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Review Article

The Use of Bernstein's Theory of Movement Control to Train the Explosive Ability of Muscles, as a Reason for Limiting Athletes' Records in Jumping and Sprinting

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Abstract

A number of prominent scientists and sports practitioners, together with the leaders of national teams, have more than once expressed the minor sentiment that "man, as a record holder, has approached his physical limit" [10].

However, we note that respected scientists, such as Doctor of Medical Sciences N.A. Agadzhanyan, Head of the Department of Human Reserve Capabilities of the All-Union Scientific Research Institute of Physical Culture, Doctor of Pedagogical Sciences V.V. Kuznetsov, Academician, member of the UNESCO College of Scientists V.I. Kandyba, collected numerous evidence of supermanifestations of people when an extreme situation occurs.

We cannot question this evidence from respected scientists. But then can we say that the current human records are the limit? Maybe scientists and trainers are doing something wrong?

Keywords: *Plateau of Human Records; Paradoxes of Muscular Dominance; Reflex-Deformation Mechanism; Bernstein's Theory of Movement Control*

Introduction

Working (1985-1991) in the group of scientific and methodological support of the national team, we searched for new ways to train athletes to achieve new human records in locomotion with rapid interaction with the supporting surface (jumping, sprinting).

And since previously a number of prominent scientists and sports practitioners, together with the leaders of national teams, expressed a pessimistic attitude that "man, as a record holder, has approached his physical limit" [10], we took the path of comparing man with the animal world and identifying limiting factors. factors.

We proceeded from the fact that both people and animals were originally predators, which means they used identical and uniform life resources, as well as methods of obtaining them. Both humans and animals are made up of a single set of amino acids. However, considering this state through the prism of abstraction, we can state that the modern amino acid substance "man" is three times inferior to the amino acid substance "animal" in running and jumping. Is it then right to say that the amino acid substance "man" itself is not capable of more? Does your skeletal system fail? Is the calcium injection slower? Is the frequency of nerve impulses inferior? Is acetylcholine different?...

Evolution could not direct the improvement of these and other factors along ineffective paths. The Creator could not deprive man, since from his words it follows "For to everyone who has, more will be given, and he will have abundance" (Matthew 25:29). Technical progress could not "do this to us" either, since it came much later than our "loss" was outlined.

This means, as they say, "something went wrong". In previous publications [1-4,7,8], we gave clear explanations of these issues and identified what exactly "went wrong". More specifically, ancient man, for some time now, in his fast locomotions, "switched" from the deformation work of the musculoskeletal system to muscular-contractile mechanics, the efficiency of which is at least two times lower. This mechanics came to modern sports, was organically integrated into the system of training athletes and, on the basis, so persistently trained by athletes, of the explosive ability of muscles, for a long time stalled the achievements of athletes in running and jumping.

In order not to outrage the reader with our provocative statements and to simplify his familiarization with our previous works concerning the issue of locomotion of running and jumping, we allow ourselves to provide a compilation of the main points of our previous developments.

In the course of our research, we identified many paradoxes of the muscular-contractile paradigm of the mechanics of explosive repulsion, obtained on highly qualified athletes [1]:

1. Not the reality of the graphics of A.P. Strizhak, who studied the biodynamics of the high jump using the Fosbury flop method [1];

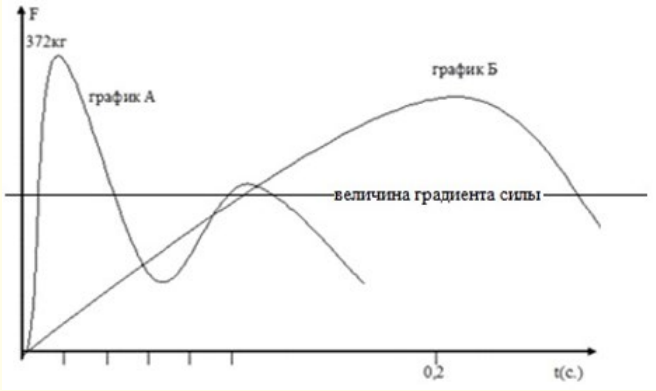

Figure 1: *Actual indicators of push-off dynamometry for high jumpers (according to Strizhak A.P., [15]) - graph A, and the maximum physiological capabilities of a person (according to Mitreykin V.G., Andris V.D. [1]) - graph B.*

According to this graph, obtained on a dynamographic stand (UDS 5), the high jumper, already 0.02 s, after setting her foot for take-off, pressed on the tension platform with a force of 372 kg. This is at least fifteen times the ceiling of human capabilities. This applies to both the force of pressure with one foot on the strain gauge platform and the force gradient indicator. According to Mitreykin V.G., Andris V.D., this indicator for the lower leg muscles is 0.117s [1].

2. Ultra-high power of pressure on the tenso platform, in the so-called "repulsion phase" (7000 W), exceeding the power of all energy sources available to humans (6000 W) [1].
3. The cytoplasm, in which the sarcoplasmic reticulum, as well as the actin and myosin filaments that form the structural basis of myofibrils, are "immersed", has a high density. Therefore, the cytoplasm acts as a brake for the rapid contraction of actomyosin.

According to the physical law, when a body moves in a liquid, with an increase in the linear speed of the body, the resistance of the medium does not increase adequately, and not twice, but by the square [13]. That is, if we set the task of doubling the contraction rate, we will get a fourfold increase in cytoplasmic resistance, and if we set the task of "catching up" with animals and increasing the contraction rate threefold, then we must be prepared for a ninefold increase in cytoplasmic resistance. Moreover, spherical bodies, such as actin and myosin, have the shape of spherical beads and are subject to the greatest turbulent (vortex) braking resistance [12]. Nature seems to have specially created mechanisms to slow down the rate of myofibril contraction.

4. Lack of correlation between all indicators of muscle explosiveness and the strength of the hip extensor muscles with the result in a competitive exercise (high jump) [1].

NN p/p	Study indicators	Correlation coefficient	Characteristics of dependence (on the Chaddock scale)
1.	Correlation coefficient between the level of explosive qualities and competitive results among the country's leading jumpers (men) in 1986-1987.	0.3938	Weak
2.	Correlation coefficient between the level of explosive qualities and competitive results among the country's leading jumpers (men) in 1987-1988.	0.0377	Absent
3.	Correlation coefficient between the current level of explosive qualities and the competitive result of Alexey Emelin, for the period 12.1988-03.1990	- 0.2462	Negative
4.	The correlation coefficient between the current level of explosive qualities and the competitive result for the period 12.1988-03.1990, for Grigory Fedorkov	- 0.0772	Negative
5.	The correlation coefficient between the current level of explosive qualities and the competitive result for the period 05.1988-06.1990, for Leonid Pumolainen	- 0.2857	Negative
6.	The correlation coefficient between the current level of explosive qualities and the competitive result for the period 12.1988 - 03.1990, for Maxim Dovzhenko	- 0.0335	Negative
7.	Correlation coefficient between the current level of explosive qualities and competitive results for the period 12.1988-04.1989. Denisov A.	- 0.0289	Negative
8.	The correlation coefficient between the current level of explosive qualities and the competitive result for the period 12.1988 - 04.1990, for Mikhail Khabarov	- 0.04423	Negative
9.	Correlation coefficient for the hip extensor muscles and competitive results in the high jump in women.	- 0.06	Negative
10.	Correlation coefficient for the plantar flexor muscles and and competitive results in the high jump in women.	- 0.4039	Negative

Table 1: *Summary table of correlations of competitive results with the strength and explosive abilities of elite male and female jumpers.*

5. Exorbitant indicators of the action of centrifugal forces in the high jump, using the Fosbury flop method. During the run-up, which is carried out in an arc and when performing swing movements, centrifugal forces arise, the total value of which, for example, for Olympic champion Anna Chicherova exceeds 358 kg [1].

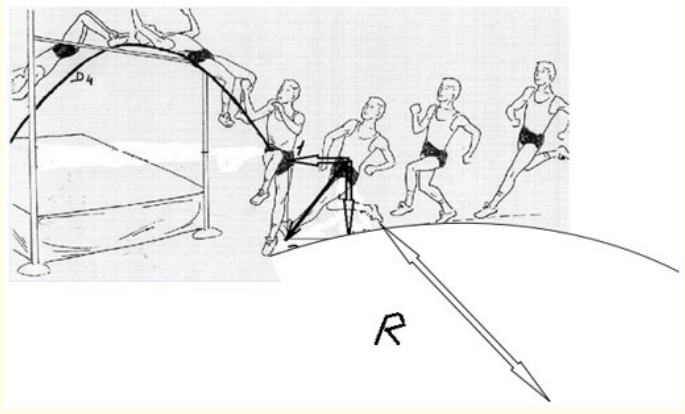

Figure 2: *An example of the action of centrifugal force during an arc run.*

How, under the conditions of this additional burden, can an athlete push off from the track and give her body a vertical take-off speed of more than 4 m/s.

These and many other facts indicate the inability of the muscular-contractile paradigm to substantiate all the paradoxes that contradict the fundamental principles of human physiology and indicate that in the high jump using the Fosbury flop method, it is not muscular-contractile, but other mechanics that are used. We conducted a study and found out that muscular-contractile mechanics is not the only way to carry out locomotion in living beings.

American biologist Miriam Rothschil and Cambridge Laboratory scientist Malcolm Burrows, using the example of a flea, showed us that another way to achieve vertical flight speed is possible - based on the use of deformation energy [5,9]. We also found out that cats [4], as well as humans [1], also jump by pre-deformation. The possibility of implementing this mechanism in humans is indicated by the studies of V. Tyup, Serov, Shekhter [1,16], as well as our analytics [1-3].

Tyupa V showed a model for using elastic work (Figure 3).

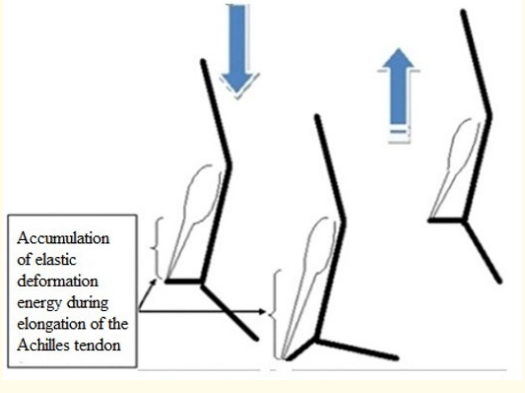

Figure 3: *Performing an elastic rebound due to the return work of the Achilles tendon, manifested due to the energy of elastic deformation.*

With this mechanics, tendons come into play, while the length of the muscle bundle is kept unchanged.

When applying the muscular-contractile principle of performing a high jump, there is no explanation for how one can give the body a vertical speed of more than 4 m/s, in the presence of an additional burden of 358 kg. And with the reflex-deformation mechanism, this enormous value (358 kg) becomes a force that deforms (stretches) the tendons, and the cytoplasm becomes an assistant in counteracting muscle stretching, in transit, transferring the load to the tendons [1].

At the same time, using the example of a cat, we identified the following fundamental feature of the operation of the musculoskeletal system - the push-pull mode of operation. It turned out that the cat exerts its muscular efforts not to push away, but to deform (stretch) the tendons.

But then the tendons lift it up [4]. The cat does not push off, but with sharp, short-term pressure it deforms the tendons, which then allow it to jump onto an elevated surface. But where do the advantages of deformation mechanics come from? Let's consider an example related to hitting a ball [4]. The football player runs up and kicks the football hard. According to Wikipedia, the record for the ball's flight distance is 96 meters, and the record for the ball's flight speed reaches 250 km/h (Figure 4).

Figure 4: *What allows the ball to fly a distance of 96 meters?*

We carried out our own calculations and obtained more modest results. The muscles of the kicking leg, due to muscular contraction, will in no way be able to give the ball a speed of more than 114 km/h. Where does this more than twofold increase in speed come from then?

The muscles of the abdominals, rectus femoris and medialis muscles are capable of dispersing the lower leg (m) 3.78 kg (5.05% of the football player's body weight = 75 kg) and the foot of the football player weighing (m) 1.07 kg (1.43% of the weight football player's body = 75 kg) up to three meters per second. In total, their mass is 4.85 kg. This mass acts on a ball of mass 0.46 kg. According to the formula from classical mechanics $E = mv^2/_2$, the kinetic energy of hitting the ball will be 4.14 kg m/s. This energy will be transferred to a 400 gram ball, which is 10 times lighter than the applied force. This means that the estimated speed of the ball will increase tenfold and amount to 31.6 m/s, or 114 km/h.

How, then, is the ball's speed achieved, more than twice the calculated speed (250 km/h)? (Figure 4).

There can only be one explanation here - the strength of the leg muscles is used to deform the ball. And the work of deformation doubles this speed and sends the ball almost across the entire football field... This is truly how the words of the Creator are heard, "For to everyone who has, more will be given, and he will have abundance" (Matthew 25:29).

Let's turn to sprint running. The findings of one of the world's most authoritative biomechanists, biomechanics researcher and physiologist from Southern Methodist University, Peter Weyand, state that sprinters run by striking the ground with their feet [3]. By doing this, they use their limbs as pogo sticks [2], the work of which is carried out due to the strong deformation of the spring with a subsequent return action (Figure 5). That is, a double rhythm is observed, the first beat is deformation, the second beat is the work of deformation.

Figure 5: *Pogo stick jumps performed in a push-pull rhythm.*

Based on the mechanics of Peter Weyand, we can conclude that the muscles produce a strong impact, which is aimed at deforming the elastic structures of the runner's musculoskeletal system, followed by the utilization of deformation forces. That is, in sprinting, the driving force is also deformation, and not the explosive ability of the sprinter's muscles.

For a long time, the provisions outlined here were reported to the world-famous coach Evgeniy Zagorulko, whose students won Olympic medals:

- Bykova Tamara - bronze - 1988 - Seoul;
- Elena Elesina - gold - 2000 - Sydney;
- Andrey Silnov - gold - 2008 - Pyongyang;
- Chicherova Anna - gold - 2012 - London.

Evgeniy Zagorulko adopted a different gestalt of the high jump - reflex-deformation, as a result, many Olympic gold medals.

However, there are no radical records yet. And there is no need to talk about reducing the threefold gap with the animal world. This means that the muscular-contractile principle of work "sits" firmly in us. For what reason are human locomotions carried out in an unfavorable and ineffective mode, while animals use deformation energy? How did it happen that man adopted this ineffective muscular-contractile mechanism?

We assume that the muscular-contractile principle of locomotion did not "come" to man today; apparently it appeared quite a long time ago. A person has been moving along this path for a long time and it is unlikely that he will be able to "jump" so easily from the muscular-

contractile "track" to the reflex-contractile high-speed "magnetic levitation monorail". Therefore, first of all, we must understand where that turning point was in the evolutionary history of locomotion and outline ways for humans to return to the path of reflex-deformation mechanics.

To determine the turning point of the transition from the reflex-deformation mechanism to the muscular-contractile mechanism of human locomotion, we conducted a study, the objectives of which were:

1. Identify the reason that determined a person's transition from the reflex-deformation principle to the muscular-contractile principle of jumping and fast running.
2. Outline possible ways of "returning" a person to reflex-strain mechanics.

Research Results

We believe that as soon as ancient man stood on two legs and took a stick or other tool in his freed hand, his development followed the path of conscious regulation of movements. He began to improve his skills in knocking down fruits, throwing stones, and countering other representatives of apes with a stick. Ancient man began to improve his skills through commands from the brain to working muscles. This was the reason for the "expansion" of the brain in controlling motor actions, the most important role in the execution of which belonged to the muscles, through which the brain began to control the manipulation of these tools.

It was not the reflex of retreat or prey that became the stimulus, but the commands of the brain became the stimulus for human motor actions, performed, albeit automatically, but under the control of the brain.

Even ancient thinkers tried to reveal the secret of the movement of living things. The first works in this area were written by Aristotle (3rd century BC), who was interested in the patterns of movement of land animals and humans. Problems of biomechanics occupied the Roman physician Galen (2nd century AD), Leonardo da Vinci (15th century), Giovanni Borelli (16th century), a student of Galileo and the author of the first book on biomechanics, "On the Movements of Animals," published in 1679. However, all these works were aimed at studying locomotion, where the driving force was muscular mechanics. We remember the spectacular pictures of Leonardo da Vinci (Figure 6).

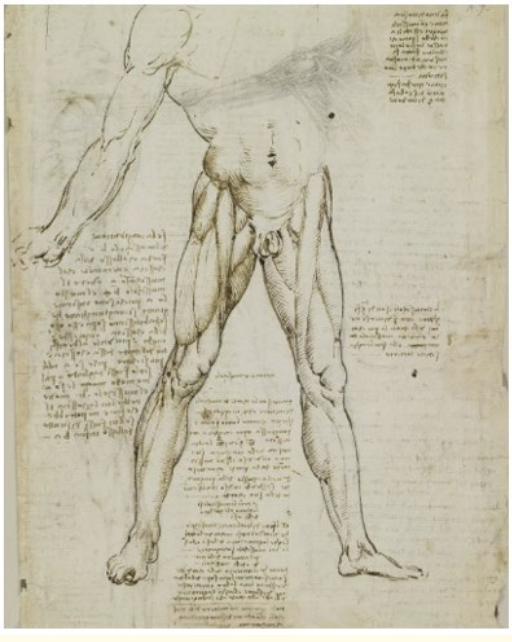

Figure 6: Example of anatomical drawings by Leonardo da Vinci..

Muscles, they are very impressive and they were the ones that occupied Leonardo da Vinci most of all, in expressing the dynamics and power of locomotion. Naturally, this dominant came to us too.

I. M. Sechenov in his books: "Reflexes of the Brain" (1864), "Essay on Working Movements" (1901), "Elements of Thought" (1878), "On the Question of the Influence of Sensory Stimulations on Human Muscular Work," described sensory irritation to human muscle function.

Physiologist I.P. Pavlov laid the foundation for the reflex nature of psychophysiological processes in animals.

A. A. Ukhtomsky (1923) he publishes the work "Dominant as a working principle of nerve centers".

N. E. Vvedensky (1886) introduces the concept of "lability", functional mobility, the speed of elementary cycles of excitation in nervous and muscle tissues.

On the platform of these studies, Nikolai Bernstein created a theory about the motor activity of animals and humans and turned it into a tool for understanding the functioning of the brain [14]. In his works "On agility and its development", "On the construction of movement" (1947), "Essays on the physiology of movements and the physiology of activity" (1966), he suggested that the control of human movements comes down to continuous correction of the movement of a link (for example, an arm or legs), carried out by the central nervous system based on signals from the organs of vision, hearing or touch. The nervous system, "giving a command" to start any movement, never leaves it without control and, if necessary, immediately corrects it, which he designated by the phrase "sensory correction" [14].

It follows from this that the control and correction of movements is carried out "by the central nervous system on the basis of signals from the organs of vision, hearing or touch... the nervous system, "giving a command" to start any movement, never leaves it without control and, if necessary, immediately corrects". That is, the cause of muscular-contractile mechanics, which arose with human evolution, is control and correction?

But before answering the question in the affirmative, let's consider one of the points presented by Nikolai Bernstein, using the example of feeding seagulls from a steamer: "when a bird, seeing a flying piece, "calculates" its possible trajectory, compares it with the direction and speed of its flight, and then the brain gives a command to the muscles to direct the body to the point where the beak meets the piece of bread".

Let us interrupt N. Bernstein's narration here and note that "the bird "calculates"... the trajectory, compares... and then the brain gives the command to the muscles," again, to the muscles..".. There is also control and correction. How then does the regulation of movements in an animal differ from the regulation of movements in a person?

Bernstein himself gives the answer to this question: "Man differs from the rest of the animal world only in that his principle of activity, combat self-organization has become conscious and is formed, among other things, in articulate speech, writing, etc.

"...became conscious" - this is where the turning point of a person switching to the muscular-contractile mechanics of jumping and running is. It was not the withdrawal reflex, but conscious expediency that became the incentive for action.

This also came to sports. By accepting Bernstein's theory of motor control, which is aimed at improving skills and abilities, and not at training speed and jumping ability, we remain in the sphere of influence of the muscular-contractile paradigm. But this is what concerns fundamental science, but what is the situation in the practice of sports?

The undoubtedly outstanding book by Vladimir Zatsiorsky, "The Physical Qualities of an Athlete," has provided significant assistance to coaches. The amazing system of using the delayed cumulative training effect of Yuri Verkhoshansky [17] made it possible to significantly increase the level of speed-strength capabilities of athletes. But these books, which introduce an understanding of muscular-contractile mechanics, lead us away from reflex-deformational mechanics.

It is no coincidence that we conducted a deep excursion into the research of previous years and all of them relate to the study of the locomotor system from the standpoint of physiology, which inevitably turns us to muscles. But locomotion is, first of all, kinematics.

And, again, the following factors:

- Serious theoretical training for future trainers in professional educational institutions, where everything revolves around muscle contraction: striated muscle, actin, myosin, sarcoplasmic reticulum, sodium-potassium pump, central nervous impulses, lability, neurotransmitter...
- Bodybuilding competitions not only "attracted dominant attention to the muscles, but also those who were especially "obsessed" called on steroids to help. They saw their progress only in steroids and therefore in building muscle strength. This focused our attention on the muscles for a long time and pushed back the revision of the muscular-contractile paradigm and the search for other mechanics.

Everything revolves around muscles. The dominance of thoughts is directed exclusively at the muscles, from Aristotle, through Leonardo da Vinci and Bernstein, to the present time.

But this is exactly what Nikolai Bernstein writes about: thoughts "formed, among other things, in articulate speech, writing, etc.," which do not even allow one to think about anything extraneous and lead away from the reflex mechanism. That is, a person has moved from reflexive to conscious self-organization. And although the coach and scientist V. Dyachkov, back in 1967, uttered the phrase "ricocheting rebound" [6], it remained unnoticed. Locomotion training is still carried out by muscles, based on knowledge of physiology, while the basis is deformation, which is the orthopedic basis of jumping and running, with a short phase of interaction with the supporting surface.

But is it possible to return to reflex-strain mechanics? The answer will most likely be positive. Respected scientists, such as Doctor of Medical Sciences N.A. Agadzhanyan, Head of the Department of Human Reserve Capabilities of the All-Union Scientific Research Institute of Physical Culture, Doctor of Pedagogical Sciences V.V. Kuznetsov, Academician, member of the UNESCO College of Scientists V.I. Kandyba, collected numerous evidence of supermanifestations of people when an extreme situation occurs. Here, for example, is evidence recorded by Professor Vladimir Kuznetsov [11]: "During an emergency landing in the North, he (the pilot) got out of the cockpit to look at the damage to the landing gear. I squatted down and suddenly felt the heavy paw of a polar bear on my shoulder! I only came to my senses on the wing of the plane, where I ended up, without knowing how, jumping in cotton trousers, a jacket and fur boots to a height of 2 meters" [11].

If we take this into account, then we can say that a person has not lost this reflex mechanism, on the basis of which deformation work of the musculoskeletal system is possible. In an ordinary situation, when movements are conscious, the musculoskeletal system works in a muscular-contractile mode. A stressful situation "brings" a person to a reflex with deformation mechanics. So, the task is to create a stressful situation? But this is not realistic when organizing the process of training athletes. And the athlete's consciousness will not turn off at a strong-willed command. So, for now there is only one way - creating conditions under which the athlete will be forced to interact with the runway only in a deformation mode. In one of the latest articles (Alexander Egorov. "Statokinetic Reflexes - The Summation of Irritation and the Escalator Springboard, Determine the Revision of the Existing System of Training High Jumpers". *EC Orthopedics* 14.3 (2023), we have already presented the effect of summation of irritations. For example, the summation of irritations is sneezing and we sneeze, regardless of the control of our consciousness.

There we also presented a solution to the problem of the effect, which we called the "escalator springboard," which also manifests itself regardless of our consciousness.

In the next article we will give a successful example of reflex-deformation work without creating a stressful situation, carried out in high-achievement sports.

Of course, if we count sports science from the time of Nikolai Bernstein, then we can note that almost a hundred years have passed. That is, let us take the liberty of saying that a hundred years have passed of the development of talented ideas and their implementation in practice, but all this is an aberration for jumping and running. Therefore, it is not possible to complete a complete paradigm of training in jumping and sprinting in one article; this will require time and, first of all, to break the conformity of scientists and practitioners.

Conclusion

1. The turning point in man's transition to muscular-contractile mechanics was the moment of human evolution, when he picked up an object of labor and began to improve his mastery of it. This allowed the brain to carry out a total expansion and spread its influence to all locomotion. Note that in animals all locomotion has a reflex basis. In humans, all movements have a conscious stimulus. The second turning point was the use of Bernstein's motor control theory as a training tool, which was intended for skill improvement and was not suitable for locomotion involving rapid interaction with a supporting surface (the runway). The next thing that delayed the transition to the right "rails" were anabolic steroids, which set off a race in laboratories and even more and for a long time attracted attention to the muscles, leaving a person in the "muscular-contractile mechanics" reservation.
2. A person is capable of radically improving his maximum capabilities, and this is indicated by his over-manifestations in a stressful situation.
3. The path of training the speed of muscle contraction, together with solving problems of muscle anabolism, is a dead end. It is necessary to abandon training of the muscular system and take the path of engaging the deformational nature of the work of the musculoskeletal system.
4. Research by scientists should be aimed at the issues of motor impulse acceptance, changes (training) of the tendon structure, or selective search for athletes with the appropriate tendon structure. But most importantly, since it is impossible to turn off consciousness in any way, you should select exercises in which the movement can only be performed in a deformation mode.

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