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Original Article

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

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Abstract.
This research deals with identifying the distinctive features of the technique of side hand strike at close range of athletes with different qualifications specializing in hand-to-hand combat. The pedagogical experiment (in the laboratory conditions) involved 10 qualified and 4 highly qualified athletes specializing in hand-to-hand combat. The research used "Qualisys Motion Capture" method for registration and analysis of athletes' movements. The research has established that athletes of high qualification have rather high coordination of inclusion of individual bio-links when performing a side hand strike at close range. At the same time, a slight advance of the maximum speed of the elbow joint at the time of a strike indicates the need for further work on the technique of masters of sports. Qualified athletes have significant reserves in this regard, namely: there is usually no preliminary phase associated with the movement of the pelvis and shoulder joint of the athlete who is striking back after taking the initial position (this phase is called swing); there is an inconsistent inclusion of individual bio-links in the work, as evidenced by the dynamics of changes in the resulting speed of individual bio-links. At the same time, it should also be noted that in the final phase of carrying the side of the striking bio-link (a few temporary moments before the strike) qualified athletes have a movement of the pelvis back, against the course of movement. As a result, the inclination of the torso relative to the vertical increases, which also leads to flexion in the right hip joint. Probably, the violation of the integrity and rigidity of the biomechanical system occurs before the moment of strike and leads to the fact that the links of qualified athletes specializing in hand-to-hand combat significantly lose speed.
Key words: technique of motor actions, side hand strike, athletes specializing in hand-to-hand combat, sports training.

Introduction.

One of the trends in modern high-achievement sports is the rapid increase in the complexity of motor techniques, which leads to new problems and unresolved issues of technical training of athletes (Kashuba et al., 2005; Kashuba et al., 2012; Kashuba et al., 2017; Nesterchuk et al., 2020; Todorova et al., 2020).

It is a known fact that achieving high results in modern sports largely depends on the effectiveness of the use of modern sports and pedagogical techniques in sports training (Gamaliy et al., 2008; Kashuba, 2008; Diachenko-Bohun et al., 2019; Vako, 2019; Kashuba et al., 2020; Kindzer et al., 2021).

Hand-to-hand combat involves the use of a large number of techniques and motor actions that are not used in sports due to the restriction of the rules. Hand-to-hand combat is also characterized by fundamentally different mental guidance and emotional saturation, not constrained by prohibitions and restrictions. The distinctive features of hand-to-hand combat are unexpectedness and unpredictability of situations (Lytvynenko et al., 2018). The system of hand-to-hand combat requires the correct organization of the training process, which involves the formation of motor skills of hand-to-hand combat and the development of the necessary physical and psychological qualities, as well as special tactical skills (Kashuba et al., 2012). The basic technique of hand-to-hand combat includes the main stances and movements, as well as strikes and defensive actions with hands and legs. Additional techniques depend on the individual features of athletes and include complex techniques that require long-term training (Vako, 2015). Despite significant advances in the theory and methodology of hand-to-hand combat (Kashuba et al., 2013), at present, not all possible reserves of training of young athletes specializing in hand-to-hand combat have been exhausted.

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The formation of motor techniques of young athletes specializing in hand-to-hand combat is one of the central problems of the pedagogical process (Vako, 2015; Lytvynenko et al., 2018).

Materials and Methods

Participants. The pedagogical experiment (in the laboratory conditions) involved qualified athletes specializing in hand-to-hand combat (n = 10) and highly qualified athletes specializing in hand-to-hand combat (n = 4).

The research used methods of registration and analysis of movements of athletes (Lytvynenko et al., 2018). The main distinctive feature of "Qualisys Motion Capture" 3D video recording and motion analysis system is that the cameras of this system capture video based on the principle of infrared radiation of the subject, which is pre-applied with a special passive marker having a spherical shape and a light-reflecting surface. Infrared video recording was performed with frequency 150 $f \cdot s^{-1}$. The objectivity of the results of the research is due to the fact that the measuring system is a set of hardware and software. The system of cameras (7 in number) is connected to a personal computer via a network cable. The cameras are connected by a single data cable, so the data coming to the user's computer is represented by a single file as a result of the synchronous operation of all cameras. The result of simultaneous operation of several cameras allows receiving 3D images. Coordinates in the three dimensions are determined automatically in real time. All operations related to setting up and managing the system (setting the recording frequency, calibration, recording, obtaining quantitative information, etc.) take place using "Qualisys Track Manager" software.

Experimental data were processed using conventional methods of mathematical statistics, such as the sampling method, descriptive statistics (Kashuba et al., 2020).

Results

The technique of the side hand strike at close range in hand-to-hand combat is conventionally divided into three phases: the initial position, the phase of attempt or swing (movement of the hand hitting the opponent), and the phase of the strike. All phases have their own tasks, but all of them, one way or another, are aimed at developing maximum strength, achieving it at the time of a strike with an accurate hit on target.

The initial position should provide optimal conditions for the realization of motor abilities of the athlete. When analyzing the technique of the side hand strike at close range of qualified athletes, the research has found that in the initial position, the angle of the torso relative to the vertical is on average 9° (S = 0.5). The angle in the right ankle joint was 89.69° (S = 3.8) (Table 1).

In the knee joint of the right leg, the angle was within 167.83° (S = 2.5). The angle in the hip joint was 174.82° (S = 3.9). It should be noted that the angle in the elbow joint of the striking hand in the process of performing the movement did not change and was within 51-53°. There was a slight decrease at the time of the strike.

According to some experts, the speed of the striking bio-link is important in the study of the second phase of motor action. Developing its maximum speed requires a certain combination in time of movements of other bio-links. It is also important that the maximum peak speed of the bio-link coincides with the moment of the strike.

Given these provisions, we recorded the resulting linear speed of the following joints: right ankle, knee, hip, shoulder, and elbow.

Table 1

Spatial characteristics of the technique of side hand strike at close range of qualified athletes specializing in hand-to-hand combat (n = 10)

The studied angle in the initial position, degrees	$\bar{X}$	S
the inclination of the torso relative to the vertical	9.0	0.5
right hip joint	174.82	3.9
right knee joint	167.83	2.5
right ankle joint	89.69	3.8
right elbow joint	52.0	2.5

The conducted experimental research has allowed establishing that the technique of the execution of a hand strike at close range by qualified sportsmen has an individual character. However, we have identified general trends inherent in this group of athletes.

Given these provisions, we considered it possible, using the example of the technique of side hand strike at close range of a qualified athlete, to describe the resulting patterns.

Thus, in the second phase of the movement, there is a sharp increase in the speed of all joints on the striking side of the athlete. At the same time, there is an active extension in the ankle, knee and hip joints. At the time of the strike, the angle in the ankle joint was 117.6°, in the knee joint – 176.64°, in the hip joint – 192.72°, respectively.

The first speed maximum was recorded for the knee joint in 0.253 s after the start of the movement. In 0.013 s, the foot joint reaches the maximum value of the speed, and at 0.32 s, there is a peak speed of the hip joint. This is explained by a similar sequence of extension in these joints, namely: first, the athlete performs extension in the knee joint, and then the ankle joint is included in the movement. In the hip joint, although the angle changes slightly, this is due to the extension in the above joints.

The next speed peak is observed for the elbow joint, which occurs at 0.413 s, which is a few fractions of a second before the strike (0.033 s). In 0.012 s, there is a peak value of the speed of the shoulder joint, which is 0.018 s ahead of the moment of the strike.

The maximum value of the resulting speed of the ankle joint of this athlete was 0.619 $m \cdot s^{-1}$, at the moment of the strike – 0.437 $m \cdot s^{-1}$. For the knee joint, the maximum of the resulting speed was 1.033 $m \cdot s^{-1}$. At the moment of the strike, the speed dropped significantly to 0.264 $m \cdot s^{-1}$. The maximum speed of the hip joint was within 1.623 $m \cdot s^{-1}$, at the moment of the strike – 1.158 $m \cdot s^{-1}$. The shoulder joint reaches a peak speed of 3.452 $m \cdot s^{-1}$, while at the time of the strike it was 1.304 $m \cdot s^{-1}$. The speed of the elbow joint has the highest rates among all joints and makes 7.459 $m \cdot s^{-1}$, at the same time, there is a sharp decrease at the moment of the strike to 5.712 $m \cdot s^{-1}$.

It should be noted that the peak value of the speed of the elbow joint is preceded (0.006 s) by the maximum extension in the right knee joint. Although the athlete performs a twist of the torso (the movement of the torso relative to the vertical axis counterclockwise), the speed of the striking link decreases sharply. Extension in the ankle joint occurs throughout the movement. From the moment of reaching the maximum speed of the arm and the maximum extension in the knee joint, there is a fixation in the ankle joint, which is maintained until the moment of the strike. After the strike itself, the angle in the ankle joint reaches a maximum.

The research has established that the technique of performing a side hand strike at close range by qualified athletes is individual and requires appropriate adjustments. At the same time, the quantitative data of the hand strike at close range by the athlete reflect the general trend characteristic of this category of athletes. The dynamics of changes in the speed of the studied joints is quite similar. Although the final speed and maximum values of the elbow of these athletes are individual, there is an anticipatory peak of the increase in the speed of the striking links before the strike, which was also found in the previous athlete.

In the initial position of highly qualified athletes, the angle of inclination of the torso relative to the vertical was 9° (S = 0.8). The angle in the right ankle joint was 76.6° (S = 1.8). In the knee joint of the right leg, the angle was within 156.73° (S = 2.6). The angle in the hip joint was 172.89° (S = 2.9). It should be noted that the angle in the elbow joint of the striking hand did not change in the process of movement and was in the range of 50-52°.

The research data allowed establishing that the technique of hand strikes at close range of highly qualified athletes is individual. Therefore, the representation of average values may introduce some ambiguity. At the same time, the research has identified the general dynamics of change of the individual indicators, which is presented below using the example of the athlete's technique of a hand strike at close range.

Thus, after taking the initial position, the movement of a highly qualified athlete begins with a rather active advancement of the right side of the pelvis, as well as the hip joint moves forward-down-right. At the same time, there is an opposite movement of the right shoulder joint – back-down-left, which leads to the reversal and tilt of the athlete's torso back. The right knee joint moves forward, slightly descending down and to the right. The angle in the knee joint of the right leg decreases. It should be noted that the angle in the ankle joint, due to the movement of the upper joints, does not change. There is a slight movement forward and down.

From the moment of maximum movement of the right part of the pelvis forward, abduction of the right shoulder and back tilt of the torso, as well as reaching the minimum angle in the knee joint of the right leg, there is a sharp increase in the speed of all joints of the athlete's striking side. At the same time, there is an active extension in the knee and hip joints. At the time of the strike, the angle in the ankle joint was 89.14°, in the knee joint – 177.45°, and in the hip joint – 192.72°, respectively. The first speed maximum was recorded for the knee joint in 0.13 s after the start of the movement. In 0.006 s, the hip joint reaches the maximum value of the speed, and at 0.22 s, there is a peak speed of the ankle joint. It should be noted that after the extension of the ankle joint and reaching its peak speed, the maximum speed is observed in the elbow joint (0.018 s before the strike). The moment of strike coincides with the maximum speed of the shoulder joint.

The maximum value of the resulting speed of the athlete's ankle joint was 1.158 $m \cdot s^{-1}$, at the time of the strike – 1.117 $m \cdot s^{-1}$. For the knee joint, the maximum of the resulting speed was 1.528 $m \cdot s^{-1}$. At the moment of the strike, the speed dropped significantly to 0.872 $m \cdot s^{-1}$. The maximum speed of the hip joint was within 2.284 $m \cdot s^{-1}$, and at the time of the strike – 0.548 $m \cdot s^{-1}$. The shoulder joint reaches a peak speed of 5.239 $m \cdot s^{-1}$. The speed of the elbow joint, as a striking part, has the highest values among all joints and makes 8.088 $m \cdot s^{-1}$, and at the time of the strike, it is slightly lower and makes 7.857 $m \cdot s^{-1}$.

The research has established that among highly qualified athletes, the modulus of speed of individual joints may differ at different times. At the same time, there is the general dynamics of change of the resulting speed, which can be connected with a certain sequence of inclusion of bio-links and extension of joints when making a strike.

The study of the technique of side hand strike at close range of athletes of different qualifications allowed establishing both general patterns and distinctive features.

In the initial position, highly qualified athletes have a tilt of the torso forward by 6-7°, while the angle in the hip joint is about 180°.

The studied motor act begins with the rotational movement of the torso and pelvis clockwise. The athlete's legs are motionless. The speed of the right shoulder joint is higher than that of the hip. This preparatory phase of the movement is quite short (lasts a fraction of a second), but largely determines the further acceleration of all bio-links, as during this time it provides a mechanism to increase the potential energy of elastic deformation of muscles and ligaments (including oblique abdominal muscles).

The next movement is counter and is characterized by active advancement of the pelvis and the corresponding hip joint, forward and downward with a counterclockwise turn. There is a flexion in the knee and ankle joints. The right shoulder joint also moves forward, but due to the fact that its speed is lower than the speed of the pelvis, there is a slight deviation of the torso back within 6° and its turn to the right.

The angle between the axis of the pelvis and shoulders increases with a maximum of 7°. Moreover, the achieved angle is maintained by all the athletes examined during the research for 0.018 – 0.024 s and coincides with the maximum value of the speed of the hip joint, as well as with the dynamics of increasing the speed of the shoulder joint. In the following moments, due to the rotational movement of the torso, as well as the extension of the right knee, the shoulder joint of the striking hand actively moves forward.

At the same time, there is a sharp decrease in the speed of the right hip joint and a further increase in the speed of the shoulder joint, which indicates the transmission of the force impulse.

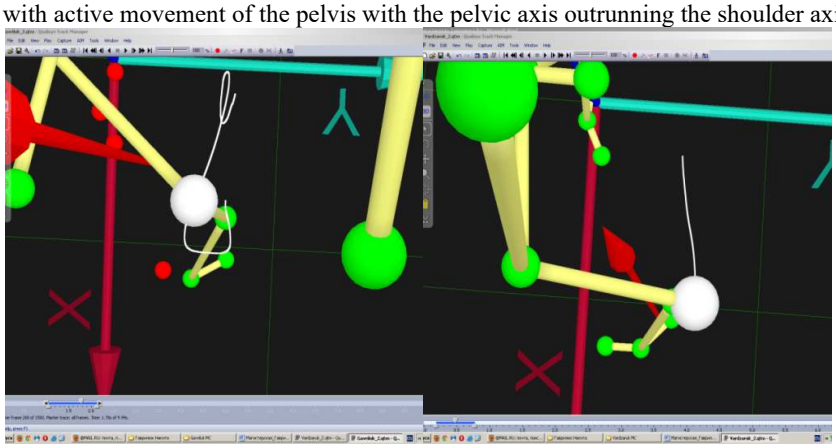
Subsequent movements are associated with a decrease in the angle between the thigh of the right leg and the torso with the completion of the rotational movement.

Among highly qualified athletes, the moment of impact coincides with the moment of maximum speed of the shoulder joint, and the elbow joint has the maximum speed slightly before the moment of the strike.

In the initial position, qualified athletes also have the forward tilt of the torso, which averages 5-7°. The angle in the hip joint is about 180°, which indicates that the leg is slightly set back.

The studied motor act begins with the rotational movement of the torso and pelvis counterclockwise. The athlete's legs are motionless. The speed of the right hip joint is slightly higher than of the shoulder joint, which allows advancing the pelvis relating to the shoulders. This increases the angle between the axis of the shoulders and pelvis.

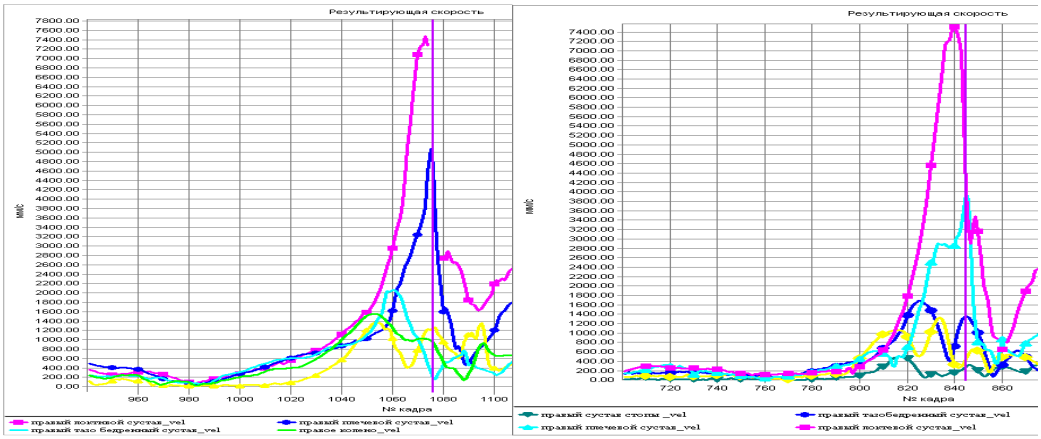
It should be noted that the examined qualified athletes specializing in hand-to-hand combat do not have a preparatory phase of acceleration, as highly qualified athletes do. After the initial position, qualified athletes perform a forward movement in the course of a future strike. Highly qualified athletes make a counter-movement – first, back (which increases the path and creates the conditions for clearer twisting), and after a few moments – forward movement with active movement of the pelvis with the pelvic axis outrunning the shoulder axis (Fig. 1).



A) B)

Fig. 1. The trajectory of movement of the right hip joint from the moment of initial position: A) highly qualified athletes, B) qualified athletes (top view; printout from the monitor screen)

Qualified athletes are characterized by rotational movements of the torso with simultaneous extension in the right knee and ankle joints. This movement ensures the advancement of the shoulder joint of the striking arm, which in turn allows slight outrunning of the right hip joint. Among qualified athletes, the moments of maximum speed of the shoulder and elbow joints, as a rule, occur before the moment of the strike. At the same time, there are considerable losses of speed of the elbow joint (Fig. 2). For some athletes, these losses amounted to 1.5–2 $m \cdot s^{-1}$.



A) B)

Fig. 2. Speed of the studied points of the body when performing a side hand strike at close range: A) a highly qualified athlete; B) a qualified athlete (printout from the monitor screen)

Discussion

Sport biomechanics studies human movements in the process of exercise. She considered athlete's motor actions as a system interconnected active movements. At the same time followed by mechanical and biological laws movements and the dependent features of the physical actions in different conditions (Laputin A N., 1995).

The general task of studying human movements in the biomechanics of sport is to evaluate the effectiveness of actions for effective achievement of the set purpose (Gamalii et al., 2018).Taking into account the physical conditions of the necessary motor task, which directly affect and create demands concerning the level of technical, physical, and theoretical training of the performer, the research also shows that achieving the desired end result of mechanical actions of the athlete requires a deep understanding of the relationship between the method of performing a sports exercise and biomechanical parameters of the performer's movement as factors in the effectiveness of this method of action (Kashuba et al., 2017; Todorova et al., 2020).

This statement complements the data of the works (Gamalii et al., 2018; Vako, 2020). The basis of its creation as a result of human psychomotor activity is the presence of the athlete's mode of action, the formation of which is inextricably linked with motor guidance (Kashuba et al., 2010; Lytvynenko et al., 2018). In general, the received results complement the data of the special literature on the control of the athlete's movement (Todorova et al., 2019), convincingly pointing to the high degree of importance not only of the leading level in movement control (cortical level of arbitrary movements), but also the so-called background levels responsible for involuntary movement control, as evidenced by the introduction of effective corrections of own actions by highly qualified athletes a fraction of a second before the decisive moments of the technical performance of a particular exercise (Vako, 2015; Kashuba et al., 2017).

Conclusions

Analysis of the special literature showed that the study of biomechanical characteristics in hand-to-hand combat very little attention was paid. Therefore, research, analysis and development of rational percussion actions of the athlete in hand-to-hand combat are relevant for improving the results of participation in competitions.

The research has established that athletes of high qualification have rather high coordination of inclusion of individual bio-links when performing a side hand strike at close range. At the same time, a slight advance of the maximum speed of the elbow joint at the time of the strike indicates the need for further work on the technique of masters of sports.

Qualified athletes have significant reserves in this regard, namely: there is usually no preliminary phase associated with the movement of the pelvis and shoulder joint of the athlete who is striking back after taking the initial position (this phase is called swing); there is an inconsistent inclusion of individual bio-links in the work, as evidenced by the dynamics of changes in the resulting speed of individual bio-links.

At the same time, it should also be noted that in the final phase of carrying the side of the striking bio-link (a few temporary moments before the strike) qualified athletes have a movement of the pelvis back, against the course of movement. As a result, the inclination of the torso relative to the vertical increases, which also leads to flexion in the right hip joint. Probably, the violation of the integrity and rigidity of the biomechanical system occurs before the moment of strike and leads to the fact that the links of qualified athletes specializing in hand-to-hand combat significantly lose speed.

Compliance with Ethical Standards

Conflict of Interest. The authors declare that there is no conflict of interest that could be perceived as interfering with publication of the article.

Competing Interests. The authors declare that they have no competing interests.

Ethical Approval. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent. Informed consent was obtained from all individual participants included in the study. All subjects of the institutional survey gave consent for anonymized data to be used for publication purposes.

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