DEFINITION OF BIOMECHANICAL PARAMETERS OF TECHNICAL ACTIONS IN THE MARTIAL ARTS

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Annotation. Questions of efficiency of training process and competitive activities are considered. The possibilities of accounting in preparing the athletes of the laws of biomechanics and anthropometric characteristics of individual athletes. The experiment involved 16 qualified athletes (age 19-25 years) engaged in hand to hand combat. Revealed that body movement back and forth (back slope protection and application of direct counterattacking punch) should be regarded as rotational propulsion. It is shown that the length and mass of the parts of the body affect the moment of inertia. Emphasized that in order to determine the level of technical and tactical skills of athletes should conduct research in the field. The effect of the height-weight indices, the length and mass of parts of the body at the moment of inertia. Established their influence on the speed of the predominantly translational and rotational movements, the timing and energy performance of technical activities.
Keywords: biomechanical, translational, rotational, motion, unit body.

Introduction

Practical tasks of sport activity shall be solved by determination of body and its segments „ size, as well as their masses and masses‟ centers‟ positions [2,6,4]. With determination of sport movements‟ bio-mechanical characteristics it is necessary to consider that sportsman‟s body is influenced both by inner forces, manifested by muscles and by external forces (gravity and response of support) [2,3,7].

Bio-mechanical structure and energetic "value" of movement depend on both: individual anthropometric (height, mass, proportions of body) and individual, psycho-physiological factors [1,3,7,12]. Optimization of training attacks and defenses process implies determination of individually optimal posture for fulfillment of certain technique [2,3,7,13]. In the process of techniques execution‟s perfection it is necessary to determine optimal (resonance) frequency of movements and use the force of muscles‟ elastic deformation (recuperated energy) – transformation of potential energy into kinetic and vice a versa [4,7,9].

A priori, it is very important for coaches, in their work, to use results of actual researches, because their efforts are oriented on increase of efficiency of sportsmen‟s performances at competitions. The researches shall be conducted on the base of analysis of bio-mechanical systems "sportsman- objective environment" (S.S. Yermakov, 1991–1996), including basing on ergonomics [1], in conditions of usual sort practice, but not in artificially created situations and "farfetched stances" [8,11]. A.A. Kadochnikov regards hand-to-hand fight as "man-to man" interaction, i.e. interaction of two mechanisms, having 258 degrees of freedom each, which permit them to carry out different movements in space, movements, which have logical ground from the point of view of mechanics, and any situation has a lot of correct solutions (S.S. Yermakov, 2004), [http://asrusstyle.hut.ru/info3_1.html].

Physical exercise or technique must have clear purpose, complied with motion abilities and demands of a certain sportsman, complied with the stage of training process and prospects of their realization in competitions [10; lib.sportedu.ru›books/xxpi/2001n2/p3-8.htm].

The longer arm of force (distance from the axis of rotation to the place of its action) is the larger is torque moment, which is equal to product of force by its arm. With circular movement the points of body segments moves by circular trajectories, the centers of which are on the axis of rotation; the larger is arm of force (radius of rotation), the bigger is the moment if inertia. It means that *the farer sportsman leads arm or leg* aside for execution of blow (kick), the higher is the moment of his arm‟s (leg‟s) inertia, though their masse remain the same [2,4,7].

Thus, the problem of training process efficiency‟s and competition activity‟s improvement on the base of reasonable application of the laws of mechanics is rather urgent and requires special attention [2,4,5,10].

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Purpose, tasks of the work, material and methods.

The purpose of the research is to find out bio-mechanical characteristics of mainly (note of author) forward and rotational movements (attacking and counter attacking blows and kicks in martial arts) and to ground the extent of anthropometric characteristics‟ influence on the moment of inertia, speed and time indicators.

The methods of the research: analysis and generalization of scientific-methodic literature and Internet sources, pedagogical observations, anthropometric measurements, timing, methods of mathematical statistics.

Results of the research

Most of movements in bio-mechanics are compound and consist of forward and rotational components. Concerning martial arts a question appear very often: why heavy weight wrestlers have worse speed of motion and fulfillment of techniques, why they are more inert even when fulfilling mainly forward movements (to and fro)?

As a result of experiment on determination of height-weight indicators‟ influence on the moment of inertia with fulfilling of mainly forward movements, it was revealed that shifting of body weight "to and fro" with defense by

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bending back followed by counter attack (response blow-kick) can be regarded as rotational movements around five frontal axes of rotation: one – hip joints (in waist) and two (of less significance) – knee and ankle joint of front and back positioned legs. At the same time rotational movement around vertical axis occurs (see fig. 1).

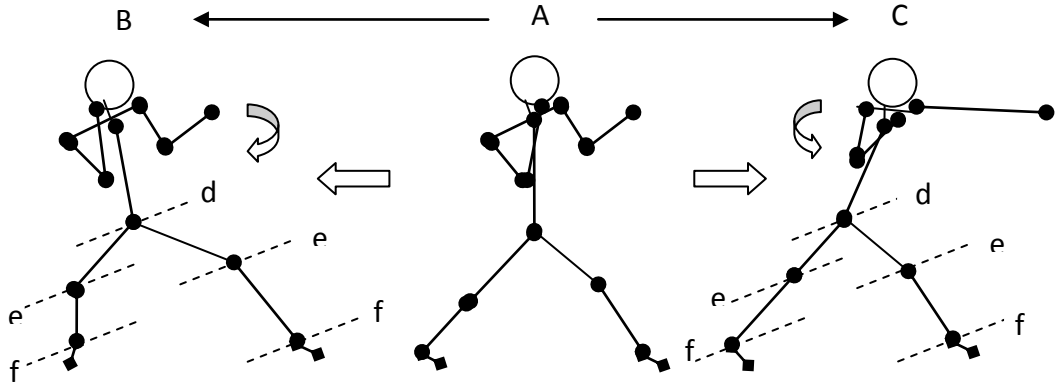

Fig. 1. Diagram of motion (shifting of weight) of body with swaying away and counter attak of straight punch standing in spot

A – initial position (battle stand);
B – position of body with *swaying away;*
C – position of body with *counter attak;*
d – frontal axis of rotation, passing through waist and hip joint;
e – frontal axis of rotation, passing through knee joint (left, right);
f – frontal axis of rotation, passing through ankle joint (left, right).

In fig.1 three positions of sportsman are given: A – battle stand (expectation of attack, punch); B – defense by shifting body weight (swaying away to fight leg with turning body to the right; C- forward punch, with shifting body weight forward and turning body to the left.

Swaying away with simultaneous turning of body to the right and shifting body weight to the leg in rear position, sportsman increases efficiency of defense and, what is rather important, efficiency of counter-attacking action, by using of elastic deformation of muscles of bent in knee joint leg, body as well as response force of rest.

Individual masses of experimental group (n=16) sportsmen‟s body segments were determined by the well known table of determination of body segment mass by its relative mass in percentage to the whole body mass. Sportsmen fulfilled defense from punch to head by swaying away and counter attack – response punch tp head. It was found that results are confidently different in three weight categories (up to 60, 70 and 75 kg) in comparison with three categories (up to 80, 85 kg and more) ($t = 3,7$; $P < 0,01$). Here differences by time indicators and their dependence on weight category, length of body and its segments) is obvious.

Evaluation of sportsman‟s body moment of inertia (by weight categories) with fulfilling of movements to and fro was determined by formula: $I = ⅓ m\ell^2$ and the following results were obtained: I (64kg) = 8,47 kg m^2 ; 67kg – 9,28 kg m^2; 73кг – 10,11 kg m^2 ; 78 kg – 11,45 kg m^2 ; 85 kg – 13,00 kg m^2 ; 91 kg – 13,92 kg m^2 .

Results of experiment prove that there is clear correlation between height, length of limbs, amplitude of punches and moment of inertia. Difference between results in weight 64 kg и 91 kg are 5,45 kg m^2. That means, that anthropometric data of sportsmen (their height-weight indicators) influence on moment of inertia, which, in its turn, influence on quickness of mainly forward movement.

The purpose of next experiment was determination of bio-mechanical characteristics of round kick, considering individual anthropometric data of sportsmen and evaluation of leg‟s moment of inertia. So, with fulfillment of round kick participants of experiments (n=16)for fulfillment of kick raised knee (thigh) and turned on rest foot at different angles. “Carry over” of thigh varied from 90 to 5 - 0 ^{o}, while turn of rest foot – from 45 to 180^o .

Analysis of sportsmen‟s round kicks techniques was resulted in construction of model of their most optimal trajectory. So, it was found out that optimal angle between position of thigh, when knee is in upper “dead point” for strong kick by given trajectory (body, middle level) is 45 ± 10^o (see fig 2).

During lifting right leg and directly executing of kick, weight of body is shifted to left, rest foot and it, together with body, becomes the axe, while the foot of rest leg becomes a point of rotation. At sector 1 – 7 (fig. 2), with leading thigh forward to target, its forward movement occurs, which practically does not influence on moment of inertia and, when knee reaches “upper dead point” ends progressive and starts, mainly rotation movement.

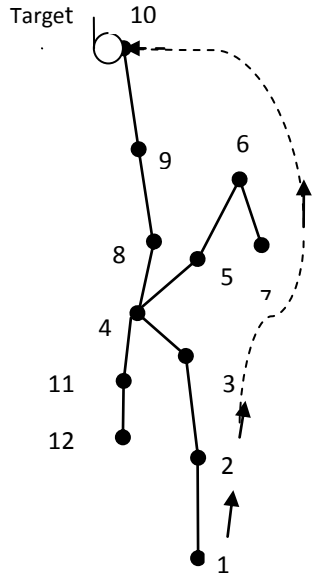

Fig. 2. Approximate diagram of round kick fulfillment (top-rear view).

1–10 – trajectory of movement of foot, leg, executing kick;
1 – right foot (rear leg);
2 – right knee;
3 – right hip joint;
4 – left hip joint;
4–5 – hip (body) position at 45° the direction of target , at the moment of bent leg lifting;
5 – right hip joint at the moment of leg (thigh) lifting;
5 – 6 – right leg thigh;
6 – right knee position in "upper dead point" for executing kick at given level;
6 – 7 – position of shin and foot;
7 – position of foot at the moment of leg (knee) lifting;
4 – 8 – approximate position of hip at the moment of atraightening of leg (kicking);
8–9 – thigh of kicking leg;
9–10 – shin and foot of kicking leg;
4–12– left rest leg (4–11thigh; 11–12shin and foot);
12 – foot of left rest leg (point of rotation during kicking).

With fulfilling of round kick it is necessary to consider leg"s movement as rotational movement of a rod. The moment of inertia of thigh was evaluated with the help of data of body segments" length and masses for every weight category by formula: $İ = {}^1/_3\ m\ell^2$.

At sector of movement $30^o \le \varphi \le 45^o$ $İ_1 = {}^1/_3\ m_б \ell_б^2$ (where $m_б$ – mass of thigh, $\ell_б$ – thigh length) because we can assume that at this time, movement of shin and foot, located parallel to the axis of rotation, do not influence substantially on the moment of thigh inertia. At the next sector $0^o \le \varphi \le 30^o$ thigh, shin and foot participate in rotation movement. That is why moment of inertia of leg was determined by formula: $İ = {}^1/_3\ (m_{б.} + m_{г.} + m_{ст.})\ (\ell_{б.} + \ell_{г.} + \ell_{ст})^2 = {}^1/_3\ m_{ноги} \cdot \ell^2_{ноги,}$

where: $m_{б.}$ – mass of thigh; $m_{г.}$ –mass of shin; $m_{ст}$ – mass of foot: $\ell_{б.}$ – length of thigh; $\ell_{г.}$ –length of shin; $\ell_{ст}$ – length of foot.

Analysis of the obtained results show that moment of inertia of leg in round kick is confidently different, depending on the length and masses of its segments: İ (64 kg) = 3,25 kg m^2; 67 kg – 3,61 kg m^2; 73 kg = 4,07 kg m^2; İ (78kg) = 4,45 kg m^2; 85 kg – 5,28 kg m^2; 91 kg – 5,30 kg m^2.

Minimal indicator was obtained with weigh 64 kg, where the length and mass of thigh are the least and maximal - with weight 85 kg, where thigh is the longest. When all leg participates in movement, the least indicator also concerned weight 64 kg – 3,25 kg m^2 and the highest was obtained with weigh 91kg – 5,30 kg m^2. It means that lendth and mass of leg obviously influence on moment of inertia in round kick.

For increasing of kick efficiency it is necessary to use energy, transmitting from one body segment to another. For example, whipping movement of foot and shin is conducted owing to energy, accumulated with thigh swing, body rotation and using of rest response force, when turning on rest foot.

Summary

Results of the researches and experiments shoe that efficiency of attacking, defensive and counter attacking actions depend on bio mechanical structure of applied techniques and individual anthropometric characteristics of sportsmen. Mainly progressive movement of body with swaying away defense and punch counter attack should be regarded as rotational movement around frontal axis, which influences on moment of inertia and on the time of movement fulfillment, depending on weight category of sportsmen, on mass of body, its length and the length of its segments.

Results of the researches witness that there is no "purely" forward movement in bio-mechanics. All movements are compound: rotational-forward.

With perfection of techniques execution special attention should be paid to optimal using of rest response forces, forces of muscles" elastic deformation (recuperated energy, acting by principle of spring"s compression-extension) and to successive involving of different body segments in oscillatory movement. П

Rotational movement around vertical, frontal and sagittal axes can be compared with action of compressed and twisted spring, which has high speed-power and energetic potential. With counter punch (counter attack) sportsmen shall consider this fact.

With fulfillment of practically any punch or kick it is very important to transform *soft kinematical chain*into integral hard lever. In this case not only the mass of end link of bio mechanical chain participates in punch but alsothe masses of other links, thus transferring to target , maximally possible quantity of kinetic energy.

Thus, revelation of the most optimal bio-mechanical characteristics of techniques, considering individual features of sportsmen, facilitate Improvement of their technical-tactic sportsmanship, increasing of training process"s efficiency and the efficiency of competition and practical activity.

The prospects of further researches are oriented on determination of bio-mechanical characteristics of front kick, side kick and defenses by leaning and turning aside.

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