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Performance evaluation of the «Uchi-Mate» throw taking into account the inertial characteristics of the movement

К.К. BONDARENKO

The article deals with the issues of biomechanical parameters in the phases of movement when performing the «Uchi-Mate» throw in judo. During the research the influence of inertial characteristics on the efficiency of throwing technique performance was revealed. The moment of inertia of the movement of COM of the attacking athlete's body (Tori) has been determined, taking into account the variability of the technique of performing the throw with a catch. The character of angular displacements of the longitudinal axis of the athlete's body depending on the speed of movement of its links is revealed.

Keywords: judo, moment of inertia, Uchi-Mate, throw phases, common centre of mass, throw structure.

В статье рассматриваются вопросы биомеханических параметров в фазах движения при выполнении броска «Uchi-Mate» в дзюдо. При проведении исследования было выявлено влияние инерционных характеристик на эффективность выполнения бросковой техники. Определён момент инерции движения ОЦМ тела атакующего спортсмена (Тори), с учётом вариативности техники выполнения броска подхватом. Выявлен характер угловых перемещений продольной оси тела спортсмена в зависимости от скорости перемещения его звеньев.

Ключевые слова: дзюдо, момент инерции, Uchi-Mate, фазы броска, общий центр масс, структура броска.

Introduction. The effectiveness of the throwing technique in judo is based on the use of two key biomechanical actions – leverage and moment of inertia [1]. The leverage action of a throw is determined by the rotation of Uke's body relative to the fulcrum created by Tori as an obstacle to Uke's movement. The rotation of Uke's body relative to the common centre of mass (COM) of his own body is determined by the moment of inertia created by Tori at the moment of the action being performed. These mechanisms of execution of throwing techniques also imply different mechanisms of energy supply of movement [2].

The «Uchi-Mate» throw is one of the most common judo techniques used in competitions [3]. In earlier studies of the performance of the «Uchi-Mate» throw, the criteria determining the change of Uke's stability angle during the performance of the «Uchi-Mate» throw with the angular parameters of Tori's torso inclination relative to the horizontal line were identified. In various nodal elements of the movement, the COM of Tori's and Uke's bodies and the COM of the two-body interaction system were determined, which made it possible to determine the instability angle as a function of the angle between the fulcrum and the COM of the body system as a function of its height [4]–[5].

The structure of formation of correctness of sports movement trajectories depends on a number of factors. First of all, it is necessary to take into account the nature of muscular efforts when performing pulling actions [6]. Along with this, the biomechanics of a motor action directly depends on the positions of the athlete's body parts at the moment of key phases and nodal elements [7]. This allows to avoid errors in the execution of the movement and reduce the possibility of injury [8]–[10]. In addition, it is necessary to differentiate the technical execution of the mastered movement element with the level of special training of the athlete [11]–[12].

The formation of rational trajectories of throwing technique largely depends on the COM position of athletes at each of the moments of movement time [13]. This is determined by the creation of dynamic forces and degrees of freedom in joint movements [14]–[15]. Improperly formed trajectories of movement of body links entail excessive stress in joint articulations and loss of force in bone levers [16]–[17]. This implies qualitative biomechanical analysis to determine the key points of movement technique and timely detection of errors with their subsequent correction [18].

The aim of the study was to determine the effectiveness of using the moment of inertia of the body when performing the «Uchi-Mate» technical action.

Research results and discussion. The study was conducted in the research laboratory of physical culture and sport of Francisk Skorina Gomel State University. The study involved qualified athletes engaged in judo, aged 18–21 years old. Based on video recordings of the execution of the «Uchi-Mate» throw, the biomechanical parameters of the movement were determined [19]–[20]. A total of 97 throws performed with maximum intensity were analysed. Video recording was performed at a speed of 120 fps. Seven phases of movement were identified in the structure of the «Uchi-Mate» throw, depending on the biomechanical tasks to be solved. The first phase of movement was determined by grabbing the opponent's judogi with a step-up. The second phase of the throw was determined by the moment of Tori's torso twisting. The third phase of the movement was performed by stepping up with the second foot to the nearest position to Uke. Then the torso of Tori was tilted with turning from Uke and transferring COM to the leg nearest to Uke, which characterised the fourth phase of the throw. In the fifth phase, a catch under one leg from the inside was performed. The sixth phase was characterised by putting Uke off balance. In the last, seventh phase, a maximum upward swing of the kicking leg was performed with a 90° or 180° rotation of the torso. The moment of inertia of the movement relative to COM Tori was calculated based on the execution of the phase of the throw.

The analysis of the «Uchi-Mate» throw made it possible to create a chronophotogram taking into account the sameness of the movements, taking into account dynamic and kinematic characteristics and indicating the main components of the movement, namely: Kuzushi (actions to put the opponent off-balance), Tsukuri (attacking the opponent – entering the throw) and Kake (moving the opponent into a parterre position) (figure 1).

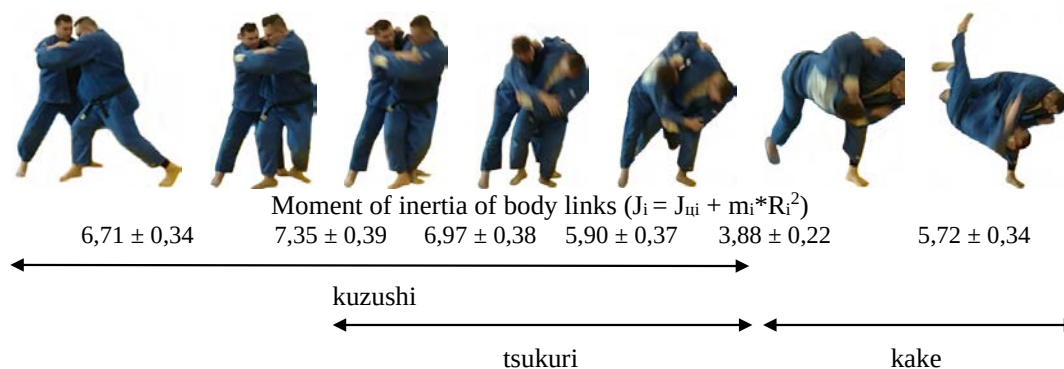


Figure 1 – Chronophotogram of the execution of the «Uchi-Mate» throw

The parameters of Tori's moment of inertia show the character of change of the body position relative to COM.

The throw is performed in the vertical rotation mode. The action takes place in the transverse plane, the axis of which is in the sagittal plane. This allows Tori to perform the throw when the forces in these projections are added together. The projection action is based on a pair of projection COM whole body and COM leg projections.

This action is not optimal, but its purpose is to direct Uke's COM along a circular path. This is facilitated by the movement of the COM pair in a circular trajectory and the use of leverage to effectively create force through the shoulders.

In certain phases of movement, leverage technique must be emphasised in order to increase the effectiveness of the throwing technique when the two COMs interact. This determines the transition from rotational to translational motion. In this case, the biomechanics of the throw can change from trajectory to leverage by delaying the application of one of the forces. In this case, the simultaneous application of two forces creates a moment of inertia with increasing force momentum. This allows to move COM along the rotational trajectory and due to the moment of inertia create the efficiency of throwing technique.

A large percentage of athletes perform the «Uchi-Mate» throw using reverse rotation at the hip joint. This action is based on the moment of inertia created by the COM torso – COM leg axis performed with reverse rotation in the sagittal plane. This action allows for less twisting of the spine during the reverse movement, but requires more force.

Performing a 180° turn while moving the opponent into a parterre position creates an external rotation trajectory. Unlike throws with a snatch, the catch in the execution of «Uchi-Mate» is performed after a straight trajectory of the approach.

The technique of «Uchi-Mate» throw based on the moment of inertia of Tori's body is performed by taking into account the independence of simultaneous actions. The biomechanical analysis can be simplified to the sum of movements in the sagittal plane and a simplified analysis in space. Given that the initial movement is created by the moment of inertia of Tori's body, it is independent of gravity. Subsequent actions represent the sum of motions based on the interaction of gravity and the additional moment of inertia of the body rotation.

When considering the phase of grabbing the opponent's judogi and stepping towards him, it should be noted that the moment of inertia action is less important than the initial lever action. However, the main objective of this phase is to maximise the contact between Tori's body and Uke's body so that one of the two forces of the COM body – COM leg pair can be effectively applied. Grabbing the sleeve of the judogi with one hand and the collar of the judogi from above with the other hand makes it easier to lift Uke and more effective to apply the moment of inertia in the frontal plane.

In different phases of the throw, the nature of its execution is influenced by the timing of a particular action. Parameters of the speed of movement of Tori links in comparison with the character of angular movements of the longitudinal axis of the athlete's body, make it possible to assess the effectiveness of the action (figure 2).

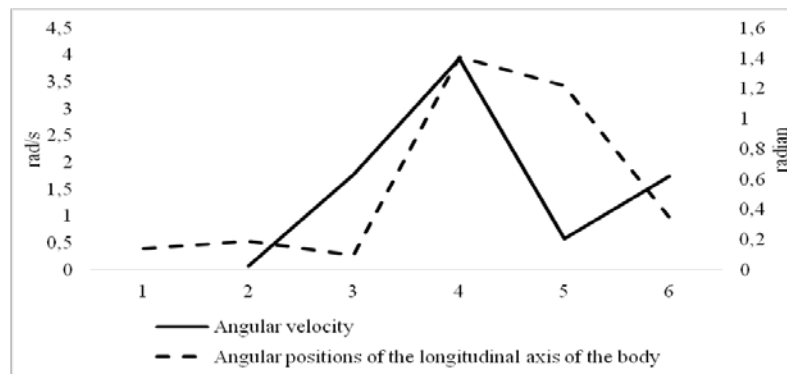


Figure 2 – Dynamics of angular positions and angular velocities of the longitudinal axis of the body in the movement phases of the «Uchi-Mate» throw

Formation of the most effective trajectories of movement of body links during the execution of the «Uchi-Mate» throw is based on the nature of rotational movements of the body with the creation of conditions for removing the opponent's body from equilibrium and the use of the moment of inertia of the body to increase its efficiency. Execution of the «Uchi-Mate» throw using the moment of inertia increases the efficiency of rotational variants and promotes changes in their mechanics of movement.

Conclusion. Biomechanical analysis of the occurrence of moments of inertia of the athlete's body and legs when performing the «Uchi-Mate» throw indicates that less energy is involved than in the occurrence of the lever action. In addition, this technique is more biomechanically simple and is based on the absence of distance and the application of torque.

The effectiveness of the «Uchi-Mate» throw lies in the use of the moment of inertia mechanism to create a condition of rotation of Uke's body around the COM of the two bodies. One option to improve the effectiveness of the throw is to create an integral mechanism for the interaction of the moment of inertia mechanism and the leverage mechanism in motion without applying them simultaneously.

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