Evaluation of the force field rotor in highly skilled martial artists when moving using the shuttle method

UDC 796.8

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Received by the editorial office on 27.03.2025

Abstract

Objective of the study was to identify the characteristics of the rotational force field in which the center of mass of athletes shifts during shuttle-like movements.

Methods and structure of the study. It is assumed that the athlete's center of gravity moves in a force field $\vec{F}$, created by the athlete and gravity. For the study, the shuttle method of movement was used. The demonstration of movement was carried out by two athletes qualified as a master of sports in jiu-jitsu.

Results and conclusions. The rotor of the force field, which is the athlete's center of gravity during the shuttle movement, is not fixed in time. For different athletes, the rotor's change from the coordinate can be either identical or opposite. Consequently, we can discuss a range of biomechanical parameters and characteristics that correspond to the correct technique, and we can also talk about various versions of the correct technique for executing the movement. A technical error refers to an action that prevents the subsequent motor task from being completed or involves an unnecessary expenditure of energy.

Keywords: *biomechanics of martial arts, jiu-jitsu, shuttle movement.*

Introduction. Bibliometric analysis of publications shows that scientific research on martial arts constitutes only a small share of all scientific information available in the field of sports sciences. A clear shortage is also felt in research on the biomechanics of technical and tactical actions.

Objective of the study was to identify the characteristics of the rotational force field in which the center of mass of athletes shifts during shuttle-like movements.

Methods and structure of the study. It was suggested that the center of gravity of each athlete is located in the force field $\vec{F}$, created by the athlete's efforts.

Research objectives:

- to plot the trajectory of the center of gravity of each athlete during movement;

- to calculate the rotor of the force field of each athlete;

- to evaluate the features of the twisting of the force field during movement in the shuttle method for highly qualified athletes.

The rotor of the force field is a value characterizing the degree of twisting of the force field:

$$rot \times \vec{F} = \left(\frac{dF_z}{dy} - \frac{dF_y}{dz}\right)\overrightarrow{e_x} + \left(\frac{dF_x}{dz} - \frac{dF_z}{dx}\right)\overrightarrow{e_y} + \left(\frac{dF_y}{dx} - \frac{dF_x}{dy}\right)\overrightarrow{e_z} \quad (1)$$

The first term characterizes the rotation around the O_x axis, the second around the O_y axis, and the third around the O_z axis. Since the experiment considered a two-dimensional image, the formula contains only one term, which describes the rotation around the O_z axis, perpendicular to the plane of the drawing:

$$rot \times \vec{F} = \left(\frac{dF_y}{dx} - \frac{dF_x}{dy}\right)\overrightarrow{e_z} \quad (2)$$

The study was conducted using the «shuttle» movement method. The movement was demonstrated by two athletes with the qualification of master of sports in jiu-jitsu. The mass of one athlete (№ 1) was 52 kg,

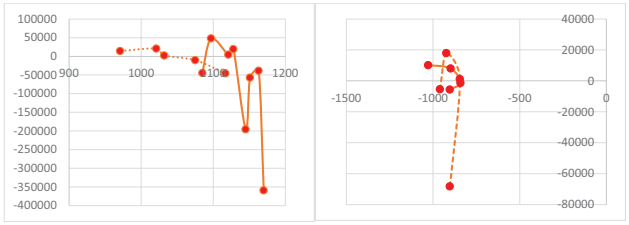
the second (№ 2) 85 kg. This difference was taken in order to more clearly demonstrate the differences and similar elements in the exercise performed by two qualified athletes. A similar selection of subjects was used in the experiment described in the article «Divergence of the force field during the process of movement using the «Shuttle» method, published in № 1 for 2025». Cyclograms with a time interval of 0.04 seconds were cut out from video recordings of movement using the «shuttle» method. The centers of gravity of each body segment were marked on them, the trajectory of the center of gravity of each of the athletes was constructed. Then, an estimate of the displacements of the center of gravity between the cyclograms relative to the coordinate axes was calculated. The projections of the velocities and accelerations of the centers of gravity were determined. The force acting on the athlete's center of gravity was determined using Newton's second law. The change in force was determined as the difference in force values between two adjacent cyclograms. The final formula for calculating the rotor value was:

$$rot \times \vec{F} = \left(\frac{F_{yi}-F_{y(i-1)}}{x_i-x_{i-1}} - \frac{F_{xi}-F_{x(i-1)}}{y_i-y_{i-1}}\right) \quad (3)$$

where F_{yi} - $F_{y(i-1)}$ is the difference in the projections of the values of the force acting on the center of gravity between two adjacent cyclograms onto the ordinate axis, x_i - $x_{(i-1)}$ – is the difference in the values of the coordinates along the O_x axis between two adjacent cyclograms, F_{xi} - $F_{x(i-1)}$ – is the difference in the projections of the values of the force acting on the center of gravity between two adjacent cyclograms onto the abscissa axis, y - $y_{(i-1)}$ – is the difference in the values of the coordinates along the O_y axis between two adjacent cyclograms.

Figure 1 shows the change in rot × $\vec{F}$, depending on the x coordinate during forward movement.

The enormous values of the force field rotor are striking. For athlete № 1, the field twist varies from -359125 Н/м to 127968 Н/м. For athlete № 2 from -68209 Н/м to -18069 Н/м. Apparently, this is a consequence of the fact that the athlete's body was considered a material point identified with the athlete's center of gravity when calculating the rotor. In reality, a significant part of the athlete's mass was supported by the tatami and the mass transferred by muscular effort was significantly less. Therefore, it seems erroneous to draw conclusions based on a comparison of digital indicators. However, it is possible to analyze the mechanical structure of oscillations.



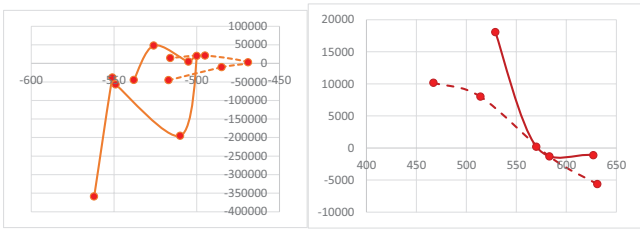
a) b)

Figure 1. Change rot × $\vec{F}$, depending on the x coordinate in the process of forward movements of athletes of the Master of Sports qualification in jiu-jitsu (solid line – first movement, dotted line – second movement, dashed-dotted line – third)

It is evident from figure 1 that the changes in the rotor of the force field have a structure close to oscillatory. In the process of forward movements, the rotor, depending on the x coordinate, can have both minimums and maximums, that is, we can talk about a different character of the field twist from movement to movement. At the same time, one cannot help but note a significant difference in the steepness of the graphs.

Apparently, it is possible to assume the existence of a certain region of permissible values of the rotor of the force field (quasi-attractors) [1-3] in which the center of gravity of the athletes moves. In addition, it seems more likely that there are several shuttle-type movement techniques, each of which has a right to exist.

Figure 2 shows the dependence of the rotor on the Y coordinates for two athletes.



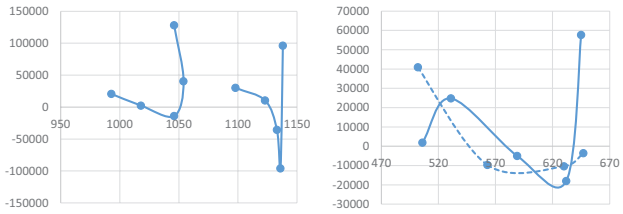
a) b)

Figure 2. Dependence of the twist of the force field on the Y coordinate during forward movements. a) athlete 1, b) athlete 2

Solid line – first movement, dotted line – second movement

In figure 2, one can observe the absence of twisting at the top point of the movement or its smallest value.

Figure 3 shows the values of *rot* × $\vec{F}$, depending on the x coordinate for backward movements of the center of gravity.

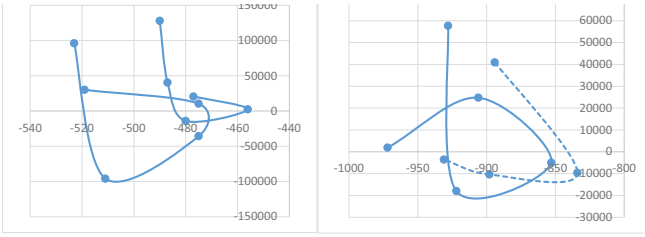


a) b)

Figure 3. The rotor of the force field in which the center of gravity of the athletes moves when moving backwards. a) athlete 1, b) athlete 2

Solid line – first movement, dotted line – second

It is evident from figure 3 that the general nature of the change in the rotor trajectory during the backward movement is preserved for both athletes. We can confidently speak of a minimum of twisting in each trajectory. Figure 4 shows the change in the rotor depending on the coordinate along the ordinate axis during the backward movement.



a) b)

Figure 4. The rotor of the force field in which the center of gravity of the athletes moves when moving backwards depending on the Y coordinate.

a) athlete 1, b) athlete 2

Solid line – first movement, dotted line – second, dash-dotted line – third

We can talk about the minimal twisting of the force field at the upper points of the trajectories for both athletes.

Conclusions. The rotor of the force field, in which the athlete's center of gravity moves during the shuttle movement, is not stationary in time. For different athletes, the change in the rotor from the coordinate can be either the same or the opposite. Therefore, we can talk about a variety of values of biomechanical parameters and characteristics corresponding to the correct technique, and we can also talk about several options for the correct technique for performing movement. A technical error will be understood as an action that makes it impossible to perform a subsequent motor task or that entails an unjustified expenditure of energy.

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