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BIOMECHANICAL STRUCTURE OF THE SPORTS AND TECHNICAL MASTERY IN JUDO

DISSERTATION ABSTRACT

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PREFACE

Judo literature most often deals with oriental wisdom, sayings, and legends.

On this basis, technical skills in sport are still too often interpreted in terms of nebulous principles, which have been called "wisdom" for centuries.

Modern sports science, on the other hand, has new information technologies and powerful technical tools for evaluating and analysing motor performance. This outlines the need to juxtapose the two approaches – the traditional of "wisdom of the ages" and the scientific analysis and synthesis of human motor actions. The problem is of utmost importance as the approach has a strong influence on the whole training process and in particular on the system for improving the technical mastery in practicing this sport.

This is not about denying any of the two approaches. It is an interesting idea to explore the possibilities for transferring the positive experience of traditional learning, in combination with modern scientific methods and tools for education and training activities.

For example, one of the most specific traditional features of this sport is the existence of a rigorous, worldwide Kyu-dan training system. It encourages the development of a rich motion culture, setting a good example for other sports disciplines. The Kyu-dan system should also be seen as a unique system for refining the basic elements of the ability to control the motor apparatus, such as - a sense of location of both the own and generalized Common Center of Gravity, the degree of balance stability, potential opportunities for developing the power structure depending on spatial characteristics, managing the "necessary future", the ability to control and manage the rhythmic structure etc.

WORKING HYPOTHESIS, AIM, TASKS, METHODS AND ORGANIZATION OF THE RESEARCH

The vast wealth and variety of throwing techniques make it a necessary precondition to reduce the object of study.

These should be techniques of the highest popularity and effectiveness. In addition, their analysis should allow for transfer to other Judo techniques, i.e. techniques must have a fundamental biomechanical structure for the widest possible cluster representation. Preliminary theoretical analysis has unequivocally established that these prerequisites are fully covered by the two most popular techniques - Seoi Nage (shoulder throw) and Uchi Mata (inner-thigh throw).

A characteristic feature of Judo's sporting activities is the uncontrollable variation of internal and external force fields.

The literature review and analysis of statistics from our and international tournaments revealed two main problems:

1. The contradiction between the classic models, unified in the regularities of the Kyu-dan system, on the one hand, and the wealth of individual differences in competitive conditions, on the other.

2. The presence of ambiguous and multidimensional relationships between kinematic and dynamic structures that make up the system of motor actions.

The first problem is related to the means and methods of initial training and the definition of the concepts of general and specific sports and technical training.

The second problem requires scientific justification and interpretation of the notion of biomechanical expediency of sports and technical actions.

The established multidimensional complexity of the cause-effect relationships and interdependencies between external and internal force fields, the huge (for the understanding of classical mechanics) number of degrees of freedom of movement, as well as the variable masses involved in the formation of force vectors, allow us to assume the existence of thinner structural interrelations between different biomechanical characteristics. In this connection, the following working hypothesis was formulated:

We suggest that revealing and exploring hidden structural interrelations and compensatory capabilities from a biomechanics point of view could improve the

performance of a racing technique refinement system while maximizing the individual characteristics of a particular competitor.

The object of this research is the concept of biomechanical expediency of sports technical mastery in high-level athletes.

The subject of the study is the quantitative evaluation and analysis of the multidimensional dynamic structure of the motor actions, depending on the Uke's reactions.

The aim of the study is to reveal the internal biomechanical structure of the system of movements of techniques in judo, based on complex biomechanical analysis, to optimize the training process and increase the level of sports and technical skills of elite judo racers.

On the way to the main goal, the following major tasks had also to be solved:

1. Development of a modern methodology for registration and analysis of dynamic characteristics in the conditions of an «active» experiment.
2. Conducting biodynamic experiments to obtain a quantitative estimate of the power vector of supporting reaction.
3. Development of a system for modeling the external force field.
4. Conducting functional-anatomical analysis for establishing the rhythmic structure in the intramuscular synergy.
5. Conducting theoretical functional-anatomical and biomechanical analysis to model the realisation efficiency.
6. Development of an appropriate mathematical formalism for the analysis of biomechanical characteristics.
7. Derivation of criteria for quantitative evaluation of sports and technical skills and assessment of individual characteristics.
8. Development of a methodology for improving the training process
9. Conducting appropriate pedagogical experiments to evaluate the effectiveness of the proposed new methods and tools for training.

METHODS AND RESEARCH ORGANIZATION

The organisation design and methodology has been developed with the aim to reveal the dynamic structure of motor actions depending on Uke's reactions (the judoka on whom the technique is applied). The structural relationships between kinematic and dynamic biomechanical characteristics were analysed. Parameters and implicit functions were sought which control the compensating mechanisms that provide the target function and control of the action system.

A deductive approach for complex analysis has been used - from statistics analysis to evaluate general patterns to laboratory planned experiments to evaluate individual features as well as pedagogical experiment to verify the education and training process.

The statistical analyses have been based on official Olympic, World and International tournaments with the participation of **more than** 400 competitors during the period from 01.01. 2012 to 30.09.2018.

The laboratory experiments were conducted during the period from 20.02.2014 to 21.06.2018.

The pedagogical experiment was carried out in an autonomous mode, the effect of the methodology being evaluated individually. The quantitative assessment of biomechanical expediency is derived from the relationship between stability and variability of the dynamic structure in the system.

In the course of the explorataion work several main groups of research methods and methods for analysis of results were used:

Research methods include:

- a. Study of the specialized scientific and methodological literature.
- b. Biomechanical theoretical analysis and modeling.
- c. Cluster analysis of sport and technical activities in the sport of judo.
- d. Statistical methods for evaluating the effectiveness and frequency of the techniques used in real competition conditions.
- e. Laboratory experiments for biomechanical (cinematographic and dynamographic) analysis of basic techniques in judo.
- f. Laboratory experiments modeling the Uke's reaction.
- g. Development of individualized models for improvement of sports technical skills.
- h. Pedagogical experiment.

The formulas developed by Volkov V. et al. (1981) were used in the calculation of technical and tactical readiness indices (activity, variability, efficiency, effectiveness, etc.).

In cinematic methods, data on the dynamic structure were obtained through solving the basic straight problem of biomechanics. In dynamographic methods, it is necessary to solve the basic reverse problem of mechanics.

The system APAS (Ariel Performance Analysis System) developed by Ariel Dynamics inc. was used in work process – namely, video-based 3D motion analysis system.

The following applications have been used for the needs of the biomechanical analysis:

- The parallel presentation module (APASView)
- The kinetic module (Kinetics), and
- The vector module (Vector) – designed specifically to explore support reactions.

The evaluation of the role of the compensatory mechanisms was carried out by means of an "active" experiment (fig.5).

The quantitative estimations are based on the 'singular' points (global and regional extremes and inflection points) of the functional curves of the force vector applied to “Uke”.

The computerized feedback to a stabilographic platform unlocks the mechanism of the dummy's response to the lead-out of balance force at a time interval determined by the global extremum of the horizontal component of the support reaction.

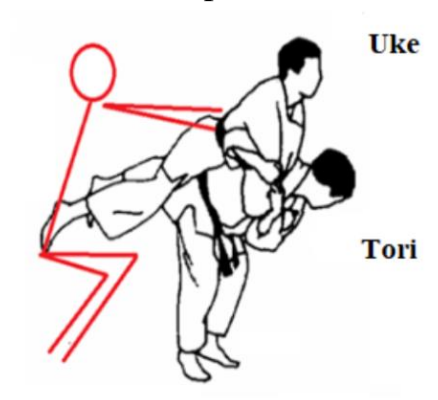


Fig.5 „Active“ *experiment*

The SPSS (Statistical Product and Service Solutions) program was used for statistical analysis.

For the purposes of the comparative biomechanical analysis, the methods of variational and correlation statistical analyses have been used.

RESULTS AND ANALYSIS

According to the methodology, the presentation of the results follows the logic of the overall study, which largely coincides with the phased temporal sequence of the theoretical and experimental work performed.

THEORETICAL ANALYSIS

THEORETICAL FOUNDATIONS OF SPORT AND TECHNICAL MASTERY

The basic principles defined by the classics of the sport of judo are usually too vague and often quite naive in their claim to be fundamental truths and regularities.

Moreover, contradictory claims can also be found regarding the role of the acceptor of action. In this field the approach of prof. R. Petrov is more accurate and scientifically substantiated (Петров, Р. 1978); this approach consists of technical and tactical complexes developed for wrestling. Unfortunately, there are no such complexes for the sport of JUDO. Even the most basic principle of prof. Jigoro Kano is deemed to be contradictory today - "Minimum efforts for maximum efficiency".

In modern-day Judo the Kudo principles that generally interpret the phase structure of technical performance are used in the training process:

1. Power formation;
2. Kuzushi (a lead-out of balance);
3. Tsukuri (preparation for the implementation of the technique);
4. Kake (completion of the throwing technique).

It is believed that the success of the attack depends largely on the first two phases – Tsukuri and Kudushi.

Here, the wavy “ikioi” (pre-impuls or acceleration in joint movement), rhythm, tight contact, etc. are usually emphasized. In the initial stages simulation performances, commonly known as kata, are usually used.

The success of any throwing technique depends to a great extent on overcoming Uke’s ability to react and counteract. This is achieved through the proper construction of the first phase – “kuzushi”. This phase plays the role of a basic “philosophy” for sporting technical mastery. The significance of this phase requires clarification of some of its basic characteristics such as the nature of the support surface, the angle of

resistance, the torques of forces, the general and specific centres of gravity, force impulses, etc.

Biomechanical foundations of sports and technical mastery

Analysing the basic principle of “tsukuri”, sports biomechanics distinguishes between two types of balance stability: static and dynamic. The role of dynamic equilibrium is essential, which is determined by the ability of the athlete to restore his temporarily lost balance.

CLASSIFICATION STRUCTURE OF MOTOR ACTIVITIES IN JUDO

The development of a **science-based** classification structure is considered to be a fundamental task of any science field. This task has led to the separation of strictly defined independent scientific disciplines (with their own principles and methodology), such as the modern sciences taxonomy, botriology, cluster analysis, etc. The link between the classification criteria and biomechanical expediency of the training process requires a detailed analysis of existing types of clustering.

The problems of classification and learning process (Go Kyo), have been addressed by Dr. Kano with a scientific methodology in accordance with the then conditions (Table 1).

This classification seems simple and understandable (it is still in use after more than 100 years), although throwing energy cannot be transmitted from only a single part of the body.

G. Koizumi (Koizumi, G., 1960), classifies the standard techniques according to Uke’s body movement:

Table 1 First Kodokan classification (1885)

<i>Te waza</i>	<i>Koshi waza</i>	<i>Ashi waza</i>	<i>Ma sutemi waza</i>	<i>Yoko sutemi waza</i>
Uki waza	Uki goshi	Okuri ashi harai	Tomoe nage	Yoko gake
Seoi nage	Harai goshi	Sasae tsurikomi ashi	Ura nage	Yoko guruma
Kata guruma	Tsuri komi goshi	Uchi mata	Sumi kaeshi	Yoko otoshi
Tai otoshi	Koshi guruma	Hiza guruma	Hikkikomi gaeshi	Daki wakare
Obi otoshi	O goshi	O soto gari	Tsuri otoshi	Yoko wakare
Seoi otoshi	Ushiro goshi	De ashi harai	Tawara gaeshi	Soto makikomi
Uki otoshi	Hane goshi	Ko uchi gari		Uchi makikomi
	Tsuri goshi	Ko soto gari		Tani otoshi
	Utsuri goshi	Harai tsurikomi ashi		
		O uchi gari		
		Yama arashi		
		O soto guruma		
		O soto otoshi		

- *Kuruma waza* – rotation techniques, for instance - Uki goshi;
- *Tenbin waza*- “scales” techniques, for instance Uchi-mata ,Osoto-gari etc.;
- *Tsumazukasc waza* - blocking techniques, for instance - *Hiza guruma*.

Geesink emphasises on the dynamic role of biodynamic chains (Geesink Anton J, 2000), while G. R. Gleeson combines throwing techniques into two groups – the first involves techniques which use torques around some degree of freedom and the second – techniques which use direct attacks at a support kinematic unit. (Gleeson G.R. 1984; Gleeson G.R. 1971).

Kolychkin (Kolychkin A. 1989) proposes an anatomical classification based on the proposal to distinguish between major and affinity movements.

There are approaches (Sacripanti A., 1990; Sterkowicz S., et al. 2013) on the basis of phase or spatial structures of the throwing techniques. This approach shows interesting similarities between techniques that have not been proven so far, for instance between O-soto gari and Uchi mata or between Sasae Tsurikomi ashi and Tai otoshi.

Obviously, each of these classifications has its own logic and right to exist, practically illustrating the multidimensional and rich content of the system and structural organization of the sports and technical actions in this sport.

Biomechanical classification

From the point of view of current scientific knowledge, it is of particular interest to develop a classification which is consistent with the basic biomechanical principles. This type of classification structure is directly related to the regularities in controlling the motor apparatus and the training process (Fig.8).

On this common basis criteria (strands) in the main structural areas should be defined.

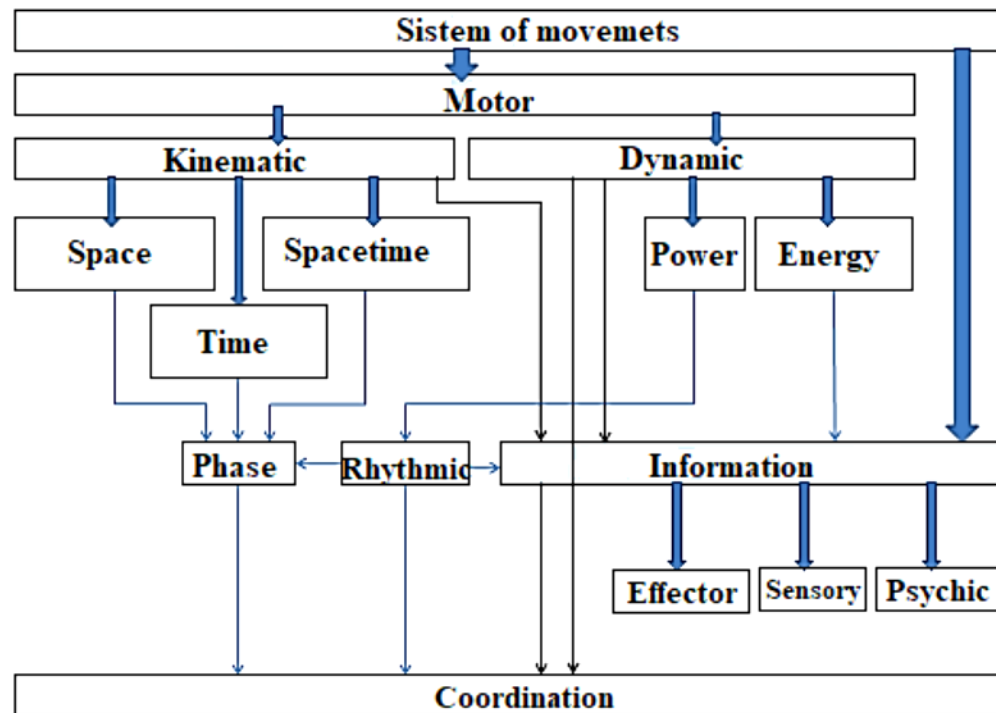


Fig . 8. *Biomechanical scheme for structured systems analysis*

Space structure – the type of trajectories and their symmetries and orientation, displacements (global and regional), kuzushi directions.

Time structure – the required accuracy of accentuating moments and time intervals, the relationship between the different phases and their rhythmic organization.

The coordination complexity has two parameters – quantitative and qualitative. In the first case, the criterion estimates the number of managed degrees of freedom, and in the second case – the complexity of intermuscular synergy. In addition, complexity can be achieved by managing the disturbing effects of the external environment.

In the field of force structure, actions with spherical and cylindrical symmetry of torques, those employing the effect of a pair of forces or multiple levers, etc., may be classified.

Fig. 8 shows clearly that motor actions represent a complex systematic organization with a multifaceted structural interdependence between the vast number of heterogeneous parameters, which are too often the subject of study in various scientific disciplines – physiology, biomechanics, psychology, anatomy, etc. The main problem of each researcher is to reach adequate description of the “wholeness” of the system against the goal set. This wholeness is conditioned by the strong biomechanical

and psychological connection between the basic techniques (postures, grips, mode of movement, ukemi, etc.) and special techniques (tachi waza, katame waza, etc.).

In all martial arts there is one basic problem that lies in the coordination between the goal of mastering techniques capable of completely defusing the adversary and the need to maintain the health of practitioners. In this sense, fall techniques are at the heart of the psychological mechanisms involved (often subconsciously) in structural construction of an attack.

According to the second law of dynamics the force of fall is determined by

$$F = m \frac{\Delta V}{\Delta t} \quad (16),$$

where m is the mass of a body, and ΔV и Δt are respectively the speed and amortization time.

The technique involves control of all three characteristics.

Creating a counter-force impulse is a second strategy in accordance with Newton's third principle of mechanics.

One of the most distinctive features of judo is the fact that it allows for a relatively constant grip. It also reflects all local, regional and global displacements of the individual kinematic units of a human body. Therefore private goals are not limited to the possible modes of capture, but they also relate to the development of an appropriate sense of control over the application points, the ability to "yield", i.e. releasing some kinematic units without significantly affecting their their own CCG in order the focus of the "attack" to "hang".

The throwing (nage waza) techniques which are the subject of this study are presented in Table 2.

Regardless of the classification structure, the kuzushi phase is fundamental for success. It can be implemented through the following strategic plans:

- Through direct impact by a grip application.
- Indirect lead-out of balance using the partner's natural response, i.e. using a lead in the direction of Uke's defensive reaction.
- By blocking the movement of the support.
- A strategy with maximum speed of execution (even without actual removal of equilibrium) to takes defense response time.

Table 2. Throwing techniques

<i>Nage waza</i> <i>Throwing techniques</i>	<i>Tachi waza</i> <i>Standing throwing techniques</i>	<i>Te waza</i> <i>Hand throwing techniques</i>
		<i>Koshi waza</i> <i>Hip throwing techniques</i>
		<i>Ashi waza</i> <i>Foot throwing techniques</i>
	<i>Sutemi waza</i> <i>Sacrifice throwing technique</i>	<i>Ma sutemi waza</i> <i>Back sacrifice throwing techniques</i>
		<i>Yokosutemi waza</i> <i>Side sacrifice throwing techniques</i>

Simple walking, for its part, is a series of distortions and rebalancing.

Through the movements of “tai sabaki” can be mastered one of the basic principles in Judo – using external force in the interest of one’s own attack. On the other hand, biomechanical analysis should also take into account the fact that each phase (**Kuzushi**, **Tsukuri** и **Kake**) has its own private purpose. With this it is also possible to trace the so-called chain errors that usually remain hidden to the outside observer.

In this sense, it can be considered that the effectiveness of judo techniques depends on the characteristics of the attack position (Kumi Kata grip, Shisei posture, Attack angle, Distance from uke); Shintai (Ayumi Ashi, Tsugi Ashi, Tai Sabaki); Kuzushi (lead-out of balance); Nage (throw).

The release of any degree of freedom of movement "excludes" the mass of the relevant kinematic unit and thus may be affected to reduce the effectiveness of the attack.

Following the private objectives of the individual phases, the basic principles involved in the decomposition of forces can be determined - in the case of tsukuri-kuzushi over the whole angle of 360 ° in the horizontal plane and 90 ° in kake in the vertical plane.

Figure 9 illustrates the case of spherical symmetry in a circular trajectory according to Sacripanti A. (1987).

Figure 10 shows the case of helical technique with cylindrical symmetry.

The analysis of biomechanical expediency proves that such performance is characterized by minimal work and least energy loss. The condition in this case is that the bending radius of the spiral is proportional to the distance r from the axis of rotation.

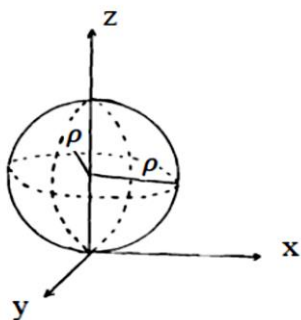


Fig.9 Spherical symmetry in a circular trajectory

$$I = 2m \int r dr$$

$$\rho = r$$

$$r^2 = x^2 + y^2 + z^2 \quad (17)$$

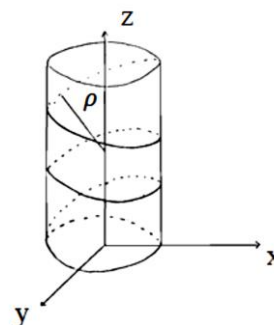


Fig.10. Helical technique with cylindrical symmetry

$$I = 2m \int r dr$$

$$\rho = (1 + k^i)r$$

$$x = r \cos \varphi$$

$$y = r \sin \varphi \quad (18)$$

From the trajectories described by the kinematic units of the uke, it is possible to distinguish some internal mechanisms that shape the dynamic structure of the techniques. Thus can be distinguished:

- Techniques where Tori (a judoka who performs the technique) uses a pair of throwing forces to Uke
- Techniques where Tori uses a physical lever to throw Uke.

However, the fact that uke's reactions are also actively involved in the overall system, so that in practice the picture is much more complicated should not be overlooked.

Figure 12 shows examples of the use of a pair of forces for the sagittal, frontal, and transverse planes, respectively.

From the sport-pedagogical point of view, the main role of *coxo-femoral articulation* becomes clear in this group as well as the need for special preparation of the articulation both in terms of its motor functions and the nervous and muscular mechanisms for its control.

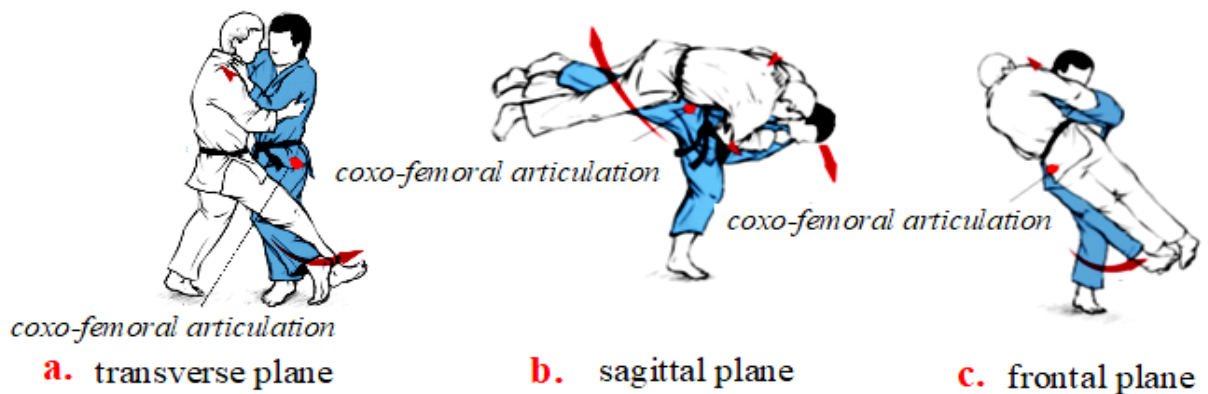


Fig.12 Pairs of forces for the sagittal, frontal, and transverse planes

The techniques from the **Physical lever Group** include all throwings that result from rotating the Uke's body around a pivot (pelvis, leg, foot, etc.). Substructures may vary depending on the length of the lever arm applied to the Uke's body.

This kind of classification makes sense only insofar as it points to a different approach in training methods and means for improving motor capacity. At the same time, the fact that forces are vector quantities and the torque arm is not uniquely determined by their point of application but largely depends on the direction of the force vector is not taken into account here.

In this case too, biomechanical classification reveals examples of similarities which are hidden to the Kyu dan system, such as between the techniques of *Ashi Guruma* and *Hiza Guruma*. И в този случай биомеханична класификация разкрива примери за подобие скрити за кю дан системата, като например между техниките *Аши Гурума* и *Хидза Гурума*.

One of the goals of the phase structuring of judo is to find the right training methodology. At the same time, the individual phases should not be analyzed as completely separate and independent structural units.

FUNCTIONAL AND ANATOMICAL ANALYSIS

Depending on a particular technique applied, a kinematic chain forms differently and by varying degrees of involvement of individual muscle groups. Moreover, the physical qualities known in sports science acquire the character of sports technical mastery and depend on the control of the motor apparatus and are externally defined as intramuscular synergy.

In this sense, it is appropriate to use terminology from robotics to distinguish between types of local, regional and global spatial displacements. Since the time interval for which the first most responsible phase of each throwing takes place in a few tenths of a second, it is obviously that the question is not about maximum speeds, but maximum acceleration.

Since the time interval, for which the first most responsible phase of each throw takes place within a few tenths of a second, it is obviously not about maximum speeds, but maximum acceleration.

This theoretical conclusion is namely the reason for drawing the working hypothesis that the explosive force in specific judo grips is a characteristic of intramuscular synergy, i.e. of SPORT AND TECHNICAL MASTERY. This requires implementing a functional and anatomical analysis, which evaluates kinematically the performance of the MAJOR MUSCLE GROUPS.

In case of leading-out of equilibrium - kuzushi - the movement in the left shoulder joint is unfolding and removal, and in the elbow there is folding and internal rotation. The movement is performed: for the shoulder joint by m. deltoideus - comb and shoulder part, m. trapezius - ascending and transverse part and m. triceps brachii; for the elbow joint: m. brachialis; m. biceps brachii; m. brachioradialis; m. pronator teres.

At the end of this movement the blades are fixed parallel to the spinal column by the rhombus muscles and the transverse part of the trapezius muscle. Movements for the upper jump joint are performed in a retreating mode by the following muscle groups: the back of the thigh – m. triceps surae (consisting of a pair of muscles - bicephalous m. gastrocnemius и m. soleus); m. fl. digitorum longus; m. fl. halucis longus; m. tibialis posterior; for the knee joint - m. quadriceps femori (a large muscle group that includes four predominant muscles in the front of the thigh: rectus femoris, vastus lateralis, vastus medialis и vastus intermedius; for the hip joint m. gluteus maximus; m. biceps femoris; m. semimembranosus; m. semitendinosus; m. adductor magnus; Fixators for the hip joints are: m. gluteus medius, m. gluteus minimus and the thigh medial group. The throwing is performed by rotation of the trunk to the left, folding in the upper jump joint, unfolding in the knee joint and unfolding - with internal rotation in the hip joint.

For the lower limb, the same muscle groups participate, but in overcoming mode of work. Folding with left rotation is performed by m. obl. externus abdominis; m. obl. internus abdominis; m. rectus abdominis and the left group own muscles in the

back. The movement is simultaneous with the right shoulder in which unfolding with bending and internal rotation is performed. The muscles involved with overcoming work mode are: m.latissimus dorsi; m.pectoralis major; m.seratus anterior; m.trapezius; m.deltoideus in the clavicle part.

For the purposes of the pedagogical experiment, it is necessary to evaluate separately the mode of work of each particular muscle group, as well as the change in directions, i.e. rhythm in the work of muscles agonists and antagonists.

MAJOR TRENDS IN THE DEVELOPMENT OF WORLD JUDO

Structural development of technical mastery is directly dependent on changes in the rules of sport. On the other hand, the global trends in the development of this sport make it possible to develop scientifically sound methodologies for the training process.

Starting in Tokyo with only 31 competitors in the 1956 World Championships, their number reaches 755 judokas out of 124 countries in 2018 in Baku, Azarbeidzhan.

The 2012 Olympic Games in London were attended by 387 judokas from 135 countries, which placed the sport of Judo in the third place in popularity in the world of sport. According to IJF data, over 40 million people worldwide practice judo today. (www.ijf.org).

The exceptionally rich sports calendar contributes to the exchange of experience and the continuous development of effectiveness in the confrontation between attack and defense. Therefore, the analysis of historical trends and regularities of success and frequency of use of specific sports techniques is of particular importance.

At the Baku World Championship the medals were distributed between 22 countries and between 26 countries during the Olympic Games in Rio de Janeiro. (Fig.18).

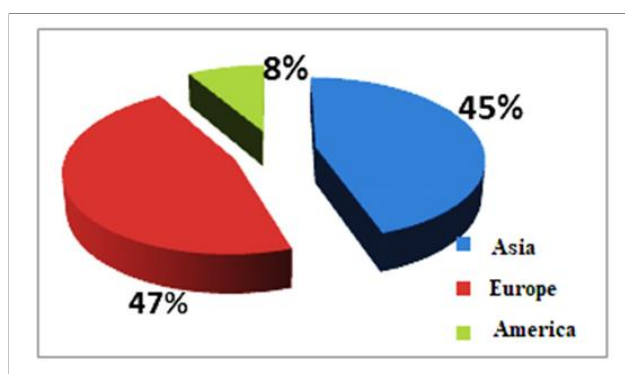
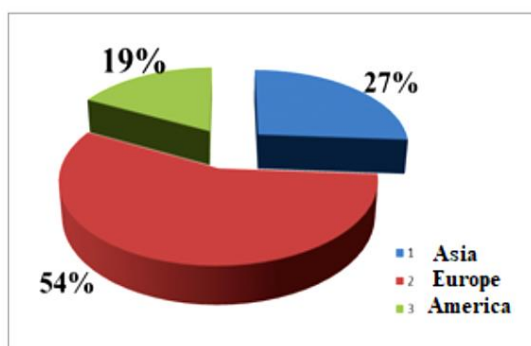


Fig. 18 *Olympic Games in Rio de Janeiro*

Fig.19 *Baku, Azerbaijan, World Cup 2018*

At the 2018 Baku World Cup, Europe recorded a 5% decrease (the medals were 27) (Fig.19). Nearly 30% go to Asia, predominantly to Japan.

A number of amendments have been made in recent years to the international rules for conducting judo competitions. This has led to non-acceptance of passive play and fictitious attacks, which in turn increased the dynamics of the sport, all of which put new requirements for sports technical skills preparation.

The generalized statistical analysis outlines the strongest countries with a markedly stable ranking of all major championships - Japan, Russia, France, South Korea, Brazil, Azerbaijan and Georgia. In such a fierce competitive environment, in order to secure at least 1 medal from World Cup or Olympic games, each team must have minimum 3- 4 competitors with real potential for winning a prize.

The statistical analysis also outlines a tendency in which a group of techniques are used as a basis for achieving high evaluation, while others perform certain tactical tasks. Thus, techniques such as Ko-uchi-gari, Ko-soto-gake, O-uchi-gari, Sasae-tsurikomi-ashi and similar ones are applied too often, but mainly as preparatory and tactically supportive ones and as techniques that ultimately carry point scores. The direct effectiveness of these techniques is about 30% of that of *Seoi Nage* and *Uchi Mata*.

Despite the emerging global trends, several basic schools can be distinguished, which have their own peculiarities and specific differences. The most prominent is the Asian school with its typical representatives of Japan and South Korea, Mongolia and some other representatives of the former USSR countries. The latter are strongly influenced by their national fightings. The sport of Judo in Europe, after the initial imitation of the Japanese style, acquired a different look from that of Asia. The Russian school (based on sambo and national fighting styles) contributed to a certain extent to the evolution of judo and its separation from the typical Asian style.

Irrespective of the existence of different schools, the practice has unified the sporting technical means in terms of frequency and effectiveness of their application.

Following the analysis of the competitive development of the sport of Judo, the elaboration of an adequate new classification structure separately from the established framework of the kyu dan system is of particular interest for the education and training process. The picture of the applicability and effectiveness of techniques has historically

undergone more or less significant variations. For example, the data from the 2018 Baku World Cup (Table 7) differs significantly from Syd Hoare's analysis (Table 6).

Table 6. *A comparative historical analysis by Syd Hoare (1987)*

#	cluster	technique	total
1	Te-waza	Morote Seoinage	88
2	Ashi-waza	Uchi-mata	76
3	Ashi-waza	Osoto-gari	71
4	Ashi-waza	O-uchi-gari	43
5	Te-waza	Tai-otoshi	43
6	Koshi-waza	Harai-goshi	35
7	Ashi-waza	Kosoto-gari	31
8	Ashi-waza	Kouchi-gari	25
9	Te-waza	Ipon Seoinage	16
10	Ashi-waza	Tsuri-komi-ashi	11

Table 7. 2018 Baku World Cup

#	cluster	technique	waza ari	ippon	total	%
1	Te-waza	Seoi-nage	56	23	79	10.35%
2	Ashi-waza	Uchi-mata	43	23	66	8.65%
3	Te-waza	Sumi-otoshi	52	11	63	8.26%
4	Koshi-waza	Sode-tsurikomi-goshi	25	19	44	5.77%
5	Ashi-waza	O-uchi-gari	30	14	44	5.77%
6	Te-waza	Ippon-seoi-nage	26	8	34	4.46%
7	Ashi-waza	Ko-soto-gake	18	14	32	4.19%
8	Ashi-waza	Ko-uchi-gari	19	10	29	3.80%
9	Ashi-waza	Ko-soto-gari	20	7	27	3.50%
10	Ashi-waza	O-soto-gari	15	12	27	3.50%

Of particular interest is the comparative analysis of the frequency of use of technical actions and their effectiveness during the last World and Olympic Games (Table 8).

Table 8. The ten most effective techniques

Nº	OG 2012	WC 2014	WC 2015	OG 2016	WC 2017	WC 2018
1	Morote	Uchi mata	Eri seoi nage	Uchi mata	Eri seoi nage	Eri seoi nage
2	Uchi Mata	Morote	Uchi mata	Sode tsuri	Uchi mata	Uchi mata
3	Ippon Seoi nage	Ippon Seoi nage	Sode Tsuru	Ippon seoi	Sumi gaeshi	Sumi-otoshi
4	Harai Goshi	Sode Tsuru	O uchi gari	O uchi gari	Sode tsuri	Sode-tsurikomi
5	O Uchi Gari	Eri seoi nage	Sumi gaeshi	Eri seoi nage	O uchi gari	O-uchi-gari
6	Ko Uchi Gari	Harai goshi	O soto gari	Sumi gaeshi	Uki Waza	Ippon-seoi-nage
7	Yoko Tomoe	O uchi gari	Morote	O soto gari	Soto Maki Komi	Ko-soto-gake
8	Sumi Gaeshi	Sumi gaeshi	Soto Maki Komi	Morote	Morote	Ko-uchi-gari
9	Eri Seoi Nage	Soto Maki Komi	Ko uchi gari	Harai goshi	Tai otoshi	Ko-soto-gari
10	Sode Tsuru	Ko uchi gari	Tai otoshi	Uki Waza	Yoko tomoe	Tai otoshi

Legend: OG 2012 – Olympic Games London; WC 2014 – World Championship Chelyabinsk, Russia; WC 2015 – World Championship Astana, Kazakhstan; OG 2016 – Olympic Games Rio de Janeiro, Brazil; WC 2017 – World Championship Bucharest, Hungary; WC 2018 – World Championship Baku, Azerbaijan

Insofar as the competitive result is conditioned by the perfect mastery of a limited number of techniques, those who are more effective deserve attention. On this basis, the techniques of Seoi nage and Uchi Mata appear to be fundamental to the whole system of sports and technical skills. (Table 8). In this case, it is not about expressing preferences to certain techniques; it should be emphasized that they actually have not only too high efficiency, but also remarkable, constantly maintained at all types of tournaments, high frequency and efficiency of use. Fig. 21 shows the different types of wins at the Baku World Championship.



Fig. 21. *Distribution of the wins by type in Baku*

In addition to these fundamental characteristics of Seoi Nage and Uchi Mata we should also take into account their fundamental role for the biomechanical structuring of all throwing techniques in the direction of Tori.

STRUCTURE OF SPORT AND TECHNICAL MASTERY

Judo refers to sports with a non-standard characteristic of motor actions in a highly variable external force field. In other words, the structure of the motor system depends on a particular situation, i.e. the competitor is forced to solve different, spontaneously occurring motor tasks in extremely variable conditions.

On the other hand, the sport is individual and each athlete has his or her own style and motor stereotypes. The existing practice leads to the conclusion that by analogy with physical training, the concepts of general and special technical training (STT) have the right to exist. The adopted traditionally Kyu Dan system has its scientific logic and universal applicability only with regard to the general sports technical training. STT requires detailed development and differentiation according to the individual characteristics of both the individual and the biomechanical structure of the grips.

At the Baku 2018 World Championship, men used 50 and women 47 different techniques in the four main directions (fig.22 and table 10). It is obvious that the sport of judo essentially requires the maximum "complexity" of technical training, since mastering the various performances makes the defense work most difficult.

Rank correlation, however, does not take into account the actual weight in the frequency of techniques used. For example the technique of *Seoi nage* used by men exceeds nearly two times *Seoi nage* used by women.

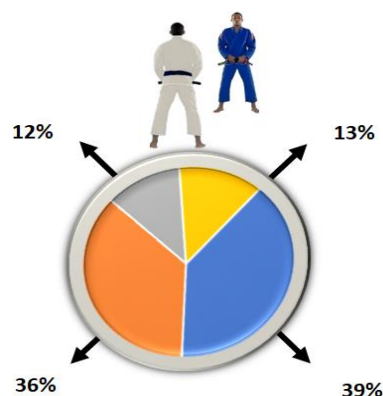


Fig. 22 Percentage distribution of forward (left-right), backward (left-right) WC 2018, Baku

Table 10. Percentage distribution forward vs. backward

	forward	%	backward	%
2012	412	21%	1511	79%
2014	906	21%	3412	79%
2015	1564	26%	4491	74%
2016	908	25%	2680	75%
2017	1214	24%	3809	76%
2018	1448	25%	4454	75%

Fig. 23 represents the results as grouped by clusters.

The percentages are illustrated graphically in Fig. 24 (Fig. 25. Percentage distribution between men and women). Gender differences are obvious and easy to explain - men rely more on arm strength and do not worry about sacrificial techniques. Women are focused on utilising the capabilities of more powerful muscle groups.

Insofar as the ultimate goal of the competition is to achieve victory, the effectiveness of sport and technical action is essential. The statistical measurement of this efficiency is illustrated in Table 12, Table 13 and Figure 27.

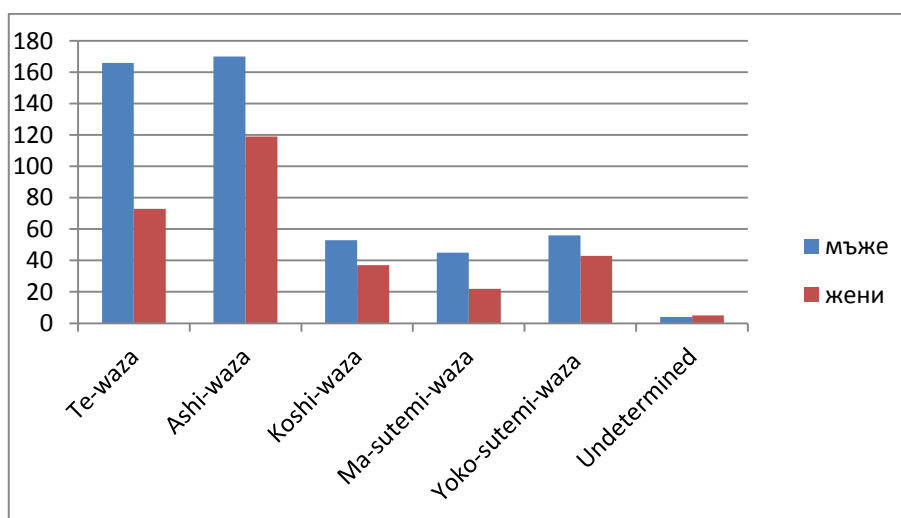


Fig. 23. Men to women ratio by clusters, Baku 2018

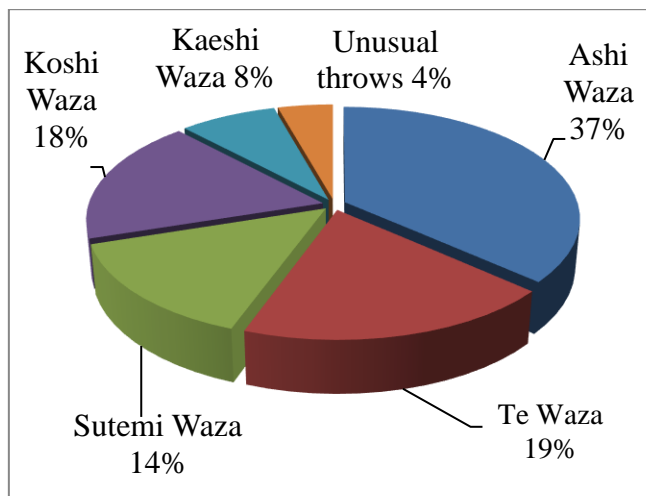


Fig. 24. Total men and women by clusters, Baku 2018

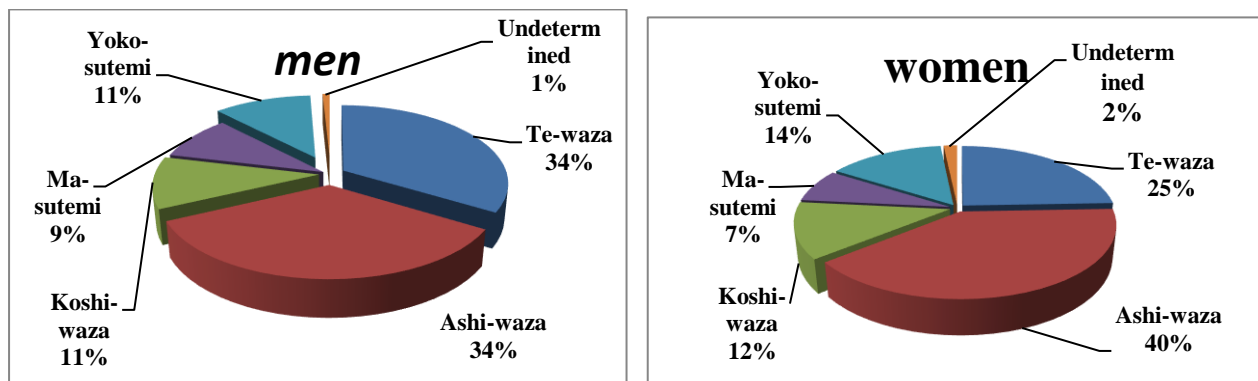


Fig.25 Percentage distribution of men and women, Baku, 2018 WC

Table 12. Dynamics of the results obtained

competition	attacks without results	ippon	evaluation	total	efficiency
OG 2012	1945	161	425	2370	30%
WC 2014	3677	181	646	4323	22%
WC 2015	5350	178	705	6055	16%
OG 2016	4153	191	521	4674	17%
WC 2017	4279	139	744	5023	21%
WC 2018	5999	389	958	6957	22%

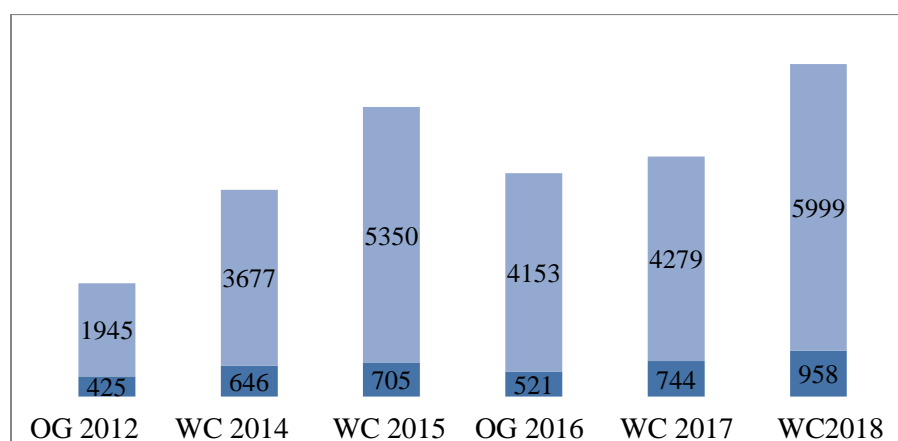


Fig. 27 Statistical measurement of efficiency

Table 13. Statistical measurement of efficiency

Score	OG 2012	WC 2014	WC 2015	OG 2016	WC 2017	WC 2018
No score	1945	3677	5350	4153	4279	4668
YUKO	152	222	259	169	0	0
WAZA	112	243	268	161	605	569
IPPON	161	181	178	191	139	389
Total	2370	4323	6055	4674	5023	5626

Obviously, in both genders, the fight between attack and defense is on the same level. The comparison between the games in London and in Baku shows no development in terms of the attractiveness aimed by the World Federation (fig.28 and fig.29). It can be said that new changes of the rules of competition must be considered.

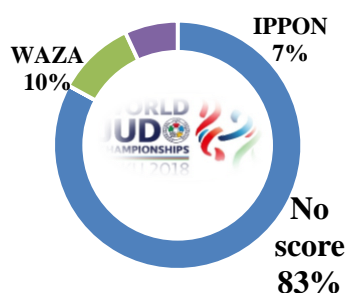


Fig. 28. Effectiveness
WC 2018 Baku

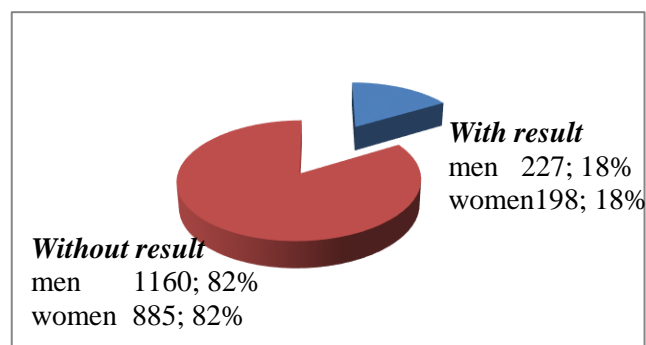


Fig. 29. Number of attacks - men, women -
OG 2012

In the sport of judo, ippon score plays a special role. Statistics show that 45.7% of the men's attempts and 40.8% of women's attempts completed with this assessment result.

Tables 14 and 14a through 18 and 18a show statistical results on the effectiveness of the clustering techniques used. The data presented in this way can be misleading, since 100% efficiency (e.g. with *Okuri ashi barai*) may be due to single attempts.

Some general regularities and some gender differences become visible. There is a common development of the techniques *Ko soto gake*, *Tai otoshi*, *Uchi mata gaeshi*, while the differences are in the effectiveness of *Sode tsuri komi* and *Uki otoshi*.

On the other hand, the techniques *Koshi guruma*, *De ashi barai*, *Soto maki komi* etc., are significantly more successful with female judokas, while, for example, the *Sode tsuri* technique fits better with men..

Of particular interest in countering techniques is the *Uchi mata gaeshi* – nine scores from 10 trials.

On this basis, it is also logical to conclude that less commonly used techniques carry a surprise factor that also leads to a high success rate.

It is only natural that when an attacking technique proves to be successful, after a certain period of time the defense will find adequate reactions and force the attack to develop in another direction. Last but not least is the fact that for obvious reasons (anthropometric indicators) the cited statistics are strongly influenced by the weight categories.

With the increased sports and technical skills, biomechanical expediency implies that individual characteristics are gaining significance. For example, there are elite competitors whose main techniques are outside the statistical classification. In addition, some are so individualized that they can hardly be uniquely identified to commonly accepted groups in the Kyu dan system.

Regardless of the significant informational value of statistical approaches, this type of analysis should not lead in the process of improving the sports and technical mastery. On one hand, sports and technical intelligence after each competition prepares adequate defences for the next competition, and on the other, elite competitors generally differ from the general statistical picture and the individual peculiarities are leading for them. Therefore, if the training work follows the statistical conclusions uncritically, the methodology will be lagging behind and following the events.

However, another tendency is significant, and this is the World Federation's aspiration to increase the attractiveness of the fights. In this sense, the anticipating methodology should increase its focus on those techniques that carry higher grades.

Following the partial conclusions of the statistical review on the development of

judo sports, it is possible to distinguish with high degree of certainty two techniques - *Seoi nage* and *Uchi mata* - which are also the basis of the Kyu-dan system.

These techniques are leading, both in terms of frequency and effectiveness of performance during a contest, and as a biomechanical structure on which technical skills in training work are formed. These techniques proved to be leading, both in terms of frequency and effectiveness of performance during a competition, and as a biomechanical structure on which technical skills in training work are formed. These techniques prove to be leading for the whole cluster of tori throwings. Therefore, their biomechanical analysis is essential, both for the initial training according to the Kyu dan system and for the individualization of high sportsmanship.

BIOMECHANICAL EVALUATION OF THE TECHNIQUES SEOI NAGE AND UCHI MATA IN JUDO

KODOKAN PRINCIPLES OF SEOI NAGE

Fig. 30 illustrates the *Seoi nage* technique and the corresponding power structure is illustrated in Fig. 31. The starting position of the *Migi Shizentai* coincides with the *Kuzushi* phase.

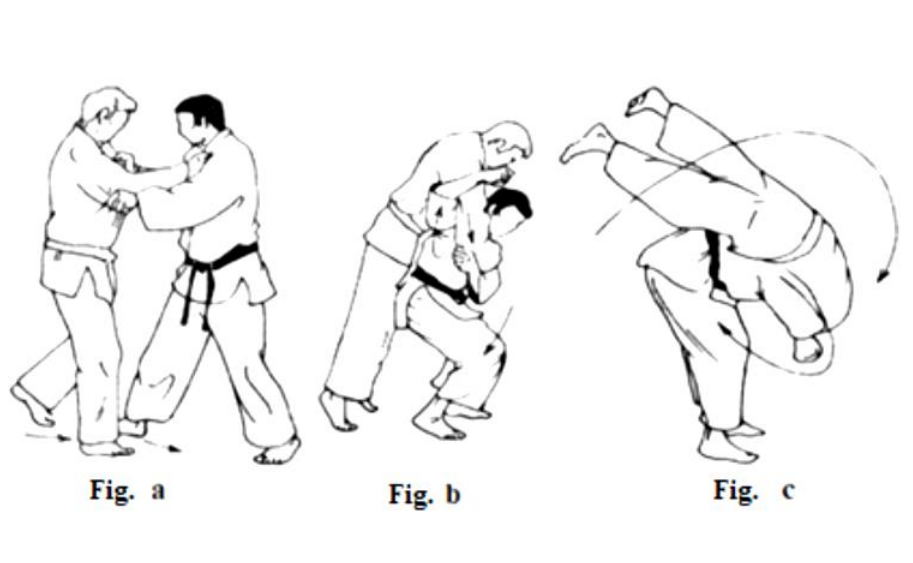


Fig.30. *Classic version of Seoi nage performance*

DYNAMIC STRUCTURE

The generalized power diagram for Seoi Nage is presented in Fig. 31.

After Kuzushi, the uke's body is influenced by the forces F_M weight of the athlete with an application point in CCG, F_M force of the left hand grip directed forward and past the tori's body ensuring the maintenance of the kuzushi achievement (fig. 32).

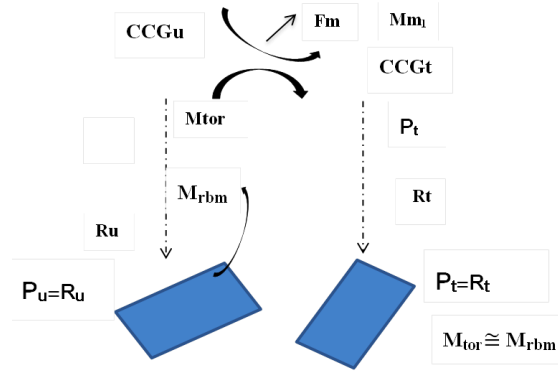


Fig. 31. The power structure of Seoi nage - a starting position (migi shizentai)

Legend: CCGu – CCG uke; CCGt – CCGtori; Pu – weight of uke; Pt – weight of tori; Fm – muscle strength; Mm1 – muscle torque; Ru – reaction of the uke support; Rt – reaction of the tori support; Mtor. - torque; Mrbm – restoring balance moment

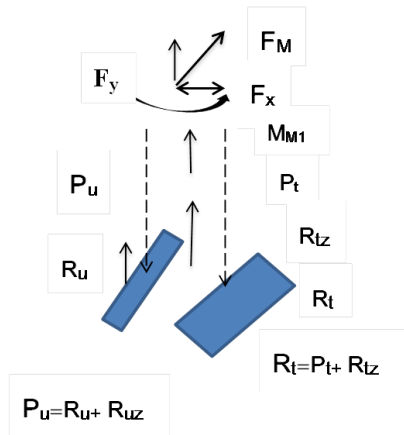


Fig. 32. Seoi Nage power structure in the Kuzushi phase

Legend: Mtor - torque (turning); Fm – muscle strength; Fx, Fy – decomposition of forces, Mm1 – torque of muscle strength; Pu – weight of uke; Pt – weight of tori; Ru – reaction of the uke support; Rt – reaction of the tori support

This force largely depends on the kinematics in the positions of the two bodies. It can be considered that F_M is composed on the torque Mtor of F_M and the resistive

P_u (weight of uke). Therefore, it is not the absolute value of M_{tor} , that matters but the outweighing torque created by the weight of the tori relative to that of uke's weight.

Vertically directed force is actually intended to reduce this resistance moment; that's why it is considered a mistake if the right forearm of the tori is not horizontal under the uke's shoulder.

The throwing (fig.30c) kake is due to the pair of forces F'_M и F''_M . (fig. 33). Of these the identification of F''_M is difficult as it is the result of the support reaction, inertial forces and the two competitors' weight. Moreover, this force is not concentrated in a single support point and the torque vector can only be determined indirectly from the external kinematic picture in video-computer analysis.

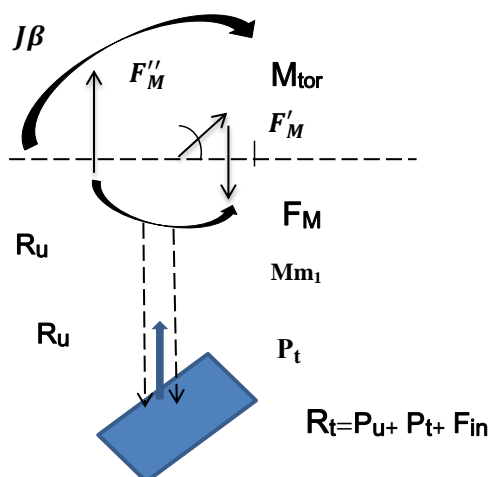


Fig. 33. Generalized diagram of the uke and tory power structure in the Kake phase

Legend: $J\beta$ – moment of inertia; M_{tor} - torque (turning); F_m – muscle strength; M_{m1} – torque of muscle strength; R_u – reaction of the uke support; R_t – reaction of the tori support; P_y – weight of uke; P_t – weight of tori; F_{in} – inertial force

KODOKAN PRINCIPLES OF UCHI MATA

Fig. 34 represents the classic version of the Migi Shizentai performance.

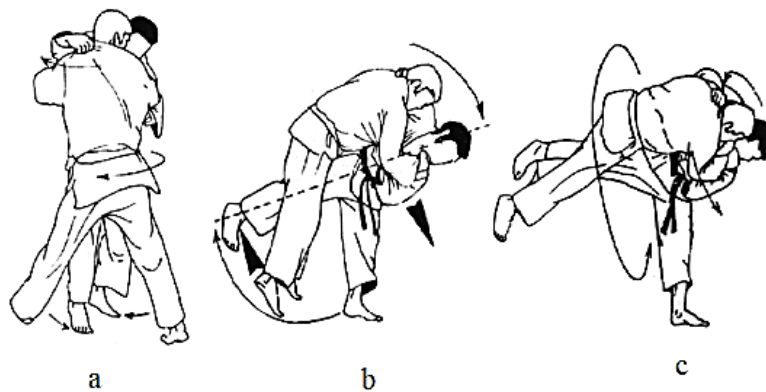


Fig. 34. *Classic version Uchi Mata*

DYNAMIC STRUCTURE

The coordinated execution of the two actions provides the necessary lead-out of balance (forces F_{M1} and F_{M2} on fig. 35) by forcing the uke to make a wider step to the left than usual. During all the time tori should not reduce the effect of the force F_{M1} . A generalized strength diagram for the Uchi Mata technique is presented on figure 35.

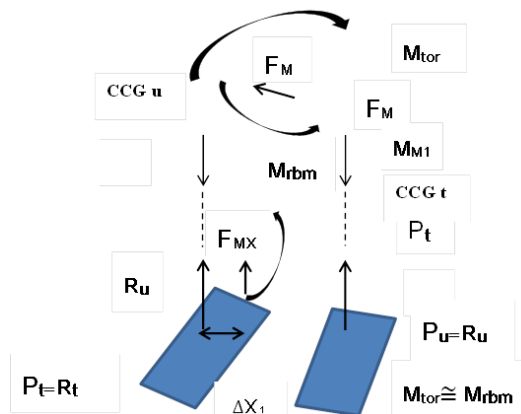


Fig. 35 *Strenght structure of Uchi Mata from starting position (Migi Shizentai)*

Legend: CCG u – CCG uke; CCG t – CCG tori; P_u – weight of uke; P_t – weight of tori; F_m – muscle strenght; M_{m1} – torque of muscle strenght; R_u – reaction of the uke support; R_m – reaction of the tori support; M_{tor} – torque (turning); M_{rbm} – restoring balance moment

Therefore, the tori must initially create a torque around the transverse axis of the uke's body by the forces F_{M3} , F_{M4} and P_u (fig.37). Apart from the magnitude and direction of these axes, the magnitude of the moment will also depend on the distance between them; optimum efficiency would be obtained if the center of rotation coincides with the location of the common center of gravity, since in this case the inertial forces have a minimum value.

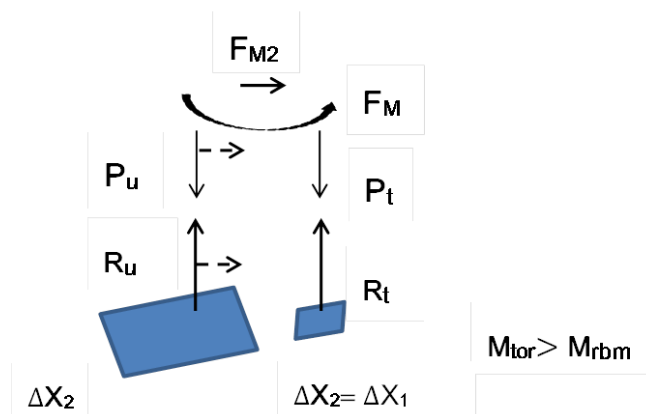


Fig.36. Strength structure of Uchi Mata in the Kuzushi phase

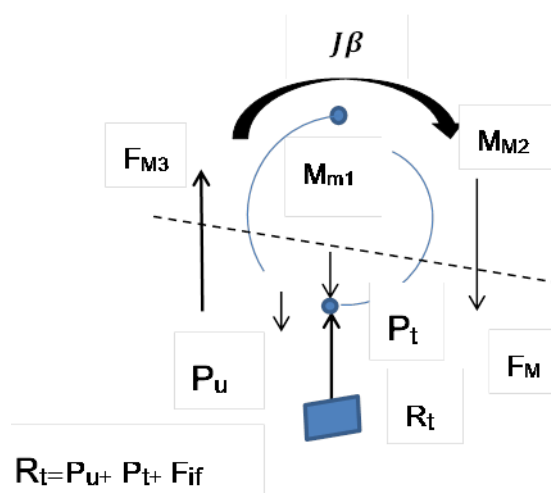


Fig. 37. Generalized diagram of the strength structure of uke and tori in the Kake phase

Legend: $J\beta$ - moment of inertia; M_{tor} - torque (turning); F_m – muscle strength; M_{m1} – torque of muscle strength; R_u – reaction of the uke support; R_t – reaction of the tori support; P_u – weight of uke; P_t – weight of tori; F_{if} – inertial force

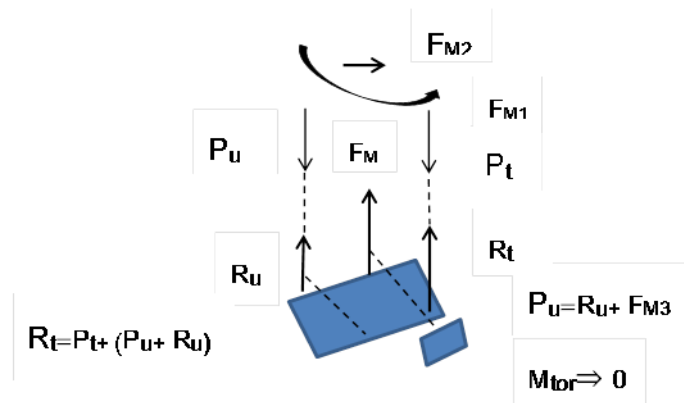


Fig. 38. *Strength structure of uchi mata*

The second characteristic is the creation of torque around the longitudinal axis which is created by the force F_{M2} and the uke's own weight P_u . (fig. 38)

EXPERIMENTAL ANALYSIS

Due to the presence of considerable internal forces through constantly imposed grip, a biomechanical analysis requires a complex evaluation of the kinematic and dynamic structures of the system. Nevertheless, the active external force of the Tory support reaction appears to be an integral indicator that uniquely determines the motion of the generalized CCG. The nature of this force vector necessitated the use of a computerized three-dimensional tensometric platform to obtain its quantitative evaluation.

Twenty-four competitors from the national team of Bulgaria were surveyed. For fifteen of them, the *Seoi Nage* technique is a major grip in competitive conditions, while in the other nine the Uchi Mata technique plays this role.

Tables 19 and 20 present data from the variational analysis of the power characteristics for the two surveyed groups.

The first conclusion of the comparative analysis is to confirm the assumption that the basic technique has a much higher standardization and stability of the biomechanical structure.

Table 19. *Variational analysis Seoi Nage*

Competitor (characteristics)		Basic technique Seoi Nage						Additional technique Uchi Mata					
		I phase	S	V%	II phase	S	V%	I phase	S	V%	II phase	S	V%
Phase duration in sec.		39	3.8	9.7	120	7.5	6.3	50	5.1	10.2	124	15.2	12.3
Fmax	x	126	8.6	6.8	280	19.9	7.1	78	4.5	5.8	258	28.6	11.1
	y	720	61.9	8.6	1640	193.5	11.8	660	38.2	5.8	1600	174.4	10.9

	<i>z</i>	122	4.4	3.6	200	17.8	8.9	112	7.5	6.7	150	22	14.7
t of Fmax	<i>x</i>	18	0.8	4.8	44	4.5	10.2	26	1.7	6.4	52	6.2	11.9
	<i>y</i>	26	1.1	4.1	46	1.19	2.6	30	1.5	5.1	50	4.6	9.3
	<i>z</i>	21	1.4	6.8	38	1.8	4.8	28	20.4	73	58	4.9	8.4
Fmax impulse	<i>x</i>	52	2.9	5.6	26	1.7	6.8	46	3.4	7.5	22	1.7	7.8
	<i>y</i>	102	6.3	6.2	232	16.2	7	88	2.3	2.6	210	16.4	7.8
	<i>z</i>	44	1.7	3.9	66	2.5	3.8	42	2.6	6.3	52	7.6	14.6
Fmax gradient	<i>x</i>	28	0.5	1.8	62	5.6	9.1	18	0.7	3.9	66	6.1	9.3
	<i>y</i>	30	0.7	2.2	70	2.7	3.9	16	0.4	2.8	60	2.6	4.4
	<i>z</i>	52	1.1	2.2	54	2.5	4.6	26	1.1	4.4	28	1.3	4.8

Significant differences may also be found in the direction along the Z axis. This direction, although not in the throwing direction, takes into account the compensatory mechanisms and the stability of the technique.

Given that the grip is performed from a static position in a laboratory, the values of the variation coefficients are a measure of the degree of automation of the technique.

Table 20. *Variational analysis Uchi Mata*

Competitor (characteristics)		Basic technique Uchi Mata						Additional technique Seoi Nage					
		I phase	S	V%	II phase	S	V%	I phase	S	V%	II phase	S	V%
Phase duration in sec.		38	3.7	9.8	112	8.3	7.4	36	3.3	9.1	120	15.1	12.6
Fmax	<i>x</i>	91	7.5	8.2	99	8.6	8.7	101	9	9	56	0.8	1.4
	<i>y</i>	720	70.5	9.8	1430	173	12.1	660	79.9	12.1	1360	127.8	9.4
	<i>z</i>	126	7.7	6.12	210	20.6	9.8	140	11.5	8.2	180	15.8	8.8
t of Fmax	<i>x</i>	16	0.5	3.4	34	3.8	11.1	18	1.1	6.1	32	3.2	10.1
	<i>y</i>	10	0.4	4.1	32	1.3	4.1	19	0.7	3.8	31	3	9.8
	<i>z</i>	26	1.6	6.1	48	2.2	4.6	21	1.4	6.8	36	2.9	8.1
Fmax impulse	<i>x</i>	38	2.3	6.1	122	8.8	7.2	40	2.3	5.8	138	11.2	8.1
	<i>y</i>	112	8.3	7.4	280	20.7	7.4	72	5.6	7.8	244	21.5	8.8
	<i>z</i>	52	2.1	4.1	72	3.7	5.1	37	3	8.2	82	7.2	8.8
Fmax gradient	<i>x</i>	22	0.8	3.5	34	3.4	9.9	20	0.7	3.8	39	2.8	7.2
	<i>y</i>	16	0.4	2.8	52	2	3.8	14	0.4	3.1	42	1.3	3.1
	<i>z</i>	26	0.9	3.7	30	1.1	3.9	30	1.2	4.1	36	1.7	4.8

An interesting fact is that the power characteristics by absolute values do not differ significantly in statistical sense. More significant differences are observed in the area of temporal characteristics, and especially in the evaluation of the rhythmic structure. Such a result can be easily explained by the fact, that the experiments are carried out in a laboratory setting, i.e. the motor task is strictly defined in terms of the

kinematic conditions. At the same time, the significant differences in the time structure is an indication that this kind of biomechanical characteristics prove to be much more sensitive parameters for the quantitative evaluation of sport and technical skills.

A significant conclusion from the statistical analysis of the dynamic structure as opposed to the phase structure is the high degree of individualization. The statistical conclusions here were compromised by the unacceptably high values of the coefficients of variation. This confirms the fact that, despite the external resemblance based on the basic judo principles, the internal force structure is subject to a number of individual characteristics for each individual competitor. The result is important and should be considered in quantifying evaluation of biomechanical expediency. It is about conforming the models to both the general principles and the individual characteristics of the competitors.

Insofar as our main task is to find ways to improve the already established and stable biomechanical structure of the movement system, we also conducted experiments to evaluate the individual biomechanical features in the implementation of both techniques.

The comparative analysis between the mathematical models of individual competitors reveals individual peculiarities in the construction of the grips. In some cases the focus is mainly on the gradient of the force vectors to realise kuzushi, while in others, the attack is built at the expense of blocking the degrees of freedom of movement. This also leads to significant differences in the rhythmic structure. There are, of course, very strong causal relationships between kinematic and dynamic structures in the system of motion. For example, the established amplitudes of the differences in the angle of the force vector at Tsukuri (660 to 740) largely determine the differences in the absolute values of support reactions.

Figures 39-42 show dynamometric records of the studies of the participants in the study with the highest indicators of realisation efficiency.

The first competitor (*Seoi Nage*), significantly more slowly and less substantially lowers his own CCG in the first phase of performance.

The gradient by which the force is transmitted to the body of the uke is also smaller. In addition, during the main phase certain stages in the development of the explosive force can be observed. This difference between the first and the next global maximum is obviously due to technical imperfection and impaired intramuscular synergy. On the other hand, the global maximum is the highest among all the performers, which shows that this competitor has considerable potential for improving his technique.

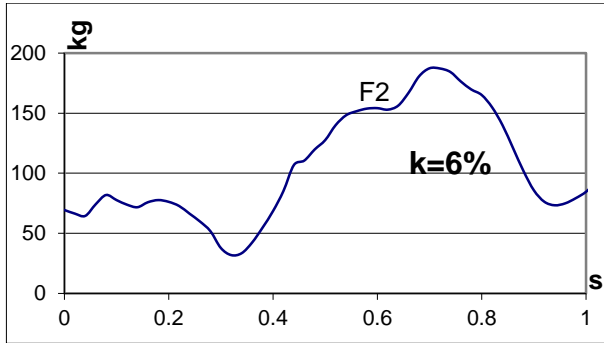


Fig. 39. Generalised power structure of competitor №1 (*Seoi Nage*)

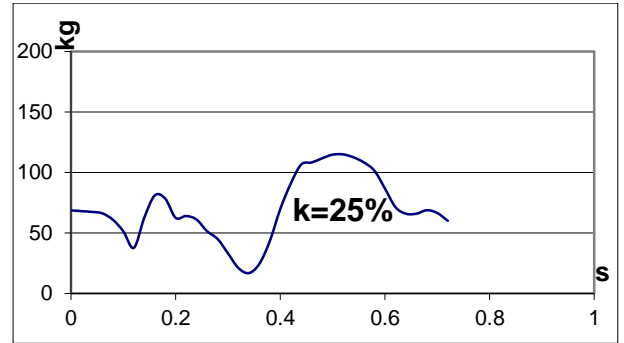


Fig. 40. Generalised power structure of competitor №2 (*Seoi Nage*)

Of particular interest is the dynamometer of the second competitor (*Seoi Nage*). In this case, the power structure is very properly constructed from a biomechanical point of view; a major drawback, however, is the poor realization of power capabilities. Obviously, this competitor has a solid technical base, but the power component should be upgraded. With *Uchi Mata*, competitor №1 demonstrates better technique in terms of force structure, with the highest values of the force gradient, both in the downward

and upward part of the curve.

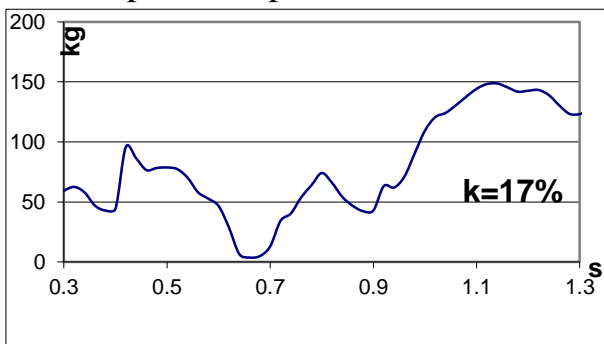


Fig. 41. Generalised strength structure of competitor №1 (*Uchi Mata*)

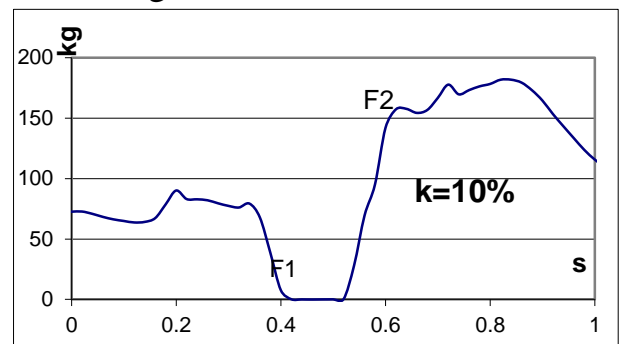


Fig. 42. Generalised strength structure of competitor №2 (*Uchi Mata*)

In this case, the first phase ends with a relatively long period during which the supporting reaction is zeroed. Tori accomplishes this phase by reaching the absolute

maximum for the rate of decline of his own CCG. The upward gradient of strength is an achievement that implies a high level of sports-technical component in terms of intermuscle coordination.

The wide plateau after the first local maximum also determines the significant momentum of force and hence the amount of movement transmitted on the body of the uke.

A significant disturbance in the structure of the first phase is observed in competitor №2 (*Uchi Mata*), since unreasonably from a biomechanical point of view he prolongs the kuzushi time, respectively the reaction time and counter uke's actions. Here again, however, the technique should not be interpreted unambiguously, since this defect could be overcome by the specificity in the kinematic structure which is not recorded by the experiment.

In any case, however, low maximum values, despite maintaining a plateau for a relatively long period of time, is a significant drawback of the technique. Another significant disadvantage is the presence of a local maximum at the level of own weight, which, despite maintaining a plateau for a relatively long period of time, is a significant drawback of the technique.

In individual terms, the large number of repetitions demonstrate stability of the functional curves, both in terms of time structure and strength structure. This can be explained by the fact that the studied persons are competitors with stable sports and technical skills and the experimental setting ensures the standard of the external conditions. Tables 21 and 22 represent data on the variability of the main characteristics of 10 performances.

Table 21. *Variability of key characteristics of Seoi nage*

competitor	F1	S1	V%	F2	S2	V%	F3	S3	V%	F4	S4	V%
characteristic												
№1	36.1	1.1	3.04	152.4	2.2	1.44	191.2	2.4	1.25	164.2	3.2	1.94
№2	19.4	2.3	11.85	109.2	1.9	1.73	117.7	3.3	2.8	109.1	3.2	2.93

Table 22. *Variability of key characteristics of Uchi mata*

competitor	F1	S1	V%	F2	S2	V%	F3	S3	V%	F4	S4	V%
characteristic												
№1	0	0	0	159.3	3.1	1.94	178.6	2.3	1.28	186.3	3.6	1.93
№2	5.2	1.2	23.07	126.2	2.3	1.82	153.3	2.6	1.69	144.1	2.1	1.45

It becomes clear that with both techniques the individualisation and refinement of the already high level of sport and technical skills is too multidimensional in nature and the general quantitative evaluation can be sought in the following areas:

- the explosive force gradient during the main phase (max);
- the time interval during the kuzushi phase (min), and
- the strength impulse of the supporting reaction.

The exceptional stability of the biomechanical structure in individual performances, regardless of significant particular features, leads to two conclusions: the sport-technical action is mastered to the level of dynamic stereotype and the performances are guided by a "personal strategy" for ensuring biomechanical expediency.

IMPLEMENTATION PARTICULARITIES IN COMPETITIVE CONDITIONS

In competitive conditions, the techniques are not always implemented according to the "kata" forms of the Kyu dan system. In order to receive a more detailed evaluation, we performed a video analysis of 60 techniques that were evaluated during the International tournaments "Liberation". It turned out that in 95% of cases the kuzushi phase which is considered to be basic by the theory was not observed. This result also required pilot dynamometer studies to directly measure uke's stability.

Fig. 43 shows a dynamogram of a vertical component of the supporting reaction when performing Seoi nage.

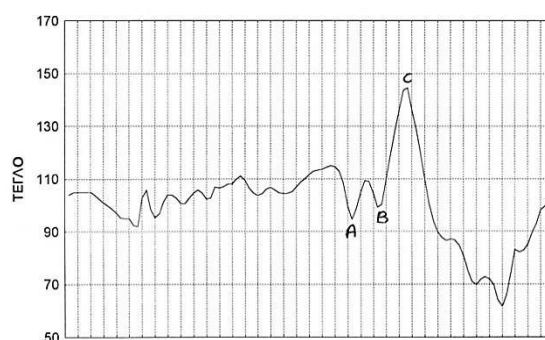


Fig.43. *Dynamogram of the vertical component of the Seoi Nage suport reaction*

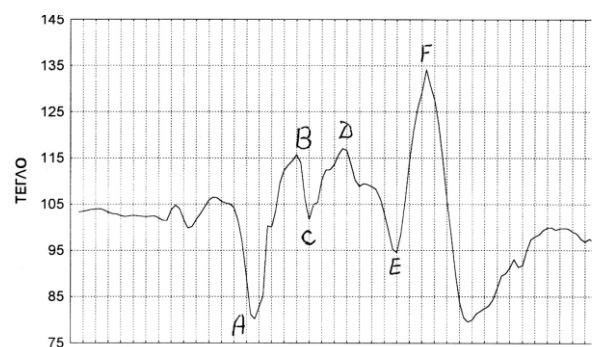


Fig.44. *Seoi Nage's dynamogram before the kake starts*

The smaller amplitude variations during the tsukuri and kuzushi phases are noticeable. Vertical component changes are due to D'Alembert's extra inertial forces, but are also influenced by internal intramuscular forces transmitted through the grip between uke and tori.

Here, the degree of smoothness of the curve is outlined as a qualitative parameter of the technique. In this sense, the presence of two minima (p. A and p. B in Fig. 43) is an indication of imperfections in performance.

In all cases, immediately prior to the start of the kake (p.B in Fig.1 and p. E in Fig. 44), local minima are observed below the static force level (the weight of the competitors).

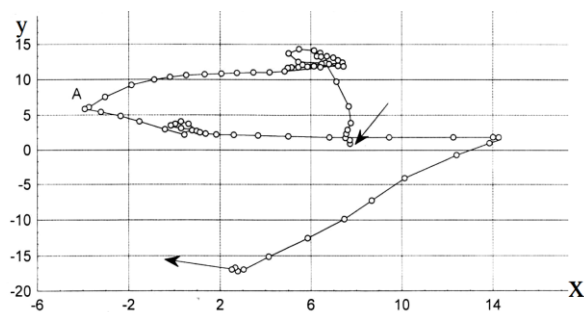


fig.45. Seoi nage – CCG

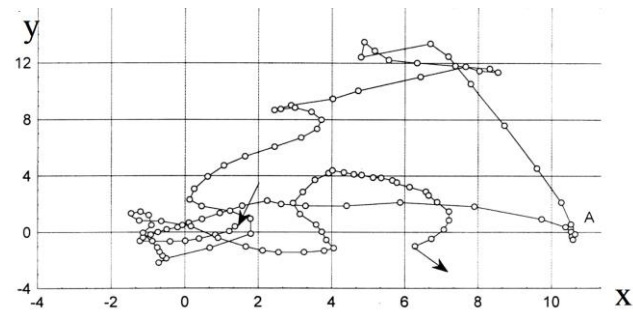


Fig.46. Uchi mata - CCG

Fig. 45 and Fig. 46 show the projection movements of the CCG in the performances of *Seoi nage* and *Uchi mata*, respectively.

It is noticeable that the beginning of the Kake does not take place at the lowest angle of resistance, i.e. during the kuzushi phase there are times with much more unstable equilibrium for uke. Therefore, we consider that the large amplitudes at *Uchi Mata* are regular and they are a consequence of the specifics of the technique.

What is more significant, however, is that the projection of the center of gravity does not leave the supporting surface of the athletes throughout the time of the tsukuri and kuzushi. At *Uchi mata*, the amplitude is only 12 cm, the throwing occurs after moving the CCG only 5 cm. The analogous data for *Seoi nage* are 18 cm and 6 cm. There is also a significant difference with respect to displacements in the frontal plane for the *Uchi mata*, kake occurs after moving the CCG by only about 2 cm, whereas in the *Seoi nage* the displacement is about 18 cm. It should be remembered that the intermediate data when the Tori moves his supporting surface are overestimated as they are influenced by the additional inertial characteristics. The most important thing in this case is the fact that in virtually none of the cases examined, the CCG did not leave the competitors' support area before the start of the kake.

Fig. 47 shows the movement of the CCG of the uke in Uchi mata. The state of balance disturbance is clearly evident, since the amplitude from A to C is within no more than 6 cm, and then the kinematic structuring of the technique completely restores the equilibrium at p. D which is the beginning of the kake phase.

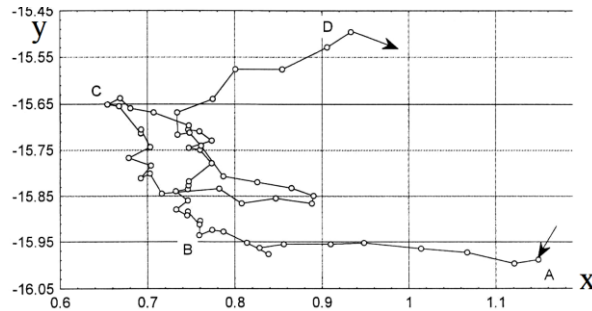


Fig.47. Uke – CCG in Uchi mata

It becomes clear that in all the investigated cases **kake** was performed without the phase of kuzushi. However, the videometric analysis highlighted a significant feature due to the mutual positions of uke and tori. Although the CCG projection of the uke remains within its support surface outlined by the feet, the additional support surface on the tori body plays a significant role. This surface has the meaning of a supporting reaction, but does not help stabilise the resistance to throw, on the contrary - any uke defensive action creates an external force in this place, suggesting a Tory technique. In this sense, it is wrong to speak of kuzushi, but rather to properly limiting the degrees of freedom of movement.

The specificity of the performances in competition conditions was evaluated by an "active" experiment using a controlled uke's reaction.

The subject of the study are elite competitors for whom Seoi nage is the basic technique.

The results obtained raise questions about the training process regarding the measure between standardisation and individualisation of sporting technical mastery.

From a biomechanical point of view, the assessment of sportsmanship is achieved with the help of a multidimensional benchmark, depending on the characteristics of the target functions of the specific motor tasks (e.g. "stability-variability, arbitrariness-automatism, etc.).

For all studied persons the overall kinematic structure proved to be extremely stable, with the variation coefficients for the phase structure of the whole group not exceeding 3.8%.

The following figure 48 shows the curve obtained by mathematical modeling based on the particular points on the power function of the support reaction vector.

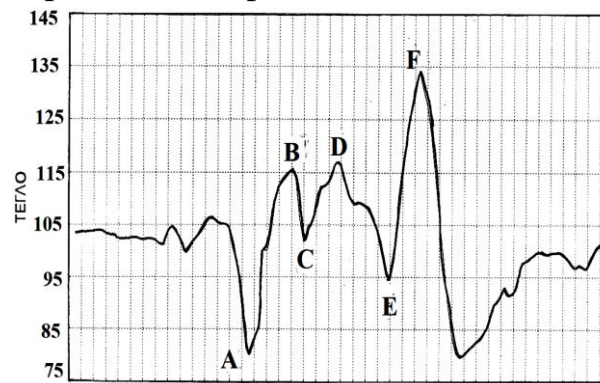


Fig. 48. *Modeled curve for estimating particular points at the Seoi nage technique*

The analysis of this curve shows the critical zones in the dynamic phase structure, which are limited by the resistance of the attacker to the direction opposite to the attack.

The functional curve contains the observed general regularities in the development of dynamograms in all performances. Due to the relatively high qualification of studied persons and the standardisation of conditions, a steady dynamic stereotype is observed in each of them. The dynamometer records thus obtained, based on the extremum and inflection points on the curves, allow to determine the phase structure in the motion system. In other words, time data of biomechanical characteristics across different "pathways" realize the intended objective function. In the terminology of sports science, one can speak of different "tactics" in the inter-structural construction of technical mastery.

According to the methodology, the performed active experiment has modeled an adequate Uke reaction in accordance with the biomechanical expediency of the disclosed phase structure.

The obtained results have established the existence of new, hidden biomechanical characteristics, which may be realized only under conditions of variability of the external force field. This leads to the need for fundamentally new theoretical considerations in the development of methods and tools for improving training work.

The problem with a quantitative analysis is precisely the uncontrollable nature of the external force field. In all cases, the measurement involves comparative procedures with an adequate biomechanical model - statistically or mechanically determined. On this basis the basic criteria for biomechanical expediency of sporting technical skill are derived. Their rigorous mathematical justification and proven practical applicability in

a number of sports disciplines (athletics, gymnastics, etc.) necessitate their verification for the needs of the sport Judo.

The experiments in this study have proved that the criterion for the starting force and the most favorable position of the maximum power does not have the necessary significance for the level of the sports technique of a judoka. The reason is in the hidden nature of the formation of the power structure and the presence of a number of compensatory mechanisms in the motor system.

The coordination criterion concerning private impulses is compromised by the fact that different curved masses, different number of kinematic units participate in the motion system.

The counteraction criterion, insofar as it depends on the role of internal forces on the distribution of impulses, cannot be quantified because of the undefined nature of the degrees of freedom of movement..

The criterion for keeping the momentum also proved to be uninformative, since external forces directly interfere with the relationship between angular velocities and inertial characteristics.

A major disadvantage of the general criteria for biomechanical expediency of movements is the fact that they do not comply with basic principles in the specificity of the motion system under study.

Other major areas in which indicators of technical mastery can be developed are the volume of technical actions, their versatility, rationality, efficiency and mastery.

The volume of technical preparation is quantified by the volume of sports and technical actions that the competitor has mastered. The statistical analysis proved very limited values of this indicator for the competitive set of techniques, even with the most elite competitors.

The experimental facts show that in Judo sport, where variability is too pronounced, this criterion does not correlate with high sportsmanship.

The criterion for versatility definitely has a place in the analysis of sports racing equipment. This criterion clearly has a direct bearing on the formation of uke's reactions and thus implicitly participates in the evaluation of the effectiveness of the technical action. The small volume, however, also greatly limits its importance for quantifying biomechanical expediency.

The significant differences found between formal (kata) and competitive performances illustrate the difficulty of formulating reliable criteria for rationality

according to classical biomechanics. On the other hand, the strong influence of individual characteristics in high-ranking judokas invalidates statistical methods for assessing comparative effectiveness through discriminatory features.

Due to the multidimensional nature of sports technique, the strong influence of individual characteristics and the hidden nature of the compensatory mechanisms largely invalidates all known classical biomechanical criteria for assessing the biomechanical expediency of mastered judo techniques.

PEDAGOGICAL EXPERIMENT

Two types of pedagogical experiment were carried out.

In the first case, a methodology to improve the realisational efficiency of the integral blasting characteristic of nage waza was experimented.

The used methodology was developed on the basis of cinematographic and anatomical-functional analysis of the used techniques. The comparative analysis was carried out through the discussed hardware and software.

In the second case, an experiment was conducted to refine the internal biomechanical structure that shapes the biomechanical expediency of motor action in nage waza. The methodology used is based on the disclosed compensatory mechanisms that shape the behavior of the biomechanical characteristics under the conditions of a variable external force field.

The two strands in the pedagogical experiment carry information about different parameters of sporting technical mastery.

A.Realisation efficiency

Judo techniques are implemented within a time interval of about 1 sec. It becomes clear that, to the greatest extent, success is determined by the realised explosive power. However, there is a significant difference between the explosive power evaluated by known pedagogical tests as quality and that realised under conditions of complex intramuscular synergy. Therefore, it can be assumed that the quality of the explosive force is only one component of the "explosiveness" of the attack. On this basis, the coefficient of realization efficiency or biomechanical expediency of the technical parameters of the attack could be defined in view of the potential power capabilities of the Tori.

For the purpose and tasks of our study, laboratory experiments were conducted to perform a comparative analysis between the ability for explosive contraction of the

major muscle groups on the one hand and the realisation of this potential in the face of complex technical actions in the most popular techniques in judo - *Seoi nage* and *Uchi mata*.

The APAS computer system was used, which enables the registration and evaluation of the power structure in isometric, isokinetic and isotonic modes. The experiment was performed under isokinetic mode at constant speed regardless of the input muscle force ($V = 0.05\text{m} / \text{s}$).

Twenty-four competitors from the Bulgarian National Team were surveyed.

Each competitor performs a squat and straightening to determine the individual range of motion, which is determined by the units of his entire kinematic chain (anthropometric data).

The muscles that are actively involved in straightening are: quadriceps femoris muscle in the knee; in the hip joint - gluteus and back thigh; and in the ankle joint - extensores.

Insofar as the desired realisation efficiency uses a comparison between achievements in static and dynamic modes of muscular work, it is necessary to verify the results by means of correlation analysis. In this case, the values of correlation coefficients are for *Seoi nage* $r_1 = 0.78$ and $r_2 = 0.81$ for *Uchi mata*.

At first glance, the high values of correlation coefficients counteract the idea of an adequate assessment of realisation efficiency, placing higher demands to the sensitivity of the coefficients sought. Therefore, the analysis was performed comprising individual performances that showed different behavior of the investigated power characteristics.

Figures 49-52 show the results of typical individual cases of measuring the muscular strength of the lower limbs in overcoming quasi static mode (velocity 0.05m/s). The test is interesting to provide a comparison with the realisation of this muscle strength when performing a technical action. What is impressive is the good realisation of the "explosive" power of the first and fourth competitors, where $\text{Grad } F$ during the main phase significantly exceeds that of the test trials. While the maximum results achieved for the main muscle group and the complex technical action of the first competitor do not differ significantly, in the case of the fourth competitor this difference is significant.

Moreover, the maximum possibilities of the latter are significantly lower than all others. It should be noted that the maximum capacity of the latter is significantly lower

compared to all others. In other words, the low extreme values of the support reaction in complex motor action are not only due to the low power capabilities of the respective muscle groups.

These results are accompanied by some conventionality about the regular relationship between static and dynamic muscle forces.

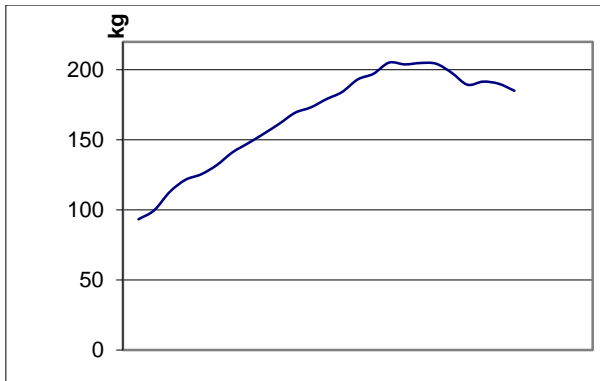


Fig. 49. *Squatting and straightening to determine individual range of motion in isokinetic mode with $V = 0.05\text{m/s}$ - competitor № 1*

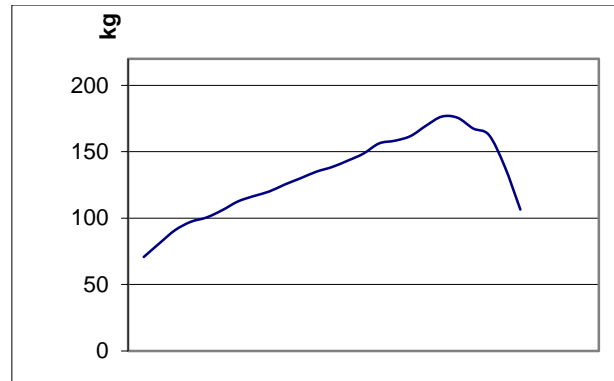


Fig. 50. *Control squatting and straightening in isokinetic mode with $V = 0,05\text{m/s}$ - competitor № 2*

A distinctive individual feature is demonstrated by the second competitor, to whom the global minimum in performance significantly exceeds the maximum muscle strength of the lower limbs. Obviously, this competitor, by way of rational intermuscular synergy, manages to include other muscle groups in different modes of work in order to increase the momentum transmitted to the uke. The difference shown is significant.

This fact also explains the gradual nature of the curve, with the first part completely covering the capabilities of the lower limbs, and the second degree being realized by the extra muscle groups involved. The biomechanical expediency of the future development of the individual technique here requires refining the temporal structure and optimizing the intramuscular synergy so as to minimize the first plateau after the local maximum.

The third competitor demonstrates greatest imperfections both in terms of phase structure and in terms of realisation efficiency, where the difference in the muscle strength test and the global maximum is greater than 125N.

Obviously, this competitor must improve both the structure of the motor action and the parameters of the coefficients of realisation efficiency.

In quantitative terms, the coefficients of the four competitors can be determined as a percentage of the test results.

It is of interest to derive such a coefficient for realisational efficiency on the basis of direct explosion measurement using the Eurofit 1988 standardized test (Eurofit 1988) ^[106] – vertical bounce. This motor task has a qualitatively new characteristic of complexity, in which the level of intramuscular synergy plays a much more decisive role.

By abstracting from the complex morpho-functional relationships in the structure of the musculoskeletal system, based on theoretical mechanics, the creation of models in two- and three-dimensional space allows to study the interconnection and conditionality of the dynamic and kinematic parameters of motion. In this sense, functional-anatomical analysis of the movement of the vertical bounce makes it possible to simplify the model to the participation of four units in the movement - the foot as a whole, the knee joint, the hip joint and the torso with the head as a whole. If we assume that the movement begins with simultaneously created driving moments in the hip, knee and ankle joints, then the maximum moment in the hip joint will exceed that of the knee joint by about 1.5 to 2 times, and the moments of the knee and ankle joints will equal.

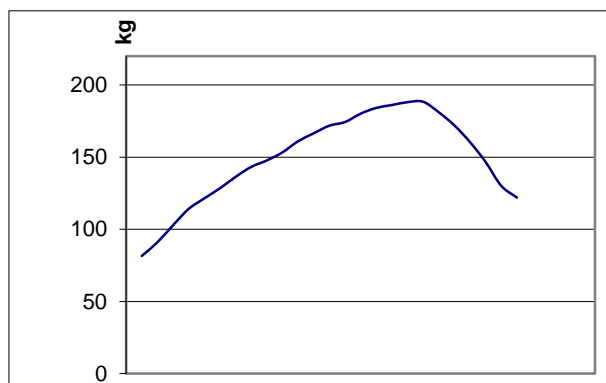


Fig. 51. Control squat and straightening in isokinetic mode with $V = 0,05 \text{ m/s}$ - competitor №3

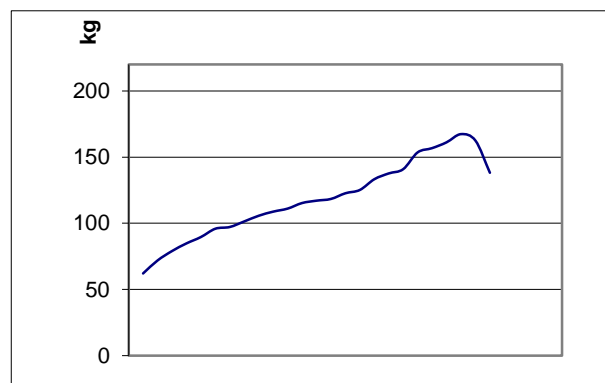


Fig. 52. Control squat and straightening in isokinetic mode with $V = 0,05 \text{ m/s}$ - competitor №4

The movement begins with the extension in the hip joint, as the acceleration of the trunk causes an increase in the load on the lower limbs (and thus the increase in the force on the support) and the extension of the muscles of the knee - extensors, in which forces of elastic deformation occur. This leads to a reduction in the strength of the extensors in the hip joint and, on the other hand, to the maximum force in the knee joint

extensors and ankle flexors, i.e. on the basis of new intramuscular synergy, the biomechanism of extension of the lower limbs and trunk is again included.

The anatomic-functional analysis of this type of movement requires particular attention to the two-particle muscles involved in the different kinematic units - straight thigh muscle, back thigh muscle, three-headed thigh muscle. Stretching (in the squat), the muscles of the posterior group have twice the shoulder in the hip joint than in the knee. At the lower support, the angle of muscle pull in relation to the knee joint reaches 90 degrees and these muscles become synergists of the muscles in the anterior thigh.

Such biomechanical models are not adequate enough for the overall biomechanical structure, but they clearly show the possibilities of interference in the different phases of movement in order to improve the intramuscular synergy.

On this basis, the coefficients of realisation efficiency are calculated relative to the maximum power maxima and the impulses of the force of the support reactions.

B. Structural interconnections (systemic structural construction) - individualization It is a generally accepted fact that the success of the sport and technical actions of throwing techniques in judo depends to a great extent on the "explosiveness" of the attack, which should overcome the speed of the opponent's reaction to the stage of Kake or block his degrees of freedom of movement. The most characteristic feature of judo techniques is their complex coordination structure. Externally manifested explosiveness is actually a complex coordination structure whereby individual muscle groups can work not only in static but also in a retreating mode. However, over the course of a single performance, different muscle groups can perform changing, often antagonistic, functions and modes of operation. In terms of tactical construction of the technical implementation, the first phase is largely limited by the starting power and speed, while the real part - the separation of the partner from the ground has the character of an explosive force. Taking into account these fundamentally different modes of work and intramuscular synergy, in the pedagogical experiment, we tried to refine the training process by dividing into different parts the types of modes of work. The additional motor tasks assigned to the experimental group included independent, purposeful exercises for maximum rapid realisation of the first phase (uchi komi) and the maximum development of the explosive force in the position of the real throw. Performances at sub-maximal speeds of the first phase and maximum explosive force of the actual part (kake) were then performed, gradually increasing the speed of the first phase. The technique was performed against a dummy in order to avoid uncontrolled reactions of the partner. In practice, we provided feedback through video recording, reducing the speed of the first phase in the event that the "explosiveness" of the second phase was broken. The above training regimen was performed in each training session for 5 consecutive days and contained 60 throws in a series of 10, with a rest interval of 3 minutes. This methodology allowed us to reveal the significant influence of psychomotor mechanisms on the way of execution, since in any case, at the beginning of the experiment, the desire to perform more rigorously the overall technique led to lower results than the requirement for an extremely standardized technique of the studied persons with many years of racing practice in all cases (24 judokas from the Bulgarian National Team) with the exception of only one competitor. After the fifth training session, the timing of performance improved statistically significantly with respect to both phases. In fact, from a biomechanical point of view, although it is not singled out as a separate phase in the sports literature, the transition between tsukuri and kake is most important. Therefore, we believe that

the data obtained about shortening the time interval until the second support leg is placed and the partner's separation from the ground is realised are the most essential part of improving the technical mastery of the explosive force's realisation efficiency in the execution of the technique.

BIOMECHANICAL PARAMETERS OF THE COORDINATION STRUCTURE IN THE SPORT OF JUDO

Judo sport offers actions with coordinating complexity in all areas of the evaluation benchmark.

The methodology involves laboratory experiments to evaluate the force structure of locomotor actions. The experiments prove the expected significant differences between “kata” coordination and performances in the conditions of "randori".

Videometric analysis evaluates the stability of temporal, spatial and spatial-temporal structures.

Improvement of the sports-technical mastery of the high-ranked athletes requires obtaining reliable information on the structural interconnections of the coordination structure. The experiments performed prove that the leading system-forming mechanisms (depending on the specific target functions of the motor tasks in the individual phases) are at the heart of the notion of biomechanical expediency of motor actions during nage wasa.

In this sense, the notion of "biomechanical expediency" in the control of the motor apparatus depends on motor tasks in two independent directions of coordination complexity in the various sports disciplines. The concept has one meaning in sports disciplines with a stable structure of the system (e.g. gymnastics, athletics, swimming, etc.), and quite another, in disciplines with a variable external environment (martial arts, sports games, etc.). In the first case, biomechanical appropriateness is functionally defined and mathematical models of efficiency can be developed, while in the second case, coordination capabilities are much more dependent on the efficiency of the compensatory mechanisms. In Judo sport, there exist two vectors of coordination complexity. The problem with quantitative analysis is precisely the uncontrollable nature of the external force field.

Improving the technique of high-ranked judokas faces two major problems. The first is related to the high degree of individualization, and the second is due to the well-established structure of the motor habit, achieved through multiple repetitions in the training process. In practice, it turned out that it is much easier to influence and model the technique of beginner performers. What is more, the elite competitor may need to

make an effort for a partial destruction of the stabilised old structure, before the new one is built.

The pedagogical experiment was conducted with 24 high-grade judoists, all wearing black belt with weight categories within 5 kilograms. At the beginning and end of a one-month period, laboratory experiments were conducted to analyze the function of the support reaction. The motor task required multiple / 10 / performances of Seoi nage against a dummy on a three-dimensional tensometric platform. Two statistically indistinguishable trial groups were constructed, playing the role of control and experimental in the subsequent stages of the study. The indistinguishability criterion was sought based on the values of the compensatory reactions against the force impulse at the critical minimum of the horizontal component of the support reaction. In order to avoid the involvement of preliminary and conscious artificial correction, external force was formed on a random basis.

The next period of the pedagogical experiment included training sessions for the experimental group with the implementation of techniques against reactions exceeding their force minimum values. In the initial experiments this external interference completely destroyed the movement system of some of the studied persons. In our planned experiment, we sought to set impulses at the limit of admissible. We kept this idea in the way of trial and error. The training program included 15 training sessions, each with 10 performances.

The control group performed the same training program, but without the simulated uke reaction.

According to equilibrium stability theory, quantification in its purest form can be obtained on the basis of the minimum value of the force vector in the direction of equilibrium disturbance - point A. On the other hand, the support reaction vector is three-dimensional.

Therefore, the idea of the planned experiment was to execute controlled external effects at different moments in the phase structure, while looking at the compensatory possibilities for ensuring stability of the system.

It can be seen from the obtained results, that in contrast to the general uniformity of the dynamograms in the execution of “kata”, the experiments with a reacting dummy lead to a completely individualised picture in the dynamic development.

Fig.53 and Fig.54 present two typical cases that are significantly different, both in terms of static and dynamic stability. In the first case, at critical F_{min} values of 3 kg, the competitor manages to compensate an external reaction of 10 kg, while in the

second case at critical F_{min} values of 12 kg, the reaction of 5 kg completely destroys the balance of the technique.

Obviously, the refinement of sport and technical skills must be planned in a strictly individual plan. One of the most important features of the technique in high-ranked athletes is the established stability in the movement system. The latter proved to be statistically significant for the compensatory reactions against the controlled external power impulses. The control group remained statistically indistinguishable throughout the study period, both in terms of static and active experiment.

The control group also remained statistically indistinguishable for static experiments. However, on this basis, all the judokas in this group have substantially increased their compensatory capacity to overcome defense reactions.

The results obtained from the pedagogical experiment lead to some significant partial conclusions. First of all, it is the fact that the initial structure of the technique remains unchanged in all studied persons. It is clear that a technique that has been built over the years retains its stable character, and it should be a priori expected that the system will retain its structural interconnections.

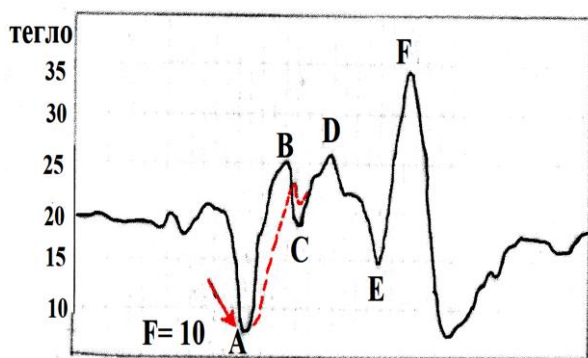


Fig. 53. *Dynamogram of planned active experiment*

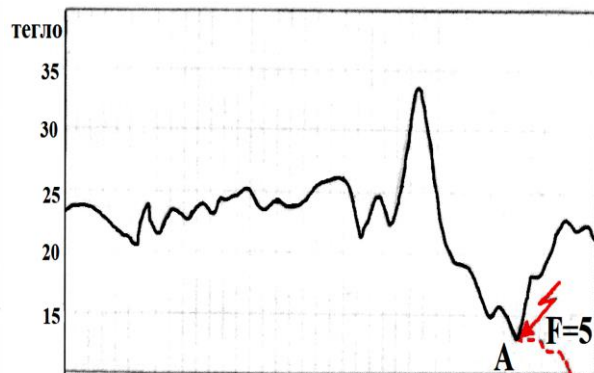


Fig. 54. *Dynamogram of planned active experiment*

At the same time, the hidden compensation mechanisms prove their possibilities for improving the competition technique. The second important for the training work fact is that the changes occurred in the experimental group have pronounced individual characteristics. Moreover, the scope of the effective changes is too wide and indicates that the methodologies contain the potential for improvement along the path of individualisation.

The active experiment opens up completely new opportunities for the development of methods and tools for improving the training process. Conditions are created not only for the adequate modeling of the multidimensional sports and technical structure, but also for the synthesis of sports and technical techniques and "foresight of the future". The pursuit of sports competitive success in conditions of extreme

competition and the compilation of techniques from different styles and schools around the world is unthinkable without the scientific provision and the introduction of advanced innovative methodologies. An interesting, separate direction in this sense is also the possible development of a sports and technical intelligence system on this basis. Bulgarians have proven their genetically grounded qualities in the field of martial arts and power sports. Therefore, it is worth not only, but we are obliged that these natural qualities be supported by sports science.

CONCLUSIONS

1. The analysis of the traditional principles that have historically been underpinning the technical mastery of judo showed that in many cases they are not in line with the principles of modern sports science. The comparative analysis, performed on basic throwing techniques, reveals a much richer structure of scientifically justified "biomechanical expediency" than the "wisdom of the ages" as defined by the sport's creators.
2. The strong traditionalism of Japanese Judo has imposed a rigorous content worldwide for general technical preparation. Forms of study are regulated: uchi komi, kata, kakari-geiko, yakusoku geiko. The established Kyu-dan system could be refined from a biomechanical point of view, but this is hardly necessary due to its already imposed popularity, its use for the worldwide unification of examination standards, etc. Independent importance for the theory and practice of this sport is gained by the discovered new intermediate phase between kuzushi and kake with a direct influence on the success of the attack.
3. Although Eastern philosophical parables illustrating traditional principles do not have universally valid relevance, their widespread popularity and emotional imagery play an essential role in promoting sport, motivating beginners, and nurturing certain psycho-physical qualities.
However, the performed comparative biomechanical analysis leads to the conclusion that the Kyu-dan system has its place only for the cultivation of the common motor culture, mainly in the initial stages of training. In high sportsmanship, with increasing weight, leading are not the general laws, but the individual characteristics of the competitors.
4. Our experiments have proved that the notion of "explosive power" in the context of complex technical actions in judo throws has dimensions in sporting technical skills as it depends on the management of intramuscular synergy in the overall kinematic chain. Integrally, this quality manifests itself as a superposition of the force vectors in the individual kinematic units.
5. It turns out that the target function in individual competitors is achieved through different structural construction of the attack system. The following styles of defense override strategies are mainly distinguished - by kuzushi, by blocking degrees of freedom, or by reducing Uke's response time. Therefore, the quantitative criteria sought for the assessment of sportsmanship have strongly expressed individual characteristics, depending on the strategy for defense overcoming.

6. The experiments conducted outline a new biomechanical aspect of the concept of sports equipment. Biomechanical grounds are revealed for defining a new concept of "tactical composition" for the sports-technical solution of a particular motor task. This concept is most responsible for the optimal use of the individual capabilities and characteristics of a particular competitor. Unlike the tactic that takes into account the protection capabilities, the tactical characteristic of the technique has the meaning of its individual motor quality.
7. The mathematical modeling of the results of the laboratory experiments revealed the multidimensional nature of the force structure of the attack, its complex-composite function with a number of intermediate arguments. All of these results have a strong individual character and do not allow the creation of common models for the improvement of high sporting technical skills.
8. The active experiment performed revealed an unexpected implicit characteristic of the power function. A very important conclusion appeared that static experiments, which are too popular in the sports science literature, do not provide reliable information on the quantitative interpretation of the term "biomechanical expediency" in this kind of locomotion. Hidden for the trainer and the researcher remain the decisive for the end result the compensatory possibilities and the structural interrelations between the external and internal for Torsion force fields.
9. The conducted pedagogical experiment proved the possibility, despite the highly stabilized structure of actions in high-ranked athletes, to achieve a timely effect on the realization efficiency of throwing techniques. This effect, of course, can be achieved under the conditions of a planned active experiment by controlling the effect on the individual singular points / extremes / of the functional curve of the force vector for each particular judo.

RECOMMENDATIONS

1. The Kyu dan system for the improvement of sportsmanship is at the heart of all Eastern martial arts. This idea may reasonably be adapted to other sports disciplines.
2. For the purposes of Judo training, the Kyu dan system has the meaning of a general motor culture and should only be used in the initial training or demonstration stages.
3. Improvement of sports-technical mastery in high-ranking athletes should take into account both the individual characteristics of the particular competitor and the multidimensional nature of the derivative notion of "tactical composition" of technical actions. In this sense, the idea is to develop a new type of Kyu dan system, directly aimed at the reality of racing practice. The biomechanical analysis outlines the possibility of a systematic link between the two schools - the historical traditions and modern sports science.
4. The multidimensional nature of the techniques disclosed in separate performances also defines the new content of the concept of the volume of sports and technical mastery.
5. As biomechanical expediency can be ensured through different coordination structures and compensatory mechanisms, competitors should not only refine more types of techniques but also more ways to perform the same technique.
6. The developed modern methods for video-computer analysis provide new opportunities for sports and technical intelligence. Future larger-scale research would provide an opportunity to formulate individual model characteristics of the attack and defense of both domestic and foreign competitors. This methodology is to be refined with the help of planned laboratory experiments
7. To the extent that the technical implementation of throwing techniques in Judo sports is accomplished within about one second, the sensory control mechanism of the motor apparatus is essential. There are specific opportunities for individual approach in improving the sports equipment.
8. Putting into practice the notion of "tactical composition" of the sports-technical solution of a specific motor task, will allow to the greatest extent

to use the individual capabilities and peculiarities of the individual competitor.

9. The developed technology for evaluation and improvement of the sports and technical skills should be made available to the sports professionals and implemented in the work with the young hopes and elite judo competitors of Bulgaria.

CONTRIBUTIONS

1. On the basis of a thorough biomechanical analysis, significant differences in the biomechanical structure were found between the performances of the judo techniques of the nage waza in competitive conditions and as "kata".

Obviously, the basic judo principles embodied in the Qu Dan system have the necessary meaning in initial training. In high sportsmanship, the individual characteristics of a particular competitor are becoming increasingly important.

2. The performed cluster analysis of the throwing techniques in Judo groups them according to biomechanical quantitative criteria and allows for a science-based refinement of the classical Kyu dan system.
3. The developed system for control and modeling of the external versus "Tory" force field reveals structural interrelationships hidden for classical dynamometric analyzes. It turns out that the notion of "biomechanical appropriateness" should also take into account the extremely high importance of compensatory mechanisms.
4. The developed individualized models for improving the training process were tested with the help of pedagogical experiment. It is proved that regardless of the dynamic stereotype of elite players, it is possible to achieve a timely effect for improving their technical and technical skills.
5. Although not distinguished as a separate phase in the sports literature, the transition between tsukuri and kake is crucial to the formation of the explosive force. This fact should be taken into account when planning training methods and tools.
6. For elite competitors, the multidimensional nature of target functions is also revealed. Despite the classic existence of the first mandatory phase in Judo - Kuzushi, it can be replaced by blocking the degree of freedom of movement or speed characteristics that prevail over Uke's reaction. In this sense, it is appropriate to develop the idea of "tactics" in the "technique" of motion action.

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