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Technique of the biomechanical analysis of execution of upward jump piked

Nataliya ***Batieieva***[1]
Petro ***Kyzim***[2]

[1]*Kiev National University of Culture and Arts, Kiev, Ukraine*
[2]*Kharkov State Academy of Physical Culture, Kharkov, Ukraine*

Purpose*: the biomechanical analysis of execution of upward jump piked.*

Material & Methods: *the following methods of the research were used: theoretical analysis and synthesis of data of special scientific and methodical literature; photographing, video filming, biomechanical computer analysis, pedagogical observation. Students (n=8) of the chair of national choreography of the department of choreographic art of Kiev national university of culture and art took part in carrying out the biomechanical analysis of execution of upward jump piked.*

Results: *the biomechanical analysis of execution of upward jump piked is carried out, the kinematic characteristics (way, speed, acceleration, effort) of the general center of weight (GCW) and center of weight (CW) of biolinks of body of the executor are received (feet, shins, hips, shoulder, forearm, hands). Biokinematic models (phases) are constructed. Power characteristics are defined – mechanical work and kinetic energy of links of legs and hands at execution of upward jump piked.*

Conclusions: *it is established that the technique of execution of upward jump piked considerably influences the level of technical training of the qualified sportsmen in gymnastics (sports), in aerobic gymnastics (aerobics), diving and dancing sports.*

Keywords: *biomechanical analysis, technical training, upward jump piked, a sportsman (an executor).*

Introduction

The development of modern dancing sports, gymnastics, and jumps in water causes the need of constant improvement of all parties of training of the qualified sportsmen, including technical. Traditional methods of technical training in these sports do not meet modern requirements of skill level of sportsmen [2; 9; 10; 21].

The analysis of scientifically-methodical literature confirms perspective in training of coaches-choreographers of the directions of choreography (national, classical, modern), and also in the theory and practice of many sports (artistic and aerobics gymnastics (aerobics), diving, acrobatic rock'n'roll but other). This analysis also confirms the lack of researches, in which influence of the biomechanical analysis of basic movements on improvement of technical training of the qualified sportsmen, was considered.

Communication of the research with scientific programs, plans, subjects

The research was conducted in implementation of the complex scientific project for 2015–2017. "Theoretic-methodical bases of formation of culture of physical health at student's youth" (number of the state registration is 0115U0066767).

The purpose of the research:

the analysis of biomechanical characteristics of the performance of upward jump piked.

Research tasks:

1. To define perspective of technical training of the qualified sportsmen of dancing sports, gymnastics, jumps in water.

2. To define biomechanical characteristics of the performance of upward jump piked.

Material and Methods of the research

Methods of the research became: theoretical analysis and synthesis of data of special scientifically-methodical literature; photographing, video filming, biomechanical computer analysis, pedagogical observation.

Students (n=8) of the chair of national choreography of the faculty of choreographic art of Kiev national university of culture and art took part in carrying out the biomechanical analysis of performance of upward jump piked. Video filming, on the basis of which have received time-lapse performance of upward jump piked , was used in our researches. The essence of video filming was that knowing the frequency of shots (the accelerated shooting – 59 shots/s) and passing of way of the general center of mass of bio-links (foot, shin, hip, shoulder, forearm, hand) (in time from 1–3–5.... shots etc.) necessary characteristics were calculated: trajectory, speed, acceleration, effort.

The mathematical model of creation of trajectory of the center of weight (CW) of links of leg is used in the work: feet, shins, hips; arms: shoulder, forearm, hand [2; 8].
1. Creation of segment of passing of CW of body links:
Lex. – length of body of the executor;
l(r) –linear size of link of body.

$$l(r) = \frac{l_{CW\ body\ links} \times L_{ex.(linear)}}{L_{ex.(photogram)}}, \quad (1)$$

where l_{CW} – reference point size on the photogram;
Lex. (executor) – real linear size of reference point;
l(r) – real linear size of CW of body links.

2. Definition of the way *S* passing body links in the area of segment:

$$S = \frac{\pi r n}{180}, \quad (2)$$

where π – 3,14;
r –radius of CW of body links (segment);
n –angle of passing of CW of body links in the area of segment.

3. Determination of speed of movement of CW of body links on time (V_F):

$$V_k = \frac{S}{t} \quad (3)$$

4. Definition of acceleration of movement of CW of body links:

$$\alpha = \frac{V^2}{r} \quad (4)$$

5. Definition of acceleration of linear movement of CW of body links:

$$\alpha = \frac{V_1 - V_0}{t};\ \alpha = \frac{V_2 - V_1}{t};\ \alpha = \frac{V_3 - V_2}{t} \quad (5)$$

6. Definition the effort (*F*) made for CW of body links in time (in shot):

$$F = m(\alpha - g), \quad (6)$$

where m mass of link of body;
a – acceleration of movement of CW of body links;
g = 9,8 m·s^{-2}.

The size *dF/d*j is used in the work – difference of value of effort, which is attached to the body GCW in the following shots to previous, which were divided into difference of bending-extension of knee-joint of the sportsman (executor) [3].

Results of the research and their discussion

The creation of performance of upward jump piked has the sequence: running start, jumping on support (floor), take-off, unsupported movement (flight), landing. We carried out the biomechanical analysis of performance of upward jump piked in take-off phases, unsupported movement (flight).

The certain phases of performance of upward jump piked by us on the basis of its biomechanical analysis (tab. 1).

It is established that the spending time for performance of upward jump piked equals 0,63 s. From them:

1) 0,27 s – the general actions of body links: swing movements of hands, actions of links of legs (take-off from support-floor) for removal of GCW of body in the unsupported movement;

2) 0,03 s – the vertical unsupported movement of all body links;

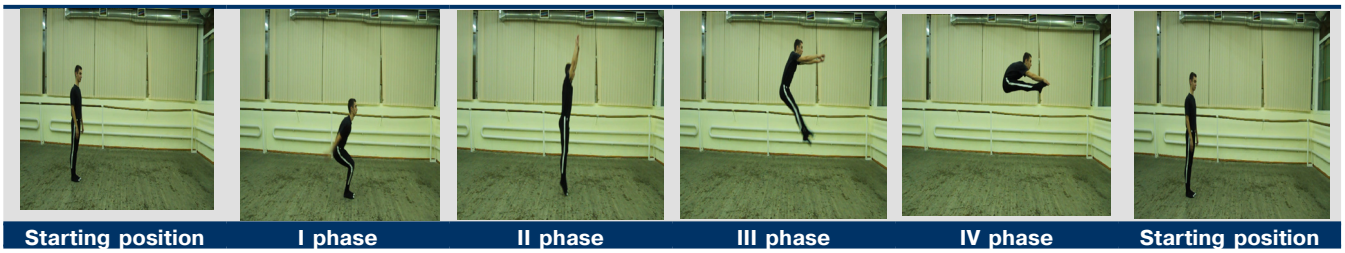
3) 0,33 s – links of legs and hands on segment performed by upward jump piked.

We defined the biomechanical kinematic characteristics of links of hands, legs at take-off from optimum pose and their actions in the unsupported movement when performing upward jump piked for the solution of tasks of the research: way, speed, acceleration, effort (pic. 2–13).

Take-off by legs from support is followed by swing movements of hands which give kinetic energy for acceleration of GCW of body of breakaway from support and increase efficiency of knee stretching.
In figures 2–5 biomechanical characteristics of the movement of CW of links of hands are provided when performing upward jump piked.

The data of biomechanical characteristics of the movement of CW of links of arms when performing upward jump piked (t – 0,238 s):

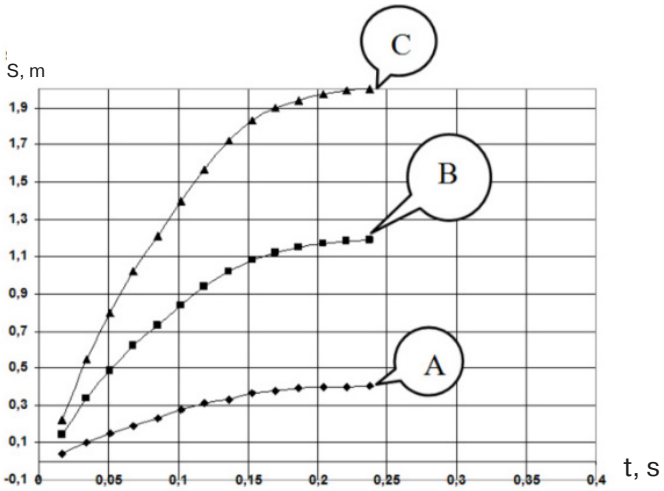
S: shoulder – 0,4 m; forearm – 1,19 m; hand – 2,04 m.
V: shoulder – 0,96 m·s^{-1}; forearm – 3,12 m·s^{-1}; hand – 4,83 m·s^{-1}.



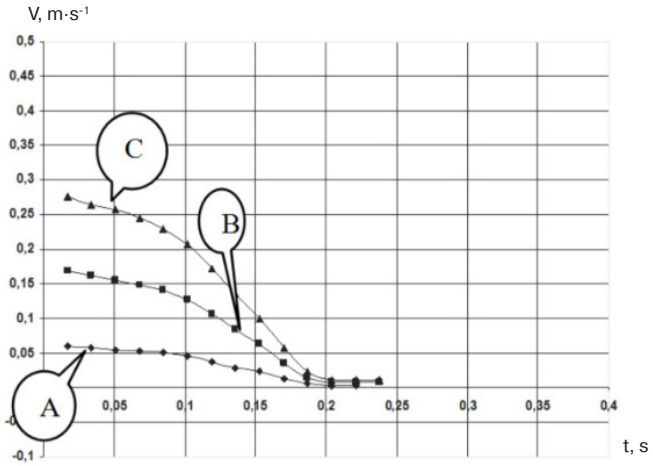
Pic. 1. The main phases of performance of upward jump piked

Table 1
Phases of performance of upward jump piked

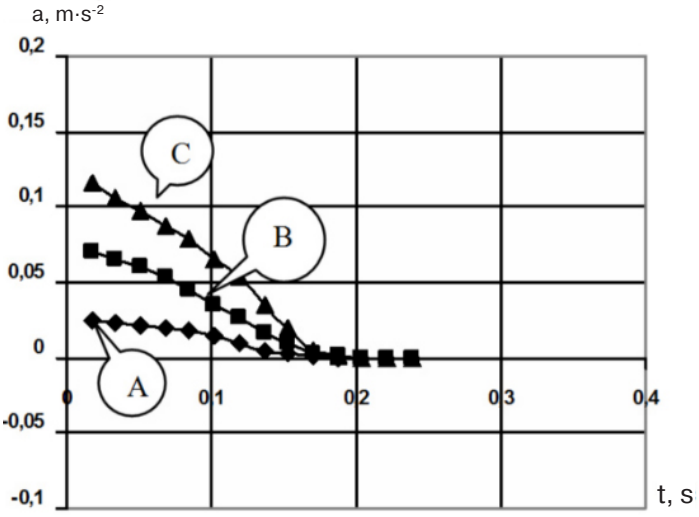
Phase	Characteristic	Time of performance, s
I	The optimum pose to start performance of upward jump piked	0–0,63
II	Outlet in the unsupported movement	
III	Performance of upward jump piked	
IV	The maximum height of body in unsupported movement when performing upward jump piked	



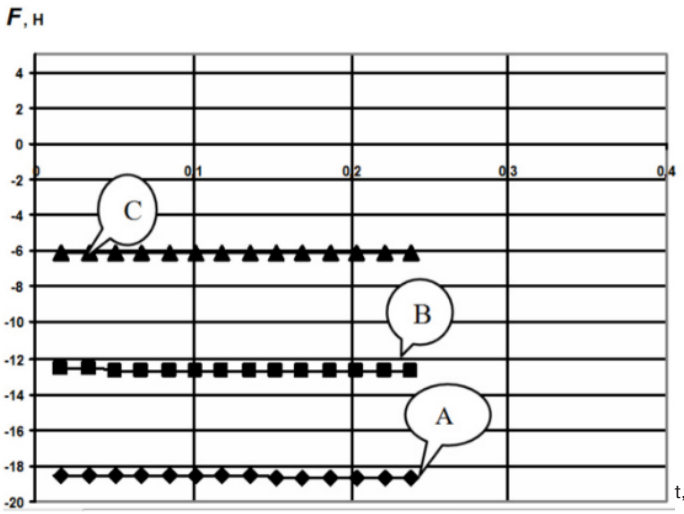
Pic. 2. Schedule of way (*S*) of CW of links of arms



Pic. 3. Speed (*V*) of CW of links of arms

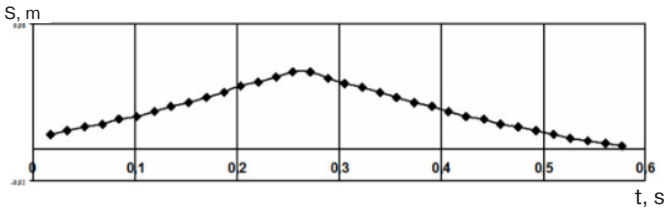


Pic. 4. Acceleration (*a*) of CW of links of arms

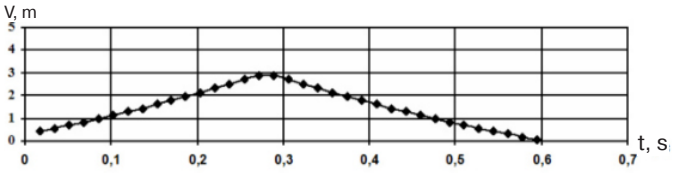


Pic. 5. Effort (*F*) is made for CW of links of arms

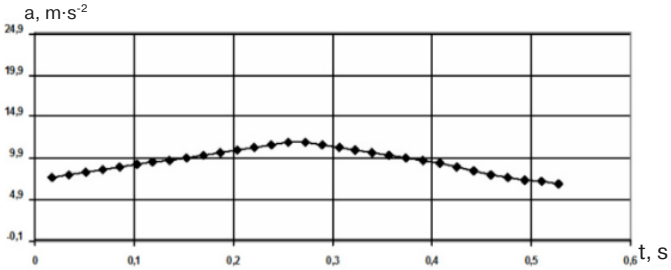
Note: *A – trajectory of the movement, speed, acceleration, effort of CW of* ***shoulder;*** *B – trajectory of the movement, speed, acceleration, effort of CW of* ***forearm;*** *C – trajectory of the movement, speed, acceleration, effort of CW of* ***hand****.*



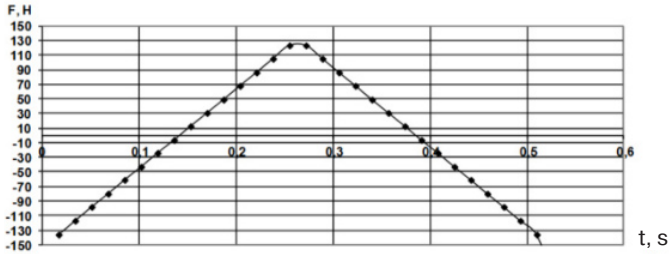
Pic. 6. The schedule of trajectory of way (*S*) of GCW of body when performing upward jump piked



Pic. 7. The speed (*V*) of GCW of body when performing upward jump piked



Pic. 8. Acceleration (*a*) of GCW of body when performing upward jump piked



Pic. 9. The effort (*F*) made for GCW of body when performing upward jump piked

a: shoulder – 6,4 m·s^{-2}; forearm – 24,3 m·s^{-2}; hand – 35,3 m·s^{-2}.
F: shoulder – –6,4 H; forearm – –18,8 H; hand – –15,8 H.
In phase of take-off, leg stretching distances of GCW of body of the sportsman (executor) from the place of support (pic. 6–9)

Take-off in jump from support provides acceleration of GCW of body of the sportsman (executor) and moves him in the direction of the unsupported movement.

The optimum pose of the beginning of take-off of legs (extension of knee-joints – 84°) is defined out of which the sportsman brings body in the unsupported movement.

The biomechanical kinematic characteristics of GCW of the sportsman's body when performing upward jump piked:

Way ***(S)*** of GCW of body of the sportsman – 0,75 m:

– in phase of take-off of legs from support – 0,33 m,
– in the vertical unsupported movement – 0,09 m,
– in the unsupported movement of performance of upward jump piked – 0,33 m.

Average speed ***(V)*** of GCW of body of the sportsman – 1,54 m·s^{-1}.
Average acceleration ***(a)*** of GCW of body of the sportsman – 9,8 m·s^{-2}.
Average effort ***(F)*** of GCW of body of the sportsman – 12,33 H.
Joint actions of links of body of the sportsman in the phase of take-off and the vertical unsupported movement gave opportunity of performance of upward jump piked in the unsupported movement (the III–IV phases; pic. 10–13).

We have numerical value of effort of CW of links of legs with the sign minus on the schedule (pic. 13). It indicates that the counteraction of force of attraction is directed towards effort of CW of links of legs [1]. The growth of efforts **(F)** of the center of mass of **foot** and the center of mass of **shin** differs by the direction from growth of effort **(F)** of the center of mass of **hip.**

The average data of biomechanical characteristics of the movement CW of links of legs when performing upward jump piked in the unsupported movement up:

S: hip – 0,18 m; shin – 0,6 m; foot – 0,92 m.
V: hip – 1,03 m·s^{-1}.; shin – 3,29 m·s^{-1}; foot – 5,1 m·s^{-1}.
a: hip – 5,79 m·s^{-2}.; shin –18,03 m·s^{-2}; foot – 28,06 m·s^{-2}.
F: hip – –68,5 H; shin – 48,6 H; foot – 44,3 H.

On the basis of the received kinematic characteristic,s we defined power characteristics of links of legs and hands – mechanical work ($A = \int_0^s F_s dS$) and kinetic energy ($E_k = \frac{mV^2}{2}$) [1] when performing upward jump piked in the unsupported movement up.

Mechanical work of swing actions of hands of the sportsman when performing upward jump piked equals: *A shoulder* – –2,56 J; *A forearm* – –22,37 J; *A hands* – –32,23 J.

Kinetic energy of links of hands performed by upward jump piked to the top point up equals: *E shoulder* – 0,87 J; *E forearms* - 6,33 J; *E hands* – 23,32 J.

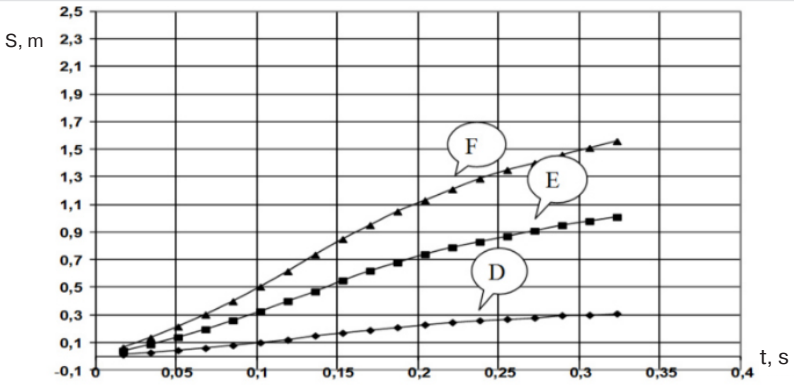
Mechanical work of links of legs of the sportsman in take-off phase from support when performing upward jump piked equals: *A* – 149,5 J.

Kinetic energy of links of legs in take-off phase from support equals: *E* – 74,7 J.

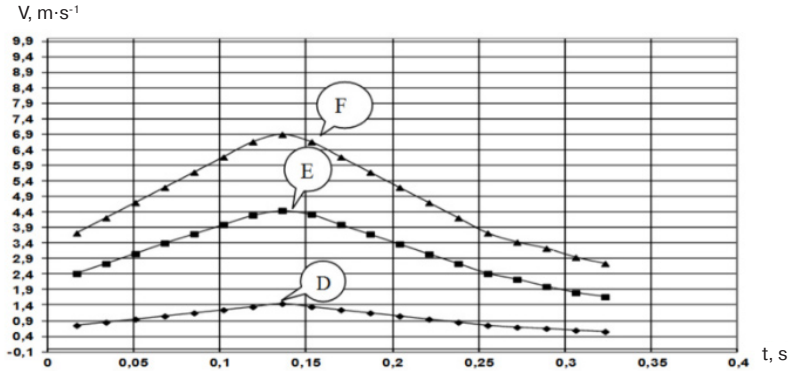
Mechanical work of removal of links of legs to the top point equals: *A feet* – 65,6 J; *A shins* – 55,5 J; *A hips* – 21,78 J.
Kinetic energy of links of legs performed by upward jump piked to the top point equals: *E feet* – 32,77 J; *E shins* of – 34 J; *E hips* – 8,02 J.

By results of the research, we can claim that power characteristics of performance of upward jump piked have such values:

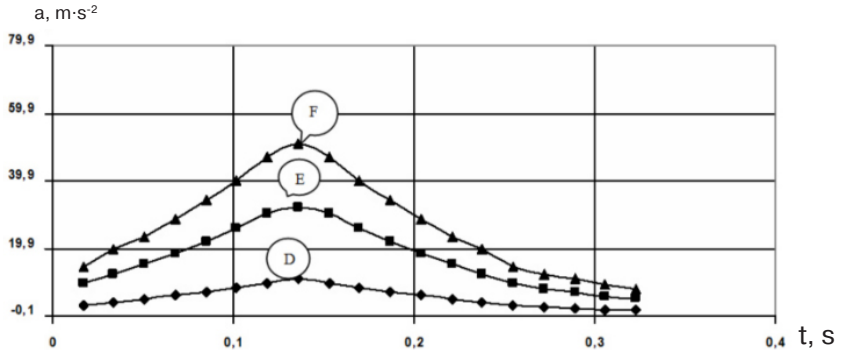
– mechanical work – 349,16 J;



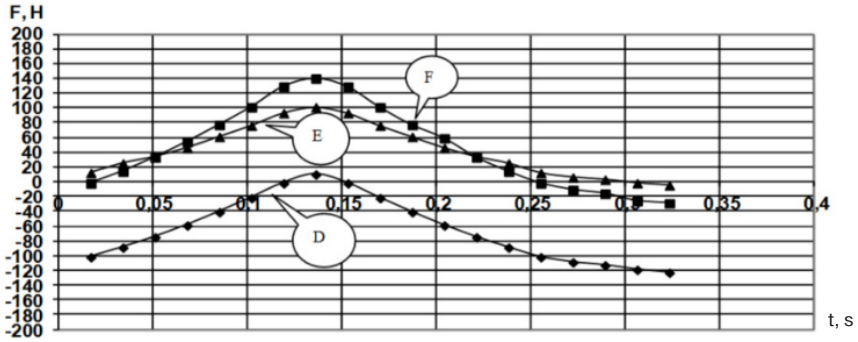
Pic. 10. **The schedule of trajectory of way *(S)* of CW of links of legs when performing upward jump piked in the unsupported movement:**



Pic. 11. **The schedule of speed *(V)* CW of links of legs performed by upward jump piked in the unsupported movement**



Pic. 12. **The schedule of acceleration (*a*) CW of links of legs performed by upward jump piked in the unsupported movement**



Pic. 13. **The schedule of efforts (*F*) of CW of links of legs performed by upward jump piked in the unsupported movement up**

Note: *D – trajectory of the movement, speed, acceleration, effort of CW of* ***hip****; E – trajectory of the movement, speed, acceleration, effort of CW* ***shins****; F – trajectory of the movement, speed, acceleration, effort of CW of* ***foot****.*

– kinetic energy – 180,01 J.

1 Dz ≈ 0,238846 calories (1 calorie = 4,184 Dz) [1].

The received researches by data demonstrate that the sportsman (executor) spends 83,45 kcal. (time of performance 0,63s) on performance of upward jump piked.
Power consumptions of internal friction of the musculoskeletal system of the sportsman (executor) and expense of radiation of thermal energy of body of the executor to the environment are not considered in the calculation [1; 5].

Conclusions

The biomechanical analysis of performance of upward jump piked gives the creative approach to the technique of development of the difficult elements, movements joint with kinds of jumps in dancing sports, gymnastics, jumps in water which will allow more effectively and rationally, with smaller physical expenses to improve technical training of the qualified sportsmen (executors).

Prospects of the subsequent researches have to be in the search of ways of application of fundamentals of biomechanics in this direction with introduction of methodical recommendations and writing of grants.

Conflict of interests. The authors declare that there is no conflict of interests.
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Nataliya Batieieva: *PhD (Physical Education and Sport), Associate Professor; Kiev National University of Culture and Arts: Shchorsa 36, Kiev, 01133, Ukraine.*
ORCID.ORG/0000-0001-8575-5506
E-mail: kyzim@mail.ru

Petro Kyzim: *Associat Professor; Kharkov State Academy of Physical Culture: Klochkovskaya 99, Kharkov, 61058,Ukraine.*
ORCID.ORG/0000-0001-5094-3988
E-mail: kyzim@mail.ru