377.

12. Vako, I.I., Grygus, I.M., Nikitenko, O.V. (2023). The use of modern multimedia resources practice of sports and physical education. *Rehabilitation & Recreation*. 14. 258–268. DOI: <https://doi.org/10.32782/2522-1795.2023.14.31>.

Received on: 27.10.2023

Accepted on: 16.11.2023

Published on: 28.12.2023