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Original Contribution

COMPARATIVE BIOMECHANICAL ANALYSIS OF PERFORMANCE AGAINST A REAL TARGET AND A "KATA" IN KARATE

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ABSTRACT

Objective: The aim of the present study is to perform a biomechanical quantitative analysis of uniform techniques performed against a real and fictitious target. Methods: The subjects of the study were *karatekas* (kyokushinkai), a total of 16 experienced individuals. The technical level of the experienced individuals was between first *kyu* and second *dan*. The experiments were carried out with the help of video computer equipment for movement analysis. Results: Naturally, in the real hit, at most two maxima were observed, while in the marking one there were a number of (more than 4) local extrema. During real performance, the acceleration path is significantly longer which leads to the need to exert much larger inertial forces. This is probably due to the fact that in the demonstrative performance the competitor fails to use the maximum potential of his explosive muscle forces. Conclusion: The derived characteristic for the number of extrema on the functional curves from the space-time characteristics demonstrates a stable regularity, through which the degree of sports and technical mastery and the objective differences between real and formal strikes in karate can be reliably assessed.

Keywords: sports and technical mastery, force impulse, acceleration

INTRODUCTION

By declaring karate an art, some attribute to it a higher standing among other sports disciplines. In general, we can claim that every sport contains artistic elements, yet an additional characteristic of sports activity is distinctive, as well. This is the absence of a preliminary scenario and the need for creativity in the specific moment: creativity that expresses the entire essence of an individual with all their qualities - physical and spiritual (1-3). In this respect, martial arts (judo, wrestling, sambo, etc.) seem to have advantage to other sports disciplines, due to the richer opportunities for an overall personal expression. Therefore, we can fully agree with the old masters of Eastern martial arts who saw in their practice a system for the education (physical and spiritual) of the younger generation through the means of attack and defense. Nowadays, karate is seen as a sport that helps the harmonious development of the personality, representing a favorite means and method for physical strengthening of millions of people around the world. It is a sport in which high sportsmanship is scientifically proven to be a result of physical qualities, technical mastery, tactical skill, mental qualities and knowledge of the *karateka* (4-9).

The concept of modern karate encompasses numerous varieties of styles and schools. In almost all styles, there are two relatively independent tendencies for improvement - the execution of the *kata* and the confrontation with an opponent or real target (*makiwara*). Although at first glance the motor tasks are the same, in the case of real goals, the control of the motor apparatus should also take into account the role of the external force field. From a biomechanical point of view, this fact sets different initial conditions for the functional dependencies provided by the control system (10). This theoretical conclusion is also confirmed by the competition results, where the same competitors have different success rates depending on the "external" conditions. The

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establishment of quantitative parameters describing the differences in biomechanical expediency when solving such motor tasks is of essential importance for optimizing educational and training work (11-12). Such a scientific task is of particular importance for Eastern martial arts, since their methodologies are subject to strong traditionalism, often without the necessary scientifically sound justification.

METHODOLOGY

Objective: The aim of the present study is to perform a biomechanical quantitative analysis of uniform techniques performed against a real and a fictitious target.

The participants were Bulgarian *karatekas* (kyokushinkai), 16 in total, with a balanced gender distribution and an average age of 25 years. The technical level of the experienced individuals was between first *kyu* and second *dan*. The experienced individuals had the motor task of performing *tsuki* and *mawashi geri* with maximum force impulse. The experiments were performed with the help of a video computer set for movement analysis.

Limitations of the study. Since this study is within the goals of the Heritage BG Scientific Center for Excellence, all experts were recruited through a public announcement. The participants gave informed consent for the publication of their data. The study was conducted from May 2023 to February 2025.

RESULTS

The analysis shows that there is a significant difference between the performances in real and fictitious conditions. **Figure 1 and 2** present the accelerations of the foot and the lower limb's center of gravity in *mawashi geri*.

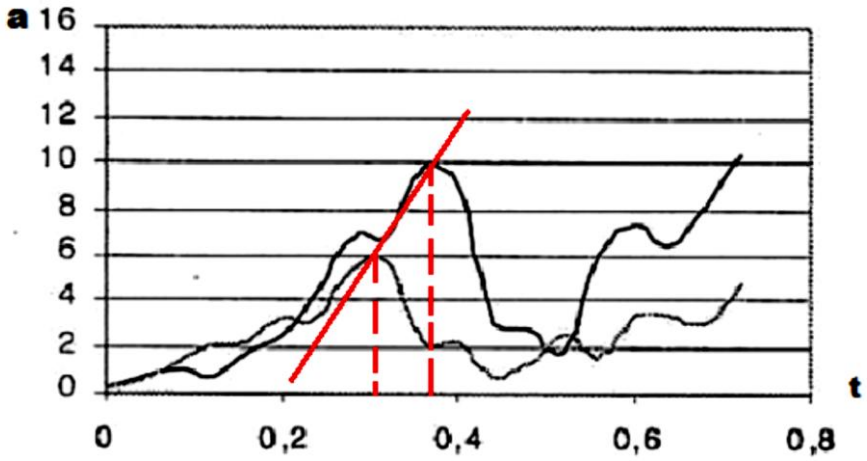

Figure 1. Accelerations of the foot and CG of the lower limb - during the kata

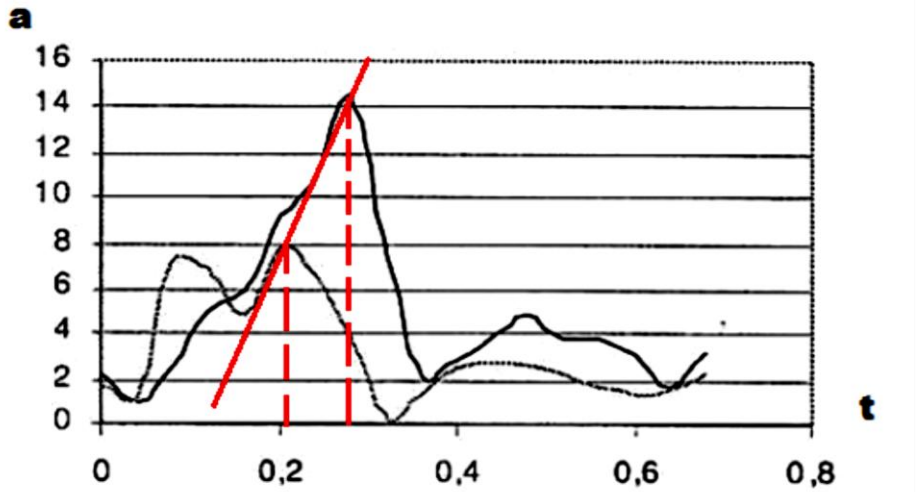

Figure 2. Accelerations of the foot and CG of the lower limb - against makiwara

Table 1 illustrates the results of the variation analysis of the biomechanical characteristics - maximum value of the acceleration of the foot, the difference between the accelerations of the pelvis and the tangent of the angle between the maximums achieved between the pelvis and the foot.

Table 1. The results of the variation analysis of biomechanical characteristics

characteristic	a max	S	V%	tg	S	V%	a	S	V%
makiwara	14.1	1.8	12.77	24.4	2.3	9.43	6.2	0.6	9.68
kata	9.9	1.9	19,19	16.2	2.8	17,28	6.1	0.8	1,31

The last characteristic, in addition to the absolute values of the accelerations, also takes into account the rhythm of the performances. It is noteworthy that in the *kata* performance, two phases of the foot movement are clearly defined, which are determined by the technique requiring whip-like extension of the lower leg (about 0.3 seconds from the beginning). In the case of a *makiwara* strike, the kinematics have the opposite meaning. Apparently, due to the greater maximum loads, probably due to the later involvement of the antagonist muscles, the control of the CCG experiences certain difficulties, and in this case two distinct phases are formed for the private center of gravity. It becomes clear that the greater complexity of the motor task, involving synergy between more powerful muscle groups along complex kinematic chains, leads to significantly greater differences in the movement system. However, the trends are preserved from the analysis of hand strikes, with one exception – in *makiwara* the presence of a wave-like function in the movement of the pelvis is established. A similar fact in hand strikes was interpreted in *kata* performances of *zuki* as instability in the kinematic structure. Here, however, it probably carries information about the biomechanical expediency, since immediately after this wave much higher acceleration values are demonstrated. It should be noted that different performers observe different variations, forming a phase structure, specific both to the type of blows and to the particular performer. In general, when performing in *makiwara*, three to four phases can be found, outlining a step-like nature of the increase in acceleration in individual cases, including a violation of the monotony of the increasing function.

To the extent that the functions of the registered accelerations reflect the force characteristics, we observe a very large discrepancy between the techniques of performance in *kata* and real conditions **(Figure 3 and 4).**

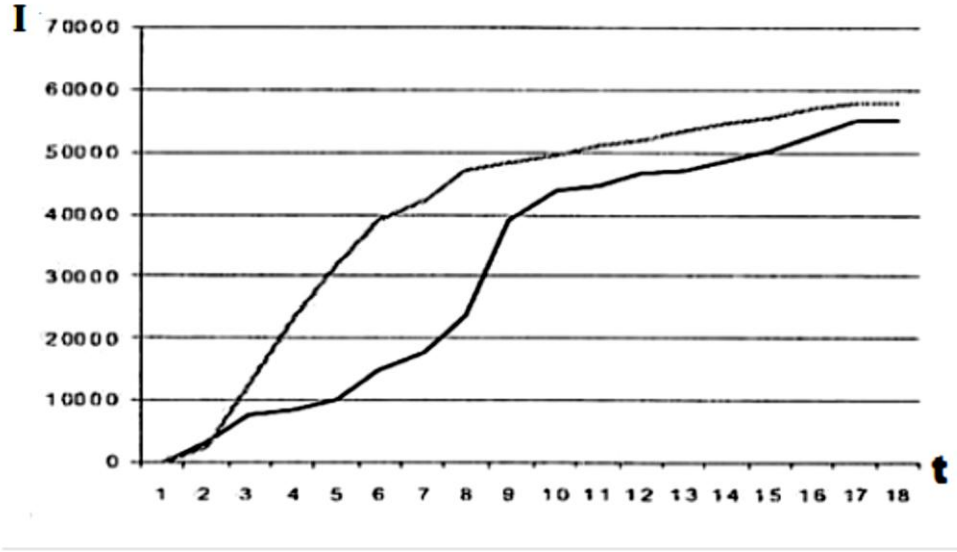

Figure 3. Force impulse - at kata (a)

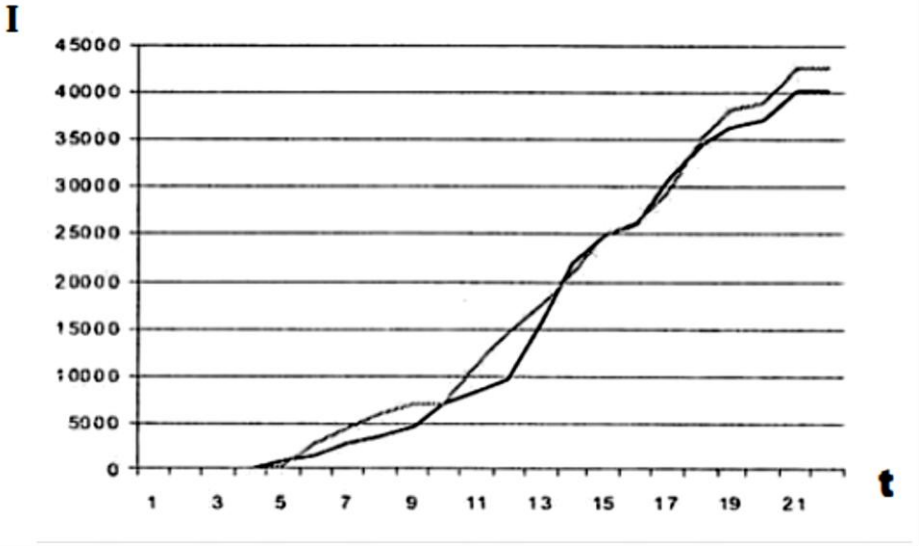

Figure 4. Force impulse - against makiwara (b)

In the *kata* performance, in all cases there are only two phases for acceleration of the feet with a larger or smaller period, disrupting the monotonically increasing nature of the function. The phase structure of the acceleration of the private center has exactly the opposite character.

Individually, up to four phases can be detected, more or less, disrupting the smoothness of the positive acceleration function, while in the execution against the makiwara, the phases are always two with a more or less pronounced minimum between the two maximum values.

CONCLUSION

From the experimental data obtained in this study, the following more significant conclusions and recommendations could be drawn:

- Performances in the form of *kata* and against *makiwara* differ significantly in terms of spatio-temporal characteristics, and hence in the dynamic structure that provides them.
- Obviously, these differences are not only external and formal in nature and should be taken into account when planning and implementing the educational and training process on the path to improving sports and technical mastery.
- Interesting behavior is also demonstrated by the derived characteristic for the number of extrema on the functional curves from the space-time characteristics. This parameter demonstrates a stable regularity, through which the degree of sports and technical mastery and the objective differences between real and formal strikes in karate can be reliably assessed.

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Declarations of informed consent have been signed regarding the publication of survey data. ChatGPT is used for English grammar revision and translation.

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