BIOMECHANICAL ASPECTS OF TRAINING MEANS SELECTION IN TRACK ANDFIELD JUMPS

Abbreviations

BM	biomechanism
CFJ	coxofemoral joint
KJ	knee joint
AJ	ankle joint
COG	center of gravity
CNS	central nervous system
s.p.	starting position

At present, having taken a systemic-structural approach, general biomechanics studies features of the locomotor system of a man, biomechanical characteristics of movements, composition and structure of motions in sport exercises and movements.

This approach suggests to single out spatial and temporal elements in a system of movements. Just here, we see a contradiction, as a material system cannot be subdivided into spatial and temporal elements. From the point of view of contemporary philosophy of scientific cognition, it is incorrect to think of processes, properties, or relations as being systems. They all are no more than manifestation of various properties of a material object, while a system is a model of an original material object, the latter also consisting of material elements.

An approach used by J.G. Hay (2002) is the most recognized in sport biomechanics now. Its essence (illustrated by a vertical standing jump) consists in subdivision of the trajectory of the body center of gravity (COG) into a few segments. The following identification of biomechanical characteristics responsible for the COG displacement and velocity of displacement is based on common sense. For example, arms lift-up shifts the COG upwards; legs extension produces the same effect; legs length ensures a certain position of the body COG at the end of take-off. On the ground of common sense, important parameters are selected and subjected to correlation analysis in order to find their relationship and to obtain multiple regression equations. The logic of this approach is similar to that of an empirical research aimed at formulation of an empirical law, which does not reveal the essence of a phenomenon, although enables to make some suggestions.

In biomechanics we may be unfamiliar with brain organization and the central nervous system (CNS) can be considered as a “black box”. Here lies the boundary between physiology and biomechanics. A biomechanist must be proficient in programming deliberate motor actions aimed at reaching a preset goal, i.e. motor programs. Physiological concepts of movement control do not substantiate the laws of mastering motor actions. However, to achieve success, a coach needs knowledge both in biomechanics and physiology in order to create training programs aimed at the development of motor programs of a competitive movement in an athlete. Thus, to work out a plan of technique development of a track-and-field athlete, it appears necessary to model a competitive movement, as well as training means to be used besides the principle movement.

To model the locomotor system of a man, we must use ideal models from theoretical mechanics. Theoretical mechanics uses models including the following elements: two- or three-dimensional space, time, point mass, perfectly rigid body (a rod), hinge, kinematic chain, ideal liquid or gas, etc. All these models are used in biomechanics, although to create an adequate model of a locomotor system, a model of muscle is needed. Hence, the subject of biomechanics matches that of theoretical mechanics only partially.

At every single instant, human existence can be considered as a combination of biomechanisms. In general, the concept of biomechanism includes biochemical objects (mitochondria, myofibrils, etc), physiological systems (cardiovascular, endocrine, immune, central nervous and other systems), and the locomotor system.

In biomechanics this concept should be referred to mechanics, in particular, to the theory of machines and mechanisms. Let us define a biomechanism (BM) as an aggregate of certain body parts movements, independent of other parts movements, transforming one type of energy into another that leads to changes in the position and speed of the athlete's body COG while accomplishing a certain movement task in certain external conditions (Seluyanov, Shalmanov 1995, Shestakov 1998, 2000).

To control a multilink system, the CNS combines separate links into subsystems (key kinematic mechanisms), which can act independently, although in doing so to pursue a common goal. A biomechanism as an integral system consists of a set of components, each possessing its own properties, which can manifest themselves in human movements in different ways.

The following components are singled out in a biomechanism:

1) Muscle as:

- a converter of chemical energy into mechanical one;
- a resilient element, capable of storing and returning energy;
- a ductile element, capable of damping external loads;
- an energy (power) transmitter from energy sources.

2) Bone as:

- a lever for force and power transfer;
- a pendulum for energy conversion;
- a rod for support and reaction against external loads.

3) Joint as:

- a hinge joining bones in a kinematic chain;
- a hinge restricting mobility of joined bones.

Besides that, we should take into account controlling units containing control programs (motor programs that are formed, stored and functioning in the athlete’s CNS).

It is noteworthy that a CNS model must meet strict requirements. The model must reflect the process of controlling the object (in our case, the locomotor system) as well as model environment conditions and their relationship. Important is for both processes to be modeled as parallel that is not taken into account in contemporary mathematical models. The ability to perform deliberate movements means that a person can control target-oriented movements of the body or its parts more or less precisely. As the purpose of a movement is supposed to be solved by a certain BM and perceived by consciousness, it can be controlled and changed deliberately. The problem of movements spatial & temporal parameters differentiation, i.e. a method of performing a motor action, or, in other words, technique of a movement is, probably, solved by means of conscious control of certain BMs (Shestakov 1998, 2000).

Hypothesis. Our investigation aims at confirmation of the hypothesis that the concept of bimechanism (BM) forms the basis of the approach to selecting technique development means in track-and-field. We examined one of the most important components of track-and-field jumps, i.e. a take-off.

The following BMs can be identified in the take-off in track-and-field jumps:

- BM of the support leg and body extension (LBE);
- BM of the arms and swinging leg swinging motion (SM);
- BM of the "overturned pendulum" (OP);

In their publications (An. Shalmanov, Al. Shalmanov, 1990) the authors underscore three factors that play a key role in *the biomechanism of the support leg and body extension*. They are:

- consecutive extension of the coxofemoral and knee joints;
- differently directed changing angles in the coxofemoral and knee joints in the transition phase from shock absorption to take-off;
- optimal legs bending in the knee joints.

Swinging motions contribution. This mechanism increases the vertical component of the COG velocity after take-off. It ensures:

- additional load on muscles-extensors of lower limbs at the end of shock-absorption phase; and growth of the support reaction force due to the accelerated motion of the swinging links;
- growth of the swinging links velocity till the start of the knee joint extension;
- correct position of the swinging links at the end of take-off.

The essence of the *"overturned pendulum" biomechanism* consists in the ability to increase the COG vertical velocity due to the athlete's body pivoting over the point of bearing.

Relatively independent kinematic mechanisms are interdependent at dynamic level, i.e. realization of any of them affects the efficiency of the others. The role and contribution of the key kinematic mechanisms to the result demonstrated by an athlete depend on the type of a jump, initial conditions and the task set. There exist different ways of realization of any BM as well as different interaction between BMs within the same jumping event.

Objective and methods. We have analyzed biomechanical parameters of the take-off in a group of elite Russian male jumpers (n = 50) in competitive conditions (during official contests). The aim of this part of the research was to compare the contribution of different BMs involved into take-off in track-and-field jumps. Video recording was made by a digital camera JVC-9800 with the speed of 50 frames per second. Having been captured by standard computer programs, the image of the jumper's body was modeled by virtue of an anthropomorphic 12-segment model (created by Prof. V.N. Seluyanov). The computer complex consisted of a few modules: calculation of mass-inertial parameters of an athlete; calculation of kinematical and energy characteristics of movements of separate body links and the whole body based on videotape processing (it allowed to determine linear and angular indices of the body links kinematics as well as potential, kinetic and full energy of each link). The unique feature of this module is the capability to determine changes in length and contraction speed of 9 major muscles of the lower extremities. It permits to determine key peculiarities of the athlete's technique and to simulate conditions, under which top results could be achieved. Mathematical processing was done in the Scientific Research Institute of the Russian State University of Physical Education, Sport and Tourism. The accuracy of measurements was determined in a metrological study and accounted for 0.01 m (linear parameters) and 0.02 mps (velocity parameters).

Having analyzed the results, we determined the contribution of BMs into take-off in jumps regarding changes in the full energy of separate segments and links of the athlete's body. Simulation modeling enabled us to make conclusions concerning not only the ratio of BMs contribution into take-off in every jump event and a comparison of different jumps (horizontal and vertical), but to monitor the change of BMs contribution into take-off in case of 5% increase of the athlete's COG velocity at the last step of the approach run in each type of jumps and its effect on the result.

Results demonstrated by the athletes in the course of the experiment attained the level of master of sport, international class. The simulation modeling showed that the growth of the approach speed would provide real chances of getting into the World championship finals.

Table 1. Jumping results: real and obtained by simulation modeling

Parameter	Long jump	High jump	Triple jump	Pole vault
real result (at the registered COG velocity), cm	805±12	228±2,3	1715±35	565±5.5
Simulated result (at the modeled COG velocity), cm	820	232	1740	575

Table 2 displays proportion (in %) of the BMs contribution into take-off based on changes in the full energy of the athlete's body links measured in the experiment.

Table 2. Contribution of different BMs into take-off in track-and-field jumps (%)

Biomechanism	Long jump (%)	High jump (%)	Triple jump (%)	Pole vault (%)
Leg and body extension	15,8	14,3	16,1	18,9
Swinging links	69,8	70,2	70,5	67,9
Overturned pendulum	14,4	15,5	13,4	13,2

The greatest contribution of the BM of swinging links into the take-off is at once apparent. The contribution of the BM of the takeoff leg extension is more pronounced in pole vault and less pronounced in high jump, whereas the contribution of the BM of "overturned pendulum" is greater in high and long jumps.

High and long jumps are the most similar in what concerns the structure of BMs operation at take-off, although the execution of the jumps is quite different (horizontal and vertical directions).

We decided to find out what would happen, if the athlete's speed at the last step of the approach run (just prior to take-off) increased by 5%. We took the value 5%, because the examination of strength-velocity qualities of top-class athletes permitted to suppose such an increase of speed to be attainable by advanced jumpers, who seem to be capable of bearing higher strength loads.

An increase in speed will naturally lead to an increase in the body links energy. The question arises, if the energy growth will be proportional to the speed of the COG in every BM.

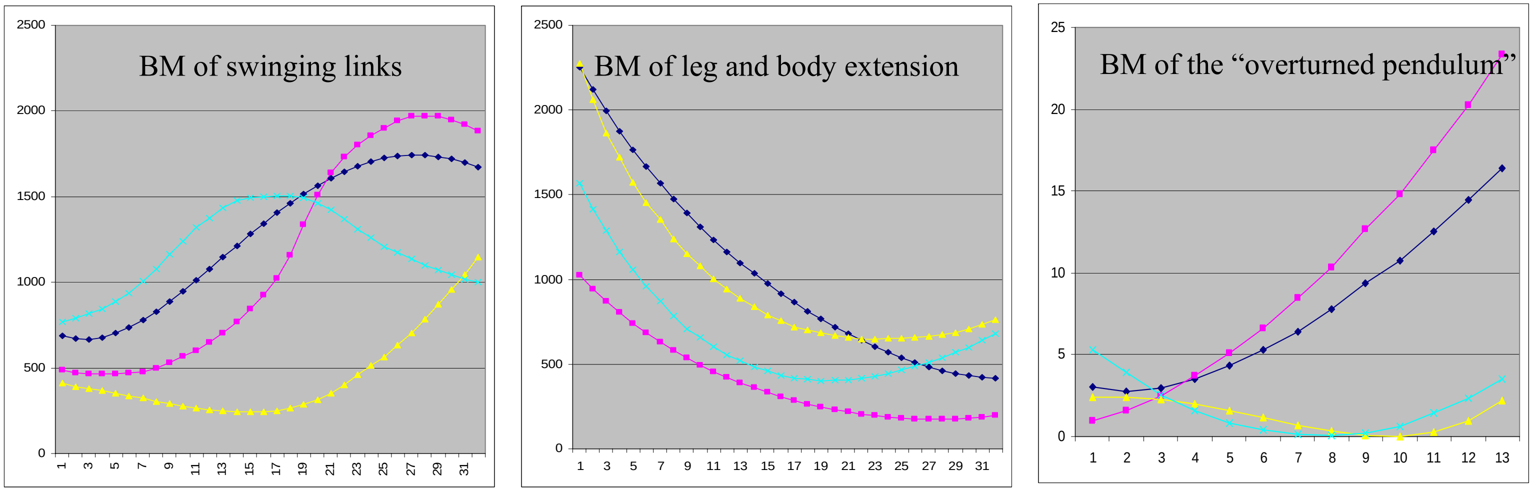
Important changes were observed in the BM of swinging links (fig. 1). In high and long jumps the contribution of this BM not only increased, but started earlier. As for triple jump, both temporal and amplitude parameters of the BM of swinging links grew. In pole vault the increase was proportional to the increase of the COG velocity. The structure of the BM of the takeoff leg extension for all the jumps under study remained the same. Considerable changes took place in the BM of "overturned pendulum" in high and long jumps. Its contribution became more important in triple jump, but nearly did not change in pole vault.

Changes in the ratio (in %) of BMs contribution into take-off are shown in Table 3.

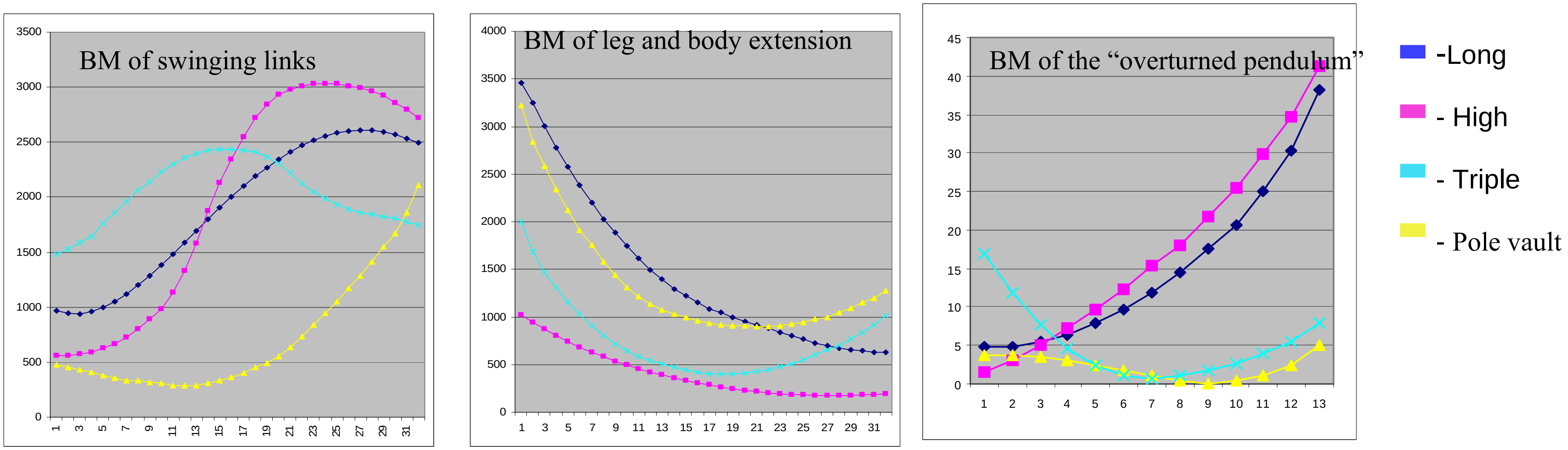
Table 3. Changes in BMs contribution into take-off obtained by modeling a 5% increase in velocity at the last step of the approach

Biomechanism	Long jump (%)	High jump (%)	Triple jump (%)	Pole vault (%)
Leg and body extension	13.5	13.7	12	18.7
Swinging links	71.5	72.6	75.5	68.9
Overturned pendulum	15.0	14.3	12.5	12.4

We should also note an increase in the total energy of the BMs, the greatest being observed in high and triple jumps.



Total energy of each BM (kj) at registered COG velocity



Total energy of each BM (kj) at simulated COG velocity

Figure 1. Change of BMs contribution to take-off

Table 4. Changes of the total energy in every BM (in %) obtained by modeling a 5% increase of speed at the last step of the approach

Biomechanism	Long jump (%)	High jump (%)	Triple jump (%)	Pole vault (%)
Leg and body extension	53	52.2	52	51.9
Swinging links	56.6	61.81	56.59	63.9
Overturned pendulum	57.9	59.25	57.67	54.1

On present evidence it may be suggested that high and long jumps are the most similar in the structure of take-off, lesser similarity being found with triple jump and pole vault. Therefore, horizontal and vertical jumps reveal a certain resemblance in the structure of take-off.

The greatest increase in the body COG speed can be reached by intensifying movements of swinging links (as in amplitude, as in temporal parameters). At the same time, training means and methods aimed at the development of the BM of the takeoff leg and body extension should not be excluded from training programs, because the links of this BM would have to bear the increased loads resulting from more intensive work of the swinging links. This will provide efficient work of the BM of "overturned pendulum".

Data obtained in this part of the research permit to conclude that the structure of take-off in track-and-field jumps is formed according to a certain motor objective that depends on the character of the jump.

The speed of the athlete's body COG at takeoff in all jumping events is controlled to a great extent by swinging movements of the body links, in other words, it depends on amplitude and temporal parameters of the swing.

Pedagogical requirements to training means selection

In running jumps the efficiency of key kinematic mechanisms and, consequently, the efficiency of the athlete's interaction with the support depends on movements pattern executed by an athlete and aimed at realization of the following pedagogical requirements:

For all jumps:

- to run as fast as possible in the approach;
- to start active swinging movements before touch-down;

For taking off in long and high jumps:

- to lower the body COG at the last 2-3 approach strides;
- to plant the takeoff foot by a "paddling" movement, but at less angle with the support (i.e. in front of the body) and to lean the trunk backwards from the vertical.

The degree of realization of some of the requirements differently affects the realization of the others. For example, the COG lowering at the last approach strides in high and long jumps (contrary to triple jump and pole vault) creates favorable conditions for a correct placement of the takeoff foot and less angle of the body lean with the support, in spite of setting higher requirements for strength-velocity qualities of the takeoff leg muscles. This should increase the contribution of the "overturned pendulum" and swinging links BMs in the phase of the body and takeoff leg pivoting upon the point of support, so that the trunk becomes positioned vertically above it. The subsequent forward-downward rotation of the takeoff leg causes lowering of the knee and coxofemoral joints that is compensated by the mechanism of the takeoff leg and body extension. When the takeoff leg is planted "under" the trunk at take-off (a popular method of learning technique in long jumps), the takeoff leg is lowered (forward-downward rotation), that can be considered as a technique fault, because in this case the efficiency of the BM of the takeoff leg and body extension and the contribution of the "overturned pendulum" decrease.

The realization of some of the requirements mentioned above does not always favor the realization of the others. For instance, a too fast approach increases high-impact and inertia loads on the takeoff leg, in particular, when it is placed at narrow angle with the support.

Taking into account the takeoff structure in a given type of jumps and the pedagogical requirements listed above, any training program in track-and-field should include special means, each affecting technical skills depending on the core and form of a certain movement.

The revealed phenomena allowed to set objectives for the second part of the research aimed at biomechanical investigation of training means most frequently used for technique development in track-and-field jumping events.

To examine biomechanical features of take-off in special exercises primarily used in technique development sessions by track-and-field jumpers (in different jumping events), we have carried out a laboratory experiment on a special complex "Qualisys" (Sweden) using high-speed recording camera (240 frames per second). 5 elite male track-and-field jumpers, regularly performing in international competitions took part in the experiments (2 long jumpers, 2 high jumpers, 1 pole-vaulter). The age of the subjects was 22±1.4 yrs, duration of practicing track-and-field jumps 7±2.3 yrs, height 1.84±0.04 m, weight 74±3.1 kg. Exercises performed in the experiment included: long jump, long jump over a hurdle (0.96 m) placed in 1 m distance from the take-off spot, long jump taking off a raised or lowered board (0.05 m), jump up with touching an object suspended at 2.5 m height and in 1 m distance from the take-off spot, a pattern of 3 hops after an approach run. All exercises were performed after 6 running strides at the maximal approach speed.

Results of the second part of the research and their discussion

Biomechanism of the takeoff leg and body extension.

In jumps the greatest mechanical impact directed at stretching biarticular muscles of the lower extremities, in particular, rectus femoris, is achieved at take-off due to simultaneous forced bending of the takeoff leg in the knee joint (at shock absorption) and its active straightening in the coxofemoral joint. In this case, the tractive force produced by this muscle is aimed at the knee joint extension. This element of the BM of the takeoff leg and body extension at the phase of interaction with the support outwardly looks as the leg flexion with the simultaneous driving of the pelvis and knees forward while leaning backwards.

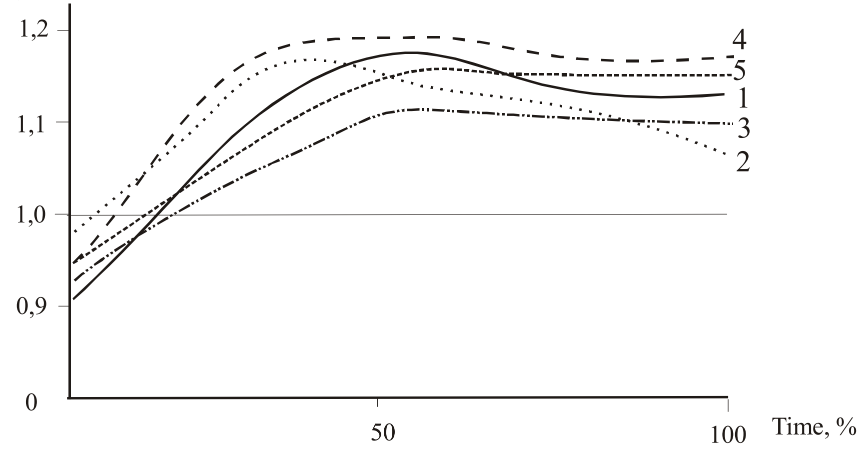
Biceps femoris has two functions in running jumps. According to our data and that reported in other studies, the takeoff leg hits the takeoff board at the angle of 59-74° with the horizontal, the angles in the coxofemoral and knee joints varying within the range of 165-170° and 160-175° correspondingly, depending on a jump event (table 5). The trunk having "run against" the support leg planted on a takeoff board, starts pivoting forward. Less angles of the support leg touch-down and body lean (measured clockwise with respect to the horizontal) were observed in the following exercises: jump up with touching a suspended object by hand, long jump from a raised platform (0.05 m).

Table 5. Kinematic characteristics of take-off in exercises under study (°)

Exercise	Angle in the ankle joint (AJ) at touch-down	Angle in the knee joint (KJ) at touch-down	Angle in the coxofemoral joint (CFJ) at touch-down
Long jump,°	67	169	171
Long jump over a hurdle	65	172	175
Long jump from a raised takeoff platform (0.05 m), °	60	165	170
Long jump from a lowered takeoff platform (0.05 m), °	74	174	168
Jump up with touching an object by hand, °	59	175	172
pattern of 3 hops, °	70	160	165

The analysis of the dynamics of αCFJ/αKJ (fig. 2) and values of angles in the involved joints in different types of jumps showed that the speed of contraction in biarticular muscles is lower than in those being monarticular, and consequently, the tractive force produced by biarticular muscles is greater.

It led us to suggest that biarticular muscles play more significant role in providing efficient interaction with the support in jumps. In this context, training means and exercises should be selected so that they could develop strength-velocity qualities of those muscles in plyometric regimen of contraction, primarily with oppositely directed change in angles (as in the pairs CFJ-KJ and KJ-AJ).



1- Long jump, 2 - Long jump over a hurdle; 3- Long jump from a raised takeoff platform (0.05 m), 4 - Long jump from a lowered takeoff platform (0.05 m), 5 -Jump up with touching an object by hand, °

Figure 2. Changes in angles in the coxofemoral and knee joints (αCFJ/αKJ) of the takeoff leg at take-off

Maximal results in jumps are reached when the angle of the knee joint flexion at shock absorption is optimal. These optimal values are different for different jump events. Similar in all the jumps is that the amplitude of the forced leg bending varies within the range of 25-35° and is independent of the type of a jump.

The examination of the three key features of the BM of legs and body extension demonstrated that at dynamic level the structure of the locomotor system determined the specificity of interaction with support in jumping exercises. Under otherwise equal conditions, the following factors are thought to be the most important: 1) maximal values and ratio of force momentums in the joints being involved, and 2) plyometric regimen of contraction of monarticular and, in particular, biarticular muscles.

Swinging links motion

Additional stretching of the lower extremities muscles at the end of shock absorption is provided by external mechanical load originating from the vertical component of inertia forces (F_{in}) applied to the centers of mass of swinging links and transferred to the centrifugal force (F_{cf}), directed along the kinematic chain. The value of F_{in} depends as on the swinging movement of swinging links, as on the accelerated lift of the linkage points of those links: for arms – the shoulder girdle lift and trunk straightening; for the swinging leg – lift of the pelvis (due to the takeoff leg straightening and/or trunk pivoting over the point of bearing in accordance with the BM of the "overturned pendulum"). Contribution of the accelerated lift of the linkage points of the swinging links can be estimated from the difference between the values of F_{in} and F_{cf}.
The links are accelerated by:

- positive force momentums in the shoulder joints and the coxofemoral joint of the swinging leg;
- a decrease of the swinging links radius of inertia (arms flexion in the elbow joints and the swinging leg flexion in the knee joint). According to the law of kinetic momentum conservation, it leads to an increase in the angular velocity of rotating links.

Deceleration of the swinging links goes on in the reverse order – the radius of inertia grows and the sign of the force momentum changes from positive to negative one due to the action of antagonist muscles. This enables an abrupt reduction of F_{in} in the centers of mass of the swinging links up to zero that, consequently, reduces the load on the lower extremities muscles at the end of the transfer from the plyometric regimen of their contraction to the myometric one. It is the effect of a sudden release of a stretched active muscle (Hill A.V., 1938). Therefore, at that instant the swinging links should have gained the maximal momentum in the direction of the take-off, and the lower extremities should work on the acceleration of the trunk solely.

Table 6. Maximal vertical component of inertia forces of the swinging links centers of mass at take-off (N)

Exercise	F_{in}, swinging leg	F_{in}, upper extremities
Long jump	1253±54	655±24
Long jump over a hurdle	1080±36	583±35
Long jump from a raised takeoff platform (0.05 m)	1345±44	674±64
Long jump from a lowered takeoff platform (0.05 m)	1437±87	812±75
Jump up touching a suspended object by hand	1315±89	702±72
pattern of 3 hops	1214±65	733±32

Results displayed in table 6 show that inertia forces in swinging motions caused significant changes in the COG vertical velocity at take-off, which were due to:

- creation of additional load on muscles-extensors of the lower extremities at the end of shock absorption phase (inertia forces being transferred to the support by kinematic chains);
- growth of the swinging links velocity until the start of the knee joint extension;
- swinging links position at the end of take-off.

Biomechanism of the "overturned pendulum"

According to our data, the highest (0,06 m) lift of the pelvis (or the marker attached at the point of the CFJ axis of rotation of the takeoff leg) at shock absorption takes place in long running jumps with the take-off from a raised platform, despite the knee joint flexion.

It was found out that in a hop performed after an approach run the center of mass of the takeoff leg thigh was raised by 0.03 m, while the motion of the swinging links was directed forward-downwards. As consequence of these compensatory movements in long jumps the body COG moves in parallel to the support, and in triple jump (step and jump phases) the body COG is lowered towards the support (table 7).

The evidence concerning the BM of the "overturned pendulum" proved that its efficiency depends to a certain extent on the position of the athlete's body at touch-down. The less is the touch-down leg angle and the more is the body backward lean, the longer will the distance used for accelerating the pelvis, trunk, and the whole body be.

Table 7. Shift of the marker placed at the CFJ axis of rotation of the takeoff leg at shock absorption

Exercise	Shift of the marker, mm
Long jump	1.2±0.09
Long jump over a hurdle	4.6±0.55
Long jump from a raised takeoff platform (0.05 m)	6.1±1.4
Long jump from a lowered takeoff platform (0.05 m)	3.0±0.8
Jump up touching a suspended object by hand	5.1±1.3
pattern of 3 hops	-2.1±0.07

Practical recommendations

Findings of the second part of the research demonstrate that there exist specific biomechanical characteristics of training means used by track-and-field jumpers.

We have found out that in training exercises the take-off is performed using relatively independent BMs, similar to those recorded in competitive jumps. Being dependent of the motor task (conditions of performing the exercise), key biomechanisms appear to be interdependent on the dynamic level, i.e. the contribution of one of them affects that of the others. The role and contribution of the BMs depend on the type of an exercise or conditions of its execution, initial conditions, and a motor task set to an athlete. There exist different ways of realization of any BM as well as different interaction between BMs within the same jumping event.

Specific features of take-off in the examined exercises permitted to classify all the training means into four groups:

- training means, mostly involving the BM of legs (takeoff leg) and body extension (group I)
- training means, mostly involving the BM of swinging links (group II);
- training means, mostly involving the BM of an "overturned pendulum" (group III);
- training means, involving the combination of the BM of swinging links with the BM of the "overturned pendulum" (group IV).

Table 8. Contribution of different BMs in track-and-field technique development exercises (%)

Exercise	BM of leg and body extension	BM of swinging links	BM of the "overturned pendulum"	Group
Long jump after a short approach run	17	68	15	I
Long jump over a hurdle	15	65	20	III
Long jump from a raised takeoff platform (0.05 m)	13	65	22	II

Long jump from a lowered takeoff platform (0.05 m)	10	74	16	III
Jump up with touching a suspended object by hand	13	70	17	IV
pattern of 3 hops	18	69	11	I

Thus, different special exercises are intended to exert specific effects on the structure of takeoff, those effects being dependent on the specifics of the content and form of an exercise.

This comparison of technical drills differs from the conventional one, in which every kinematic or dynamic parameter of an exercise is compared with the similar parameter of an actual competitive jump.

Several specific exercises that are currently used in training athletes in different jumping events are listed below as examples. All the exercises are classified into groups I – IV and may be recommended for practical use by athletes of a corresponding specialization. The list of exercises is not full because of the scope limitations for materials to be presented, but it provides general notion about aspects of training means selection for solving concrete training tasks taking into account jumpers' specialization.

Group	**Jump event**	**Exercises**
I	Triple jump Long jump Pole vault	After 4–6 running strides jump onto a pile of mats landing on a swinging leg. Important is to bring pelvis forward at the take-off.
III	High jump Long jump	After 4–6 running strides jump in a "stride" over 2 hurdles; the distance between the take-off spot and the first hurdle is from 180 to 220 cm, the distance between the hurdles 80-90 cm.
III	Triple jump Long jump Pole vault	After 6-7 strides of a direct approach run make a long jump over a bar set at the height 70-80, 90-100, 110-120, or 130-140 cm, taking off in 80-90 cm from the nearest upright.
IV	High jump Long jump	After 4-8 running strides make a long jump attempting to touch a suspended object by the chest or head. Take off in a distance of 2-2.5 m from the projection of the hanging object.
II	Triple jump Long jump	Alternate leg bounds in a pattern: floor (the takeoff leg) – floor board (the swinging leg) – low vaulting horse (the takeoff leg) with touching a suspended object.
I	Triple jump Long jump High jump	A barbell 20-30 kg on the shoulders. After 2-3 walk steps plant the takeoff leg on the board (5-10 cm lower than the surface of the approach) and pushing off by the swinging leg quickly straighten the takeoff leg with the following swing by the swinging leg.
II	High jump Long jump	Standing on a gymnastic bench, feet shoulder width apart, a barbell (10 – 30 kg) on the shoulders. Step forward, straighten the support leg bringing the swinging leg forward simultaneously and putting it on a bar of wall bars. The distance between the bench and the wall bars – 200 – 280 cm.
II	Triple jump Long jump Pole vault	Stand with one foot in front, the other one behind the trunk. Grip the hanging rope at the head level. Push off the takeoff leg bringing pelvis to the rope. While moving the rope in a circle, perform giant strides. Important is to bring pelvis forward in proper time.
IV	Triple jump Long jump Pole vault	Stand on a platform 70-80 cm high, the swinging (takeoff) leg in front, the takeoff (swinging) leg behind. Jump down landing on the takeoff (swinging) leg and bounce up onto a platform 20 – 30 cm high trying to shorten the touch-down to take-off phase as much as possible. The

		take-off is similar to that of a long (high) jump.
IV	High jump	After 6-8 approach strides in a curve leaning into the arc, make a long jump attempting to touch a suspended object by the chest or head. Take off in a distance of 2-2.5 m from the projection of the hanging object.
IV	High jump	The same exercise as the previous one, but after a swing turn the knee of the swinging leg inside (towards the takeoff leg). When taking off turn the trunk so that the shoulder opposite to the takeoff leg is brought forward.
III	Triple jump Long jump High jump	Jump down from a platform 50-80 cm high, land on one foot, and jump over a hurdle trying to make the touch-down to take-off phase as short as possible. The height of the hurdle should be gradually increased. The distance from the platform to the hurdle 3-5 m.
III	Triple jump Long jump High jump	The same as the previous one, but landing on both feet.
IV	Triple jump Long jump	After 2-4 running strides make a triple jump starting from a raised platform. In the third phase (the jump) clear a hurdle set at 50-80 cm height.
I	Pole vault	Starting position (s. p.): Grip onto a pole (in a vertical position) by the right hand, keeping the arm straight, do one step backwards and grip the pole by the left hand 30 – 40 cm lower than the right one. Without moving in any direction try to touch the pole by chest lifting the knee of the swinging leg.
I	Pole vault	S. p. – similar to the previous one. While stepping forward, do a take off and hang on to the pole.
II	Pole vault	After 4-6 running strides take off and hang on the pole. At the end of the legs swing make a half turn counterclockwise to face the approach runway.
I	Pole vault	After an approach run jump and grip on to a hanging rope, swing legs upward-forward and turn counterclockwise. Clearing a bar can be added.
II	Pole vault	When performing a pole vault swing legs upward trying to reach the upper end of the pole by them.

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