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Review Article

Loss of Energy in the Hip Link, when Performing Jumps and Sprinting. Selection of Exercises to Increase the Degree of Acceptance of the Incoming Impulse

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Abstract

In previous issues of this magazine, we have considered the mechanics of jumps. Using abstraction, we tried to get away from the pedagogical clichés of jumping training. To do this, we studied human hopping locomotion through the prism of orthopedics, rejecting the conformity of coaching concepts [1-6].

We have shown that training the speed of muscle contraction [10] is a mistake, because the muscles, due to the high density of the cytoplasm, as well as the spherical structure of actin and myosin filaments [9], are not adapted to a fast, overcoming contraction [1]. For fast running and jumping, evolution and the creator endowed a person with a completely different motor mechanism based on the deformation and return work of elastic elements. This principle of obtaining kinetic energy is at least twice as effective as the muscular-contractile mechanism [1,4].

Different mechanics also determine completely different methodological directions for training athletes, where the main factors are the characteristics of a single structure of the elastic interaction of an athlete-jumper for a post-deforming response. In this case, the acceptance factor is the most important. We considered the acceptance factor in sufficient detail in the November issue (2022) of the journal *EC Orthopaedics* [6].

However, another link was revealed where energy loss is possible, which we designated by the term "pelvic bridge".

To study this link in the human musculoskeletal system, we conducted a study, the objectives of which were:

1. Analyze the significance of the rigidity of the pelvic bridge.
2. Conduct a pedagogical experiment to identify the effectiveness of a new direction in the training of jumpers and sprinters.

Keywords: *Ricocheting Rebound; Acceptance; Unified Structure of Elastic Interaction; "Pelvic Bridge"*

Research Results

Modern data of scientific and methodological literature and opinions of trainers of practitioners differ. In favor of the rigidity of a single structure of elastic interaction during jumping and running, we quote the words of Peter Weyand, Ph.D., professor of applied physiology and biomechanics [7] - one of the world's leading human performance experts, specializing in running and jumping performance: "...try to keep your body rigid when you land. Elite sprinters don't let anything 'sway' - not their ankles, not their knees, not even their head - so they don't lose power when they bounce off the ground again" [8].

At the same time, most trainers-practitioners pursue the goal of relaxing free muscle groups during running and jumping. But we tend to rely on the authoritative opinion of a prominent scientist.

His opinion was the dominant direction in our experimental study of the pelvic link. The analytics showed that contrary to P. Weyand's instruction about the importance of the rigidity of the entire structure of an athlete during a run or a jump, the human body has a large set of mechanisms and properties that actually dampen the energy of driving influences. Apparently, this is not surprising, since, for example, in the body, both the S-shaped spine and the arch of the foot are designed to dampen brain vibrations [9].

This should also include internal organs (as a damper), as well as limbs (as consoles), which, due to their autonomous heterochronous oscillations, lead to fragmentation and separation of energy, the emergence of parasitic oscillations that interrupt the internal rhythm with the support of the reaction of the musculoskeletal system athlete and reduce the efficiency of running or jumping [6].

We have already pointed out that coaches characterize athletes according to their own, intuitive signs (markers): "loose", "voiced", "sticks to the track", "jumps", etc. But if we move from coaches' intuitive assessments to objectification, we note that that the unifying characteristic of these assessments is the ability, or not the ability of an athlete to ricochet off the supporting surface (treadmill) [1,2,4].

Let us once again pay attention to the comparative table of the elastic moduli of elastin, collagen, rubber and steel (Table 1).

Modulus of elasticity (Young's modulus) of some materials

Material	Young's modulus *(Pa)*
Ellastin	10^5-10^6
Collagen	10^7-10^8
Erythrocyte Membrane	$4 \cdot 10^7$
Smooth muscle cells	10^4
Muscle at rest	$9 \cdot 10^5$
Bone	$2 \cdot 10^9$
Tendon	$1{,}6 \cdot 10^8$
Nerve	$18{,}5$-10^6
Vein	$8{,}5 \cdot 10^5$
Artery	$5 \cdot 10^4$
Wood	$12 \cdot 10^9$
Rubber	$5 \cdot 10^6$
Steel	$2 \cdot 10^{11}$

Table 1: *Comparative values of elastic moduli of rubber and steel [4].*

Presented by us in one of the previous publications [4], on the basis of which we concluded that for an ideal rebound, it is not the elastic properties of elastin, collagen, or rubber that are important, but the rigidity of the steel crystal lattice (Figure 2), where the main factor is the stiffness internal connections (Figure 1).

Considering a jump or a sprint run from these positions, we note that in order to successfully obtain a rebound interaction with the runway, an athlete must be assimilated to a rigid crystal lattice to the maximum extent.

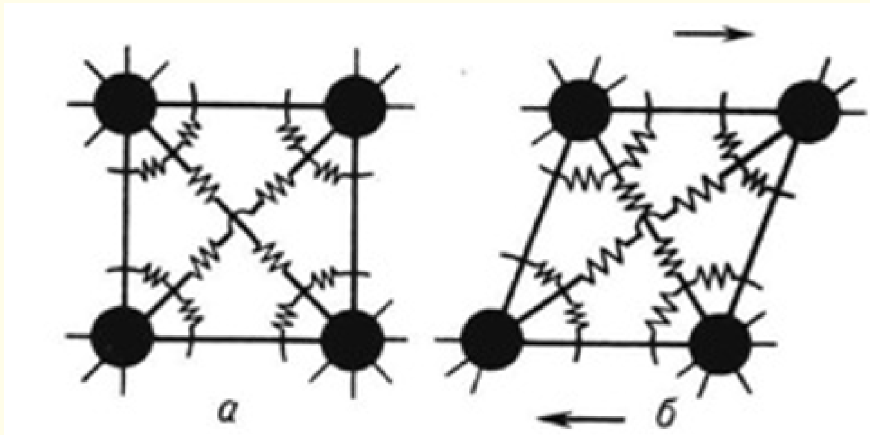

Figure 1: *Model of the operation of the crystal lattice of a metal under the action of deformation forces.*

In this regard, in addition to the previously mentioned factors, we want to pay attention to the pelvis-femur knot, or rather the "bridge" between the spinal center line and the thigh axis of the supporting leg, where energy loss is also possible (Figure 2).

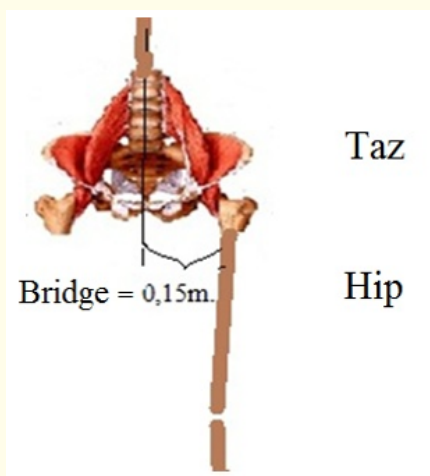

Figure 2: *"Bridge" between the axial line of the spine and the axis of the thigh of the supporting leg.*

In particular, one axis runs along the thigh of the pushing leg, and in the opposite direction, centrifugal and gravitational forces act, the value of which, according to our calculations, exceeds 350 kg [1]. These opposite centerlines do not match. With a pelvis width of 30 cm, the value of this divergence of the axes is 15 cm. Thus, a bridge is created on which, with an insufficiently rigid fixing connection between differently directed forces, the energy of the vertical impulse of force can be lost (Figure 3).

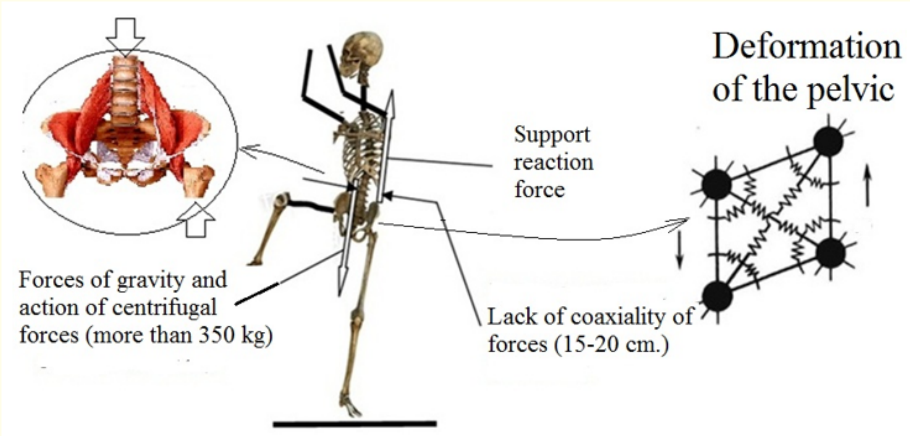

Figure 3: *Non-coincidence of the axes of the support reaction force and the gravitational force, as a special case of cantilever energy dissipation.*

On figure 4 shows the pose of a runner with a collapsed pelvis.

Figure 4: *Squeezed pelvis, characteristic of long-distance runners.*

This phase state is specific to the running posture of long-distance runners and marathon runners. During the run, they take 10 - 40 thousand steps, and perhaps this posture is the most rational for long-term locomotion. But it is categorically not acceptable for jumping and sprinting. For sprinting and jumping, the rigidity of the pelvic lattice is important (Figure 2 and 3). Its preservation is provided by many muscles, the most important of which are:

- Gluteus maximus;
- Gluteus medius muscle;
- Small gluteal muscle;
- Piriformis muscle;
- Psoas muscle;
- Iliac muscle (Figure 5).

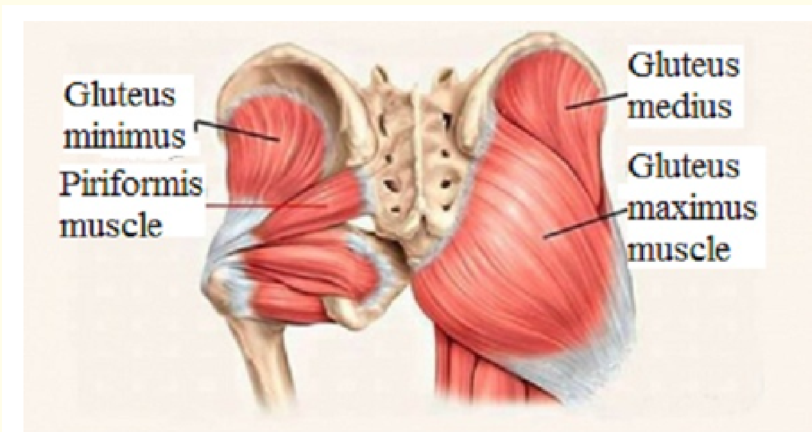

Figure 5: *The main muscles of the pelvic lattice involved in maintaining the rigidity of the entire structure.*

However, many trainers are expected to object that relaxation and free movement of the pelvis is important for running, an example of which is the posture shown in figure 4.

To resolve this dilemma, we conducted a pedagogical experiment in which athletes from the specialized school of the Olympic reserve No. 3 of the Ministry of Sports of Chuvashia participated. For the experiment, a control group (trainer - Nazarova Larisa Anatolyevna) and an experimental group (trainer - Sharikova Uliana Petrovna) were created. Athletes-girls (13 - 14 years old, experience in sports is 3-4 years) of these groups specialized in sprinting, hurdling and jumping, with a level of training - medalists of municipal and regional competitions. The duration of the experiment was 3 months (from October to December 2022).

The control group trained according to the generally accepted methodology, which provides for the development of the strength of the leg extensor muscles. For this, exercises with weights, running uphill, running with resistance, strength exercises with their own weight, etc. were used.

The concept of training the experimental group was to refuse to develop the strength of the extensor muscles of the legs. The main attention in their preparation was given to the task of strengthening the structure of the pelvic bridge. To strengthen the structure of the pelvic bridge (Figure 1, 3 and 4), we recommended the use of the following exercises (Figure 6):

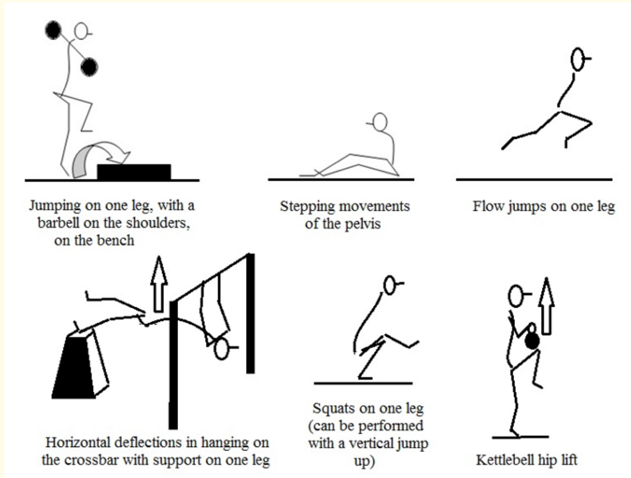

Figure 6: *Exercises to strengthen the muscles of the pelvis and pelvic floor, recommended to the participants of the pedagogical experiment.*

- Jumping on one leg, on a low pedestal (15 cm) with a barbell on the shoulders of 12 - 25 kg;
- "Caterpillar" - sitting on the mat, the legs are extended forward, perform stepping movements with the pelvis, up to 300 "steps" in the approach";
- Jumping on one leg;
- Deflections in the hanging on the crossbar;
- Squats on one leg (the same with vertical jumping to the top;
- Standing on one, lifting the kettlebell with the hip.

The effectiveness of the training programs was determined in control tests, for which a triple jump was used for a distance, after jumping off the bench (height 30 cm) on one leg. This test was chosen due to the fact that it most fully reflects the strength of the pelvis to the vertical punching effect. The results of the experiment are presented in table 2.

Based on this table, we see a significant superiority of the training program aimed at strengthening the pelvic bridge. The increase in the control group was + 0.87%, while in the experimental group it was + 8.5%. That is, almost a 10-fold superiority of the training program proposed by us.

In fairness, it should be noted that in the control group, subject No. 3 had a decrease in test indicators - minus 0.30m. Perhaps this fact is associated with the pubertal period of age maturation. However, a mathematical calculation shows that even the exclusion of this circumstance, associated with the natural processes of growing up, does not “save” the control group from “losing”.

With the exclusion of this fact of age development from the sample, the initial average group indicator will be 5.66m. After a three-month experiment, the average group indicator of the control group will reach 5.77m, that is, the increase is 0.11m, or 1.94%, which is 4.25 times less than in the experimental group.

N p/p	Results of the control group				Results of the experimental group			
	Surname I.	Before	After	Growth	Surname I.	Before	After	Growth
1.	Efremova Ya.	5,53	5,55	0,02	Spirina C.	5,63	5,85	0,22
2.	Dmitrieva M.	5,61	5,75	0,14	Zakharova A.	5,50	5,93	0,43
3.	Andreeva E.	6,00	5,70	- 0,30	Sharikova A.	6,09	6,56	0,47
4.	Sosnova K.	5,95	6,05	0,10	Antonova A.	5,73	6,09	0,36
5.	Timofeeva P.	5,47	5,63	0,16	Korsakova K.	5,79	6,83	1,04
6.	Kazankova Yu.	6,15	6,35	0,20	Agafonova K.	6,00	6,53	0,53
7.	Artemieva A.	5,30	5,33	0,03	Yushkova V.	5,60	5,99	0,39
	Group average	5,71	5,76	0,05 (+0,87%)	Group average	5,76	6,25	0,4 (+8,5%)

Table 2: *Test results (triple long jump after jumping off the bench (height 30 cm) on one leg) of the control and experimental groups before and after the experiment (in meters).*

It should be noted that the factor of strengthening the pelvic bridge was used in the training of jumping athletes, who, as you know, perform very successfully at world-class competitions. This was already noted in the work of our scientific and methodological support, when preparing the national team for the 1988 Olympiad in Seoul. In particular, this factor was adopted in the training of long jumper Elena Belevskaya (silver medalist of the 1987 World Championship, participant in the 1988 Summer Olympics - 4th place), who has in her arsenal one of the longest jumps in world history - 7.39 m (1987 - coach Valery Bunin).

The training of this factor was also successfully used in the practice of one of the prominent world-class coaches Evgeny Zagorulko, who trained Olympic champions E. Yelesina (2000/Sydney), A. Silnova (2008/Beijing), A. Chicherova (2012/London) and etc.

In particular, in his work, exercises in stream jumping on one leg, on a pedestal with a barbell on his shoulders, were used on a large scale (Figure 7).

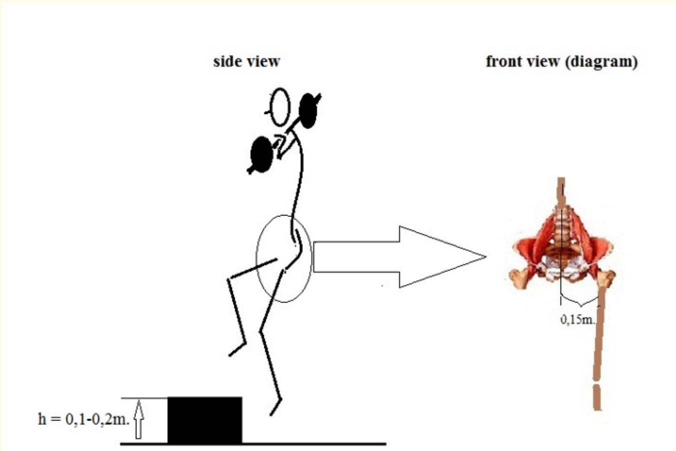

Figure 7: *The load on the "pelvic bridge" when performing the exercise of jumping on the pedestal, on one leg with a barbell on the shoulders.*

Discussion

Speaking about the training of the ricochet rebound when jumping and running, we would like to make the following remark.

Due to its evolutionary development, man has acquired many features of the bone skeleton that protect the brain and the whole body from concussion. To do this, a person has developed an S-shaped spinal column, spring properties of the feet, damping properties of internal organs and cantilever properties of the limbs. Accepting this fact of the human structure, the question arises: will it be right for us to strive not to extinguish, but rather to train an athlete to recochet hard from the runway?

Yes, at present, in fact, thanks to technological progress, a person does not need to jump high, run fast, etc. However, we believe that a person should not "give his body" to a comfortable state, with complete "attachment" to mechanisms. A person should not strive to wear an exoskeleton and be surrounded by remote control devices. The vital activity of the cells of the human body is based on the expenditure of energy and plastic substances, with their subsequent supercompensation. Therefore, in the discussion whether to go in the direction of gaining comfort, or to improve oneself in running, jumping and other physical manifestations, there is only one answer - to improve one's physical condition, in proportion to technical progress. Our series of publications [1-6], designed to improve human musculoskeletal locomotion, performs exactly this task.

We determined that in jumping and running, the most important factor in increasing the acceptance of the incoming ricochet impulse is the absence of disunity in the oscillatory circuit of all body structures. This applies to the dampers of the internal organs and the cantilever connection of the limbs. In this study, we continued to search for ways to improve the physical capabilities of humans and identified the need to stop the energy loss in the hip joint during running and jumping.

Conclusion

1. The model of work of the musculoskeletal system proposed by us in previous publications, which is based on deformation and acceptance, determines completely different training approaches based on minimizing the loss of the incoming motor impulse formed by deformation forces.
2. Our research has shown the importance of strengthening the pelvic bridge.
3. Our pedagogical experiment revealed a four to ten-fold superiority in the efficiency of training jumpers and sprinters, aimed at strengthening the pelvic bridge.

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