DETERMINATION OF SPORTSMEN'S INDIVIDUAL CHARACTERISTICS WITH THE HELP OF MATHEMATICAL SIMULATION AND METHODS OF MULTI-DIMENSIONAL ANALYSIS

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Abstract. *Purpose:* to create the most general mathematical models for determination of sportsmen's individual motor abilities' characteristics and individual features of qualified judo wrestlers' fighting style. *Material:* in the research 22 sportsmen – judo wrestlers of average weight categories (60-81 kg) participated. *Results:* model, on the base of which it becomes possible to determine individual characteristics of sportsmen, has been found. With the help of factorial 4 main factors analysis of judo wrestlers' complex fitness have been marked out. Cluster analysis of judo wrestlers' testing indicators showed that all tested sportsmen could be divided in 3 groups (clusters). *Conclusions:* the received results witness about effectiveness of mathematical simulation methods, as well as methods of factorial and cluster analysis for determination of individual fighting styles of elite judo wrestlers. In their practical work coaches should apply principles of mathematical simulation for determination of individual features of fighting styles and work out methodic of judo wrestlers' individual training.
Key words: judo, style, fight, mathematical model, individualization.

Introduction

At present, the problem of individual approach to sportsmen's training process has been acquiring more and more importance [1; 9; 10; 17; 21; 24]. It is connected with becoming more complex conditions of sport wrestling as well as with reducing of quantity of trainees in groups of primary training and restriction of sport selection possibilities [13; 14; 27; 30; 31; 33]. Besides, main problem of elite sports is impossibility to increase infinitely scope and intensity of training loads. It points at demand in searching new ways of training process's perfection [35; 36]. Одним из таких путей является индивидуализация процесса подготовки в спорте [3; 4; 5; 6; 7; 10; 39].

In different kinds of sports authors distinguish different styles of sport fighting. In martial arts they are [1; 8; 9]:

- Variable fighting style;
- Sportsmen of fast style during long time;
- Power fighting style;

In sport games sportsmen are classified by functions. For example, in basketball they are: "center players", "wingers", and "backs" [3; 4; 36]. In volleyball players are: "forwards of the first rate", "tying runs", "libero" [4; 6; 10]. In cyclic kinds of sports authors distinguish sportsmen with prevailing speed-power qualities, sportsmen with prevailing endurance and sportsmen with better coordination [36].

In sport physiology [23; 26; 29; 32; 34; 38] there is physiological substantiation of sportsmen's individual characteristics. For example sportsmen with prevailing speed-power qualities have more white muscle fibers in muscles' composition. Sportsmen with prevailing endurance have more red muscle fibers [11; 22; 38].

However, as on to day general principles of sportsmen's classification, by individual characteristics of certain qualities' prevalence, has not been worked out.

Purpose, tasks of the work, material and methods

The purpose of the work is *Цель работы* – to create the most general mathematical models for determination of sportsmen's individual motor abilities' characteristics and individual features of qualified judo wrestlers' fighting style.

The methods of the research: analysis of literature sources, methods of determination of sportsmen's functional state (method of variation pulse metering, determination of aerobic workability by treadmill testing), psycho-physiological methods (time of simple response to sound, time of visual motor response of choice, error in reproduction of time intervals), methods of determination of physical condition and physical fitness, determination of

http://dx.doi.org/10.15561/18189172.2015.1207

vestibular stability, methods of mathematical statistic with application of factorial and cluster analysis.

Indicators of variation pulse metering were registered automatically with the help of special device Cardiolab.

In treadmill testing, for registration of functional potentials we used loads of constant value during 3 minutes with speed of track - 8 km.p.h^{-1}. We registered heart beats rate (HBR) after every 10 sec. of work and HBR of restoration to initial level, also after every 10 sec. [6; 8; 9].

Psycho-physiological characteristics were determined with the help of computerized tests [6].

Sportsman's height and body mass were determined as indicators of physical condition. Physical fitness indicators were determined by hand's strength (dynamometry), back strength and high jump from the spot (contact platform).

Vestibular stability was determined with the help of Barany mechanical armchair. Rotation of arm chair was ensured by hand during 20 sec at speed of 2 r.p.sec. $^{-1}$. After every 2 sec. we registered HBR with the help of monitor of continuous heart beats rate registration «Polar». HBR was also registered after rotation during 10 sec., after every 2 sec. and after 90 sec. on completing the work. In the research 22 sportsmen – judo wrestlers of average weight categories (60-81 kg) participated [8; 9].

Results of the research

Mathematical substantiation of interconnection of different sport wrestling styles' formation, considering prevalence of different physical qualities and anthropometric indicators:

According to data of leading specialists in theory and practice of sports [39; 40], mathematical models, based on fundamental laws of physics and mathematics (i.e. borrowed from fundamental sciences) are the most purposeful and versatile. In this connection it is important to search universal mathematical models for determination of sportsmen's individual characteristics.

The conducted analysis of possible manifestation of physical qualities' individual characteristics resulted in determination of the most versatile model of main physical qualities manifestations' interconnection, on the base of which it became possible to determine individual characteristics of sportsmen.

General quantity of work and energy resources can be expressed as follows:

$$A = F \times V \times t \quad (3),$$

Where, A –work, F – force, V – velocity, t – time.

Then general quantity of energy resources can be expressed:

$$A = F \times V \times t \quad (4).$$

Now we apply this formula to tasks of sport training. With equal A (i.e. equal possibility to fulfill external work and general quantity of energy resources) work can be fulfilled mainly at the account of force (F) increase with reducing of velocity (V) and general time of work (t). In this case sportsman will incline to "judo wrestlers of power fighting style": to work of power character. The work can also be fulfilled at the account of increase of velocity (V) with other parameters' reduction. In this case sportsman will have more expressed speed parameters. The work can be ensured by prevalence of power and speed (F×V): power of load and reduction of time for work's fulfillment (t). In this case sportsman will have more expressed speed-power qualities.

The work can also be fulfilled at the account of increasing of general time for its fulfillment (t) with reduction of its power (F×V). In this case sportsman will manifest prevalence of endurance.

Besides, work can be executed at the account of uniform manifestation of all indicators and optimal regulation of these indicators' manifestation in required scope and in required moment of time. In this case sportsman will have expressed coordination abilities.

Naturally, with increasing of fitness level total increase of energy potential occurs as well as increase of potentially possible quantity of executed external work (A). However, individual bents to manifestation and development of different motor abilities are maintained with any energy potential level.

Let us regard possibilities of practical application of this model for determination of sportsmen's individual types and prospects for training process individual planning.

According to the above delivered main physical laws and received by us earlier data, we can determine how sportsmen belong to the mentioned above groups.

According to formula (4) A = F×V×t and received earlier [4; 6; 7; 36] results we can conclude that in *martial arts* [1; 8; 9]: "judo wrestlers of power style" is an evident prevalence of strength indicator (F) and power endurance (F×t); "judo wrestlers of speed fighting style during long time" – prevalence of velocity (V) and speed endurance (V×t); "judo wrestlers of variable fighting style" – prevalence of coordination abilities, i.e. ability of nervous system for regulation of indicators optimal correlation in product (F×V×t).

Physical-mathematic laws of bio-mechanical and physiological parameters' changes in connection with changes of body linear sizes:

One of aspects of theoretical conception of sport training individualization in situational kinds of sports is influence of body length on absolute and relative indicators of different physical qualities.

There are strict mathematical laws of interconnection between body linear sizes and absolute and relative values of strength, oxygen consumption and other physiological and bio-mechanical values [2; 15; 16; 17].

These laws determine indicators of absolute and relative values of physiological and bio-mechanical parameters and influence on human way of life, level of human motor functioning. It is conditioned by dependence of metabolism on body linear sizes and mass. It determines laws of sportsmen's individual distinctions, which shall be taken in consideration in individual planning of loads, and recreational means, diet and way of sportsman's life.

Application of methods of multi-dimensional analysis for determination ofjudo wrestlers' individual fighting styles:

From the point of bio-mechanical and physiological laws theoretical substantiation of individual characteristics shows that it is necessary to apply effective methods of determination of sportsmen's individual abilities. Methods of multi-dimensional analysis: factorial analysis, cluster analysis, combined application of these two methods are rather effective. Combination of factorial and cluster analysis is quick and effective for determination of individual tactic manners of elite judo wrestlers' fighting styles.

At first stage of our research we determined general and individual factorial structures of elite judo wrestlers' fitness. Also we determined their individual fighting styles (cluster analysis). For this purpose we analyzed indicators of complex testing of judo wrestlers, which included the data about psycho-physiological potentials, physical condition and physical fitness. In factorial analysis we excluded indicators, which obviously correlated between each other (in total we selected 15 indicators for factorial analysis) (see table 1).

With the help of factorial analysis (principle component method) we marked out 4 main factors by Cattle's "method scree". For characteristic of every factor we analyzed all of indicators, composing it. First factor (28.6% from total dispersion) (see table 1) included the following indicators: HBR for 2 sec. during rotation on Barany's armchair (r=0.95); HBR on 90th sec. of restoration after standard load on treadmill (r=0.94); HBR just after rotation on Barany's armchair (r=0.93); mean value of HBR (r=0.95); HBR after 10 sec. after rotation on Barany's armchair (r=0.88), HBR in rest (r=0.68).

It should be noted that first factor included indicators vegetative balance level from side of central nervous system (CNS). For example increase of HBR in rest, mean HBR in heart rate, HBR at the beginning and just after rotation on Barany's armchair show activation of sympathetic sector of vegetative nervous system. On the one hand HBR increase in response to rotation witnesses about adequate reaction of vestibular apparatus to rotation, which is accompanied by activation of sympathetic sector of vegetative nervous system. On the other hand, increase of HBR in rest and mean HBR values witness about activation of sympathetic sector of vegetative nervous system. It can reflect insufficient level of sportsmen's functional fitness. However, in our case increase of HBR in rest can be regarded also as quick switching on of muscular energy supply systems in response to start of testing. In this case testing is perceived as irritator, to which organism responds as to muscular work.

So quick switching on of energy supply systems, quick entering the state of "combat readiness" (even with testing in rest state) witness about adequate regulation of vegetative balance by CNS and about high responsiveness of sympathetic sector of vegetative nervous system. Basing on the above delivered the first factor was named "Sympatheticotonia".

Table 1. Rotated matrix of testing indicators' components of elite judo wrestlers (n=22)

Description of indicators	Factor №, contribution in total dispersion			
	1	2	3	4
	28,6%	28,5%	9,4%	9,2%
HBR during rotation on Barany's armchair, bpm $^{-1}$	0,95			
HBR at 90 sec. after rotation on Barany's armchair, bpm $^{-1}$	0,94			
HBR just after rotation on Barany's armchair, bpm $^{-1}$	0,93			
HBR at 10 sec. after during rotation on Barany's armchair, bpm $^{-1}$	0,88			
HBR in rest, bpm $^{-1}$	0,68			
Age, year		-0,92		
Body mass, kg		0,85		
Strength of hand, kg		0,81		
Back power, kg		0,72		
Body length, cm		0,68		
Time of simple response to sound, m.sec.			0,94	
Height of jump, cm			-0,75	
Reproduction of 1 sec. time intervals, error, m.sec.			0,74	
Coefficient of variations in heart rate, m.sec.				0,96
Time of choice reaction, m.sec.				0,64

Second factor (28.5% from total dispersion) included the following indicators: age (r=-0.92), body mass (r=0.85), strength of hand (r=0.81), power of back (r=0.72), body length (r=0.68) (see table 1). It is easy to notice that indicators of the second factor reflect to larger extent level of power abilities, absolute power. Exclusion is indicator of age, which is in second factor with negative correlation coefficient. It can be explained by the fact that younger sportsmen turned out to be stronger. Basing on the received data we named second factor "Strength".

Third factor (9.4% from total dispersion) included the following indicators: mean value of response to sound time (r=0.94), qualification (r=0.80), height of jump (r=-0.75), reproduction of 1 sec. time intervals (r=0.74) (see table 1). Indicators of third factor characterize quickness of reaction and explosive power. However, these indicators entered the factor with sigh, opposite to positive characteristic of these qualities. In this connection we characterized this factor as opposite to development of explosive power and reaction's quickness. Such quality is endurance. In wrestling it is special endurance or speed endurance. That is why third factor was named "Speed endurance".

Forth factor (9.2% from total dispersion) consisted only of two indicators: coefficient of variations in heart rate (r=0.96) and mean value of time of choice response (r=0.64). From the received data we can see that with increasing of activity of para-sympathetic sector of vegetative nervous system quickness of choice reaction slows. It is natural reflection of ability for organism's general relaxation. In this connection the forth factor was named "para-sympatheticotonia".

As we can see in table 1 the highest contributions in total dispersion are made by first and second factors. It is logical to conclude that the most significant in elite judo wrestlers' fitness structure are indicators of nervous system's responsiveness. They reflect in sympatheticotonia and indicators of power abilities. Less significant (though rather important) are indicators of speed endurance and ability to relax. These indicators are expressed in para-sympatheticotonia.

Further we found individual factorial structure of sportsmen's fitness and for this purpose we determined percentage of every factor of each sportsman (see table 2).

In table 1 we can see that in all sportsmen there is different expressiveness of different factors, in spite of practically equal qualification and weight category. It witnesses about presence of substantial individual distinctions that should be manifested in different fighting styles and demand in usage of individual training programs for elite judo wrestlers.

For determination of individual fighting styles we conducted cluster analysis of sportsmen's testing indicators, results of which were comparable with individual factorial values.

Table 2. Examples of individual factors' expressiveness in structure of elite judo wrestlers' fitness (%) and belonging to cluster in cluster analysis (conventional number)

Sportsmen, conventional number	Factor 1– sympatheticotonia	Factor 2 – strength	Factor 3 – speed endurance	Factor 4 –para-sympatheticotonia	Cluster, conventional number
1	88,89	22,22	11,11	22,22	1
2	77,78	11,11	100	77,78	2
3	66,67	33,33	33,33	33,33	2
4	33,33	77,78	88,89	11,11	3
5	55,56	88,89	55,56	44,44	3
6	22,22	44,44	66,67	55,56	2
7	100	100	77,78	66,67	1
8	11,11	55,56	22,22	88,89	3
9	44,44	66,67	44,44	100	3

Cluster analysis of testing indicators of judo wrestlers showed that all tested are distributed into 3 groups (clusters) (see table 2, fig.1). Clusters were determined by degree of sportsmen's "similarity" as per indicator of complex testing (see fig.1).

As we can see in diagram (see fig.1) first cluster included sportsmen №№ 1 and 7, second - №№ 2,3,6 and third cluster included sportsmen №№ 5,6,9,4,1.

For characterizing of sportsmen of every cluster we analyzed individual factorial models of sportsmen (see table 2). We found that in first cluster sportsmen (1 and 7) the first factor was the most expressed. They have high responsiveness of nervous system, especially sympathetic sector of vegetative nervous system. Besides, they have moderately expressed second factor (see table 2, fig.2).

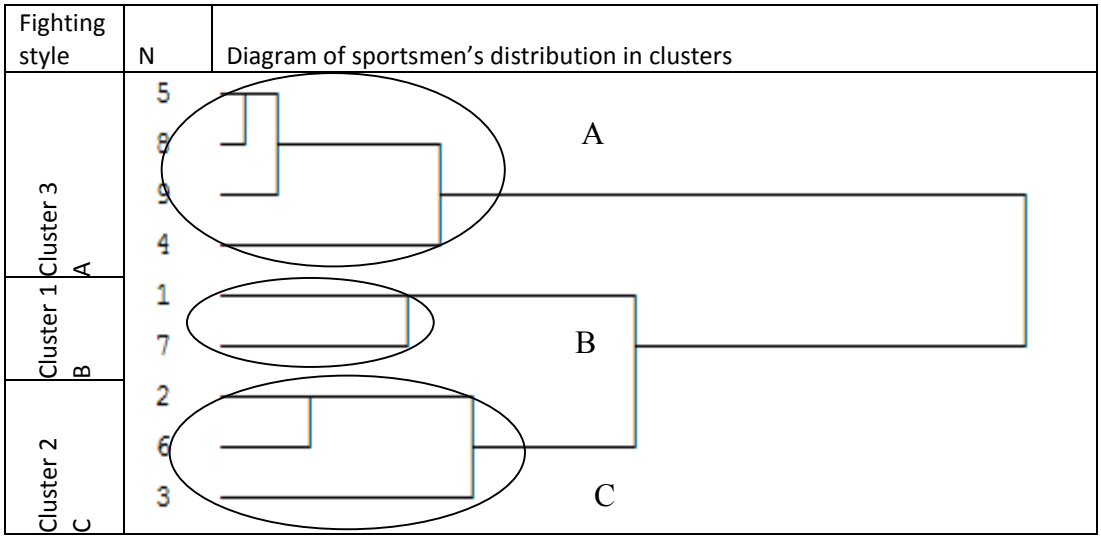

Fig. 1. Diagram of elite judo wrestlers' distribution in clusters (9 sportsmen were taken as examples): A – judo wrestlers of power fighting style; B – judo wrestlers of variable fighting style; C – judo wrestlers of speed (quick) during long time fighting style; N – number of sportsman.

Sportsmen of second cluster have third factor as the most expressed (factor, characterizing special or speed endurance, see table 2, fig. 2) in combination with activity of para-sympathetic sector of vegetative nervous system (with forth factor, see table 2, fig. 2).The sportsmen of third cluster have prevalence of second factor ("strength") in combination with development of third or forth factors (see table 2, fig.2). According to factors, prevailing in sportsmen of every cluster, the formed judo wrestlers' groups were characterized as «B» (1st cluster), «C» (2nd cluster) and «A» (3rd cluster).

1 2

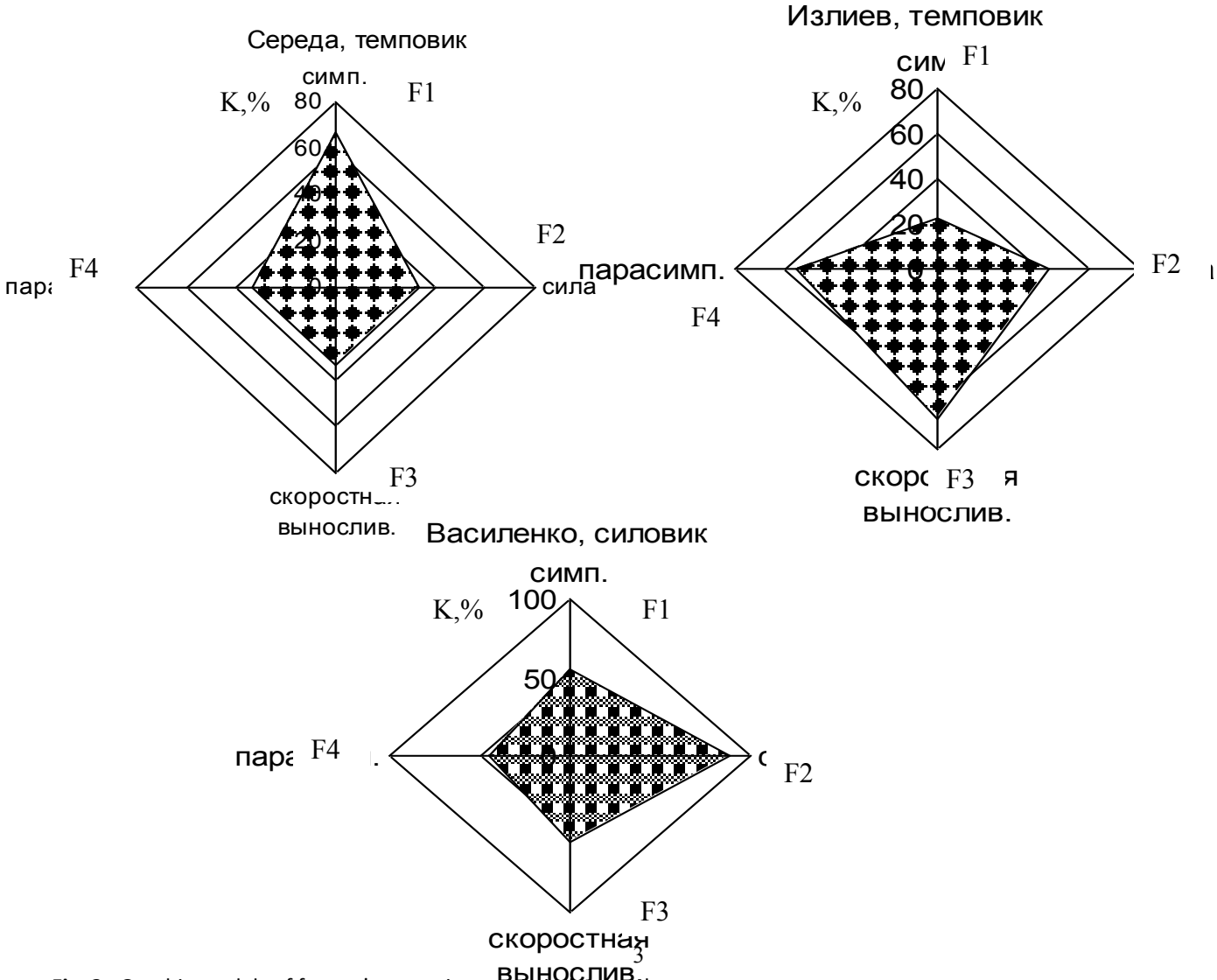

Fig. 2. Graphic models of factors' expressiveness in judo wrestlers:
F1 –factor 1, "Sympatheticotonia"; F2 – factor 2– "Strength"; F3 – factor 3 – "Speed endurance"; F4 – factor 4, "Para-sympatheticotonia"; K – individual expressiveness of factor, %;
1 – Judo wrestlers - B»; 2 – judo wrestlers - «C»; 3 – judo wrestlers - «A»

Discussion

The authors regarded problems of bio-mechanical conditioning of individual distinctions in the light of biological distinction of live organisms with different body sizes [17; 19; 20; 24]. Surely, it is impossible to extrapolate these laws on human being. However, existing of such laws determined individual distinctions of people with different anthropometric parameters.

Nevertheless, the presented in the work theoretical principles and experimental data are confirmed by researches of many authors [1; 36; 39]. Results of these researches show that with increasing of body length all relative values of indicators of vitally important functions reduce. It is reflected in indicator of physiological and pedagogic testing, indicators of visual-motor reaction and general endurance of tall sportsmen [1, 4; 5; 6; 7].

Basing on above mentioned principles we can explain the fact of presence of individual distinction of people with different anthropometric parameters as follows: with increasing of linear body size time of reaction increases as well as time of muscle's contraction and relaxing. It results in reduction of movements' frequency, in slowing of metabolism. It leaves its mark on the following: specificities of temper (typological properties of nervous system) and "comfort" mode of person's life; speed of recreation and time for super-compensation's manifestation. It results in demand in individual approach to construction of training process (quantity of exercises' repetitions, building of

micro-cycles and meso-cycles, value and character of loads and rest).

Our researches are also in concordance with the works, devoted to interconnection of strength, quickness and endurance. These physical properties are in opposite correlations and condition manifestation of sportsmen's individual characteristics, in respect to specificity of sport specialization and competition functioning [12; 37].

In our work we have offered application of multi-dimensional analysis method for determination of individual fighting styles at competitions. Methods of multi dimensional analysis are often used for combining of testing indicators in groups as per their correlations (factorial analysis). Besides, for combining of tested in groups we used cluster and discriminant analysis. For example, in works [4; 5; 6; 7] algorithms for determination of sportsmen's individual characteristics in game kinds of sports, which determine their roles, and possible interaction in training functioning are rendered.

However, the offered in this work algorithm for determination of individual fighting styles of elite judo wrestlers, is quite a novelty. From this point of view the conducted research opens new prospects of studying laws of formation and manifestation of sportsmen's individual features.

Conclusions

1. Results of mathematical simulation of different physical qualities' interconnection permit to make the following conclusions: quantity of sportsman's energy resources (amount of executed external work) can be expressed by formula. This formula reflects: proportionality of the executed work to product of force, velocity and time of the work's fulfillment; individual peculiarities of possibility of sportsmen's motor qualities development in different kinds of sports (as prevalence of one or several co-factors); in every kind of sports sportsmen can be divided into groups, differ by correlation of co-factors.

2. Mathematical simulation of changes of functional potentials' absolute and relative indicators witnesses about existence of strict mathematical dependences. These dependences explain change of physiological and bio-mechanical indicators with changing of sportsmen's anthropometric parameters.

3. With the help of factorial analysis by principle component method we marked out 4 main factors: the first (28,6%) was named "sympatheticotonia"; the second (28,5%) – "Strength"; the third factor (9.4%) was "Speed endurance" and the forth (9.2%) was named para-sympatheticotonia".

4. We have found individual factorial structure of sportsmen's fitness. Cluster analysis of judo wrestlers' testing indicators showed that all tested are divided in three groups (clusters). According to prevailing factors the sportsmen of every cluster were characterized as: «B» (1st cluster), «C» (2nd cluster), «A» (3rd cluster).

5. The received results witness about effectiveness of mathematical simulation methods, factorial and cluster analysis, applied for determination of individual fighting styles of elite judo wrestlers. Principles of mathematical simulations shall be used in judo coaches' practical work for determination of individual fighting styles and for working out of judo wrestlers individual training programs.

Conflict of interests

The authors declare that there is no conflict of interests.

References:

1. Ananchenko KV, Grin' LV. Analiz sorevnovatel'noj i trenirovochnoj deiatel'nosti dziudoistov vysokoj kvalifikacii na etape specializirovannoj bazovoj podgotovki [Analysis of competition and training functioning of elite judo wrestlers at stage of specialized basic training]. *Pedagogics, psychology, medical-biological problems of physical training and sports* 2006;9:8–13. (in Russian)
2. Bogdanov KIu. *Fizik v gostiakh u biologa* [Physicist's visiting biologist], Moscow: Science; 1986. (in Russian)
3. Kozina ZhL. Nauchno-metodicheskie puti individualizacii uchebno-trenirovochnogo processa v sportivnykh igrakh [Scientific-methodic ways of training process individualization in sport games]. *Problemy i perspektivy razvitiia sportivnykh igr i edinoborstv v vysshikh uchebnykh zavedeniiakh,* 2005;1:188-189. (in Russian)
4. Kozina ZhL. Analiz i obobshchenie rezul'tatov prakticheskoj realizacii koncepcii individual'nogo podkhoda v trenirovochnom processe v sportivnykh igrakh [Analysis and generalization of results of practical realization of individual approach conception in training process of sport games]. *Fizicheskoe vospitanie studentov tvorcheskikh special'nostej* 2009;2:34–47. (in Russian)
5. Kozina ZhL, Sliusarev VF, Volkov IeP. Efektivnist' zastosuvannia netradicijnoi formi autogennogo trenuvannia dlia vidnovlennia pracezdatnosti basketbolistiv [Effectiveness of non-traditional form of

autogenic training for recreation of basketball players; workability]. *Pedagogics, psychology, medical-biological problems of physical training and sports* 2001, vol.14, S. 8–15. (in Ukrainian)

6. Kozina ZhL. *Sistema individualizacii podgotovki sportsmenov v igrovykh vidakh sporta* [System of individualization of sportsmen's training in game kinds of sports], Lambret Academic Publishing Russia; 2011. (in Russian)
7. Kozina ZhL. Rezul'taty razrabotki i prakticheskogo primeneniia algoritma sistemnogo analiza v nauchnykh issledovaniiakh v oblasti sportivnykh igr [Results of development and practical application of systemic analysis algorithm in scientific researches in the sphere of sport games], *Slobozhans'kij naukovo-sportivnij visnik* 2006;9:157–165. (in Russian)
8. Kozina ZhL. Matematicheskoe modelirovanie individual'nykh osobennostej sportsmenov [Mathematical simulation of sportsmen's individual characteristics]. *Pedagogics, psychology, medical-biological problems of physical training and sports* 2008;4:56–59. (in Russian)
9. Kozina ZhL, Demura I. Rezul'tati zastosuvannia metodiv matematichnogo modeliuvannia dlia viznachennia individual'nikh taktichnikh maner vedennia sutichki u dziudoistiv visokogo klassu [Results of mathematical simulation methods' application for determination of individual tactic fighting styles of elite judo wrestlers]. *Teoriia ta metodika fizichnogo vikhovannia* 2010;7:17–38. (in Ukrainian)
10. Kozina ZhL, Ermakov SS, Pogorelova AO. Metodologicheskie osnovy opredeleniia individual'nykh osobennostej volejbolistok na etape specializirovannoj bazovoj podgotovki [Methodological principles of determination of female volleyball players' individual features at stage of specialized basic training]. *Physical education of students* 2012;3:53–61. (in Russian)
11. Kozina ZhL, Ostroushko SS, Riepko OO, Polishchuk SB, Popova AV, Chuprina OI. Osoblivosti sprijniattia ekstremal'noi situacii liudej z riznimi tipologichnimi osoblivostiami vishchoi nervovoi diial'nosti [Specificities of extreme situations' perception by people of different typological features of supreme nervous functioning]. *Fizicheskoe vospitanie i sport v vysshikh uchebnykh zavedeniiakh,* 2015;2:79–85. (in Russian)
12. Repko EA, Kozina ZhL, Zhigaeva MV, Mavrodi SA, Kozin SV. Skorostno-silovaia podgotovka v skalolazanii na osnove analiza razvitiia fizicheskikh kachestv elitnykh sportsmenov [Speed-power training in rock climbing on the base of analysis of physical qualities' condition of elite sportsmen]. *Fizicheskoe vospitanie i sport v vysshikh uchebnykh zavedeniiakh* 2014;2:183–191 (in Russian)
13. Iagello V, Iagello M, Kozina ZhL. Profil' stroeniia tela muzhchin, zanimaiushchikhsia bejsbolom [Profile of body composition of men, practicing baseball]. *Physical education of students* 2012; 6:140–143. (in Russian)
14. Jagiello Wladyslaw, Kozina ZhL, Jagiello Marina. Somatic aspects of sports championship in taekwon-do ITF. *Physical Education of Students*, 2015;4:51-55. http://dx.doi.org/10.15561/20755279.2015.0408
15. Alexander RMcN. Biophysical problems of small size in vertebrates. *Unknown Journal – Requested journal to be added to ULPD*, 1996;69:3–14
16. Alexander RMcN. Simple models of human locomotion. *Unknown Journal – Requested journal to be added to ULPD,* 1997;2:129–135.
17. Alexander RMcN. A minimum energy cost hypothesis for human arm trajectories. *Biological Cybernetics,* 1997;76:97–105.
18. Alexander RMcN. Muscle geometry. *Journal of Physiology*, 1998;512:315–315.
19. Alexander RMcN. Biomechanics: Stable Running, *Current Biology*, 2007;17(7):253–255.
20. Alexander RMcN. Biomechanics: Leaping lizards and dinosaurs, *Nature*, 2012;4:100-110.
21. Kozina ZhL, Sobko IN, Kolomiec NA, Jagiełło Władysław, Jagiełło Marina. Allocation algorithm for athletes group to form tactical tasks in game team sports using the methods of multivariate analysis (illustrated women Ukrainian team basketball with hearing impairments). *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2014;12:40-48. http://dx.doi.org/10.15561/18189172.2014.1208
22. Aluja A, Blanch A, Blanco E, Balada F. Affective modulation of the startle reflex and the reinforcement sensitivity theory of personality: The role of sensitivity to reward. *Physiology & Behavior*, 2015;138:332–339. http://dx.doi.org/10.1016/j.physbeh.2014.09.009.
23. Boag S. Personality assessment, "construct validity" and the significance of theory. *Personality and Individual Differences*, 2014;1:24–30. http://dx.doi.org/10.1016/j.paid.2014.12.039.

24. Brandwood A, Jayes AS, Alexander RMcN. Incidence of healed fracture in the skeletons of birds, molluscs and primates, *Journal of Zoology*, 2009;208(1):55–62.
25. Jurow IA. Empirical research of sport individuality. *Experimental psychology*, 2012;5(3):108–114.
26. Kozina ZL, Iermakov SS. Analysis of students' nervous system's typological properties, in aspect of response to extreme situation, with the help of multi-dimensional analysis. *Physical Education of Students*, 2015;3:10-19. http://dx.doi.org/10.15561/20755279.2015.0302
27. Kozina ZhL, Prusik Krzysztof, Prusik Katarzyna. The concept of individual approach in sport. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2015;3:28-37. http://dx.doi.org/10.15561/18189172.2015.0305
28. Mutter F, Pawlowski T. Role of models in sports – Can success in professional sports increase the demand for amateur sport participation? *Sport Management Review*, 2014;17(3):324–336. http://dx.doi.org/10.1016/j.smr.2013.07.003
29. Pot N, Schenk N, van Hilvoorde I. School sports and identity formation: Socialisation or selection*? European Journal of Sport Science,* 2014;(5):484–491. http://dx.doi.org/10.1080/17461391.2013.873483
30. Podrigalo LV, Galashko MN, Galashko NI, Prusik Krzysztof, Cieslicka Miroslawa. Research of hands' strength and endurance indications of arm sport athletes having different levels of skills. *Physical Education of Students*, 2014;2:37–40. http://dx.doi.org/10.6084/m9.figshare.907140
31. Rowe N.F. Sporting capital: a theoretical and empirical analysis of sport participation determinants and its application to sports development policy and practice. International Journal of Sport, Policy and Politics, 2014, 7 (1):43–61. http://dx.doi.org/10.1080/19406940.2014.915228
32. Reginald Xi Wang. *Self-determination and framing. An Interactionist Perspective on Self-Determination Theory: Place for Framing in Autonomy Support*, New York University; 2013.
33. Shiloh S, Salton E, and Sharabi D. Individual differences in rational and intuitive thinking styles as predictors of heuristic responses and framing effects. *Personality and Individual Differences*, 2002;32:415–429.
34. Stanovich KE, and West RF. Individual differences in framing and conjunction effects. *Thinking and Reasoning,* 1998;4:289–317.
35. Tavana M, Azizi F, Azizi F, Behzadian M. A fuzzy inference system with application to player selection and team formation in multi-player sports. *Sport Management Review,* 2013;16(1):97–110. http://dx.doi.org/10.1016/j.smr.2012.06.002
36. Kozina Zhanneta, Sobko Irina, Bazulyk Tatyana, Ryepko Olena, Lachno Olena, Ilintskaya Anna. The applying of the concept of individualization in sport. *Journal of Physical Education and Sport*, 2015(2),172 – 177. http://dx.doi.org/10.7752/jpes.2015.02027
37. Kozina Zh, Ryepko OA, Prusik Krzysztof, Prusik Katarzyna, Cieślicka Mirosława. Theoretical-methodological study of development of power-speed in climbing. *Physical education of students*, 2014;1:27–33. http://dx.doi.org/10.6084/m9.fgshare.903690
38. Thorpe SKS, Crompton RH, and Alexander RMcN. Orangutans use compliant branches to lower the energetic cost of locomotion, *Biology Letters*, 2007;1:148-155.
39. Tyshchenko VA. Methodological foundations of the modern training system of skilled handball players. *Pedagogics, psychology, medical-biological problems of physical training and sports* 2014;1:76–79. http://dx.doi.org/10.6084/m9.figshare.894395
40. Yermakova TS. Individualization of forming health culture in schoolchildren of Polish schools. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2015;1:29-33. http://dx.doi.org/10.15561/18189172.2015.0106

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Cite this article as: Kozina Z.L., Jagiello W., Jagiello M. Determination of sportsmen's individual characteristics with the help of mathematical simulation and methods of multi-dimensional analysis. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2015;12:41–50.
http://dx.doi.org/10.15561/18189172.2015.1207

The electronic version of this article is the complete one and can be found online at: http://www.sportpedagogy.org.ua/html/arhive-e.html

Received: 25.08.2015
Accepted: 29.08.2015; Published: 10.09.2015