Biomechanical analysis of the trajectory of movement of the center of gravity of an athlete in martial arts

UDC

Dr. Hab., Professor **A.G. Levitsky**[1]
PhD **D.A. Matveev**[2]
PhD, Associate Professor **A.A. Potsipun**[2]
PhD **A.N. Krutoy**[3]
[1]Lesgaft National State University of Physical Education, Sport and Health, St. Petersburg
[2]Saint Petersburg State University, St. Petersburg
[3]The Russian State University of Justice, St. Petersburg

Corresponding author: dmitrijmatveev@yandex.ru

Received by the editorial office on 15.09.2023

Abstract

Objective of the study was to study the essence of the process of oscillations of the athlete's center of gravity when moving using the "shuttle" method and to test the methodology for analyzing the movement of the center of gravity.

Methods and structure of the study. The essence of the analysis of oscillatory movements of the center of gravity is to construct the trajectory of the athlete's movement, as well as graphs of changes in speeds and accelerations of the center of gravity depending on the coordinate. In this case, the graphs are plotted one below the other on the same scale of the coordinate axis. This allows you to visually compare the features of the trajectory of the center of gravity with changes in speed and acceleration.

Results and conclusions. Fluctuations in the center of gravity of an athlete during movement using the "shuttle" method represent a movement of the center of gravity from one area of space to another in the forward and backward directions. In this case, the movement trajectories differ from each other. It is advisable to describe such oscillations not by individual parameter values, but by areas of parameter values characteristic of a specific state of the system.

The data processing technique used allows us to obtain more complete and visual information about the movement of the athlete's center of gravity during movement.

Keywords: *biomechanics of martial arts, sports-combat sambo, jiu-jitsu.*

Introduction. The issue of the oscillatory movements of an athlete in martial arts has been practically not considered in biomechanics, despite the fact that it is of great importance in this type of motor activity. The oscillatory movement of the athlete's center of gravity occurs when moving using the "shuttle" method or when the athlete is unbalanced before throwing [3, 4].

Objective of the study was to study the essence of the process of oscillations of the athlete's center of gravity when moving using the "shuttle" method and to test the methodology for analyzing the movement of the center of gravity.

Methods and structure of the study. To conduct the study, a video was taken in which an athlete qualified as a master of sports of Russia in jiu-jitsu performs movement using the "shuttle" method. The video recording was divided into 40 cyclograms with a time interval of 0.08 s. Three separate forward and three backward movements of the center of gravity were considered. Each movement was considered on a separate chart. The trajectory of movement was divided into a number of parts equal to the number of cyclograms.

The essence of the analysis technique used is to construct the trajectory of the athlete's center of gravity, as well as graphs of changes in speeds and accelerations depending on the coordinate. In this case, the graphs are plotted one below the other on the same scale of the coordinate axis. This allows you to visually compare the features of the trajectory of the center of gravity with changes in speed and acceleration. Previously, such a technique for analyzing oscillatory movements was already recommended for describing nonlinear oscillator oscillations [2].

Research results and discussion. Figure 1 shows the trajectories of the athlete's center of gravity during three forward and backward movements while moving using the "shuttle" method.

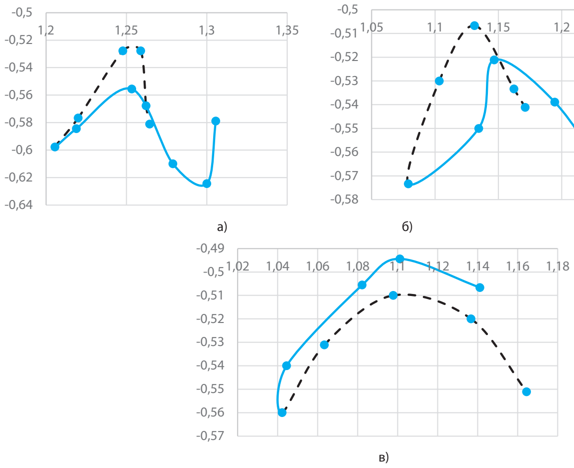

Figure 1. *Trajectories of centers of gravity during oscillations in Cartesian coordinates (blue line – forward movement, red dotted line – backward movement)*

In mechanics, harmonic vibrations mean vibrations that occur according to a harmonic law:

$x = A \sin(\omega t + \varphi)$ (1)

where is a dynamic variable, is the frequency of oscillations, is the phase of oscillations.

Also, harmonic vibrations can be described by the equation

: $\ddot{x} + \omega^2 x = 0,$ (2)

where second derivative of the coordinate with respect to time.

Nonlinear oscillations are understood as oscillations that are described by other equations. For example, in formula 2, you can take into account quadratic or cubic nonlinearity during oscillations by introducing additional terms.

Figure 1 shows that the athlete's center of gravity moves forward and backward, but does not return to its original position. The trajectories of movement also differ in their shape. Common to all trajectories is the presence of a maximum occurring approximately in the middle of the movement. In order to characterize any parameter that describes oscillations of the center of gravity (the amplitude of oscillations, the initial or final position of the center of gravity), one can use the ranges of values within which this parameter changes. Previously, the concepts of attractor and quasi-attractor were proposed in the scientific literature [1, 5]. In the most general case, this is a range of values of a quantity that correlates with a specific state of the system.

Thus, by fluctuations in the center of gravity of an athlete in the case of movement using the shuttle method, we will understand the repeated movement of the center of gravity from one finite region of space to another, while the trajectories of movement will also be located within a certain region of space, that is, as a rule, they will not be repeated.

The table shows the lengths of the trajectories of movements of the center of gravity forward and backward and their duration.

Length and duration of each forward movement

Movement number		Length (c.u.)	Time (s)
I movement	Forward	0,20	0,40
	Back	0,15	0,36
II movement	Forward	0,23	0,40
	Back	0,14	0,36
III movement	Forward	0,19	0,36
	Back	0,16	0,48

The table data shows that the duration and length of each forward and backward movement are not always the same. Therefore, it can be proposed to also use ranges of values, rather than specific numerical values, to describe the amplitude of movements and duration.

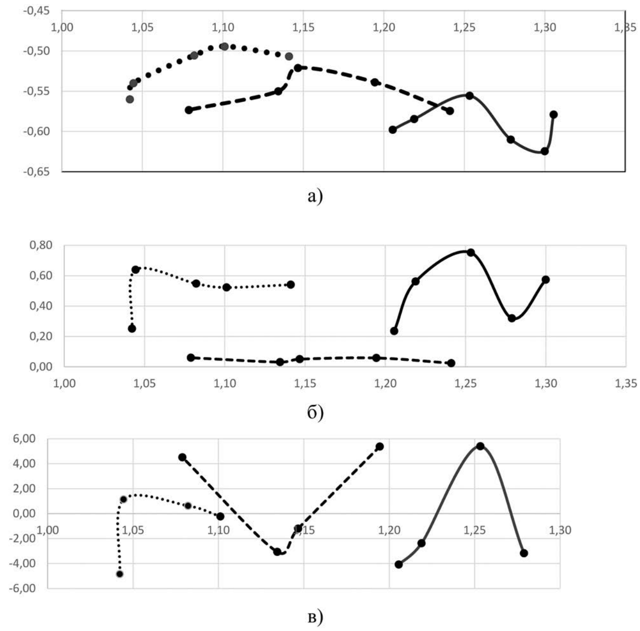

Figure 2. *a) trajectories of the center of gravity during movement b) speed of the center of gravity depending on the coordinate c) acceleration of the center of gravity depending on the coordinate (solid line - first forward movement, broken line - second forward movement, dotted line - third forward movement)*

Figure 2 shows the trajectories of the athlete's center of gravity in the process of moving forward (Fig. 1 a), changes in speed and acceleration of the athlete's center of gravity depending on the coordinate (Fig. 1 b and 1 c).

In Figure 2 you can see that the maximum speeds and accelerations do not always correspond to the highest point of the trajectory of the center of gravity. However, the maximums and minimums of velocities and accelerations, as a rule, occur at the same coordinate.

Figure 3 shows the trajectories of the center of gravity during the backward movement.

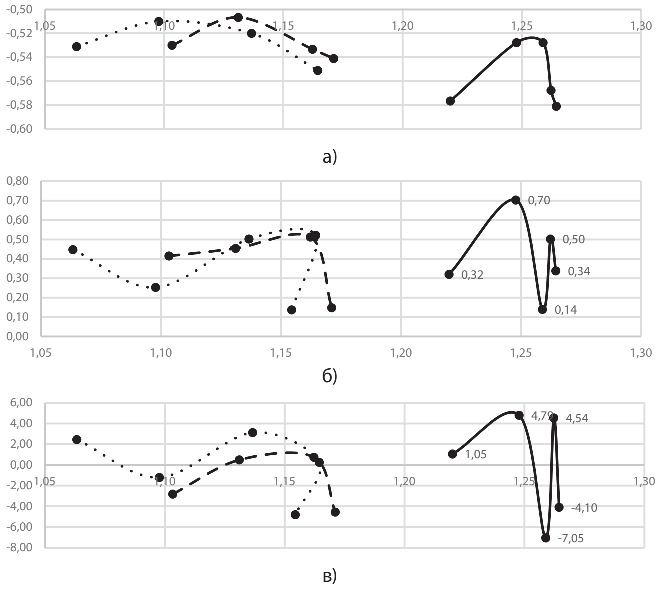

Figure 3. *a) trajectories of the center of gravity in the process of moving backwards b) speed of the center of gravity depending on the coordinate c) acceleration of the center of gravity depending on the coordinate (solid line - first forward movement, broken line - second forward movement, dotted line - third forward movement)*

It is also clear that the highest point of the trajectory does not always correspond to the maximum speed or acceleration. The maximums and minimums of speeds and accelerations, as a rule, also coincide.

Conclusions. Fluctuations in the center of gravity of an athlete during movement using the shuttle method represent a movement of the center of gravity from one area of space to another in the forward and backward directions. In this case, the movement trajectories differ from each other. It is advisable to describe such oscillations not by individual parameter values, but by areas of parameter values characteristic of a specific state of the system.

In one figure, observing the scale, it is advisable to plot the trajectory of the center of gravity, as well as the dependence of the speed and acceleration of the center of gravity on the coordinate. This allows you to study the features of the movement of the center of gravity. To describe oscillations of the center of gravity, you can also use the ranges of speeds and accelerations.

The data processing technique used allows us to obtain more complete and visual information about the movement of the athlete's center of gravity in the process of motor activity.

References

1. Eskov V.M., Zinchenko Yu.P., Zhuravleva O.A., Filatova O.E. Tri globalnyye paradigmy yestestvoznaniya i obosnovaniye tretyey paradigmy v psikhologii i meditsine. Vestnik novykh meditsinskikh tekhnologiy. Elektronnoye izdaniye. 2017. No. 1. pp. 45-54.
2. Kuznetsov A.P., Ryskin N.M. Lektsii po teorii kolebaniy i voln. Nelineynyye kolebaniya. Saratov, 2011. p. 76.
3. Levitsky A.G., Matveev D.A., Kovalev M.A., Yashkin V.A. Osobennosti peredvizheniya sposobom «chelnok» v sochetanii s udarom uraken. Uchenyye zapiski universiteta im. P.F. Lesgafta. 2021. No. 12 (202). pp. 203-207.
4. Levitsky A.G., Matveev D.A., Potsipun A.A., Oshina O.V. Biomekhanicheskiye osobennosti peredvizheniya v yedinoborstvakh sposobom «chelnok». Teoriya i praktika fizicheskoy kultury. 2022. No. 2. pp. 94-96.
5. Mukhamedov A.M. Attraktor Lorentsa v sdvigovykh techeniyakh. Izvestiya vysshikh uchebnykh zavedeniy. Prikladnaya nelineynaya dinamika. 2007. Vol. 15. No. 1. pp. 61-70.