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Review Article

Statokinetic Reflexes - The Summation of Irritation and the Escalator Springboard, Determine the Revision of the Existing System of Training High Jumpers

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Abstract

In previous publications of the journal Orthopedics, we have given a rationale for the aberration of the existing muscular-contractile mechanics of hopping and sprinting locomotions [1-4]. In these studies, instead of the previous paradigm that interprets the mechanics of locomotion based on actomyosin contraction, we positioned a different model based on the strain energy. These publications show that in locomotions with rapid interaction with the supporting surface (t = 0.08 - 0.16 seconds), the source of movement is by no means the contractile work of the muscles and not explosive repulsion. Muscles are simply not able to exhibit these fast dynamic modes, with an incredible force gradient and with an incredible energy supply by creatine phosphate [8]. In fact, in the high jump, the source of lift is the deformation energy, with the support of the cytoplasm [1].

Keywords: *Law of Exponential Development; Flea Jump; Resilin; Knee Jerk; Lift Reflex; Summation of Stimuli; Escalator Springboard; Deformation; Precipitation*

Introduction

Due to the different paradigm of the high jump, the training approaches must also change. According to the old paradigm, the training of high jumpers is aimed at improving the muscular-contractile mechanism based on the strength and frequency of nerve impulses [8] (Figure 1), as well as on muscle hypertrophy.

But as we have already noted, the force of muscle contraction achieved by central nervous impulses and its hypertrophy does not determine the jumping ability of an athlete [1,4]. It turns out that athletes train the strength regulated by brain processes, and the jump, in fact, is made due to reflex mechanisms. That is, the training exercises used in the preparation of athletes are performed at a different command level of innervation than in a real jump.

And here it is impossible not to refrain from the following comment. Apparently, it is not at all accidental that the analysis of aspects of the high jump takes place on the pages of a non-specialized magazine on running and jumping. However, we note that in American business circles they say this: “If you want to organize the mass production of good shells, do it without gunners, that is, without specialists “dressed in uniform” of established traditions and canons” [15]. It would seem a strange and controversial statement. After all,

it is the specialists who know how to do it... But on the other hand, the stereotype of existing knowledge is an insurmountable obstacle to going beyond the existing understanding and the emergence of a new eureka event. And for this it is necessary to "throw off the yoke of dominant concepts" [12], which will allow through "alienation" (from the word "alien") to go beyond the existing image [13]. The acquisition of a new understanding through the negation of traditions is possible only through the provocation of a violation of the norm [18].

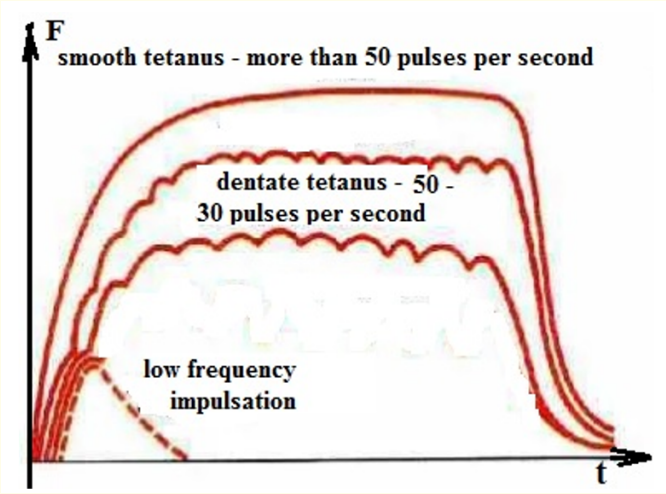

Figure 1: *The frequency and strength of nerve impulses coming to the muscle determines the degree of force manifestation (according to N.E. Vvedensky) [8].*

But is a practical trainer, or a scientist, completely absorbed in the tasks of increasing muscle contractility, able to agree with our paradigm, violate these norms and abandon the category of "explosive repulsion"? No, they will not be able to reject what is the core of their activity. Only a third-party competent view from the standpoint of orthopedics, through abstraction, is able to overcome conformism and endure other views.

And here's what's weird. Inventors and engineers have long turned to the animal kingdom to find innovative breakthroughs. And this is not accidental, because flora and fauna are an inexhaustible source of new design solutions. But for some reason, biomechanics and physiologists from sports do not try to compare the mechanics of animal and human locomotion and meekly accept the fact that an identical set of amino acids given to a person, in physical manifestations, is at least three times less effective in comparison with representatives of the animal world.

This gap in the research of physiologists and biomechanics was the reason for our analytical study, the objectives of which were:

1. Investigate the presence in humans of hidden locomotor mechanisms identical to representatives of the fauna.
2. Consider the existing human locomotor mechanisms from the standpoint of reflex activity.
3. From the point of view of the conducted studies [1-4] to analyze the validity of the existing training directions, based on the training of rapid muscle contraction, in the preparation of highly qualified high jumpers.

Research Results

It is not by chance that we raised the challenge-question of the radical lag of the physical manifestations of man from animals in the annotation. The law of exponential development, or, in other words, the Matthew effect, is deciphered by the words of the Savior: "To everyone who has it will be given and multiplied, but what he has will be taken away from him" (from Matthew, chapter 25). That is, having one will receive even more, exponentially [9] (Figure 2).

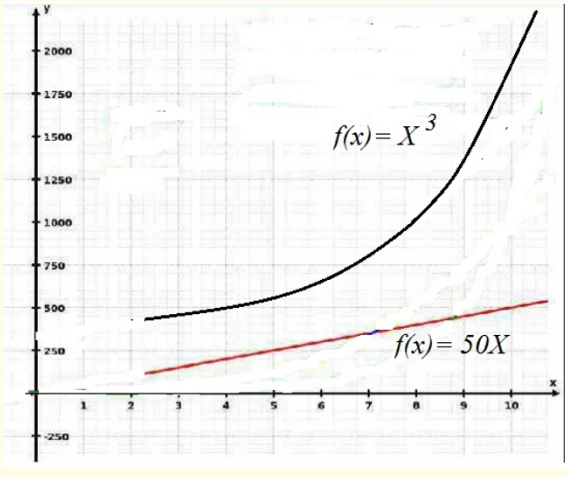

Figure 2: *Graphical representation of the law of exponential development [9] (the Matthew effect).*

And this means that the Creator, or evolution, could not, having given man a mind, at the same time endow him with an imperfect locomotor mover. By doing this, he would doom a person to the role of a link in someone's food chain. But man not only survived, he became the crown of evolution. And this means that in those distant times (1.5 - 2 million years ago), when chasing or retreating, Homo-erectus (the predecessor of Homo-sapiens) used a non-muscle-contractile mover, the low efficiency of which was proved by us, and a more perfect mover, according to our version - cytoplasmic-deformation.

But let's look at modern records of a person, from the standpoint of the manifestation of his maximum physical capabilities. So in the high jump, a person is able to jump over himself 1.25 times. And in animals, this difference is 3-15 times. The record holder in this locomotion is a flea that jumps over itself 200 times! (Table 1).

No. p / p	Representative of the fauna	Body length (cm.)	The absolute height of the jump (cm.)	The height of the jump relative to the body length
1.	Hare	50	250	5
2.	Stocky antelopes	50	500	10
3.	Red-eyed tree frog	7	100	150
4.	Flea Up to	0,5	40-70	220
5.	Cheetah	120-130	400	3,3
6.	Human (H. Sotomayor - world record holder)	195	245	1,25

Table 1: *The height of the jumps of representatives of the animal world in absolute and relative values [21].*

But why such a radical lag in jumping ability in humans? After all, a person is built from the same set of amino acids as animals. And as we assumed, the Creator, or evolution, could not endow a person with an imperfect locomotor mover.

To approach the answer to this question, let's turn to table 2, which shows the dynamics of World records in the high jump for men and women.

Men			Women		
World Record (sm)	**Record holder**	**Year**	**World Record (sm)**	**Record holder**	**Year**
2,29	Ni Zhiqin	1971	1,92	Gusenbauer, Ilona	1971
2,29	Pat Metsdorf	1973	1,92	Meyfarth, Ulrike	1972
2,30	Dwight Stones	1976	1,94	Blagoeva, Yordanka	1972
2,31	Dwight Stones	1976	1,94	Witches, Rosemary	1974
2,32	Dwight Stones	1977	1,95	Ackerman, Rosemary	1974
2,33	Vladimir Yaschenko	1978	1,96	Ackerman, Rosemary	1976
2,34	Vladimir Yaschenko	1980	1,96	Ackerman, Rosemary	1977
2,35	Jacek Wszola	1980	1,97	Ackerman, Rosemary	1977
2,35	Dietmar Moegenburg	1980	1,97	Ackerman, Rosemary	1977
2,36	Gerd Wessig	1983	2,00	Ackerman, Rosemary	1977
2,37	Zhu Jianhua	1983	2,01	Simeoni, Sarah	1978
2,38	Zhu Jianhua	1984	2,01	Simeoni, Sarah	1978
2,39	Zhu Jianhua	1985	2,02	Meyfarth, Ulrike	1982
2,40	Rudolf Povarnitsyn	1985	2,03	Meyfarth, Ulrike	1983
2,41	Igor Paklin	1987	2,03	Bykova, Tamara	1983
2,42	Patrick Sjöberg	1988	2,04	Bykova, Tamara	1983
2,43	Javier Sotomayor	1989	2,05	Bykova, Tamara	1984
2,44	Javier Sotomayor	1993	2,06	Andonova, Ludmila	1984
2,45	Javier Sotomayor	1993	2,07	Kostadinova, Stefka	1986
			2,08	Kostadinova, Stefka	1986
			2,09	Kostadinova, Stefka	1987

Table 2: *Dynamics of world records in the high jump for men and women (compilation of Wikipedia information).*

The table shows records since the invention of the Fosbury flop: 19 records in 23 years for men and 21 records in 16 years for women. A total of 40 updates over 39 years. That is, almost every year a new record was set. And suddenly a sudden stop. Since the 90s, more than 30 years have passed and not a single update. The question is, what is the reason for this 30-year stagnation? Gone are the perfectionists? No incentives? But in the late 80s of the last century, the president of the International Olympic Committee, Juan Antonio Samaranch, amateur sports, refocused on "professional tracks". Athletes began to receive the highest fees. Under these conditions, talking about the lack of incentives, or perfectionism, is not correct. The stagnation can be explained by the fact that coaches and athletes are moving in the wrong direction. They accepted an incorrect perception of the subject, or, in other words, an incorrect gestalt and the preparation went with the implementation of erroneous goals and objectives, which slowed down the manifestation of the true capabilities of a person. That is, the Creator, or evolution, endowed man with a perfect locomotor mover, but this mechanism was left without attention and turned out to be unclaimed. Have we already expressed bewilderment that sports science does not turn to representatives of the fauna for examples? Therefore, the study of the flea's jump is of great interest to us (Figure 3).

Figure 3: *Flea jump.*

The first thing we noticed in the conclusions of an English entomologist from the Rothschild family, an honorary doctor of eight universities, an academician - a member of the Royal Society, Miriam Rothschild and a British zoologist, an emeritus professor at Cambridge University, Malcolm Burroughs, is that the muscles are not able to provide such a fast movement that reaches the flea [6,7]. This evidence, sounded from the mouths of such prominent scientists, is consonant with our conclusions [1,2] about the inability of human actomyosin to perform rapid contraction in the viscous cytoplasm. In the article "A study of parasites in birds" [7], published in the journal Scientific American, the American biologist Miriam Rothschild and her colleagues describe that a flea, which does not exceed 1 - 2 mm in size and weighs 250 micrograms, is able to jump into height by 330 millimeters. A person with such jumping ability would jokingly jump over high-rise buildings. At the same time, in the first millisecond of takeoff, the flea develops an acceleration equal to 140g, that is, 140 times greater than the acceleration of gravity [7]. But if not muscles, then what, then...? Miriam Rothschild and Malcolm Burroughs uncover the secret behind the flea's phenomenal jumps. Before the jump, the flea "locks" the joint with latches in a special way and accumulates tension energy in the elastic protein resilin. When the latches are released, this energy enters into action and the flea makes a fantastic jump [6,7]. We focus your attention on the following - in a flea jump, the active energy of the muscles is spent not on muscle contraction, but on a preparatory action - resilin compression. We asked ourselves the question - is there a similar principle for the implementation of locomotion in humans? But anatomy does not mention a mechanism like latches in humans. Nor is it found in rudimentary traces. However, a reflex is known, which in physiology is called "summation of stimuli" [8]. Back in the 20s of the last century, A. A. Ukhtomsky wrote: "The dominant center is able to summarize excitations" [15]. That is, the human motor apparatus, like that of a flea, is capable of accumulating an action potential. An example of summation is sneezing, which accumulates multiple sequential irritations of the nasal mucosa that occur during the inhalation of air contaminated with dust agents or allergens (Figure 4) [5].

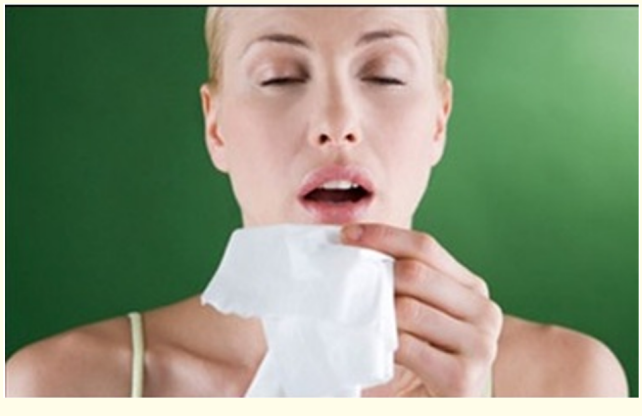

Figure 4: *Sneeze reflex, as an example of the summation of irritation.*

It is noted that the reflex response is 3 - 4 times stronger than muscle contraction! So, for example, the air flow rate during sneezing reaches 44 - 120 m/s, and the volumetric air flow rate is 12 l/s [5]. But even the most trained athlete will not be able to exhale more than 3-4 liters per second. Does reflex summation take place in the work of the motor apparatus? We can affirmatively testify to this. She finds herself both in sports and in the everyday life of an ordinary person. But first, we must mention other mechanisms that belong to the category of statokinetic reflexes, which also take part in the act of summation of stimuli: the knee reflex, the lift reflex, and also the experience that we have designated as the "escalator springboard".

1. Everyone knows the knee jerk. Its trigger mechanism is an instantaneous stretching of the tendon by hitting the own ligament of the kneecap with a hammer [8]. The resulting irritation from the proprioreceptors along the afferent pathways reaches the motor centers, in response to which, an efferent command follows to contract the thigh muscles, followed by extension of the leg at the knee joint (Figure 5).

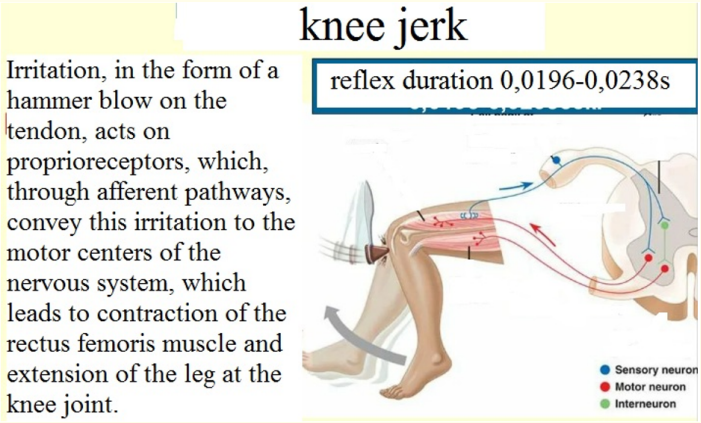

Figure 5: *Scheme of the knee jerk (according to N.V. Zimkin).*

And how does this reflex work in the high jump? What is the factor that instantly stretches the tendon? Earlier [1] we pointed out that the high jump is carried out with the help of a run performed along an arc (Figure 6).

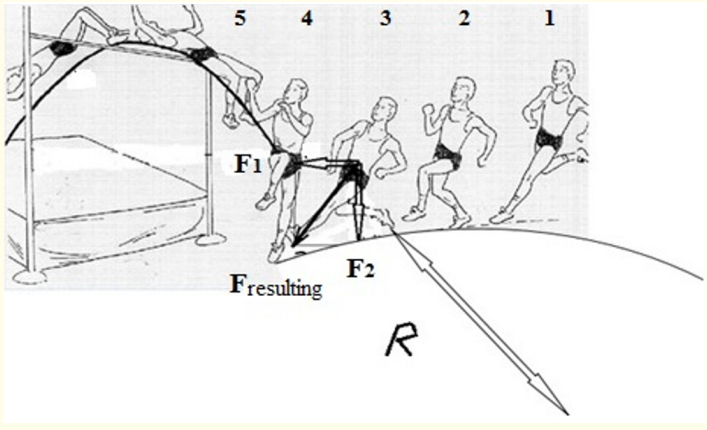

Figure 6: *Run in an arc in the high jump fosbury flop.*

When running along an arc, the action of centrifugal force (F1) and the resultant force (Fresulting), by transit through the cytoplasm, instantly transfers this resultant load to the tendons (the kneecap ligament, the ligament of the rectus femoris muscle, the ligament of the medial muscle and the Achilles tendon) [1]. There is a sharp stretching of the tendons. From the tendon receptors, as in the knee jerk, the signal comes to the motor center. These annoyances add up. In figure 7, on the example of the Olympic champion, three-time world champion Mutaz Barshim. the model of summation of stimuli is shown, at each step of its run along the arc.

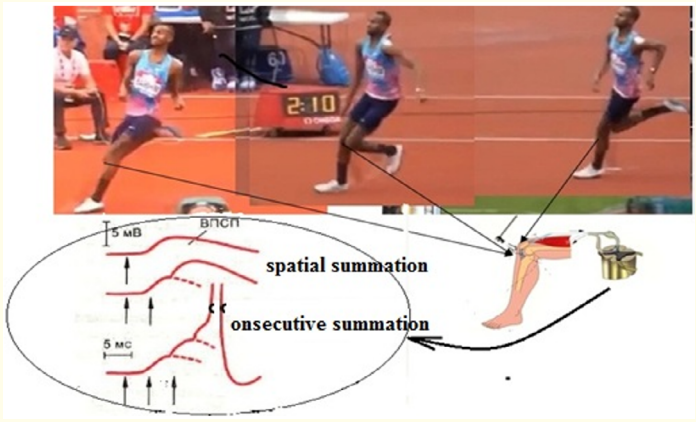

Figure 7: *Run along the arc of Mutaz Barshim, in which, as a result of the instantaneous tensile action of the kneecap's own ligament, a sequential summation of irritations occurs (compilation to video paint by M. Barshim).*

In physiology, it is noted that sequential summation is possible, coming from the same stimulus, as well as spatial summation, coming from several stimuli simultaneously [8]. So during the run along the arc, as well as in the phase preceding the final part of the jump - the rebound, there is a stream of afferent impulses from: own ligament of the kneecap; ligaments of the rectus femoris; medial ligament; Achilles tendon; otolith receptors.

Note that this effect also occurs in the lift reflex. This reflex, identified by the Dutch physiologist R. Magnus in 1924, manifests itself at the beginning of a quick lift of the elevator, or at an abrupt stop, when moving down. At the same time, the labyrinth canals of the otolithic device, due to the activity of the middle and medulla oblongata, give a signal of positive or negative vertical acceleration, in response to which the muscles of the musculoskeletal system receive a command to contract [8]. That is, irritating signals come to the motor center not only from the tendons, but also from the vestibular apparatus of the medulla oblongata.

A special case of the lift reflex is the experience that we called the “escalator springboard”. Everyone who moved on the subway escalator, in a hurry and while escaping from its tape, experienced an emotional sensation - “wow, how elastic I fluttered out (a)” (Figure 8). At the same time, there is a feeling as if some unknown force is throwing you up with a positive emotion.

Let’s look at where this athletic jumping ability and lightness can come from. The speed of the escalator tape is 0.75 m/s, and during peak passenger traffic - 1.05 m/s [14]. The speed of movement of a “hurrying person”, relative to the escalator tape, can be, for example, 3 m/s, and then its total speed will be 3.75 m/s, or 4.05 m/s, at the peak load of the subway. At the end of the movement of the escalator tape, an arcuate change in the direction of sliding of the escalator tape occurs, which creates a centrifugal force that reflexively acts on the tendons through conduction and support of the cytoplasm, resulting in an “air” jump. Using the formula [10]:

Figure 8: *The manifestation of lightness when quickly running down the escalator.*

$F = mV^2/r$ (1), where F is the value of the centrifugal force, m - 65 kg, V - 3.75 m/s, or 4.05 m/s, r = 1.5m, we get the value of the centrifugal force, which is equal to 62.7 kg (72.5 kg - at peak loading). That is, a "hurrying girl", weighing 65 kg, experiences a total load on the repulsive leg of 127.7 kg, or even 137.2 kg, which she successfully copes with without noticing it, and even vice versa, she feels athletic lightness and briskness. These 127 kg (132 kg) falling on the pushing leg are not a burden, but are the force of the deforming tendon. For this reason, the muscles do not overstrain, there is also no titanic central nervous impulse from the motor sections of the cerebral cortex! It is not the muscles that work, but the support of the cytoplasm and tendons, so the movements are light and airy. However, we note that this effect is not noticeable on the escalators of shopping centers, where the belt speed is much lower.

This example, among other things, confirms the previously put forward version of the denial of the participation of muscle strength in hopping locomotion. Therefore, before planning a lot of strength work for their athletes, we would recommend coaches to ride with the breeze on the underground metro escalator and ask themselves the question, is this jump provided with central nervous impulses and muscle hypertrophy? And is it necessary to fanatically train the explosive power of the leg extensors?

But again, back to our knee jerk. Perhaps you have already noticed a subtle weak link that calls into question our paradigm outlined in previous publications. To do this, once again consider the algorithm of the knee jerk:

1) A blow with a hammer causes a sharp irritation of the proprioceptors of the tendon;

2) This irritation along the afferent pathways reaches the motor centers;

3) The motor centers send a command to "contract" to the thigh muscles.

It turns out that through the tendon there is an initiation of a response. And this response is performed by the thigh muscles…?

A dilemma has arisen. According to our findings, when moving in the cytoplasm, actin and myosin spherical filaments are strongly inhibited in a viscous medium [1]. And the description of the knee and lift reflexes indicate the command impulse that the muscles perform.

But we have found arguments in defense of our paradigm. To resolve this dilemma, we will ask you a provocative task. The football player runs up and hits the soccer ball hard (Figure 9). The ball flies a distance of 96 meters. Question:

Figure 9: *What allows the ball to fly 96 meters?*

- What force allows the ball to fly so far?
- The kinetic energy of the kicking leg, transferred to the ball, weighing 400 grams?
- Or something different?

It is not difficult to guess that with the help of this kinetic energy, gained by the muscles of the kicking leg of a football player, the ball is deformed, which sends it almost through the entire football field. Skeptics are advised to release the pressure in the ball to zero and see if the ball flies at least 30 meters.

To confirm this mechanics of pre-deformation based jumps, we made numerous observations of the cat's jumps and found that it makes a jump due to a short impulsive movement, which ends abruptly with, as it were, an incomplete amplitude. We had a question: why does a cat push off with a short impulse and does not use the possibility of full extension in the joints to disperse its body with uniform acceleration? The analytics led us to the conclusion that the dynamics of the efforts of her jump is not similar to the mode of operation of a space launch vehicle with a linear and uniform increase in power. We assume that with a short impulse action, the cat stretches the tendons, which then move it. That is, the jump of the cat occurs in the mode of a two-beat rhythm (Figure 10). The first cycle is an impulse deformation, which instantly "catches up" with the second cycle - the reciprocal work of the tendons.

This double two-bar rhythm is similar to the musical rhythm (for example, guitarists call it from under the bar), as well as in pogo stick jumps (Figure 11). The findings of one of the world's leading biomechanics, biomechanics researcher and physiologist from the Southern Methodist University, Peter Weyand, say that sprinters run due to the fact that they sharply hit the ground with their feet [11]. By doing this, they use their limbs as pogo sticks [11], the work of which is carried out due to the strong deformation of the spring, followed by a return action (Figure 11). This, again, is an example of a dual rhythm.

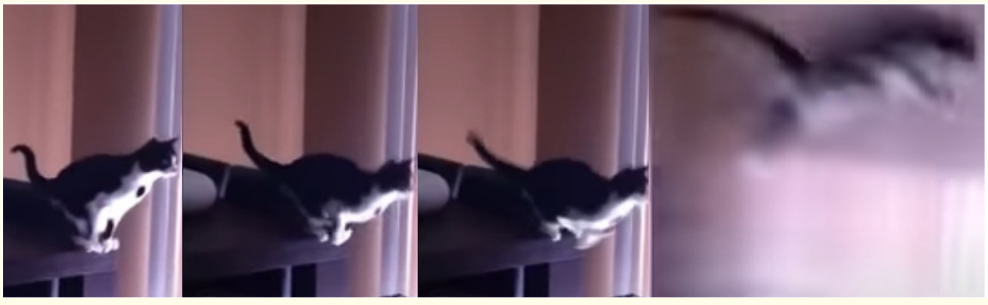

Figure 10: *Two stroke cat jump mode.*

Figure 11: *Jumping on the pogo stick performed in a two-stroke rhythm "deformation-response".*

By the way, this is also shown by the dynamometry graph (Figure 12) in the high jump, which we presented in an earlier publication [1].

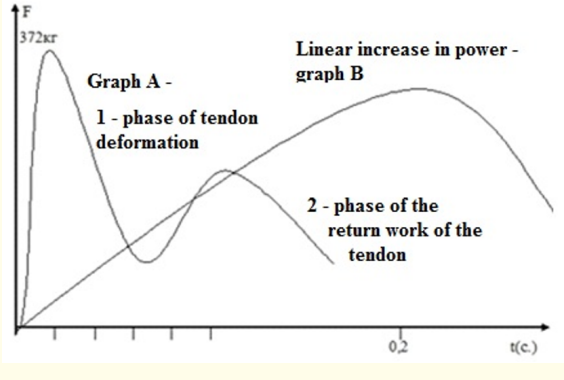

Figure 12: *Curve of dynamometry when a jumper rebounds in height from the runway (according to Strizhak A.P.) - graph A and an example of a linear increase in effort - graph B [1].*

However, the question still arises: Why such difficulties? Wouldn't it be more rational to apply a linear increase in speed? We did the calculations on the example of hitting a soccer ball and got the following results. The muscles of the abdominals, rectus femoris and medial muscles will accelerate the leg of a football player with a mass (m) of 13.5 kg (18% of the football player's body weight = 75 kg), which hits the ball with a mass of 0.4 kg, with a speed of 3 m/s. The estimated speed of the ball departure is 30 m/s, or 108 km/h. But the real speed of the ball is much higher - 200 km/h (the record is 250 km/h) (Figure 9).

The question is, due to what does this two-fold increase in the initial speed of the ball take off occur abruptly? Of course, due to the forces of deformation. That's what the two-beat rhythm is for. Is this not evidence of the incarnation of the words of the Creator about geometric growth: "To everyone who has it will be given and multiplied". No, the Creator and evolution did not deprive us. They gave man a much more efficient mover with a two-stroke rhythm of implementation. Moreover, free power is used to double the initial speed of locomotion! Brilliant! Therefore, trainers and researchers should think hard about this fact, and again, and again, having experienced the escalator springboard, "step" beyond the usual concepts.

Discussion of the Research Results

On the basis of the conducted analytics, we propose the following model of the human musculoskeletal system in hopping locomotion, from the standpoint of reflex activity.

In a high jump using the Fosbury flop method, under the action of centrifugal forces, an instantaneous stretching of the tendons occurs like a knee reflex. This causes a flow of sequential and spatial impulses from the main tendons of the muscles of the thigh of the lower leg and foot (tendon of the rectus femoris muscle, own ligament of the kneecap, ligament of the lateral muscle, ligament of the medial muscle, Achilles tendon, ligaments of the foot, and also from the otolith apparatus) to the motor centers. This flow of proprioceptive impulses is summed up and, when the threshold value is exceeded, an efferent signal is given to contract the leg muscles, which deform the tendons, followed by their return work and giving the body a lifting force. This mechanism is similar to the accumulation of an action potential, with the help of latches in a flea, with its subsequent disposal.

This two-stroke rhythm is not analogous to a linear build-up of power, such as when taking off a spaceship. The graph that we have identified in the study of A.P. Strizhak [1] indicates a two-peak, or two-stroke mode of force dynamics. The question is why the body does not apply a linear increase in acceleration, because logically this is a more optimal mode. The answer is that the push-pull mode is 2 times more efficient than a linear increase in effort. The wisdom of the Creator and evolution in the fact of the invention of the effective use of gratuitous forces, one can only be surprised.

A different paradigm of the high jump mechanism determines the revision of training approaches. The current practice of training high jumpers is focused on:

- To train the central nervous impulse with actomyosin contraction, while real jumps are made on the basis of a reflex;
- Most often carried out on the basis of training in the mode of linear increase in power, which is half as effective. Perhaps it was this connection to the muscular-contractile work of the locomotor apparatus that was the fundamental reason for the lagging of human records from the physical manifestations of representatives of the animal world.

In the same way that we cannot increase sneezing through training, we cannot train the strength of the reflex response. The basis of training can be an increase in the flow of stimuli and their summation, which we can raise due to the action of centrifugal forces, through the speed of the run-up and the acceleration of the swing.

Conclusion

1. In previous publications, we pointed out the aberration of the muscular-contractile paradigm of hopping locomotion and proposed the deformation energy of acquiring lift. In this article, we supplement our paradigm with the positions of reflex activity - the summation of stimuli. This mechanism is similar to the operation of latches, as in a flea's jump.

2. The dynamic structure of rapid interaction with the runway takes place in a two-cycle rhythm - the first cycle is deformation due to muscle efforts, the second cycle is the utilization of the accumulated deformation energy and the acquisition of lifting force, due to free tension forces.

3. A two-beat rhythm based on a reflex is about twice as effective. Therefore, sports science and practical coaches must perceive a different gestalt of the high jump and reconsider the old paradigm based on the reduction of actomyosin due to the strength and frequency of nerve impulses. Their search should be directed to:

    - Finding factors that increase the flow of proprioceptive impulses subject to summation; - increase in the acceptance of the incoming motor impulse;

    - Selection of exercises carried out in a two-stroke rhythm.

4. The reference point for the sensory perception of this mechanism is the escalator springboard.

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