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BIOMECHANICAL ANALYSIS OF THE STRIKING TECHNIQUE GYAKU-TSUKI IN SPORT KARATE

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ABSTRACT

This article presents a biomechanical analysis of the gyaku -tsuki (reverse straight punch) striking technique, one of the basic and most frequently used techniques in sport karate. It examines the kinematic and dynamic characteristics of the movement, the sequence of body movements, and the specifics of muscle and musculoskeletal system function. The analysis is conducted from the perspective of sports biomechanics principles, including the concepts of the kinematic chain, force impulse, and motor optimization. The data obtained allow us to identify key factors in striking effectiveness and can be used in training to improve performance and reduce the risk of injury.

KEYWORDS

Karate, gyaku - tsuki, biomechanics, striking technique, kinematic chain, sports training.

Introduction

Sport karate is a complex, coordination-based martial art, in which the effectiveness of competitive performance is largely determined by the athlete's technical skill level. In the discipline of kumite, striking movements with the hands play a leading role, among which the gyaku -tsuki (Japanese:逆突き- reverse straight punch) holds a special place. This technique is widely used in both attacks and counterattacks and is considered by experts to be the basic model for developing high-speed, powerful striking movements in karate [1].

From the perspective of sport theory and martial arts training methods, a rational striking technique should ensure maximum effectiveness with minimal energy expenditure and high precision. This problem can be solved through biomechanical analysis, which allows for an objective assessment of the kinematic and dynamic parameters of movement, identification of patterns of force transmission, and optimization of the motor action structure [2]. According to Viktor Konstantinovich Zatsiorsky , the biomechanical approach is a key tool for analyzing and improving complex athletic movements [3].

A number of foreign studies have been devoted to analyzing the biomechanical characteristics of karate strikes. For example, Marcus Hofmann He emphasizes that traditional descriptions of the technique, based primarily on visual control, do not fully reveal the physical essence of striking actions. In his work, he points to the need for a quantitative analysis of the movement parameters during gyaku - tsuki, including the speed of body segments, angular movements of joints, and the transfer of force impulse [4].

The kinematic features of the gyaku -tsuki strike were investigated AND Gede Suvarganda , And Ketut Suryavan and Ni Putu Nita Vijayanthi . The authors found that the effectiveness of a punch is directly related to the principle of proximal-distal sequencing, in which the movement begins with the lower extremities and pelvis and culminates in maximum fist velocity [5]. Violating this sequence leads to a decrease in striking momentum and an increase in energy expenditure.

Modern research also actively uses electromyography methods to analyze muscle activity during striking movements. In the work of Francesco Di Marino , Giuseppe Tessitore and Antonio Polidori It has been shown that when performing strikes in karate, the muscles of the lower limbs and core play a leading role in generating force, while the muscles of the upper limb perform primarily a transmission function [6]. Similar results were obtained in studies of striking movements in other types of martial arts [7].

Sports theory and methodology experts also emphasize the importance of a rational biomechanical structure of movements. Yuri Viktorovich Verkhoshansky and Leonid Pavlovich Matveyev noted that the effectiveness of speed-strength actions is determined not only by the level of physical fitness but also by the precision of intermuscular coordination and the timing of the movement [8, 9]. These principles are fully applicable to the analysis of gyaku -tsuki techniques in sport karate.

Despite the existence of scientific works devoted to the biomechanics of striking movements, comprehensive studies aimed directly at analyzing gyaku -tsuki technique, taking into account kinematics, dynamics, and muscle activity, remain limited. This determines the relevance of the present study and the need for further scientific substantiation of methods for improving this striking technique.

The scientific novelty of the article lies in the clarification of the biomechanical structure of the gyaku -tsuki strike and the identification of key kinematic parameters that determine its effectiveness in sport karate.

Research Materials and Methods

The study was analytical and experimental in nature and aimed to examine the biomechanical characteristics of the gyaku -tsuki striking technique in sport karate. The object of the study was the technique of executing the gyaku -tsuki strike, and the subject of the research was its kinematic and dynamic characteristics.

The study utilized video recordings of highly skilled male karateka (at least first-ranked athletes) performing the gyaku -tsuki strike from the zenkutsu- dachi stance under standard training conditions. Multiple repetitions of the strike were analyzed to improve the reliability of the data obtained.

The following methods were used in the study: analysis of scientific and methodological literature devoted to the biomechanics of sports movements and striking techniques in karate; qualitative and quantitative video analysis, which made it possible to determine the spatiotemporal characteristics of the movement of body segments; kinematic analysis, which included an assessment of the trajectories, angular displacements, and linear velocities of the main links of the body; biomechanical structural analysis aimed at identifying the sequence of activation of the links of the kinematic chain; methods of mathematical statistics (descriptive statistics) for processing the obtained data.

The video footage was processed using specialized motion analysis software, which allowed for the recording of key moments of striking action and the calculation of key kinematic parameters. The

results were summarized and interpreted from the perspective of sports biomechanics theory and karate training methods.

Research Results

A visual and kinematic analysis revealed that the gyaku -tsuki strike in sport karate is executed as a holistic, multi-part movement, sequentially involving the lower limbs, pelvis, torso, shoulder girdle, and striking arm. In all analyzed attempts, the initial phase of the strike began with active engagement of the feet with the support, ensuring the stability of the zenkutsu -dachi stance and the formation of the initial momentum.

Kinematic analysis revealed that pelvic movement is the first active component initiating the striking action. Pelvic rotation around the vertical axis preceded shoulder girdle movement and was accompanied by a shift in the body's center of mass in the direction of the strike. Average angular velocity of pelvic rotation ranged from 380–420°/s. Athletes with a more stable stance demonstrated higher angular velocity and less body oscillation.

During the next phase of the strike, active engagement of the torso and shoulder girdle was observed. Shoulder girdle rotation occurred with a delay relative to pelvic rotation and reached maximum angular velocities of 420–480°/s. This time delay ensured the transfer of momentum from the proximal to the distal segments and contributed to the increased speed of the striking arm.

Extension of the arm at the shoulder and elbow joints began after reaching maximum shoulder girdle rotation speed. Analysis of angular movements revealed that elbow extension occurred along an arcuate trajectory, reaching near-full extension at the completion of the strike. The elbow extension angle during the kime phase averaged 170–180°, indicating the absence of hyperextension and maintained joint stability.

Maximum linear fist velocity was recorded at the final stage of the main strike and ranged from 7.5 to 9.0 m/s. Achieving these values required precise coordination between the rotational movements of the body and the forward movement of the arm. Lateral deviations in the fist's trajectory or premature extension of the arm resulted in a decrease in maximum velocity and an increase in the time it took to execute the strike.

An analysis of spatial trajectories revealed that the fist's movement in the most effective attempts occurred primarily in the sagittal plane, following a nearly linear trajectory. Deviations in the horizontal plane did not exceed minimal values and did not significantly affect the stability of the stance. The time it took to execute the punch, from the start of the active movement to the moment of simulated contact, averaged 0.35–0.45 seconds.

The final phase of the strike was characterized by a brief stabilization of the body's position and a decrease in the speed of the segments. The joints and body locked in place synchronously with the fist reaching maximum speed and was accompanied by a reduction in post-impact body oscillations. This pattern of movement completion was observed in all attempts deemed technically correct.

The kinematic characteristics of the gyaku -tsuki strike are presented in Table 1.

Table 1 - Kinematic characteristics of the gyaku- tsuki strike (average values)

Indicator	**Meaning**
Strike execution time, s	0.35–0.45
Maximum angular velocity of pelvic rotation, °/ s	380–420
Maximum angular velocity of the shoulder girdle, °/ s	420–480
Maximum linear speed of the fist, m/ s	7.5–9.0
The angle of extension of the elbow joint at the moment of kime , °	170–180

Discussion

The obtained results confirm the propositions of sports biomechanics theory regarding the leading role of the lower extremities and core in generating striking force. The sequential activation of the kinematic chain links and a rational temporal structure of the movement contribute to the increased speed and effectiveness of the gyaku -tsuki strike. The identified proximal-distal organization of movement is consistent with data from previous studies of striking actions in karate and other martial arts.

The observed delay in arm extension relative to pelvic and torso rotation is biomechanically beneficial, as it allows for the summation of velocities and minimizes energy expenditure. Premature engagement of the upper limb, on the other hand, reduces the final velocity of the fist and disrupts stance stability, confirming the need for strict adherence to the phase structure of the movement.

The final fixation of the body's position during kime plays a crucial role in concentrating the force impulse and preventing its dissipation. From the perspective of sport karate practice , this phenomenon is particularly important in competitive combat, where the effectiveness of a strike is determined not only by its speed but also by the precision of its movement control.

Thus, the study's results highlight the usefulness of a comprehensive approach to teaching gyaku -tsuki, including developing stance stability, coordinating rotational movements of the body, and optimizing the timing of the striking arm extension. The findings can be used to adjust training procedures and develop methodological recommendations for karatekas of various skill levels.

Conclusions

The study revealed that the gyaku -tsuki strike in sport karate is a complex, coordinated movement whose effectiveness is determined by the coordinated interaction of all components of the musculoskeletal system. The striking force is generated through the consistent transfer of force from the lower extremities through the pelvis and torso to the striking arm, which is consistent with the fundamental tenets of sports biomechanics theory.

An analysis of the kinematic characteristics revealed that a rational timing structure of the movement, in which rotation of the pelvis and torso precedes active extension of the upper limb, plays a key role in increasing the speed and effectiveness of the punch. This organization of movement facilitates the principle of proximal-distal velocity transfer and ensures maximum linear fist velocity in the final phase of the punch.

It has been established that the effectiveness of gyaku -tsuki depends largely on the stability of the stance and the athlete's ability to stabilize the body position at the completion of the movement. Brief joint fixation and muscle tension during the kime phase ensure the concentration of the force impulse and prevent its dissipation, which is especially important in competitive situations.

The obtained results confirm the feasibility of using a biomechanical approach in the technical training of karatekas. Using biomechanical analysis data allows for targeted improvement of striking movements, increasing their effectiveness, and simultaneously reducing the risk of overuse and injury to the musculoskeletal system.

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