BIOMECHANICAL ANALYSIS TECHNIQUE CHOREOGRAPHIC MOVEMENTS (FOR EXAMPLE, "GRAND BATTMAN JETE")

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Abstract. *Purpose*: biomechanical analysis of the execution of choreographic movement "grand battman jete". *Material*: the study involved students (n = 7) of the department of classical choreography faculty of choreography. *Results*: biomechanical analysis of choreographic movement "grand battman jete" (classic exercise), obtained kinematic characteristics (path, velocity, acceleration, force) of the center of mass (CM) bio parts of the body artist (foot, shin, thigh). Built bio kinematic model (phase). The energy characteristics - mechanical work and kinetic energy units legs when performing choreographic movement "grand battman jete". *Conclusions*: It was found that the ability of an athlete and coach-choreographer analyze the biomechanics of movement has a positive effect on the improvement of choreographic training of qualified athletes in gymnastics (sport, art), figure skating and dance sports.
Keywords: biomechanical analysis, choreography training, grand battman jete, trainer-choreographer, athlete (executor), choreographic movement.

Introduction

Art of choreography has been asserting itself and developing opening its new branches (classic, folk, modern, ballroom dances and etc). As on to day mastering of any branch of choreography requires scientific foundation of techniques' rational fulfillment, seeking of new methods and means of training, which would permit for trainees to achieve qualitatively new level of skillfulness [16, 18]. It should be supplemented by the fact that problems of performance skills' perfection require application of discoveries and achievements of other sciences (directly connected with motor functioning) in methodic of classic dances' training. First of all it concerns anatomy, physiology, mechanic and bio-mechanic. It will help for instructor to more rationally build structure of choreographic exercises, to understand their morphology and inner interconnection of movements' elements. Besides, it would help to more accurately and unmistakably find and determine further ways of performance skills' perfection. They undoubtedly can be used in art of choreography, where body's motor functioning is one of main components of dance [7, 10, 11, 17, 19, 20, 21].

Concerning perfection of classic dance training, as on to day it requires working out of new, more effective methods of complex choreographic movements' mastering. It is known that at present methodic of classic dance training is a complex multi-factor process, in which one of important places shall be engaged by implementation and active usage of scientific principles of motor functioning [6, 12, 14, 22]. In its turn high level of development of modern dancing kinds of sports (calisthenics, figure skating) conditions demand in constant improvement of all sides of qualified sportsmen's training (including choreographic training). Considering the above said traditional methods of choreographic training in these kinds of sports have not yet met modern requirements to sportsmanship [2, 23]. It is necessary to add that at present arsenal of qualified sportsman's and future choreography coach's choreographic knowledge and skills is not sufficient for his (her) professional functioning. Rather often choreographic creation (in sports) seems to be imperfect in performance. It requires new approaches to improvement of choreographic, methodic and practical training of qualified sportsmen and choreography coaches [3].

Analysis of competition performances of calisthenics' and acrobatic rock-n-toll's masters shows that fulfillment of choreographic movements in competition programs is rather imperfect. Exception is only professional classic choreography of A.M. Deriugina's school of calisthenics. Percentage of choreography is the least in comparison with other kinds of training, such as physical, special physical. It is witnessed by data of questioning: in acrobatic rock-n-roll only 10% of respondents (coaches) consider choreography to be one of important approaches to perfection of trainee's sportsmanship [4, 13].

The fulfilled analysis of scientific-methodic literature showed that as on to day there exists insufficient level of choreography coaches' choreographic fitness (in classic, ballroom dancing and folk choreography; in gymnastic and calisthenics, figure skating, acrobatic rock-n-roll and so on). This analysis also witnesses that there are no researches, devoted to influence of choreographic movements' bio-mechanic on improvement of qualified sportsmen's choreographic fitness.

Among choreographic movements the most important and basic is grand batman jete [5]. This is a movement, which is fulfilled in classic exercise with certain physical load, standing by support (see fig.1). Grand batman jete is fulfilled standing by support from V position of feet in three directions in the following sequence: forward, aside, backward (4 times in every direction). Time of fulfillment of every movement in each direction shall be equal.

Purpose, tasks of the work, material and methods

The purpose of the research: analysis of bio-mechanical characteristics of grand batman jete's fulfillment.

The tasks of the research:

1. Carry out analysis of scientific-methodic literature, devoted to problems of choreographic training of dancing kind of sports, calisthenics and figure skating representatives.
2. Determine bio-mechanical characteristics of "grand batman jete's" fulfillment.

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Material and methods of the research:

The methods of the research were: theoretical analysis and generalization of special scientific-methodic literature's data; photographing, filming, bio-mechanical computer analysis, pedagogic observation.

In realization of bio-mechanical analysis of "grand batman jete" students (n=7) of classic choreography department of choreography art faculty participated. In our work we used filming, on the base of which we received frame-by-frame fulfillment of choreographic movement (accelerated filming with frequency of frames 59 frames per second). We determined the following characteristics: trajectory, speed and acceleration of bio-links and applied forces.

In our work we used mathematical model of building of mass center' (MC) trajectory of leg's links: foot, shin, hip [2, 8, 20, 21].

1. Construction of segment of leg links' MC movements:

L p. – body length of performer (actual linear length of bench mark);

l (r) – linear dimension of leg's link (actual linear dimension of MC of leg's links).

$$l\,(r) = l\ mc\ of\ leg's\ links \bullet Lp.(linear)/Lp.(photo\text{-}gram) \quad (1)$$

where: *l mc* – dimension of bench mark on photo gram.

2. Determination of way *S* of leg links' passing along line of segment: сегменту:

$$S = \pi rn/180 \quad (2)$$

Where: π – 3.14;

r – radius of leg links' MC (segment);

n – angle of passing of leg links' MC along line of segment.

3. Determination of leg links' MC speed by time (V_k):

$$V_k = S/t \quad (3)$$

4. Determination of acceleration of leg links' MC passing ноги:

$$a = V^2 / r \quad (4)$$

5. Determination of force (*F*), applied to leg links' MC in time (in film frame):

$$F = m\,(a - g), \quad (5)$$

Where: *m* mass of leg's link; *a* –acceleration of leg links' MC;

$g = 9.8\ m.sec^{-2}$

Results and their discussion:

V-a position I and VIII phases; II and VII phases; III and VI phases; IV and V phases;

Fig.1. Main phases of fulfillment of "grand batman jete" from V- position forward

We determined the following phases of fulfillment of "grand batman jete" on the base of ita bio-mechanical analysis (see table 1).

Table 1

Phases of fulfillment of "grand batman jete"

phase	action	Time of fulfillment, sec.
I	Moving foot from V-position forward with gradual acceleration of MC of leg's links	0 – 0.14
II	Increase of leg links' speed	0.14 – 0.24
III	Achievement of maximal speed of MC of leg's links	0.24 – 0.34
IV	Reduction of leg links' MC speed from maximal to zero	0.34 – 0.54
V	By law of gravity MC trajectories in reverse direction gradually increase speed	0.54 – 0.71
VI	Achievement of maximal speed of MC of leg's links in reverse direction with support on gravity force and application of force of leg's muscles	0.71 – 0.81
VII	Reduction of speed of leg links' MC and keeping of speed with support on force of gravity with the help of leg's muscles	0.81 – 0.98
VIII	Setting foot in initial position. Speed of leg links' MC reduces to zero	0.98 – 1.22

We have determined the following: time, spent for moving of leg links' MC upward equals to 0.54 sec., while time of returning of leg links' MC in initial position is 0.68 sec. It proves that moving of leg in I-IV phases of fulfillment of "grand batman jete" is realized with higher acceleration than dropping of leg V-VIII phases (see fig.4). Besides, we found that mean speed of leg links' MC in I-IV phases of "grand batman jete" is by 25.9 % higher than mean speed of returning of leg links' MC in initial position in V-VIII phases (see fig.3).

For solution of our tasks we determined bio-mechanical kinematic characteristics of choreographic movement: trajectory, speed, acceleration, force (see figs. 2-5).

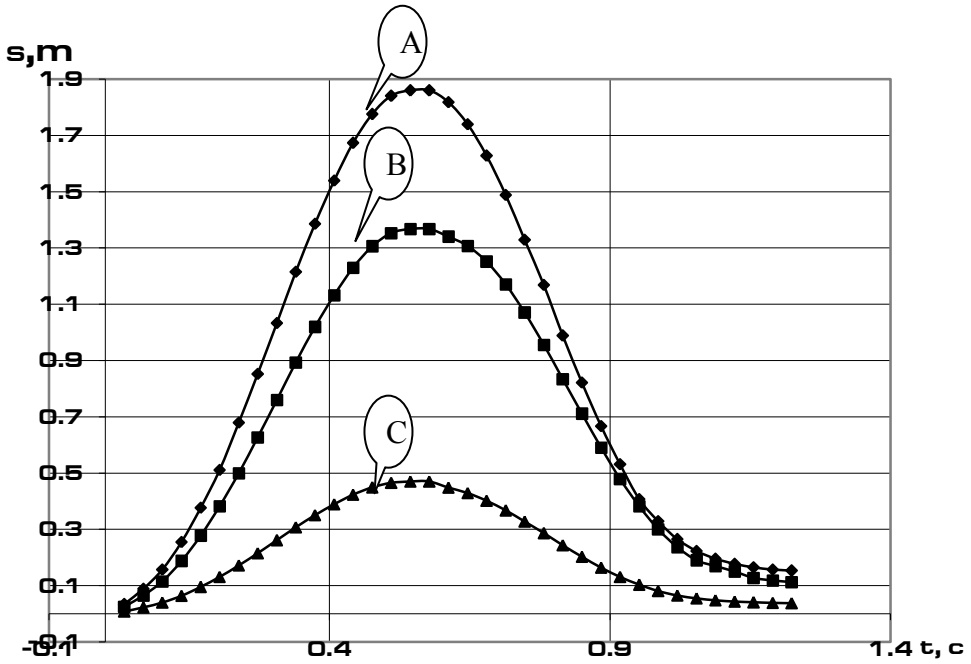

Fig.2. Trajectory of leg links' MC in fulfillment of "grand batman jete" from V position forward
A – trajectory of **foot's** mass center
B – trajectory of **shin's** mass center
C – trajectory of **hip's** mass center

Trajectories of movement (fig.2) of leg links' MC in fulfillment of "grand batman jete" V-position forward are curves, which reflect maximal numeric value of passing of leg links' MC up to their upper point and return in initial position. Characteristic feature of trajectory is equidistant MC of leg's links from each other that is proved by relation of way (*S*) to radius (*r)* of foot, shin hip segments, which equals to 1. 22 sec. Time of leg links' MC passing to upper point is 0.54 sec., time of return in initial position – 0.68 sec.

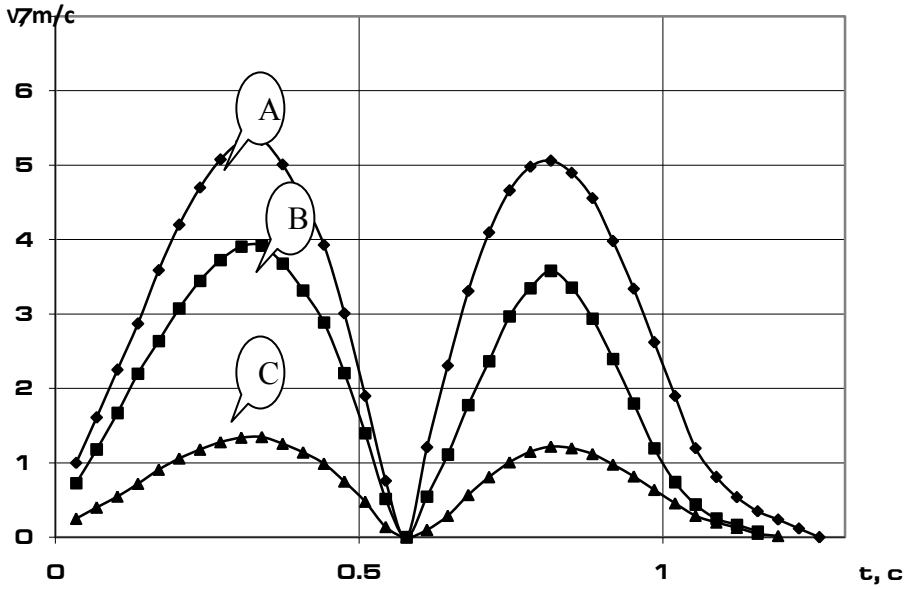

Fig.3. Diagram of speed (V) of leg links' MC in fulfillment of "grand batman jete" from V position forward
A – diagram of speed *(V) of* ***foot's*** *mass center*

B – diagram of speed *(V) of **shin's** mass center*
C – diagram of speed *(V) of **hip's** mass center*

Main phases of fulfillment (see table 1) show characteristic of leg links' MC speed before reaching upper point and return to initial position. The set speed of foot's leaving initial position (I phase) is less than initial speed of MC in reverse direction (V-phase). Maximal speed of leg links' MC in reverse direction is less at the account of **counteraction** of gravity force (VI phase).

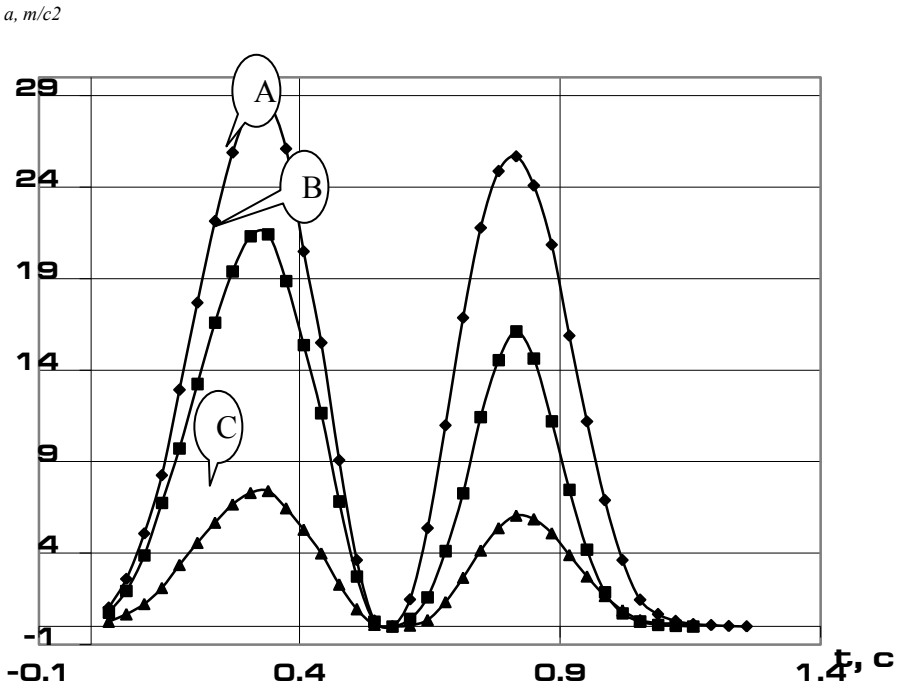

*Fig.4. Diagram of acceleration **(a)** of leg links' MC in fulfillment of "grand batman jete" from V-position forward*

A – diagram of acceleration *(a) of **foot's** mass center*
B – diagram of acceleration *(a) of **shin's** mass center*
C – diagram of acceleration *(a) of **hip's** mass center*

Diagram of acceleration illustrates fulfillment of "grand batman jete" as uniformly accelerated movement of leg links' mass centers. Characteristics of diagram of leg links' MC depend on their numeric values of segment's radius. Maximal acceleration:

*A – center of **foot's** mass:* in moving to upper point 28.6 m·sec.$^{-2}$, in reverse direction 25.68 m·sec.$^{-2}$;

*B – center of **shin's** mass:* in moving to upper point 21.43 m·sec.$^{-2}$, in reverse direction 16.1 m·sec.$^{-2}$;

C – *center of **hip's** mass:* in moving to upper point 7.4 m·sec.$^{-2}$, in reverse direction 6.05 m·sec.$^{-2}$;

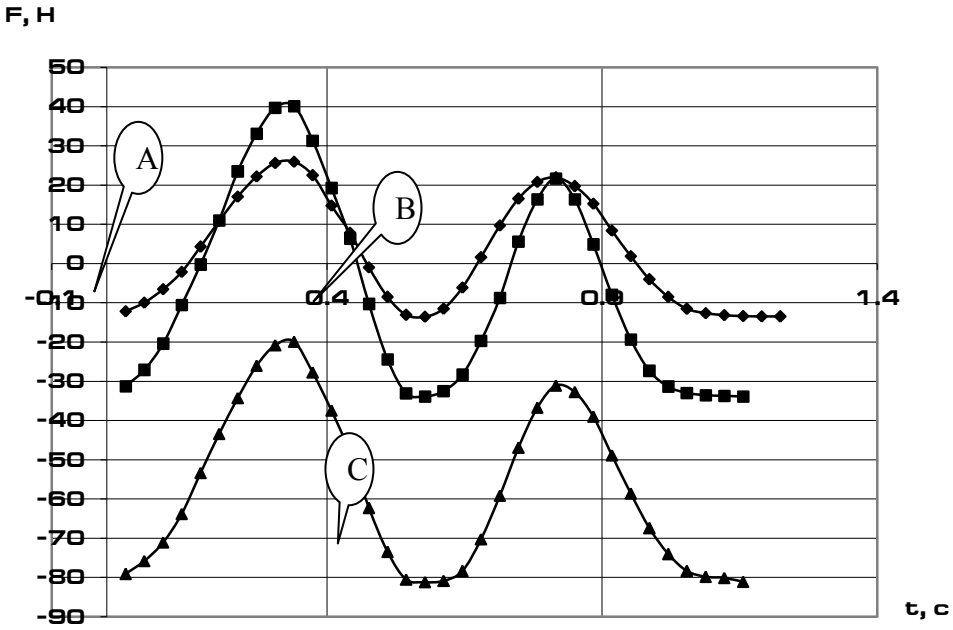

*Fig.5. Diagram of forces (**F**) of leg links' MC in fulfillment of "grand batman jete" form V-position forward*
A – *diagram of force (**F**)of **foot's** mass center*
B – *diagram of force (**F**) of **shin's** mass center*
C – *diagram of force (**F**) of **hip's** mass center*

In the diagram numeric values of force of leg links' MC with minus sign are shown. It illustrates that counteraction of gravity force is directed towards force of leg links' MC force [1]. Increase of forces (**F**) of **foot's** mass center and **shin's** mass center differ by directions from increasing of force (**F**) of **hip's** mass center.

On the base of received kinematic characteristics we determined energetic characteristics of leg's links: mechanical work ($A = \int_{o}^{s} F_s dS$) and kinetic energy ($E_k = \frac{mV^2}{2}$) [1] in fulfillment of "grand batman jete" from V-position forward. Mechanical work of passing leg's links to upper point equals to: *A foot*- 23.63 Joule; *A shin* – 30.73 Joule; *A hip* – 23.97 Joule. Though, mechanical work of leg links' returning to initial position has the following indicators: *A foot* - 21.59 Joule; *A shin* – 30.82 Joule; *A hip* – 29.34 Joule.

Kinetic energy of leg's links in moving to upper point is: *E foot* – 8.18 Joule; *E shin* – 11.06 Joule; *E hip* – 3.08 Joule.

It should be also noted that obtained indicators of kinetic energy of leg's links in fulfillment of "grand batman jete" in reverse direction (taking initial position) are as follows: *E foot* – 10.67 Joule; *E shin* – 9.01 Joule; *E hip* – 3.12 Joule.

By results of our research3 we can affirm that energetic characteristics of fulfillment of "grand batman jete" from V-position at ballet Barre in classic exercise have the following values:

- Mechanical work– 2560 Joule;
- Kinetic energy– 720 Joule.

1 Joule ≈ 0.238846 calories (1 calorie = 4.184 Joule) [1].

The data received in our research, witness that for fulfillment of "grand batman jete" from V-position at ballet Barre in classic exercise performer spends 611.44 cal.(time of fulfillment 19.52 sec.)

In calculation we did not consider energy losses of internal friction of supporting motor system of performer and losses of heat energy radiation from body into environment [1, 9].

Results of received energy characteristics prove effectiveness of fulfillment of "grand batman jete" in classic exercise. It facilitates training of performer's supporting motor system for further loading at training.

The provided bio-mechanical analysis of choreographic movement gives creative approach to methodic of mastering of classic dance's complex elements, which will permit for performers to more effectively and rationally (with less physical losses) improve choreographic fitness of qualified sportsmen.

Discussion

The provided bio-mechanical analysis of "grand batman jete" supplements methodic of choreographic movement's fulfillment, delivered in works of authors [5, 11, 16, 17, 18]. Alongside with it, in our research we received, for the first time, kinematic characteristics of "grand batman jete" (trajectory, speed, acceleration, force). For the first time (on the base of obtained kinematic characteristics) we determined energetic characteristics of leg's links – mechanical work and kinetic energy.

Methodic of bio-mechanical analysis of choreographic movements (on example of "grand batman jete") completely proves our understanding of improvement of classic dance training's methodic that can help for choreography coach to more rationally build structure of choreographic exercises, to understand their morphology and internal interconnection of movements' elements.

Conclusions:

1. We have determined phase of fulfillment of "grand batman jete".

2. We have found that in percents mean speed of foot's mass center in I-IV phase of "grand batman jete" fulfillment is higher by 29.5 % than mean speed of returning of foot's MC in initial position in V-VIII phases.

3. We determined energetic characteristics of "grand batman jete" fulfillment in classic exercise:

- mechanical work - 2560 Joule;
- kinetic energy – 720 Joule.

4. Bio-mechanical analysis of choreographic movements permits for choreography coach to enrich theoretical and practical developments in choreographic training of qualified sportsmen in dancing kinds of sports, gymnastic (sport gymnastic and calisthenics) figure skating).

The prospects of further researches imply seeking of ways for application of bio-mechanic in this direction with creation of methodic recommendations and manuals.

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Conflict of interest

Author declares that there are no conflict of interests.

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