

SHOCK METHOD AND PLYOMETRICS: UPDATES AND AN IN-DEPTH EXAMINATION

NATALIA VERKHOSHANSKY

THANKS TO DANNY RAIMONDI FOR HIS ENGLISH TEXT REVIEW

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1.1. FROM DEPTH JUMPS TO THE SHOCK METHOD



At the end of the 1950s, Yuri Verkhoshansky, a successful coach of the Track & Field jumpers, and students from the Aeronautical Engineering Institute, created a new training mean – vertical drop-rebound jump (Depth Jump). This exercise helped his athletes obtain an unexpectedly high increase in the level of specific performance: twelve of them obtained the title “Master of Sport”.

Verkhoshansky then took the opportunity to be the head coach of the Moscow United Team in the sprinting and jumping events. In 1964, his athlete Boris Zubov became both the European and Soviet record holder in the sprint events. Y. Verkhoshansky entered in the coaches staff of the soviet national track-and-field team.

Two years later, Verkhoshansky would discontinue his coaching career and concentrate his work on scientific research. In his research, the use falling weight's kinetic energy to increase the strength effort was adapted further for upper body explosive movements.

Verkhoshansky named this discovery the “The Shock Method” (1968)

1.1. FROM DEPTH JUMPS TO THE SHOCK METHOD



1959 – article “*New method of the strength preparation of jumpers*” (the bulletin “Collection of scientific works of the Central researches institute of physical culture”, page 23-28)

1961 – book “*Triple Jump*”. Moscow. Fiskultura i Sport

1964 – article “*Novelty in the strength preparation of jumpers*” (Track and Field Magazine, n 7).



1966 – article “*The dynamic structure of complex motor actions*” (Theory and Practice of Physical Culture, n.9)

1967 – article “*Are the Depth Jumps useful?*” (Track and Field Magazine, n 12)

1968 – article “*The Shock-method of the development of “explosive strength”* (Theory and Practice of Physical Culture, n.8)



1979 – article “*Some particularities of the human working movements*” (Theory and Practice of Physical Culture, n.12).

1986 – article “*The influence of Shock method on the electro-miographic parameters of maximal explosive effort*” (Theory and Practice of Physical Culture, n.12, with N.Masalgin, L.Golovina, A.Naraliev).

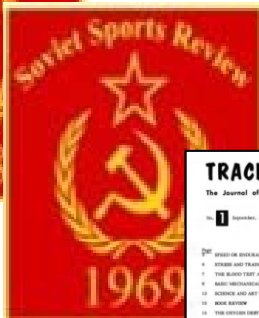
Some of Verkhoshansky's articles were translated by Dr. M.Yessis and published in the USA



Dr. **Michael Yessis**, a professor emeritus in biomechanics and kinesiology and president of Sports Training Inc. and the foremost expert on Russian training methods, has translated and published Russian training articles in the Fitness and Sports Review International for over 29 years. Having earned a Ph.D. at the University of Southern California, he travelled to Russia to meet Dr. Yuri Verkhoshansky and to learn the training techniques from the masters themselves.



1968 - *Are depth jumps useful?*, Soviet sport review, n.3, pp.75-58



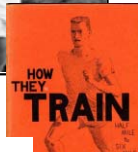
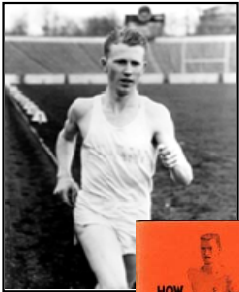
1969 - *Perspectives in the improvement of speed-strength preparation of jumpers*, Soviet sport review, n.3, pp.75-58



1973 - *Depth jump in the training of jumpers*, Track Tecnique, n.51, pp.60-61

1.2. FROM THE SHOCK METHOD TO PLYOMETRICS

Fred Wilt popularised jump training used by Eastern Bloc coaches in the USA, pioneering the term ***Plyometrics***.



Fred Wilt (1920–1994) was a distance runner in the U.S. Wilt was a member of the 1948 and 1952 Olympic teams, and famous for his legendary indoor mile encounters at that time with Wisconsin's Don Gehrman. After retiring from the FBI, Wilt coached the women's running teams at Purdue University. He edited the publication Track Technique and advised various athletes. His star pupil was 1964 Olympian Buddy Edelen, who held the world marathon record of 2:14:28. In the 1960s and 1970s, Fred Wilt became a famous writer and advocate of running. His book, "How They Train", was a long-time best seller. His most popular book "Run, Run, Run..." is an incredible collection of articles on science, history, and methods of running, reflecting his passion and desire to bring real knowledge to people.



1964 - Fred Wilt. *From the Desk of Fred Wilt: Plyometric Exercises.* Track Technique. 64:2024-2054.
1978 - Fred Wilt. *Plyometrics – What is it and how it works,* Modern athlete and coach, n.16, pp.9-12



Fred Wilt interpreted plyometrics as exercises that produce "*an overload of isometric-type muscle action which invokes the stretch reflex in muscle*"

PLYOMETRICS- WHAT IT IS AND HOW IT WORKS

By Fred Wilt

Fred Wilt, Editor of Track Technique and Canadian Coaching Certification Co-ordinator, defines the meaning of plyometrics, explains the theory behind this method of explosive - reactive movements, and lists sample drills for track and field events. The article has been reprinted from Technical Bulletin, Canada, Vol. 4, 1977.

THEORY OF PLYOMETRICS

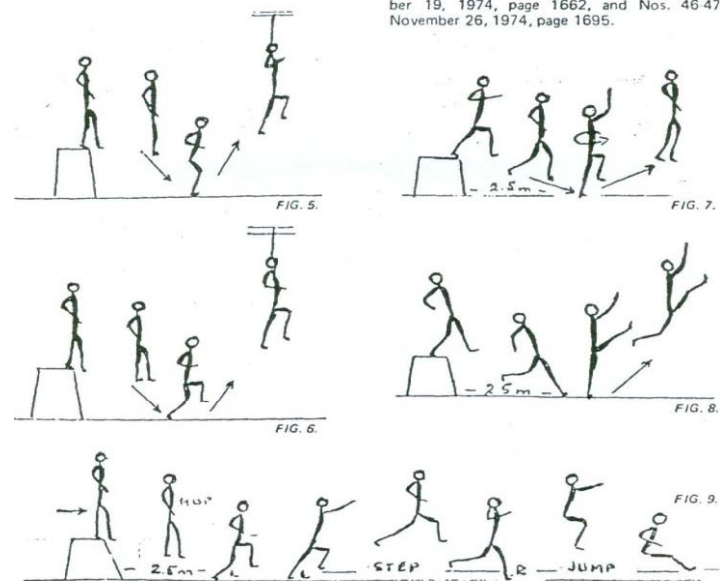
To the best of my knowledge, there has been no previous reference made to plyometric exercises in American sports literature. This word has been used for a number of years by European coaches, especially those from Germany and Russia, when describing certain training drills designed to bridge the gap between sheer strength and the power (rate of work or force x velocity) required in producing the explosive-reactive movements so necessary to excellence in jumping, throwing, and sprinting.

The word plyometric is apparently derived from the Greek word plethein, which means to increase, and isometric. My present interpretation of plyometric is that it means the exercises or training drills used in producing an overload of isometric-type muscle action which invokes the stretch reflex in muscles. I am not particularly happy with this interpretation, and it may alter when a precise definition evolves.

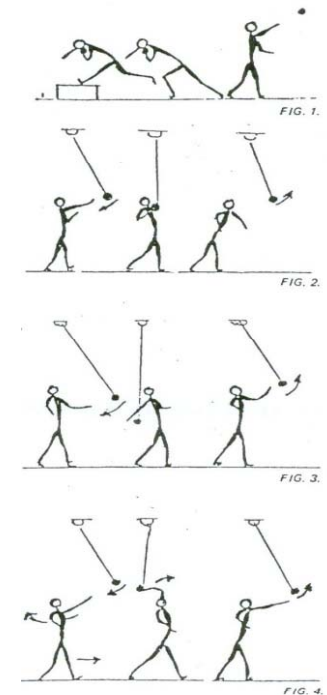
DRILLS FOR EVENTS

Plyometric drills for all track and field events are:

1. Bouncing vertically on the spot for 30 to 60 seconds, using a double-arm take-off. Use maximum speed.
2. Hops over distances of 30 to 100 metres, using long, forceful, maximum force efforts. Use first one leg, then the other, and both legs, utilizing both single and double-arm action. One to four repetitions.
3. Bouncing, then hopping off one leg and both legs, using maximum speed, over distances of 30 to 100 metres. One to four repetitions.
4. Double-leg take-off hops over 10 low hurdles placed 2 metres apart. Two to four repetitions.
5. Standing long jumps and triple jumps, using both single and double leg take-offs.
6. Triple jump box drills (hopping on and off low boxes).
7. Hopping downstairs.
8. Depth jumps. Jumping downward from a height between a low and a high hurdle, and exploding upward.



ber 19, 1974, page 1662, and Nos. 46 47, November 26, 1974, page 1695.



1.3. THE PROBLEMS WHEN USING PLYOMETRICS



2. IN-DEPTH EXAMINATION OF THE SHOCK METHOD

2.1. KINETIC ENERGY OF FALLING WEIGHT AS A MUSCLE STIMULATING FACTOR

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS

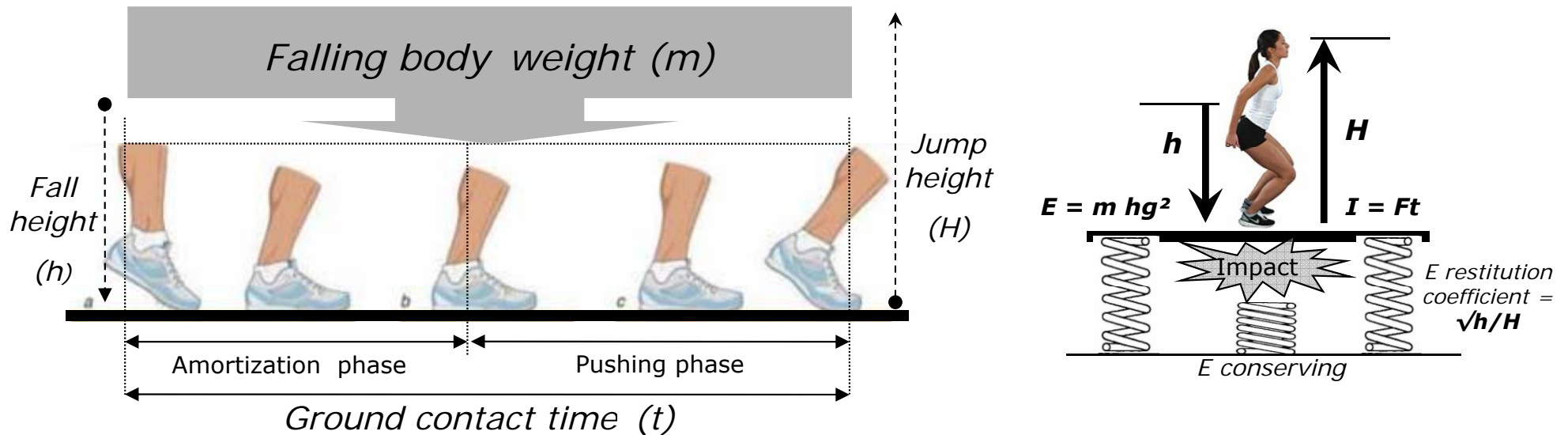
2.3. THE ESSENCE OF THE SHOCK METHOD

2.1. KINETIC ENERGY OF FALLING WEIGHT AS A MUSCLE STIMULATING FACTOR

The essential element of the Shock regime is sharp, compulsory muscular tension, initiated by the body's impact (collision*) with an external object.

***Collision** is an isolated event in which two or more moving bodies (colliding bodies) exert forces on each other for a relatively short time. Collision could occur also between the moving and unmoving bodies. An example is the foot with the underlying substrate forces during jumping and running: *ground reaction forces* are generated during amortisation phases.

Collisions involve forces, because there is a change in the velocity of the moving bodies. All collisions conserve momentum. What distinguishes different types of collisions is whether they also conserve *kinetic energy* ($E = mv^2$). Collisions can either be *elastic*, meaning they conserve both momentum and kinetic energy, or *inelastic*, meaning they conserve momentum but not kinetic energy. Elastic collision is defined as one in which there is no loss of kinetic energy in the collision.



Is the higher force, expressed in the take-off movement of depth jumps, related only to the restitution of kinetic energy accumulated during the body's falling?

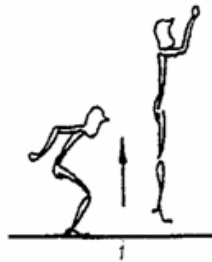


The first experiment of Verkhoshansky (1968):

The athletes executed a maximal effort vertical jump from 3 different initial positions (functional state) of the working muscles

SINGLE OVERCOMING MOVEMENT

Fast shortening of the isometrically contracted muscles, formerly lengthened and stretched under the weight of body

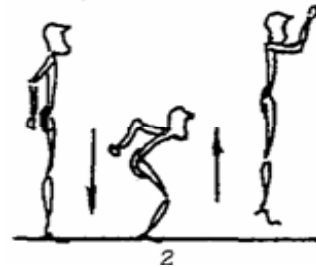


Vertical jump without countermovement

Isometric-miometric regime

COUPLING REVERSIBLE MOVEMENT

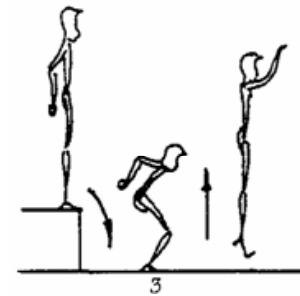
Fast shortening of the muscles, rapidly stretched under the body weight during the preceding countermovement



Vertical jump with countermovement

Pliometric-miometric regime

Fast shortening of the muscles, rapidly stretched during amortisation phase under the sharp impact of the falling body's force



Vertical Jump after landing from a drop height of 50 cm (≈20in.)

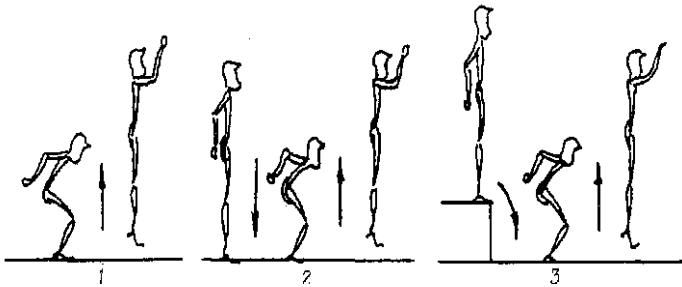
"Shock" regime

2. IN-DEPTH EXAMINATION OF THE SHOCK METHOD

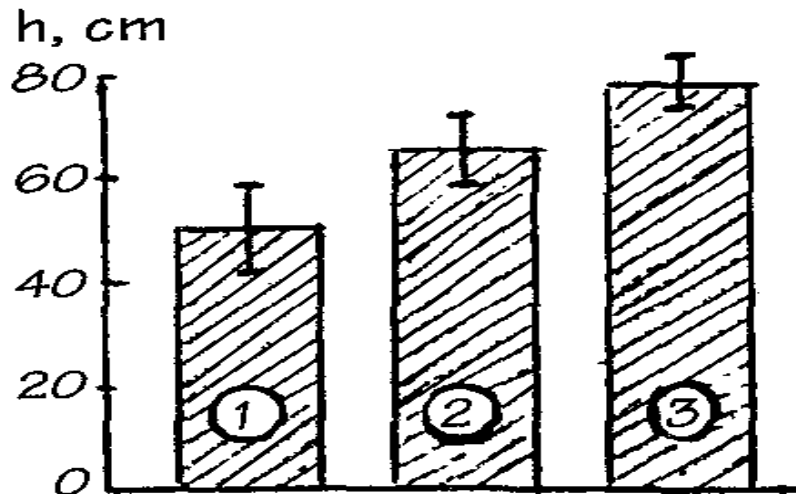
2.1. KINETIC ENERGY OF FALLING WEIGHT AS A MUSCLE STIMULATING FACTOR



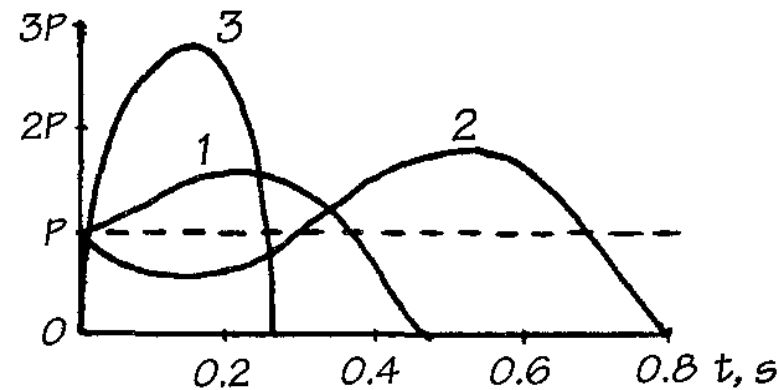
The first experiment of Verkhoshansky (1968):



The height of vertical jump (h_2) was highest when the athlete performed it immediately after landing from a drop height of 50 cm (h_1): the vertical jump height was 1.6x higher than the drop height (coefficient of reactivity $h_2/h_1=1.6$).



The height of vertical jump - H (cm)



Dynamograms of ground reaction force efforts: active force in value of the body weight (P) and the time of force employment t (s).



The second experiment of Y. Verkhoshansky (1979)

The athletes executed a maximal explosive force effort (pushing up a weight of 60% of maximal) in 4 different starting positions, which were characterised by different states (functional conditions) of muscles:

Relax

Fast push-up of the blocked weight without counter-movement

Isometric tension equal to the weight

Fast push-up of the non blocked weight without counter-movement

Voluntary dynamic counter-movement

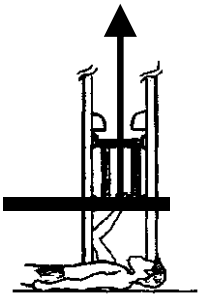
Fast push-up of the non blocked weight with counter-movement

Involuntary repetitive tension provoked by the impact with falling weight

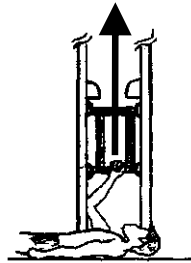
Fast push-up of the falling weight with counter-movement

SINGLE OVERCOMING MOVEMENT

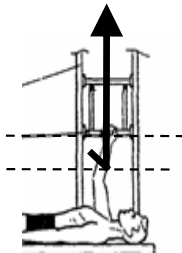
COUPLING REVERSIBLE MOVEMENT



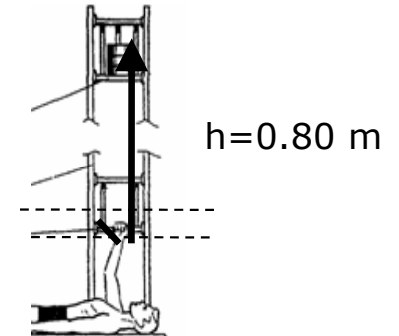
Miometric regime



Isometric-miometric regime



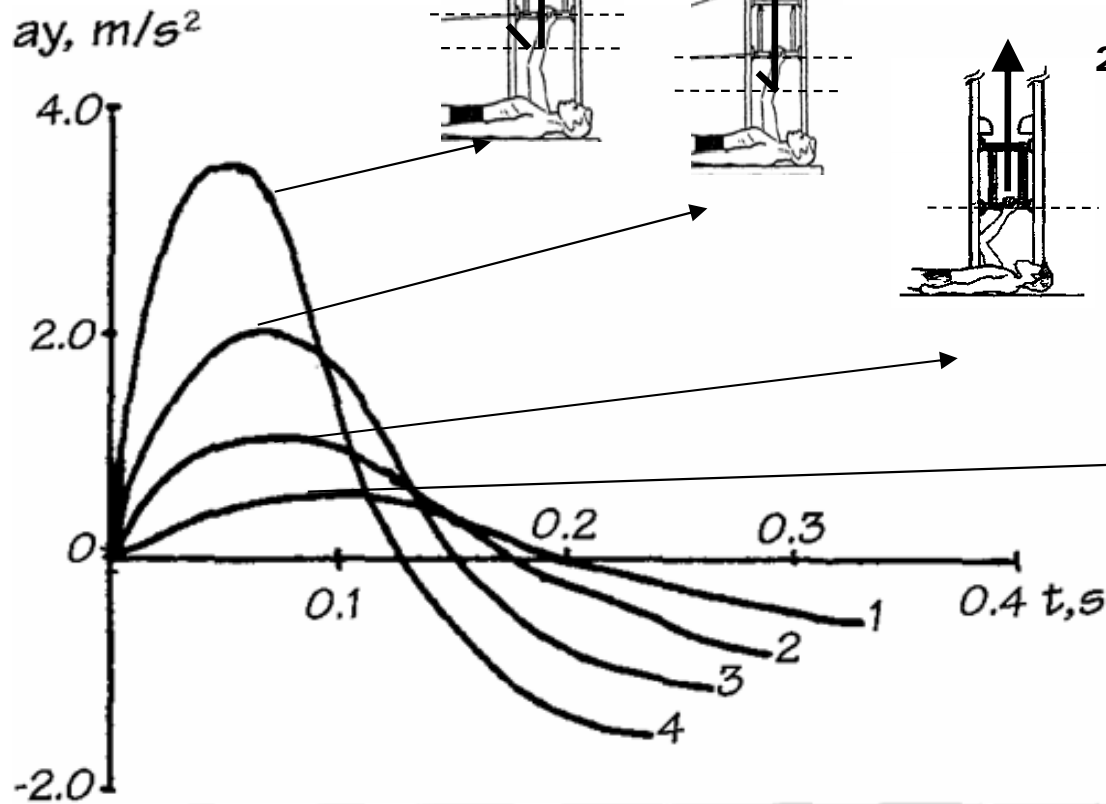
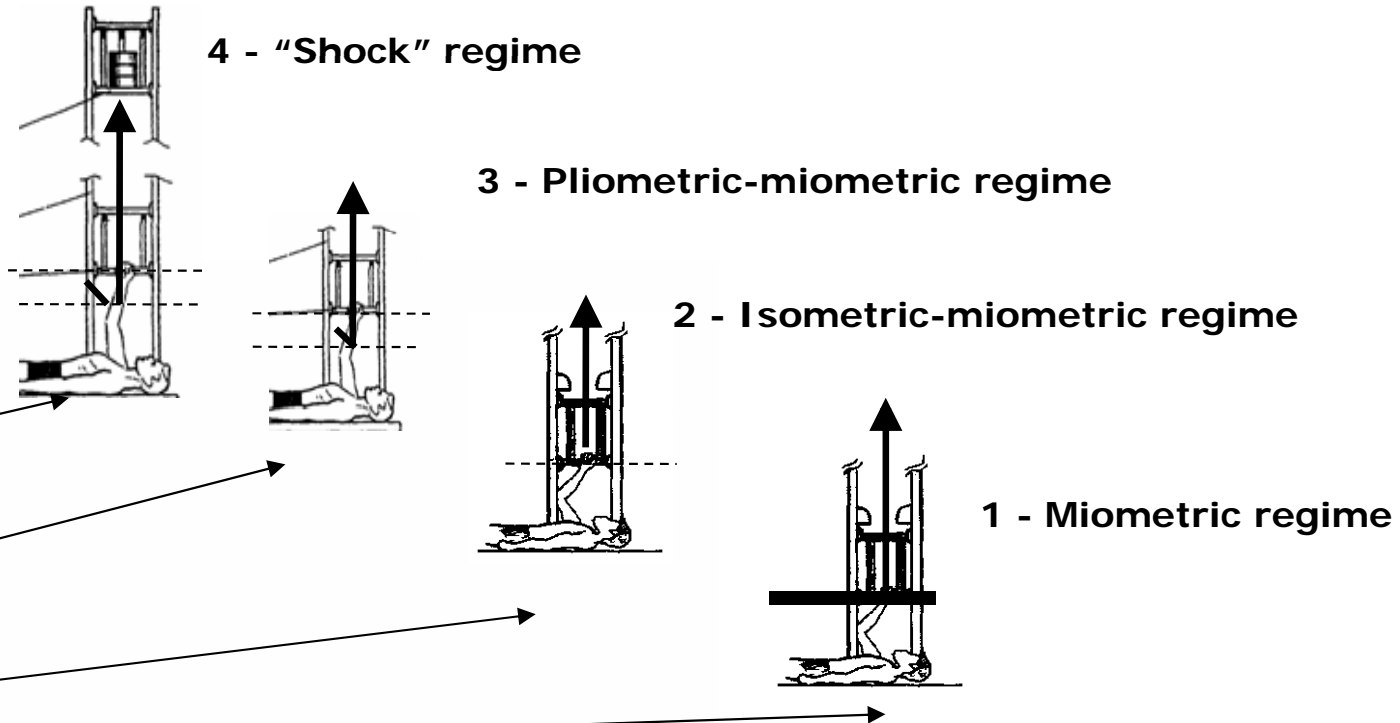
Pliometric-miometric regime



"Shock" regime

2.1. KINETIC ENERGY OF FALLING WEIGHT AS MUSCLE STIMULATING FACTOR

The second experiment of Y. Verkhoshansky (1979)



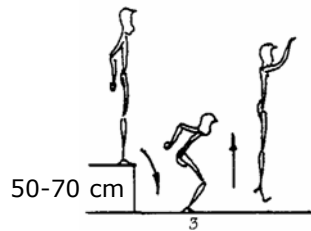
The curves of the weight acceleration during the pushing up of the weight equal to the 60% of maximal executed in 4 different initial conditions (functional states) of muscles

Conclusions: the power output of the loaded movement depends on the initial condition (functional state) of the working muscles: a greater muscle activation by an external load equates to greater power output

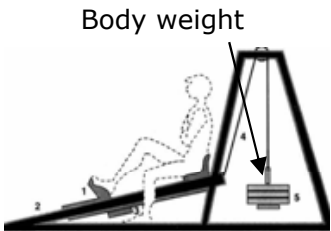


The third experiment of Y. Verkhoshansky (1986):

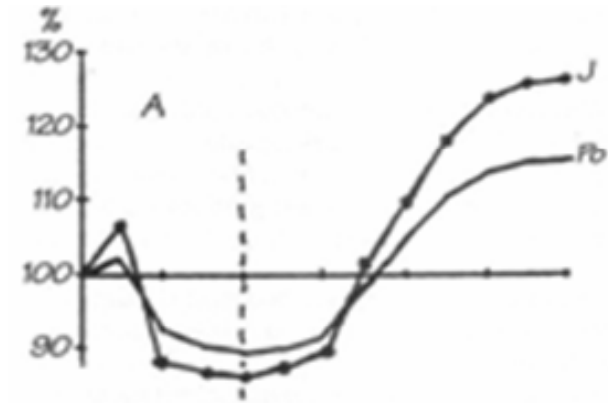
A group of volleyball players carried out, for 12 weeks (3 times a week), physical preparation workouts aimed at increasing explosive strength as expressed in the take off movement.



The training program included a concentrated volume of depth jumps, performed with a drop height of 50-70 cm (3-5 series of 10 jumps in each workout). Such workouts were carried out only during the first 4 weeks.



Every week, the athletes were tested on the UDS stand: the levels of maximum and explosive strength were evaluated in the Leg Press (in the maximal isometric force effort and in the maximal dynamic force effort with the level of external opposition equal to the body weight of athlete).



At the end of the training stage, the level of Explosive strength (J) was 26% higher and the level of Maximal strength (Po) was 14% higher than before the experiment.

If the higher force, expressed in the take-off movement of a depth jump, is related only to the restitution of kinetic energy accumulated during the body's falling, it's difficult to explain why the use of depth jumps causes an increase in the working effect of specific movements executed without impact with external force.

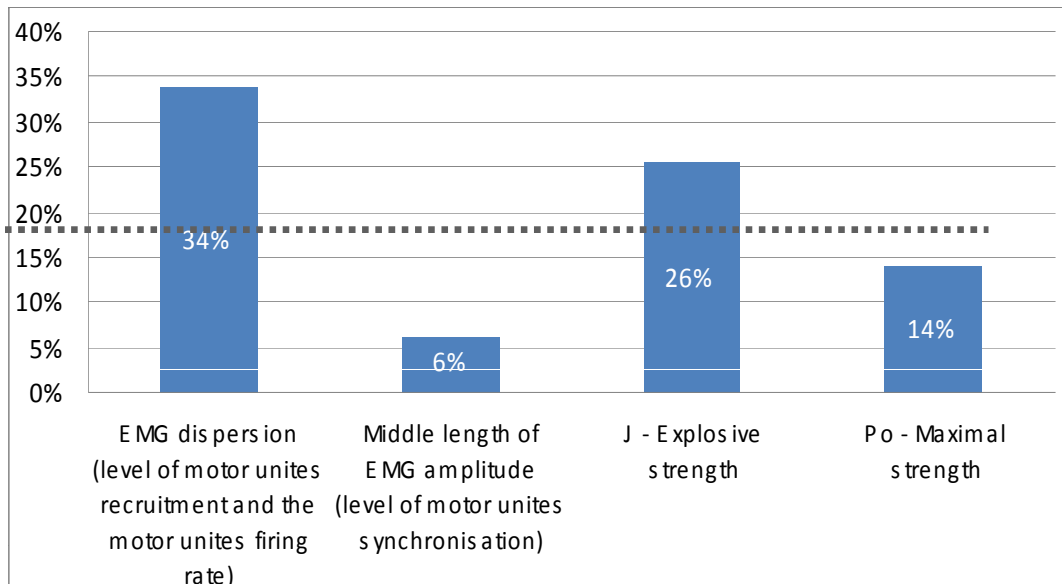
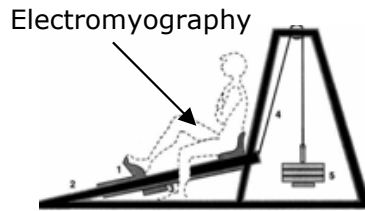
2.1. KINETIC ENERGY OF FALLING WEIGHT AS A MUSCLE STIMULATING FACTOR



The third experiment of Y. Verkhoshansky (1986):

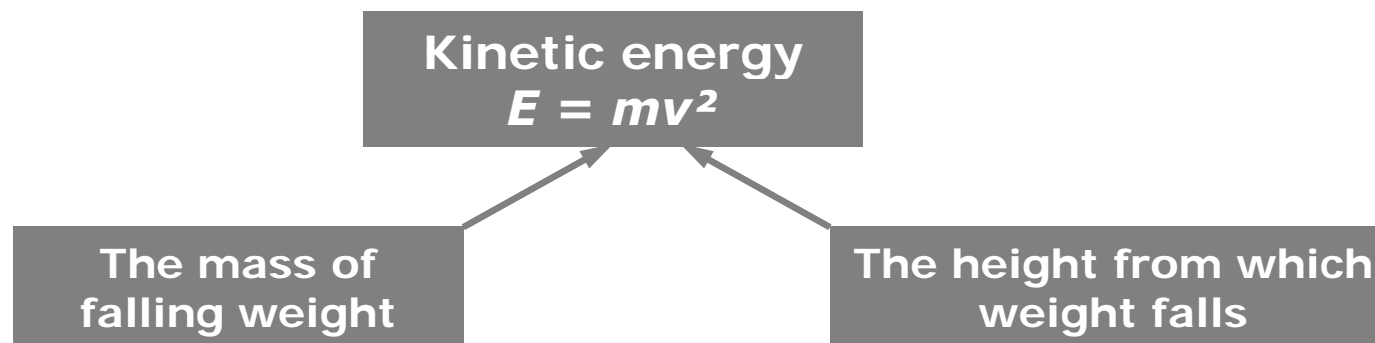
Before and after the training stage, during the UDS tests, the electrical activity of the *quadriceps femoris* was registered. The electromyograms were analyzed using the methods of R.S. Person ("Applying electromyography in the researches on man", 1969), which allowed him to evaluate:

- the level of motor unit recruitment (a measure of how many motor neurons are activated in a particular muscle, and therefore a measure of how many muscle fibers of that muscle are activated),
- the frequency with which the muscle fibers are stimulated by their innervating axon, known as *the motor unit firing rate*)
- the level of motor units synchronisation (related to the rate of force development during rapid contractions)



As a result of using the Depth jump program, both the strength and the EMG parameters were improved by 20%.

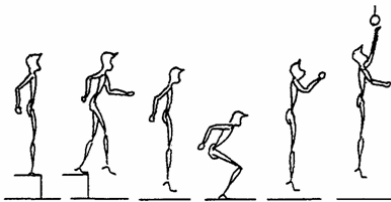
What is more important: the mass of falling weight or the height from which it falls?



2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS

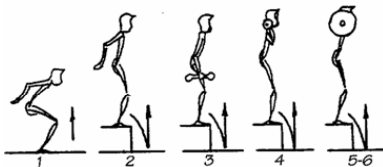


What is more important: the mass of falling weight or the height from which it falls?



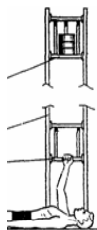
1. How does the working effect of the take-off movement in Depth jumps change by increasing the height from which the body falls?

Falling weight is standard – the height from which it falls is variable



2. How does the working effect of the take-off movement in the Depth jump change by increasing the body's weight?

Falling weight is variable – the height from which it falls is standard



3. How does the working effect of the push-up movement, executed with a rebound of the falling external object, change by increasing the falling object's weight and the height from which it falls?

Falling weight is variable – The height from which it falls is variable

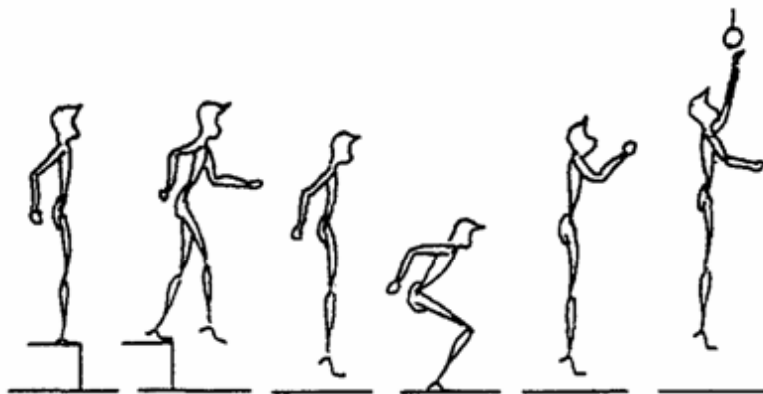
2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



1. How does the working effect of the take-off movement in the Depth jump change by increasing the height from which the body falls?

The group of 36 high level Track-and-Field athletes (sprinters, jumpers and throwers) carried out a series of 8 Depth jumps. The drop height was gradually increased by 20cm., from jump to jump, from 0.15 m to 1.55 m.

The athletes landed on the dynamometric device which registered the vertical forces applied through the ground during the ground contact phase (the F/t curve):

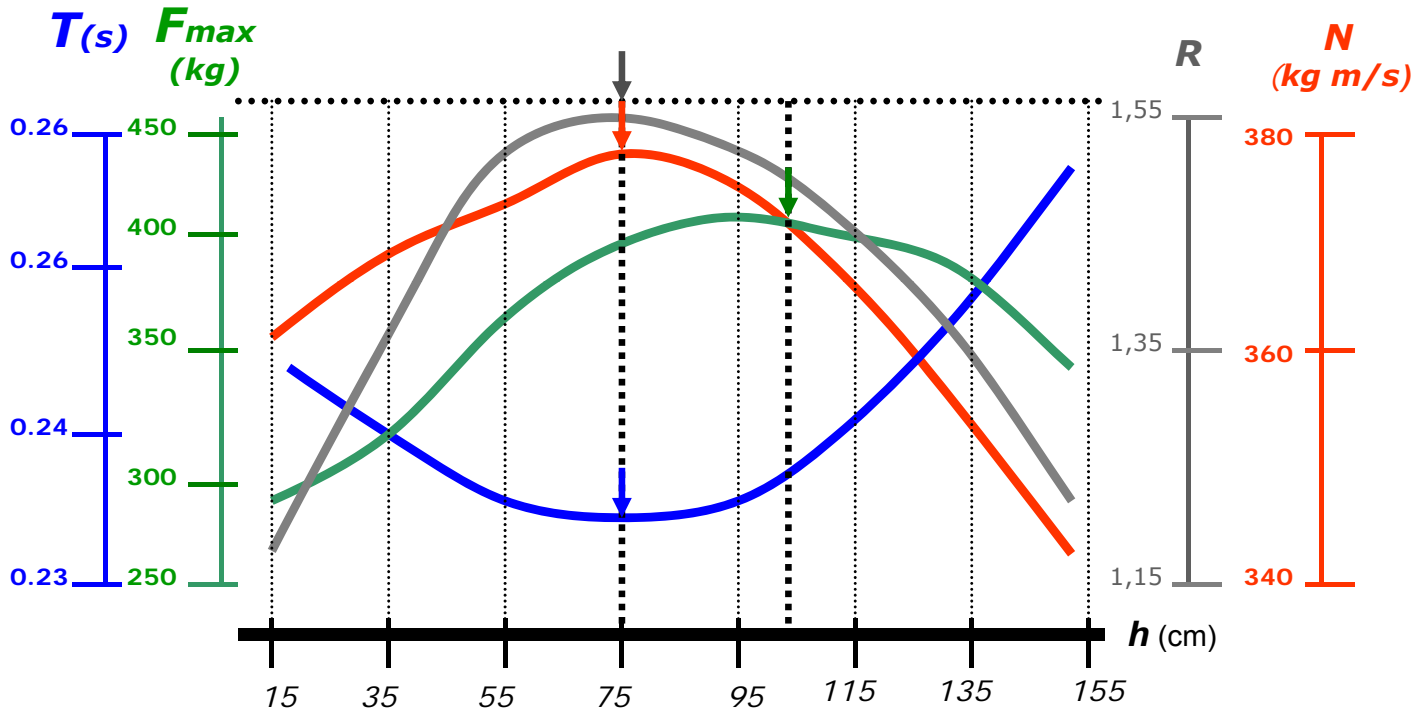


- ground contact time (t),
- maximal force (F max) expressed in take-off movement,
- power output of take-off movement (N),
- coefficient of reactivity ($R = H/h$, where H- the height of vertical rebound, h – the height of drop)

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



1. How does the working effect of the take-off movement in the Depth jump change by increasing the height from which the body falls?



Conclusions:

- 1) If the training is focused on increasing Explosive strength and reactive ability, Depth jumps should be executed with a drop height of about 0.75 m or ≈ 2.5 ft.
- 2) If the training is focused on increasing maximal strength (F_{max}) expressed in the take-off movement, the Depth jump should be executed with the drop height of 1.10 m or ≈ 3.5 ft.

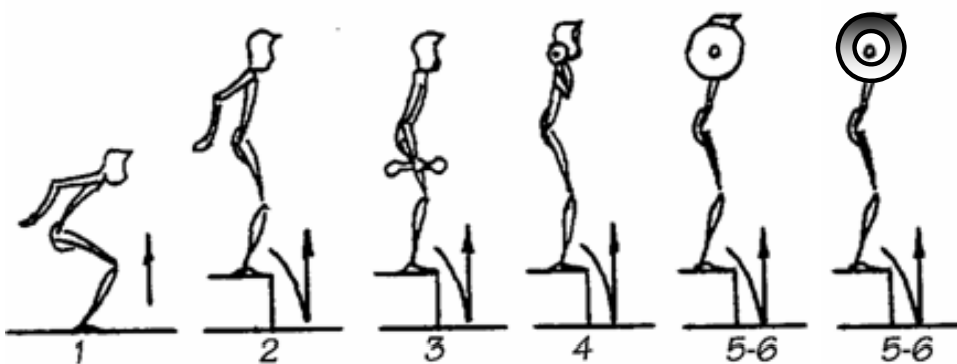
The maximal values of power output (N), coefficient of reactivity (R) and the minimal ground contact time (T) were reached in the Depth jumps executed from the height of 75 cm. The maximal level of force effort (F_{max}) was reached in the depth jump executed from the height of 95-115 cm.

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



2. How does the working effect of the take-off movement in the Depth jump change by increasing the body's weight?

4 groups of high level Track & Field athletes (jumpers, throwers, sprinters, and middle distance runners) executed 4 jump tests:



I test: counter-movement vertical jump without arm movement

II test: Depth jump from a height of 0.40 m (without arm movement)

III test: Depth jump from a height of 0.40 m, executed with 5 kg dumbbells in each hand

IV test: Depth jump with a 20 kg barbell on the shoulders

V test: Depth jump from a height of 0.40m with a 30kg barbell on the shoulders;

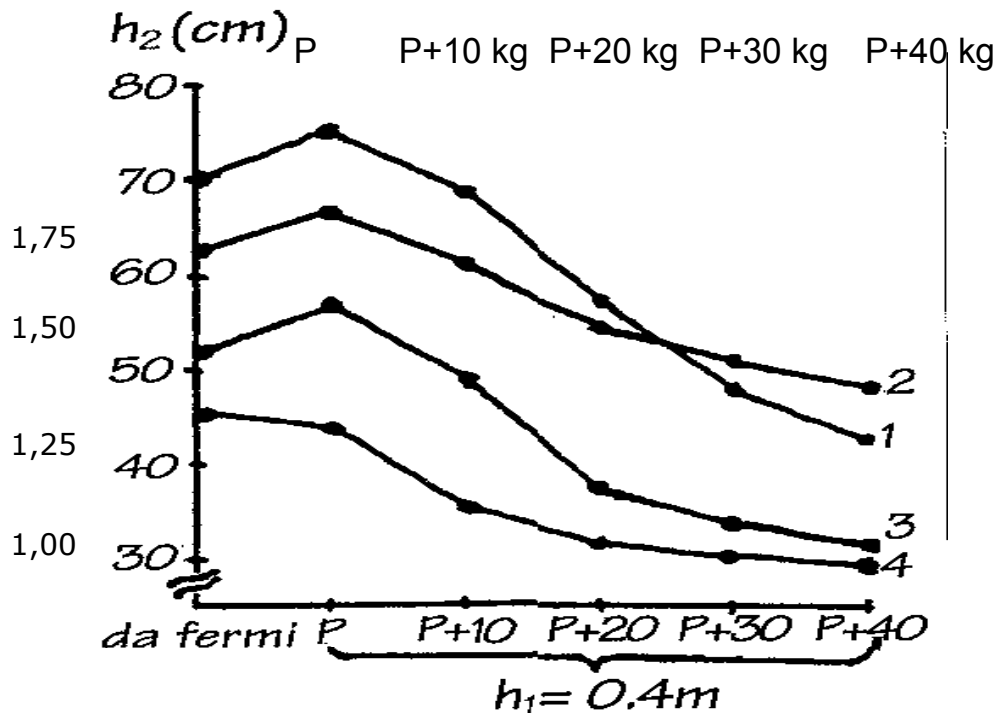
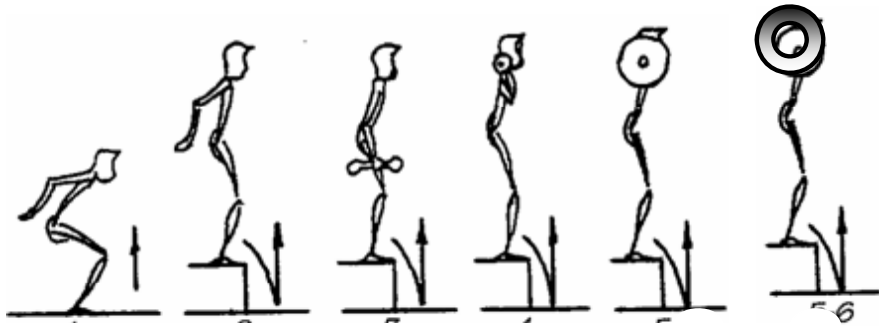
VI test: Depth jump from a height of 0.40m with a 40kg barbell on the shoulders

In each test, the flying time was registered, which helped calculate the height of jump

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



2. How does the working effect of the take-off movement in the Depth jump change by increasing the body's weight?



The maximal height in the vertical jump was reached in the Depth jump executed without weight. Adding additional body weight decreases the height of the Depth jump and, consequently, the coefficient of reactivity.

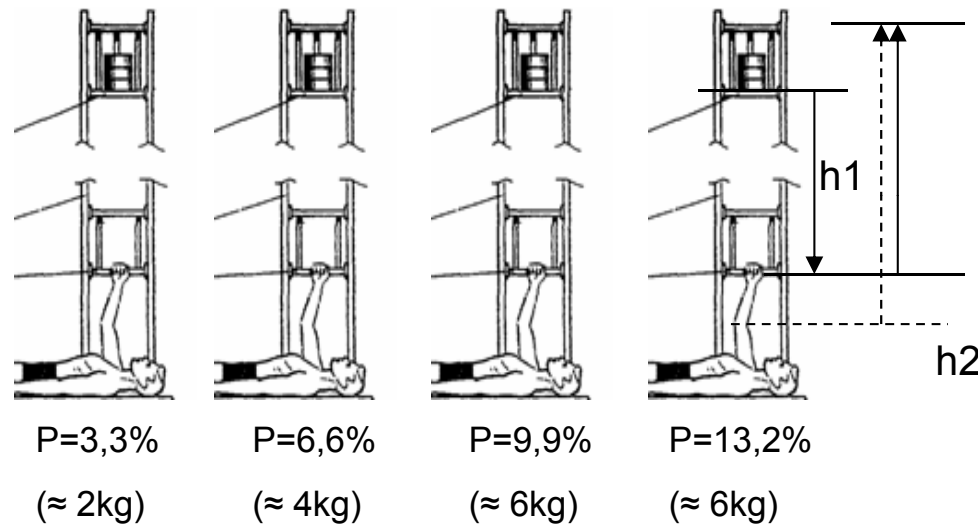
Conclusion:

Using the Depth jump with additional body weight doesn't increase the working effect of the take-off movement.

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



3. How does the working effect of the push-up movement, executed with a rebound of the falling external object, change by increasing the falling object's weight and the height from which it falls?



The differences between the 4 tests were related to the differences between regimes of the muscle's work during the yielding phase of the reversible movement:

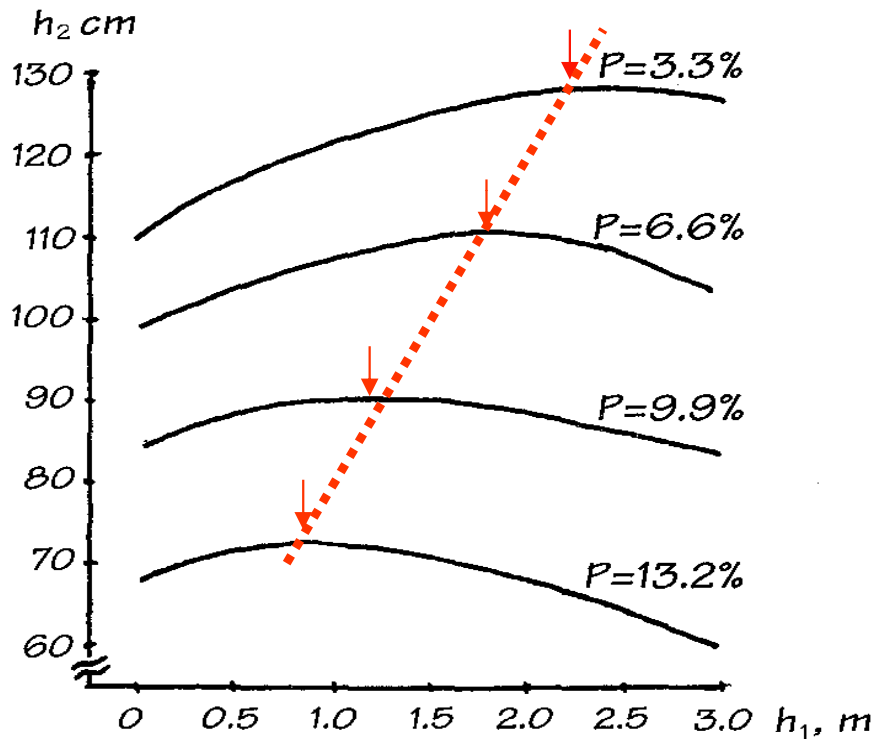
- 1) the magnitude of external force impact – the weight of falling object
- 2) the sharpness of external force impact - the height from which it fell

So, the differences between the regimes of the muscle's work, during the yielding phase of the test movement, were determined by two factors: the level of muscular tension, caused by the impact with external force, and the velocity of increasing this tension.

2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



3. How does the working effect of the push-up movement, executed with a rebound of the falling external object, change by increasing the falling object's weight and the height from which it falls?



The variations in the fly height (h_2) of different falling weights (P) from different heights (h_1)

1) By increasing the height from which the same weight falls, the maximal height of its flight increases at the beginning, but after decreases.

2) With every falling weight there is an optimal corresponding height from which it should fall to ensure the greatest height of its flight: the greater the falling weight, the lower the height.

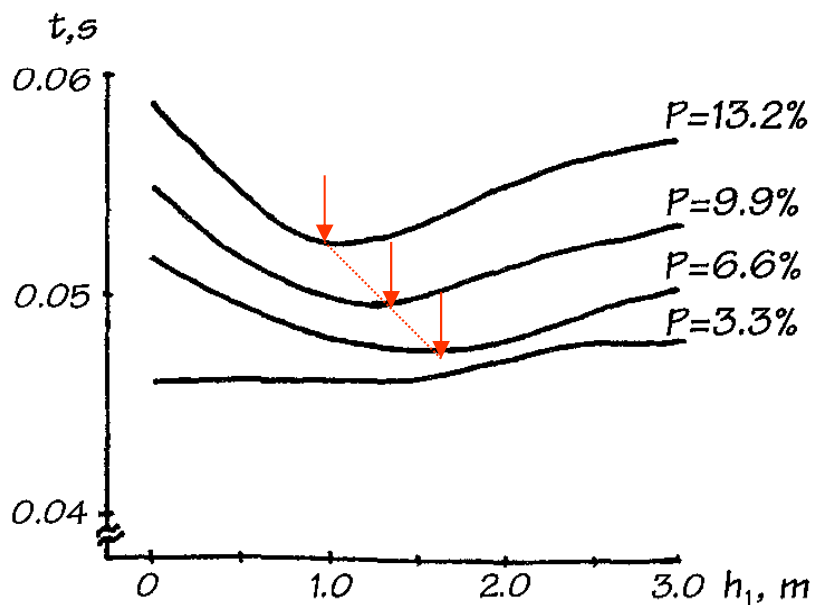
2.2. THE MASS OF FALLING WEIGHT AND THE HEIGHT FROM WHICH IT FALLS



3. How does the working effect of the push-up movement, executed with a rebound of the falling external object, change by increasing the falling object's weight and the height from which it falls?

As a rule, the maximal height of flight was reached when the duration of contact time (duration of the transition from the yielding to overcoming phase) was minimal:

Durata della fase di passaggio



Duration of the ground contact time (ts) of different weights (P), falling from different heights (h,)

- 1) Increasing the falling weight increased the duration of the transition
- 2) Increasing the height from which the same weight falls, the duration of the transition from yielding to overcoming decreases and after increases.
- 3) With every falling weight (from 3.3 to 13.2% of maximal) there is an optimal height from which it should fall to ensure the minimal duration of transition from yielding to overcoming
- 4) In a case when a relatively low weight is used (3.3% of maximal force) increasing the height from which it falls does not influence the duration of the transition from yielding to overcoming



Conclusion: Increasing the working effect of the active push up movement is influenced mostly by the sharpness of the external force's impact, related to the velocity of raising the muscle's strain.

According to Verkhoshansky (1979), it happened for the following three reasons:

CNS stimulation by the sharp external force's impact

By increasing the velocity of the magnitude of muscle strain, by influence of provoked external force (mechanical stress), the level of muscular excitation increases: the level of excitation depends on the rate of raising the magnitude of mechanical stimulus.



Emil Heinrich Du Bois-Reymond
(1818 -1896)

Myotatic reflex



Adolf Eugen Fick
(1829–1901)

Contracting muscles under stretch could produce greater force than a shortening muscle contraction (Adolf Fick, 1882).



Charles Scott Sherrington
(1857 – 1952)

When a muscle lengthens beyond a certain point, the myotatic reflex causes it to tighten and attempt to shorten (the Liddell-Sherrington reflex - the tonic contraction of muscle in response to its being stretched).

“Under conditions of constant muscle contraction, the myotatic reflex... is linearly and highly correlated with the rate of muscle stretch” (G.L. Gotlieb, G.C Agarwal. | Response to sudden torques about ankle in man: myotatic reflex. AJP - JN Physiol January 1, 1979 vol. 42 no. 1 91-106).

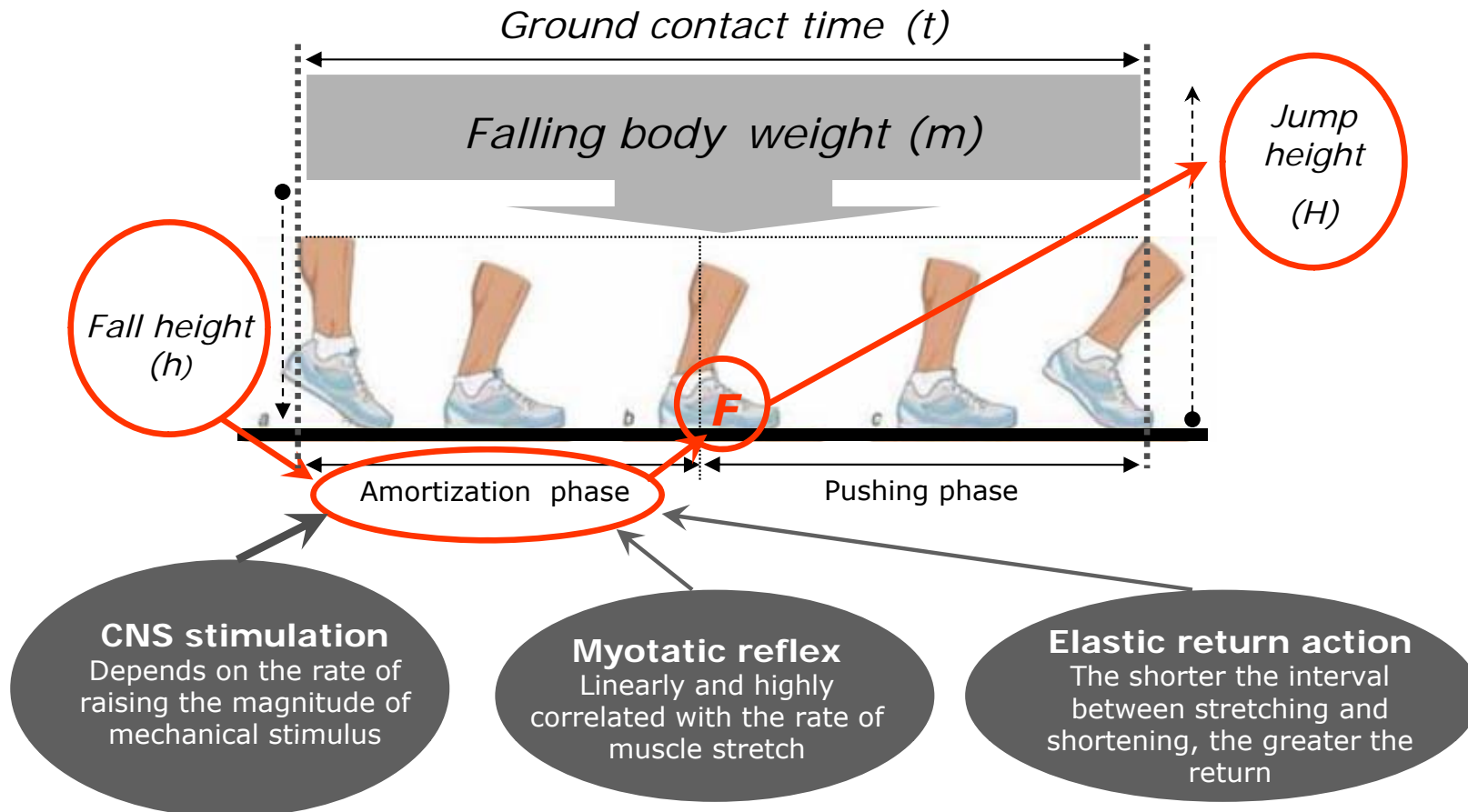
Elastic return action from the elastic component series

“The force developed by contractile component, when the muscle shortens after being stretched, is greater than that developed at the same speed and length, when is shortens starting from a state of isometric contraction” (G.Cavana, B.Dusman, R.Margaria. Positive work done by a previously stretched muscle . J Appl Physiol January 1, 1968).

“The increase of work performed is greater, the shorter the interval between stretching and shortening” (Cavagna, G.A., Saibene, F.P., Margaria, R. Effect of negative work on the amount of positive work performed by an isolated muscle, J Appl Physiol , 1965).



*"The essence of the method consists of **a stimulatory muscle strain created by the impact** with kinetic energy accumulated from the sportsman's falling body from a specific, strictly proscribed, height. The resistance of the falling body (the shell) is stopped over a short movement path. This produces a sharp muscle - tension which creates, instantaneously, a resilient potential of muscle - tension and stimulates a high-intensity central neuro - impulse on motor neurons. This in turn promotes a faster switching of the muscles from eccentric to concentric work and a more powerful contraction" (Y.Verkhoshansky, 2005).*





The shock method is a non-conventional method of stimulating the work of muscles. Its peculiarity consists of using an external stimulus not from a weight, but the kinetic energy accumulated by a free falling body.

“When free weights are employed, the magnitude of the muscles’ working tension is a function primarily of volitional effort. However, in the shock method, the activation of the working muscles is “forced.” The external factor of the weight example only assists the force produced by the muscles; on the other hand, with the shock regime the external factor (kinetic energy) forces the body to mobilize the innate motor resources”.

“If the sportsman conducts a vertical take-off after a depth jump with the aim of flying up as high as possible..., these conditions force his central nervous and physiological systems to exceed the ordinary boundaries. The creation of such conditions in training process is the forced intensification of the work regime which becomes a potent training stimulus. Apparently, under these conditions the body mobilizes any innate mechanisms designed by nature to be available for these and even more complex, extreme situations”.

3. IN-DEPTH EXAMINATION OF PLYOMETRICS

3.1. TERMINOLOGICAL ISSUES

3.2. MIOGENIC AND NEUROGENIC FACTORS IN PLYOMETRICS

3.3. NEUROGENIC FACTORS - LATER UPDATES

3.4. THE SHOCK METHOD AS A PARTICULAR FORM OF PLYOMETRICS

Plyometrics are exercises that obtain the greatest power output in the overcoming phase of movement thanks to the muscle's pre-stimulation during the yielding, eccentric (*pliometric**) phase.

* "...In correlating muscle contractions with the movements of the limbs during walking and running, Hubbard and Stetson (Hubbard AW and Stetson RH. An experimental analysis of human locomotion. J Physiol 124: 300-313, 1938) recognized that muscles underwent contractions during three different 'conditions'. The three conditions were termed '**miometric**', '**isometric**', and '**pliometric**' by coupling the Greek prefixes '**mio**' (**shorter**), '**iso**' (**same**), and '**plio**' (**longer**) to the noun 'metric', defined as pertaining to measures or measurement.... Despite their early introduction, the terms miometric and pliometric have never gained wide acceptance".

Faulkner, J.A. Terminology for contractions of muscles during shortening, while isometric, and during lengthening. Journal of Applied Physiology 95: pp 455-459, 2003.

Plyometrics exploit the benefits of the pliometric regime.

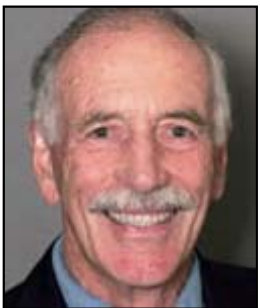
The term "Plyometrics" may be interpreted as "applying pliometric".

"Plyometric" is simply a misnomer of "pliometric"



Vladimir Zatsiorsky, PhD, professor of kinesiology, the director of Penn State's Biomechanics Laboratory:

*"I mentioned this way of training (drop jumps, etc) in my book, "Motor Abilities of Athletes", published in 1966 and translated into many languages. I do not remember whether I called this training 'shock training' or not and if I suggested this term. In any case, this is not any big deal. ...The commonly accepted in the American literature **term 'plyometrics' is a misnomer..., which was simply a synonym for 'eccentrics' MCS**".*



John A. Faulkner, Ph.D., professor of Molecular & Integrative Physiology and Biomedical Engineering, Senior Research Scientist, IoG:

"...An additional deterrent to the use of the term pliometric is the increased use of the term "plyometrics" for conditioning with highpower jumps that involve repeated, rapid, and forceful shortening and lengthening actions during almost maximum activation of large muscle groups. Despite suggestions for other terminology for this type of conditioning by Komi and later by Knuttgen** and Kraemer the popularity of "plyometrics" and the use of the term have increased dramatically".*

* Komi PV. Physiological and biomechanical correlates of muscle function: effects of muscle structure and stretch-shortening cycle on force and speed. In: *Exercise and Sport Science Reviews*, edited by Terjung RL. Lexington, MA: Collamore, 1984, p. 81–121)

** Knuttgen HG and Kraemer WJ. Terminology and measurement in exercise performance. *J Appl Sport Sci Res* 1: 1–10, 1987)

"Plyometrics are the exercises which involve SSC"



Paavo V. Komi, PhD, FACSM, FECSS.

Is a professor emeritus specialized in neuromuscular science at the University of Jyväskylä, Finland.

Professor & Director of the Neuromuscular Research Center, Department of Biology of Physical Activity, University of Jyväskylä.

*"...The stretch–shortening cycle (SSC) of muscle function comes from the observation that body segments are periodically subjected to **impact** or stretch forces.*

*...**In human walking, hopping and running** considerable impact loads occur when contact takes place with the ground. This requires pre-activation from the lower limb extensor muscles before the ground contact to make them ready to resist the impact and the active braking phase. The stretch phase is followed by a shortening (concentric) action.*

...Running, walking and hopping are typical examples in human locomotion of how external forces (e.g. gravity) lengthen the muscle. In this lengthening phase the muscle is acting eccentrically, then a concentric (shortening) action follows. ...The true definition of eccentric action indicates that the muscles must be active during stretch. This combination of eccentric and concentric actions forms a natural type of muscle function called the stretch–shortening cycle or SSC (Norman & Komi 1979; Komi 1984, 2000).

*...**SSC muscle function has a well-recognized purpose: enhancement of performance during the final phase (concentric action) when compared to the isolated concentric action"**.*

PPAAVO V. KOMI, STRENGTH AND POWER IN SPORT, 2003

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS



The benefit of plyometric training is related to its capacity to improve the so named Reactive Ability of the neuro-muscular system (allowing greater force production in the "concentric" phase of SSC) thanks to the following two factors:

- 1) **Miogenic** - the utilization of the elastic energy storage in muscle-tendon tissue
- 2) **Neurogenic** - the alteration of the timing and firing rates of the motor units involved in *myotatic reflex*

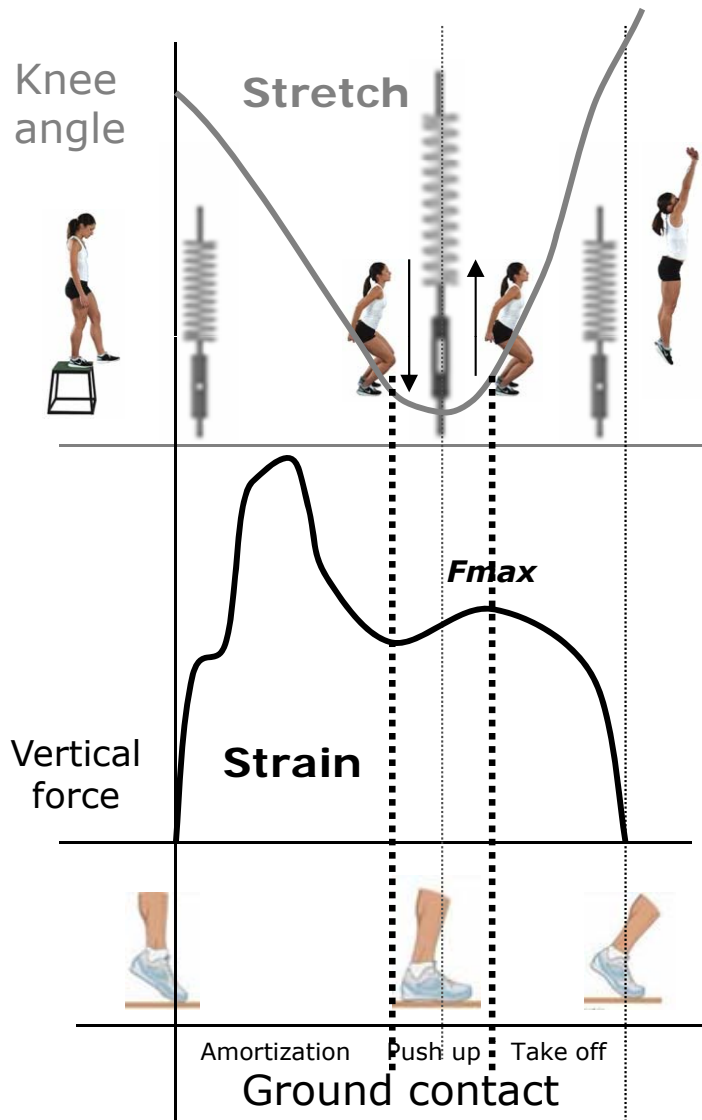
In different exercises, the contribution of these two factors could be different, depending on the character of the exercise execution; regardless, "*the principal function of plyometric exercises is to stimulate the neuro-muscular characteristics*"

Carmelo Bosco, 1977, 1985

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS

The Miogenic factors of the SSC

Elastic energy recoil adds to the force of active muscular contraction



Performance during stretch shortening cycle exercise is influenced by the visco-elastic properties of the muscle-tendon units. During stretching of an activated muscle, mechanical energy is absorbed in the tendon structures (tendon and aponeurosis) and this energy can subsequently be re-utilized if shortening of the muscle immediately follows the stretching. According to Bisciotti (2000), 72% of the elastic energy restitution action comes from tendons, 28% - from contractile elements of muscles.

In order to get the best results, the following compulsory conditions should be considered:

- the external force impact should be sufficiently high to efficiently store elastic energy in the tendons
- the external force impact should be sufficiently sharp to rapidly increase the muscle's strain: the Coupling time should be shorter than the half-life of an acto-myosinic bridge (about 120 – 150 milliseconds);
- the voluntary force effort (active push-up), should be applied at the same time when the involuntary (provoked by stretch reflex) muscular contraction occurs.

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS

The Neurogenic factors of the SSC

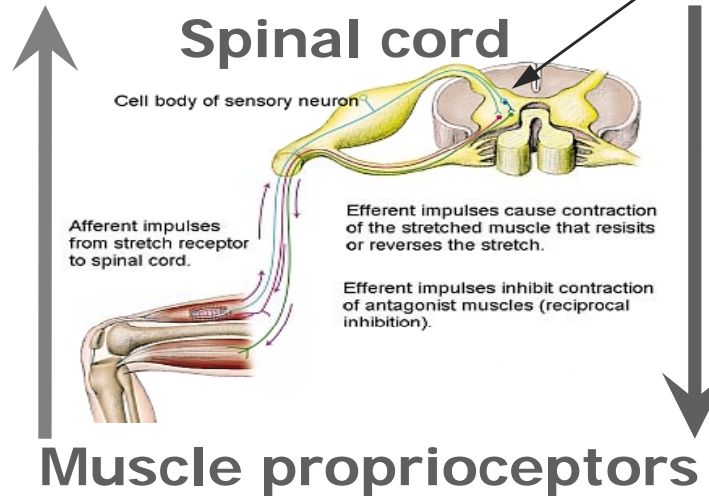
The alteration of the timing and firing rates of the motor units involved in a *myotatic reflex*

The Myotatic Reflex is a monosynaptic reflex which provides the automatic contraction of muscles when their stretch sensory receptors are stimulated)

Renshaw cell is a special inhibitory interneuron, which innervates and inhibits the very same motor neuron that caused it to fire.

When a muscle is stretched, primary sensory fibers (Group Ia afferent neurons) of the **muscle spindle** respond to both changes in muscle length and velocity and transmit this activity to the spinal cord in the form of changes in the rate of action potentials.

Likewise, secondary sensory fibers (Group II afferent neurons) respond to muscle length changes (but with a smaller velocity-sensitive component) and transmit this signal to the spinal cord.

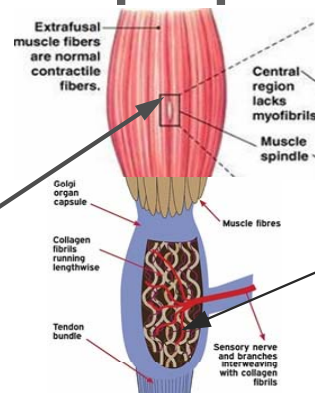


The Ia afferent signals are transmitted monosynaptically to many alpha motor neurons of the receptor-bearing muscle.

The reflexly-evoked activity in the alpha motoneurons is then transmitted via their efferent axons to the extrafusal fibers of the muscle, which generate force and thereby resist the stretch.

The Ia afferent signal is also transmitted polysynaptically through interneurons (**Renshaw cells**) which inhibit alpha motoneurons of antagonist muscles, causing them to relax.

Muscle spindles (MS) react by sending a signal to the central nervous system that in turn orders the agonist muscle to contract. This action is supported by the simultaneous inhibition of the antagonist muscle.

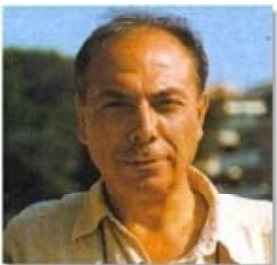
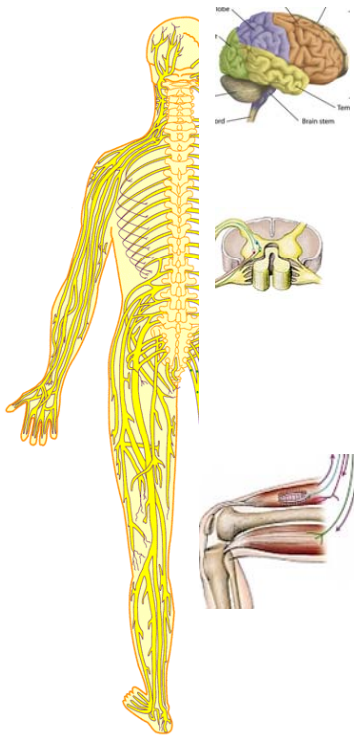


Golgi Tendon Organs (GTO) activation threshold is higher than muscler spindles, If tension is too high chances for a fibre breakdown increase, so Golgi's organs send a signal towards the central nervous system, which quickly induces a contraction inhibition.

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS

Plyometrics:

- Allow for deep and complete neuromuscular stimulation and improve intramuscular coordination between fibres in a single to synchronize a higher quantity of motor units.
- Elevate Renshaw cells' inhibition threshold, so activation at higher frequency is possible. That allows a selective recruitment of white fibres, due to the massive intervention of synchronized motion units.
- Decrease the GTO's sensitivity, which will not stop maximum (or sub-maximum) contraction (myotatic reflex inhibition)
- Bring greater elastic energy storage, faster contraction, and improves neuromuscular spindles' efficiency.
- Reinforces tendons, aponeuroses, and muscle's internal connective tissues.



"Stretch shortening cycle (SSC) affects the sensory response of the muscle spindles (MS) and Golgi tendon organs (GTO). These two structures have contrast function: MS – excitatory, GTO – inhibitory. The balance (equilibrium) between excitatory and inhibitory stimuli, creates conditions of performance, of course, always under control of the CNS" (C.Bosco).

In what way might the central nervous system influence the SSC?

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS



“...Without arguing that the external stimulus causes the emergence of a reflex, the modern physiological theory puts main emphasis on the fact that an organism's reaction to a stimulus (both unconditioned and conditioned reaction), in its form and content, is determined not by the stimulus itself but by its significance for the individual; that is, the most important role is played by factors of internal purposefulness, against the background of which an external stimulus is frequently reduced to a trigger signal.

All the facts from modern behavioral science mean that any reflex (in the narrow "classical" sense of the word) is not the element of an action, but an elementary action as integral as any other action.”

Nicholai A. Bernstein. The Immediate Tasks of Neurophysiology in the Light of the Modern Theory

3.2. MIOGENIC AND NEUROGENIC FACTORS ASSURING BENEFITS OF PLYOMETRICS

In what way might the central nervous system influence the SSC?

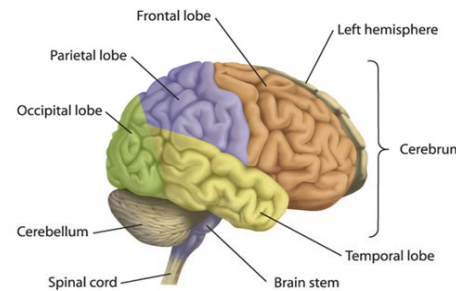
Greater cortical activation: greater activation of Gamma motoneurons related to the difficulty of a motor task.

Whereas static gamma motoneurons are continuously active during routine movements such as locomotion, dynamic gamma motoneurons tend to be activated more during difficult tasks, increasing Ia stretch-sensitivity.

Inhibitory signals arrive through the *lateral reticulospinal tract* from the brain regions, which play the role in:

- the **planning of complex, coordinated movements** (*Brodman area 6*);
- **motor control and in some cognitive functions such as attention and language** (the *paleocerebellum*);
- **motor coordination** (*red nucleus* - a structure in the *rostral midbrain*).

Cerebral cortex



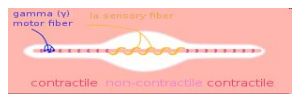
Facilitatory signals arrive through the *ventral reticulospinal tract* from the brain regions, which play the role in:

- **exchange of sense and motor information** (*Brodman area 4*);
- **motor control** - coordination, precision, and accurate timing (*neocerebellum*);
- **acoustic, ocular and vestibular control and coordination of head and trunk movements** (the *vestibular nucleus*).

Gamma motoneurons



Muscle spindles



Fusimotor system is the combination of muscle spindles and γ -motoneurons. It is the system by which the CNS controls and modifies muscle spindles sensitivity.

Gamma motoneurons are the efferent component of the fusimotor system. The function of the gamma motoneurons is to modify the sensitivity of the muscle spindle sensory afferents to stretch (not to supplement the force of muscle contraction provided by the extrafusal fibers).

In what way might the central nervous system influence the SSC?

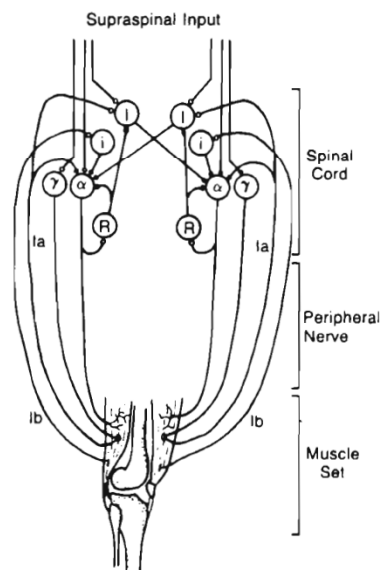
Greater cortical activation: maximising activity of high threshold motor units due to the Supraspinal influences affecting the pliometric muscular contraction



Enoka, R. M. **Eccentric contractions require unique activation strategies by the nervous system.** *J. Appl. Physiol.* 81(6): 2339–2346, 1996

"...Over the past several decades, numerous studies have established that eccentric contractions can maximize the force exerted and the work performed by muscle; that they are associated with a greater mechanical efficiency; that they can attenuate the mechanical effects of impact forces; and that they enhance the tissue damage associated with exercise.

*More recent evidence adds a new feature to this repertoire by suggesting a new hypothesis: that **the neural commands controlling eccentric contractions are unique**.... Variation in the neural strategy may be accomplished by modulation of the relative excitability within the populations of motoneurons innervating amuscle, its synergists, and the contralateral homologous muscle. The principal functional outcome of **the unique activation scheme may be to maximize the activity and thereby preserve the health of highthreshold motor units. These motor units are used minimally during daily activities but are essential for intense athletic competition and for emergency movements that require high levels of muscle power**".*



In what way might the central nervous system influence the SSC?

Greater cortical activation: additional cortical planning activity affecting the plyometric muscular contraction

Yin Fang, V.Siemionow, V.Sahgal, Fugin Xiong and Guang H.Yue

Greater Movement-Related Cortical Potential During Human Eccentric Versus Concentric Muscle Contractions

Journal of Neurophysiology October 2001 vol. 86 no. 4 1764-1772:

"Despite abundant evidence that different nervous system control strategies may exist for human concentric and eccentric muscle contractions, no data are available to indicate that the brain signal differs for eccentric versus concentric muscle actions. The purpose of this study was to evaluate electroencephalography (EEG)-derived movement-related cortical potential (MRCP) and to determine whether the level of MRCP-measured cortical activation differs between the two types of muscle activities.

...This study shows, for the first time, that the brain plans eccentric movements and processes eccentric-related sensory information differently than it does for concentric muscle contractions.

Because eccentric movements are more complex, make muscles more prone to damage, and perhaps require a unique motor unit recruitment strategy to carry out the actions, the greater NP* may reflect additional cortical planning activities or effort to deal with these "special problems."

* Negative Potential (NP)– the component of movement-related cortical potential MRCP, related to movement preparation, planning, and execution

In what way might the central nervous system influence the SSC?

Greater cortical activation and the earlier activities of neurons associated with planning eccentric actions

M.D.Grabiner and T.M.Owings.

EMG differences between concentric and eccentric maximum voluntary contractions are evident prior to movement onset.

Experimental Brain Research 2002, volume 145, number 4, pages 505-511

"This investigation addressed the question of whether the muscle activation signal prior to movement onset, as measured by surface EMG, differs if the contraction to be performed is concentric (shortening) or eccentric (lengthening).

...The results suggest that initial differences between the EMG of maximum voluntary concentric and eccentric knee extensor contractions are selected a priori and support the contention that the central nervous system distinguishes between maximum eccentric and concentric contractions.

*...The emergence of differences in activation prior to muscle length changes suggests supraspinal influences.
...a larger amount of sensory information is being processed in the brain and additional reflex-induced cortical activity resulted from stretching the muscles.*

...not only are the cortical activities associated with planning eccentric actions greater but also the neurons begin the planning activities earlier."

A greater power output of the SSC movement could be improved not only by potentiating the Myotatic Reflex, but also by the additional activation of the CNS, related to the perception of pliometric (yielding, eccentric) phase of movement as “danger” (“menace, threat”).

Pliometric (“eccentric”) muscular contractions can maximize the force exerted and the work performed by muscle, because the brain “perceive” the work in yielding regime as “special problem” which make muscles prone to damage, in consequence:

- additional reflex-induced cortical activity resulted from stretching the muscles
- additional cortical planning activities or effort to deal with these “special problem”
- not only are the cortical activities associated with planning eccentric actions greater but also the neurons begin the planning activities earlier.

The “danger” is especially high if the sudden (sharp) impact of external force occurs at the beginning of the concentric phase, which is out of the control of the motor receptors.

It is the main characteristic of the Shock Method

3.4. THE SHOCK METHOD AS A PARTICULAR FORM OF PLYOMETRICS

Stretch-shorten cycle

An active stretch (eccentric contraction) of a muscle followed by an immediate shortening (concentric contraction) of that same muscle (Wikipedia)

A common movement pattern that consists of a combination of the three types of muscle action; an eccentric action followed by a static (isometric) action, then a concentric action of the same muscle group (Answers.com)

Plyometrics

Exercises involving repeated rapid stretching and contracting of muscles (Merriam Webster)

“Exercises in which the muscles are repeatedly stretched and suddenly contracted (Dictionary.com)



Shock Method



*The specific characteristic of my method is expressed in **the shock stretch of the muscle under tension.***

(Y. Verkhoshansky).

The Shock regime could be considered a particular form of the muscle's work in in the Stretch Shortening Cycle regime, characterised by the more sharp impact of external forces during the pliometric (eccentric) phase provoked by of the body's *collision* (shock, bump) with the falling (or high-speed forthcoming) external object (sport device) or by the falling body's collision with the motionless object (ground).

4. KEY POINTS TO SUCCESSFULLY USING PLYOMETRICS

4.1. TAXONOMY OF PLYOMETRIC EXERCISES

4.2. PLYOMETRIC EXERCISES EMPHASIZING THE ELASTIC ENERGY RECOIL

4.3. PLYOMETRIC EXERCISES EMPHASIZING THE STRETCH REFLEX POTENTIATION

4.4. PLYOMETRIC EXERCISES EMPHASIZING THE CNS STIMULATION

4.5. USING THE DEPTH JUMP ACCORDING TO Y.VERKHOSHANSKY

4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

IMPACT AND NON-IMPACT PLYOMETRICS

***Plyometrics* exploit the benefits of the *pliometric* ("eccentric", yielding) regime.**

Plyometrics

| | |
|--|--|
| are defined as the exercises with a reversible regime of muscle work <u>without</u> additional external force impact | are defined as exercises with a reversible regime of muscle work <u>with</u> additional external force impact |
| <p>Merriam Webster. " Exercises involving repeated rapid stretching and contracting of muscles".</p> <p>Dictionary.com: "Exercises in which the muscles are repeatedly stretched and suddenly contracted".</p> | <p>MedicineNet.com: "Any exercise in which muscles are repeatedly and rapidly stretched ("loaded") and then contracted (as in jumping high off the ground or in push-ups with a clap between them)".</p> |
| Non-impact Plyometrics | Impact Plyometrics |

NON-IMPACT PLYOMETRICS



Pliometric exercise

the exercise is executed in pliometric (yielding or "eccentric") regime

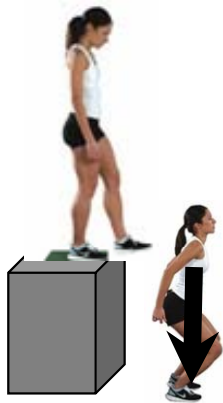
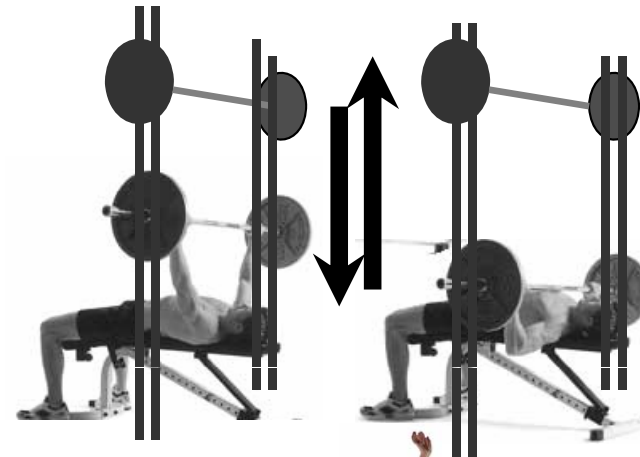
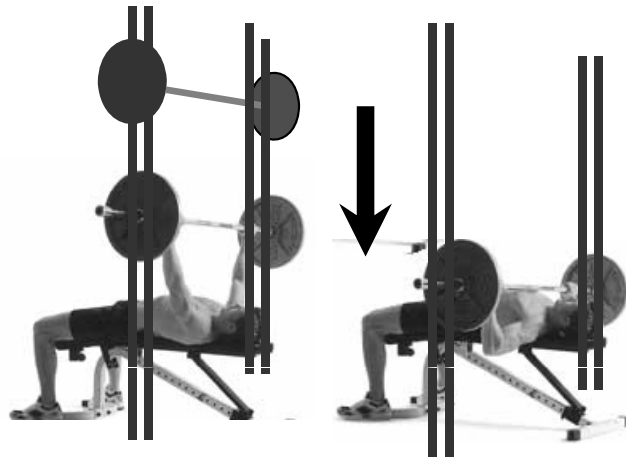
Miometric exercise

the exercise executed in miometric (overcoming or "concentric") regime

Non-impact Plyometric exercise

the exercise is executed in a reversible regime with rapid passage between the yielding ("eccentric") and overcoming ("concentric") phase

IMPACT PLYOMETRICS



Impact-plierometric exercise

the exercise executed in pliometric (yielding or "eccentric") regime with impact of external force

Impact -Plyometric exercise

the exercise executed in reversible regime with impact of external force in the yielding phase

IMPACT PLYOMETRICS

Shock Method exercises

are characterised by the sharp impact of external forces during the plyometric (eccentric) phase provoked by of the body's *collision* (shock, bump) with the vertically falling external object (sport devise) or by the vertically falling body collision with the motionless object (ground)

Repeated, rapid, and forceful muscle shortening-lengthening actions performed with their **almost maximum** activation

Single, rapid, and forceful muscles shortening-lengthening actions performed with their **maximum** activation

Multi-impact Shock method exercises

Classic Shock Method exercises



Repeated jumps, push ups and throws



Maximal effort Push-up throw and Depth jump

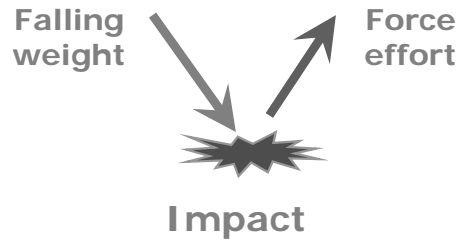
MULTIPLE-IMPACT PLYOMETRICS

Low-impact Plyometrics

Middle-impact Plyometrics

High impact Plyometrics

Angular vector of the force effort

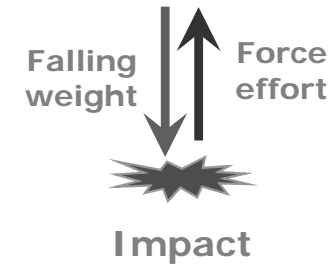


Bounding exercises



Medicine ball couple throwing

Vertical vector of the force effort



Standing jumps

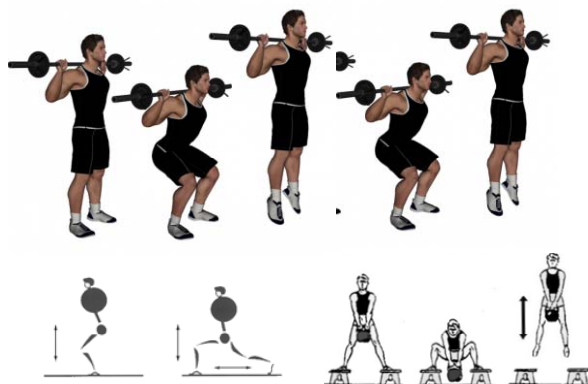
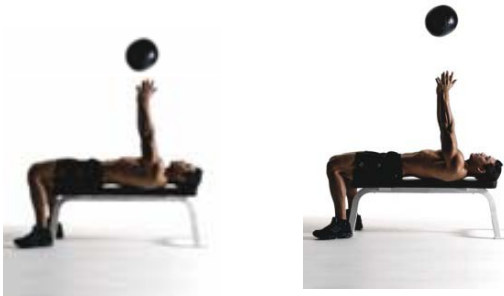


Vertical throw-ups

Classic Shock
Method jumps
and throws

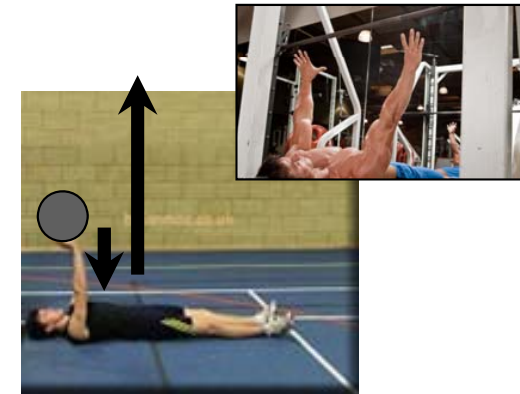
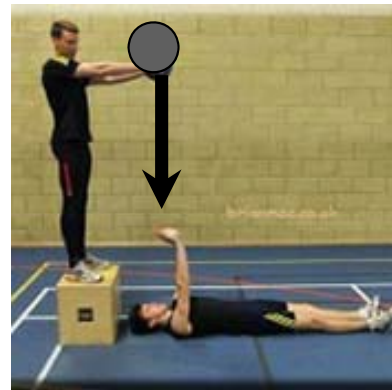
COMBINED PLYOMETRICS

Multiple-impact plyometric exercise

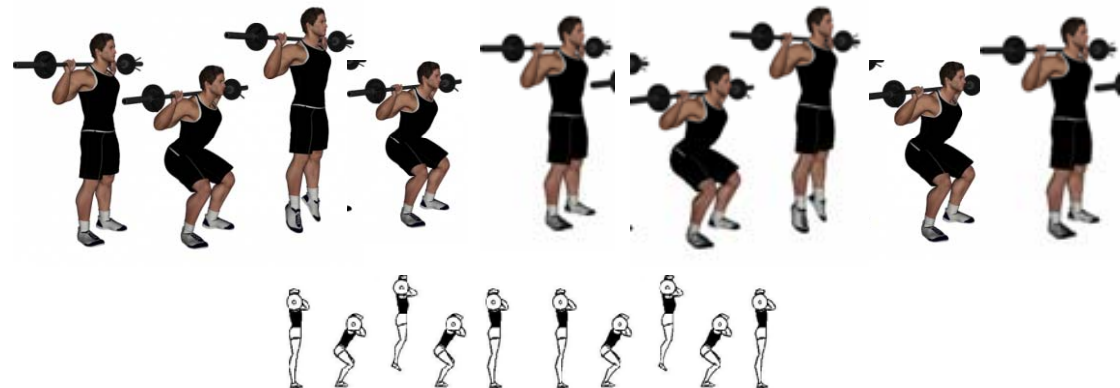


Multiple subsequent push-up
throws or jumps

Combined impact-plyometric and non- impact plyometric exercise



Stop



Multiple push-up throws or barbell jumps executed with stops
between the landing phase and the subsequent counter-
movement phase

Plyometric exercise is the exercise in which the pliometric (yielding, "eccentric") regime is used to increase the power output of movement executed in miometric (overcoming, "concentric") regime

The benefit of plyometric training is related to its capacity to improve the Reactive Ability of the neuro-muscular system (producing greater force in the "concentric" phase of the SSC) thanks to the influence of the miogenic and neurogenic factors:

Miogenic factors

Elastic energy recoil
the restitution of elastic energy, absorbed in the muscle-tendon structures

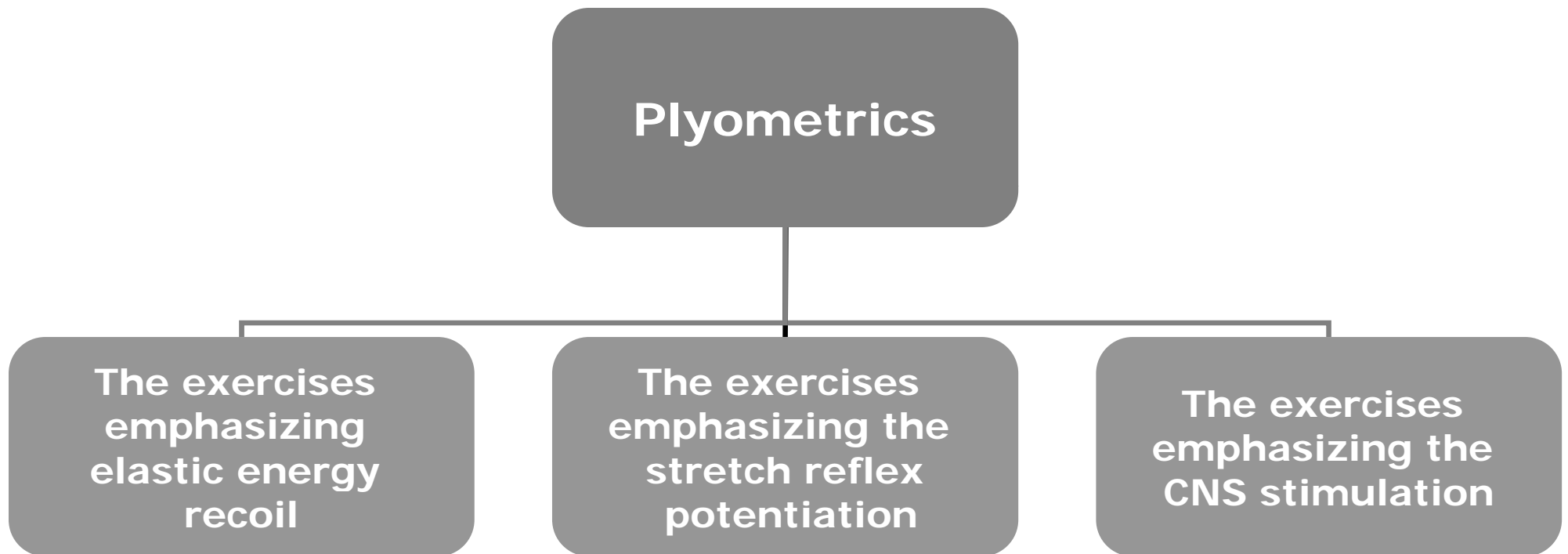
Neurogenic factors

Spinal influences
the stretch reflex
potentialtion due the stimulation of muscle proprioceptors

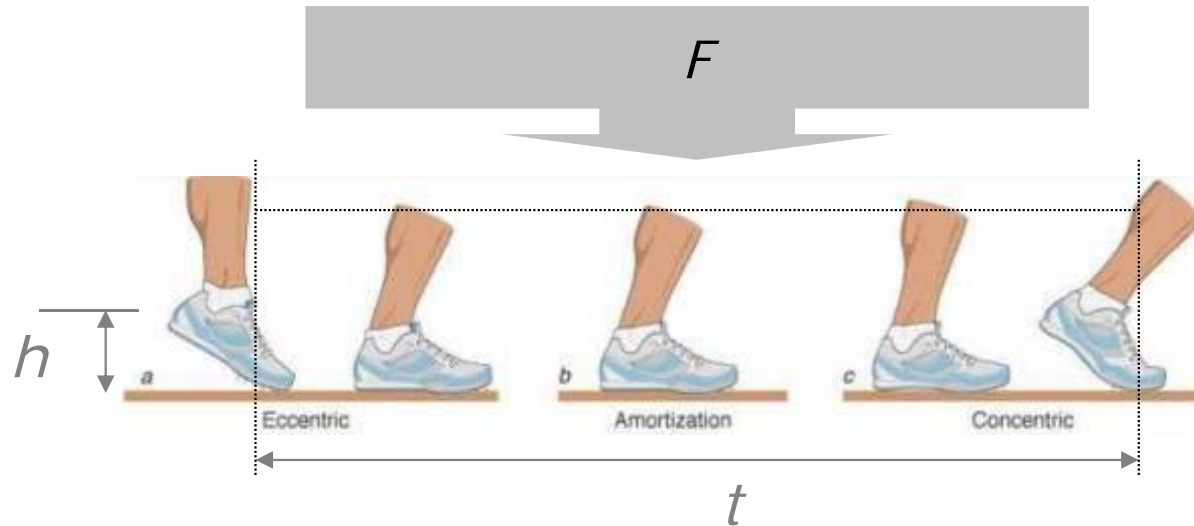
Supra-spinal influences
additional reflex-induced cortical activity
resulted from stretching the muscles;
additional cortical planning activities - the CNS pre-activation associated with planning eccentric actions

In different exercises, the contribution of these factors could be different, depending on the character of the exercise's execution.

So, the taxonomy of plyometric exercises could be based on their capacity to emphasise each one of these factors



4.2. PLYOMETRIC EXERCISES EMPHASIZING ELASTIC ENERGY RECOIL



In general, utilizing elastic energy is determined by the speed of the stretch shortening cycle and the level of muscle stretching.

To properly use the elastic energy, the stretch phase should be:

- 1) **sufficiently rapid** such that the coupling time (t) of the stretch shortening cycle will not be inferior to the half time of the actin and myosin cross-bridge cycling action (120 – 150 ms circa);
- 2) **sufficiently ample (h)** to cause the myotatic reflex to take place in the correct moment: not anticipate the eccentric phase and not be inside the concentric phase
- 3) **combined to the active muscular contraction** (external force impact - F) *"...high muscular activation during the eccentric phase of an SSC is a prerequisite for efficient storage of elastic energy, especially in the tendon" (P.Komi, 2003).*

4. KEY POINTS TO SUCCESSFULLY USING PLYOMETRICS

4.2. PLYOMETRIC EXERCISES EMPHASIZING ELASTIC ENERGY RECOIL

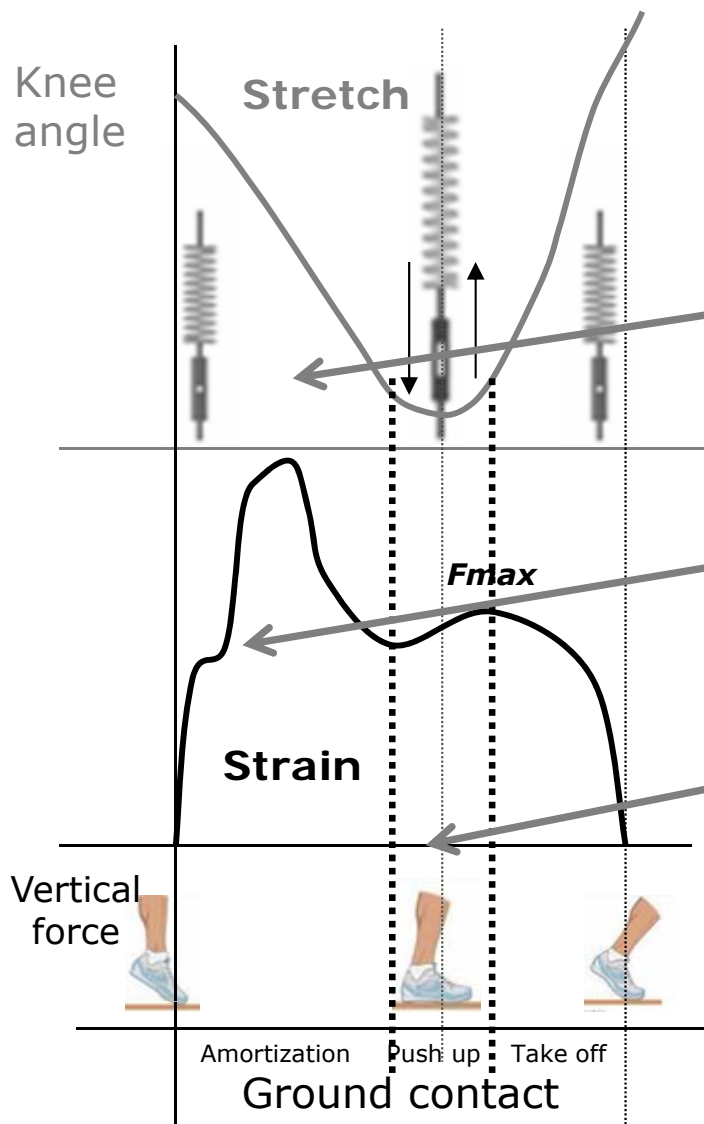


| | Coupling time |
|--------------------------------|--------------------------------|
| Sprinting | 0.10 |
| Bounding | 0.22 |
| Squat jumping (10-20kg) | 0.40 |
| Depth jumping | 0.24 -0.31 (until 0.33) |

} 120 - 150 ms

To emphasise elastic energy restitution, the combined form of running - bounding exercises should be used.

4.2. PLYOMETRIC EXERCISES EMPHASIZING ELASTIC ENERGY RECOIL



The plyometric exercises emphasizing elastic energy recoil should be executed:

- with the external force impact, which is sufficiently sharp to rapidly increase the muscle's strain and
- sufficiently high to efficiently store elastic energy in the tendons

- with the short passage from eccentric to concentric phase

Motor task

Adjusting the execution technique of SSC movement to obtain elastic energy recoil

ABC running drills



High Knees

Heel Flicks

Running exercises, originally designed for sprinters, but usually used in most sports during the warm up: run with high lifting of the thigh (high knees); run with a heel kickback (butt kicks) etc.. The exercises are executed with attention to correct technical performance and nimbleness of movement

Bouncy or springy runs



A Springy or bouncy run (or bounding extensive tempo) is a running exercise executed with shorter strides and with the forward impulse coming mainly from foot; it requires a more accentuated vertical push and a bounding overall action. The oscillatory movement of the recovery leg is minimized and the whole action is very relaxed. In fact, the athlete's relaxation is paramount for the correct execution of exercise, in particular the relaxation of the upper body combined with the intense work of the foot muscles.

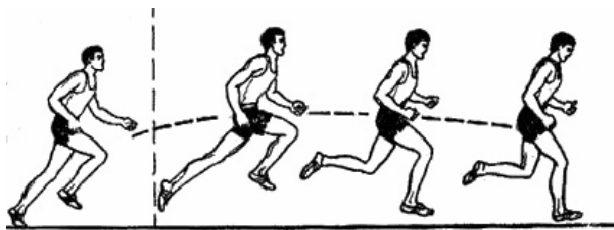
Motor task

Decreasing the Coupling time of SSC movement



The exercise is executed with a small number of repetitions and with the control of execution time

Bounding runs

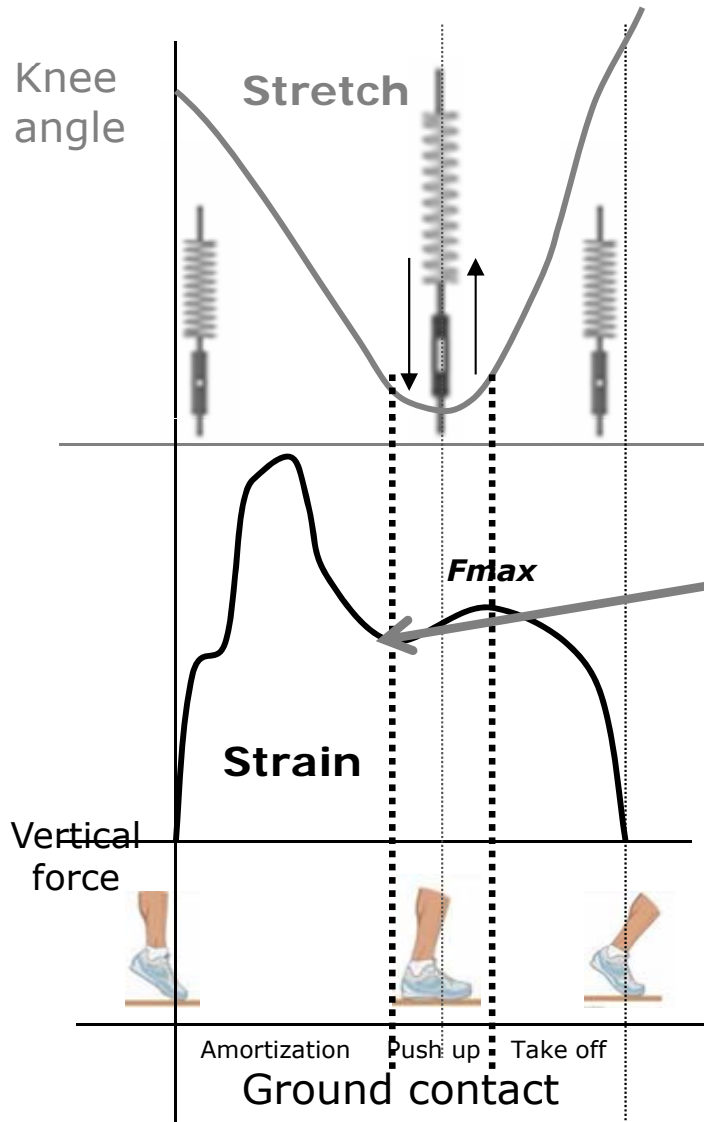


Bounding runs are very similar to the bounce from leg to leg, but it is executed with higher stride frequency and with more "spring"; it is executed for 50 m as quickly as possible (with the execution time recorded). The athlete starts by pushing off from both legs as in the standing long jump, and then lands on one and then alternates the legs consecutively, trying to increase stride frequency, but not transforming the movement into a run. The dosage of exercise depend on the time of it's execution. Usually, this exercise is carried out in 2-4 series of 3-5 repetitions with arbitrary rest intervals between repetitions and 8-10 minutes interval between series.



The difference between Bounding run and Alternate Leg-to-leg bounce

4.3. PLYOMETRIC EXERCISES EMPHASIZING THE STRETCH REFLEX POTENTIATION



The plyometric exercises emphasizing the stretch reflex potentiation should be executed with the correct moment of active force employment

4.3. PLYOMETRIC EXERCISES EMPHASIZING THE STRETCH REFLEX POTENTIATION

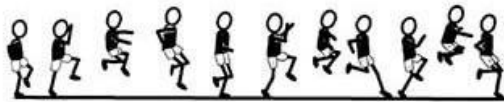
The stretch reflex potentiation due the stimulation of muscle proprioceptors by additional external force impact (F)

Motor task

**Adjusting the execution technique of SSC movements:
the muscles relaxation-tension pattern**

The exercises are executed with a great number of repetitions and with control of the movement's nimbleness

Short coupling time jumping and bounding exercises (the short time of force employment)



Alternate Leg Bounding



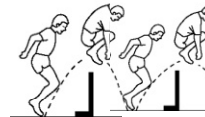
Single Leg Hops



Box Jumps on and off of a low box



Consecutive jumps over obstacles or boxes



Side-to-side double leg bounces



Side-to-side single-leg bounces

Long coupling time jumping exercises (the long time of force employment)



Repeated Long Jumps



Multiple consecutive standing jumps



Box Jumps on and off of a high box

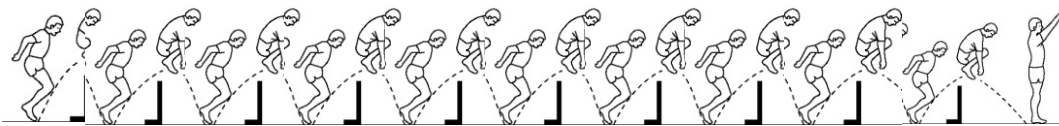
4.3. PLYOMETRIC EXERCISES EMPHASIZING THE STRETCH REFLEX POTENTIATION

Motor task

Decreasing the Coupling time of SSC movements



The exercises are executed with a small number of repetitions and with control of execution time



Hurdles bounces (leaping or jumping over obstacles) executed as quickly as possible



Side-to-side double leg bounces



Side-to-side single leg bounces

Motor task

Increasing the power output of SSC movements



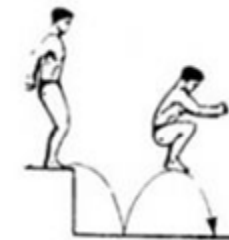
The exercises are executed with a small number of repetitions and with the control of jump length (height)

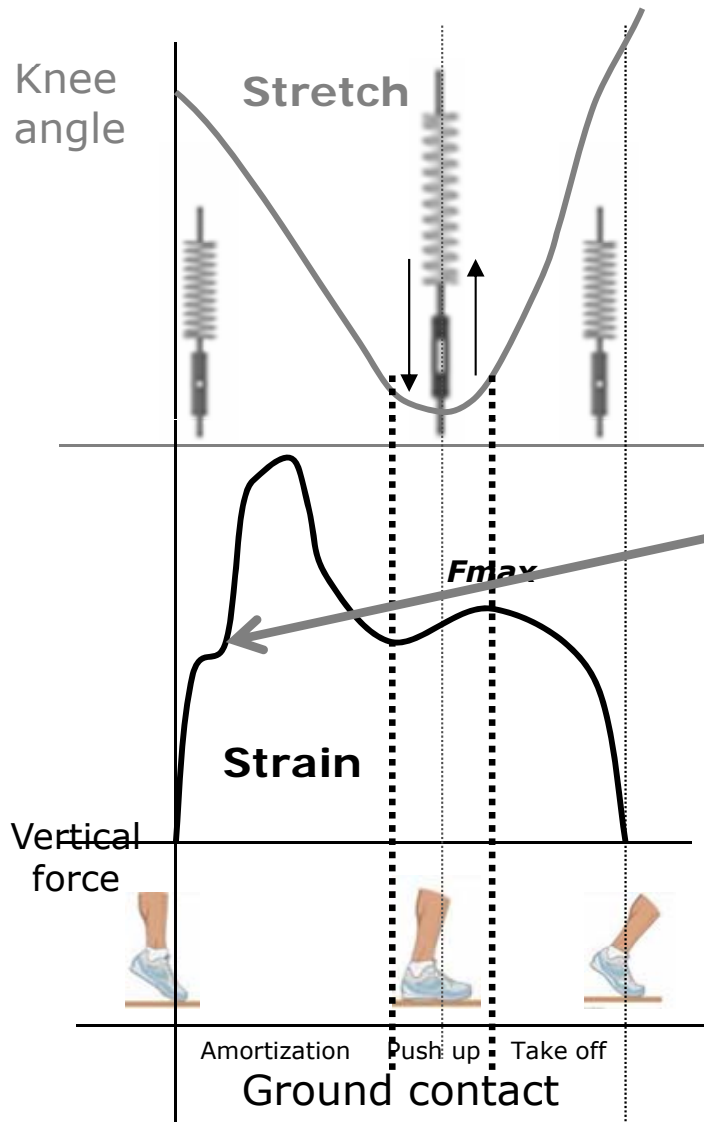


Alternate Leg Bounding



Repeated Long Jumps





The plyometric exercises emphasizing the CNS stimulation should be executed with greater impact of external force:

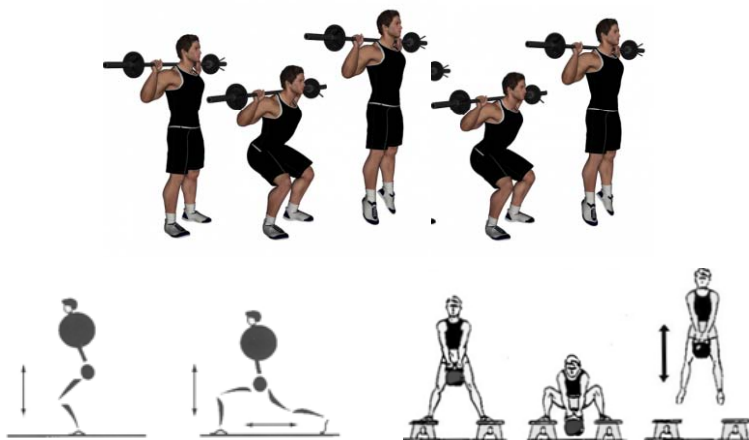
1. using overload, or
2. using *“kinetic energy accumulated from the sportsman’s falling body from a specific, strictly proscribed, height”*

Motor task

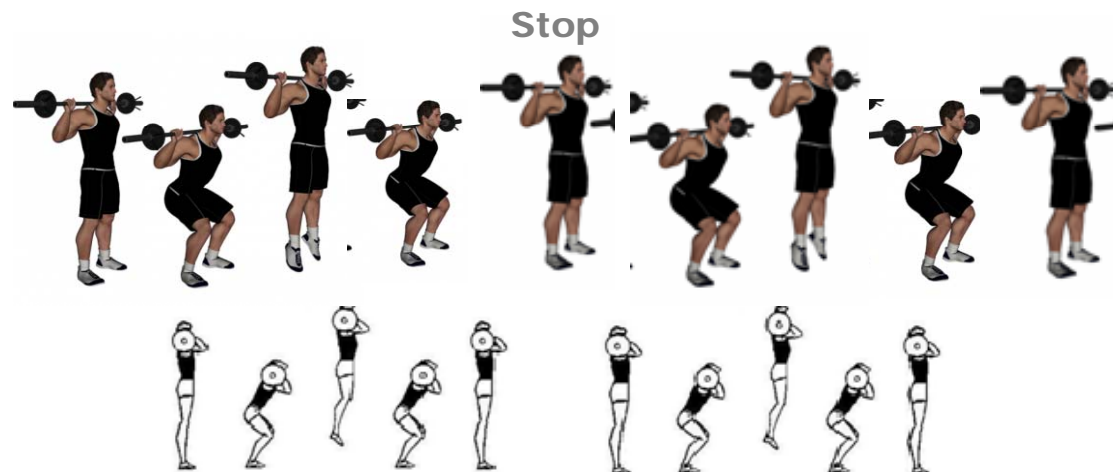
Adjusting the execution technique of SSC movements by increasing the external force's impact

Multiple-impact plyometric exercise

Combined impact-plyometric and non-impact plyometric exercise



Consecutive Barbell and kettlebell jumps



Vertical jump with barbell

4. KEY POINTS TO SUCCESSFULLY USING PLYOMETRICS

4.4. PLYOMETRIC EXERCISES EMPHASIZING THE CNS STIMULATION



“If the sportsman conducts a vertical take-off after a depth jump with the aim of flying up as high as possible..., these conditions force his central nervous and physiological systems to exceed the ordinary boundaries. The creation of such conditions in training process is the forced intensification of the work regime which becomes a potent training stimulus. Apparently, under these conditions the body mobilizes any innate mechanisms designed by nature to be available for these and even more complex, extreme situations”.

TAUBE, W., LEUKEL, C., LAUBER, B. AND GOLLHOFER, A.

The drop height determines neuromuscular adaptations and changes in jump performance in stretch-shortening cycle training.

Scandinavian Journal of Medicine & Science in Sports, 2011



"... In order to maximize the mechanical output of knee extensors and plantar flexors during drop jump training, athletes should utilize a "bounce drop jump technique," i.e., to reverse the downward velocity into an upward one as soon as possible after landing (Bobbert et al., 1987a). This "recommendation" was founded on the essential need for effective storage of elastic energy in the transition from the eccentric to the concentric phase (Kyrolainen & Komi, 1995; Komi, 2003).

This strategy, however, does not seem beneficial in increasing the rebound height, as there was only a trend toward augmentation." Hunter and Marshall (2002) presumed that if subjects were not advised by instructions like: "Keep the duration of ground contact as short as possible," or "Bend your knees very little," subjects would automatically adapt their jumping strategy in the direction of a lower leg stiffness, greater depth of countermovement, and longer ground contact times.

4. KEY POINTS TO SUCCESSFULLY USING PLYOMETRICS

4.5. USING THE DEPTH JUMP ACCORDING TO Y.VERKHOSHANSKY



KEVIN R. FORD, GREGORY D. MYER, ROSE L. SMITH, ROBYN N . BYRNES, SARA E . DOPIRAK, TIMOTHY E. HEWETT.

Use of an overhead goal alters vertical jump performance and biomechanics.

Journal of Strength & Conditioning Research 2005 Volume: 19, Issue: 2, Pages: 394-399

This study examined whether an extrinsic motivator, such as an overhead goal, during a plyometric jump may alter movement biomechanics. Our purpose was to examine the effects of an overhead goal on vertical jump height and lower-extremity biomechanics during a drop vertical jump and to compare the effects on female (N = 18) versus male (N = 17) athletes

Greater vertical jump height ($p = 0.002$) and maximum takeoff external knee flexion (quadriceps) moment ($p = 0.04$) were attained with the overhead goal condition versus no overhead goal.

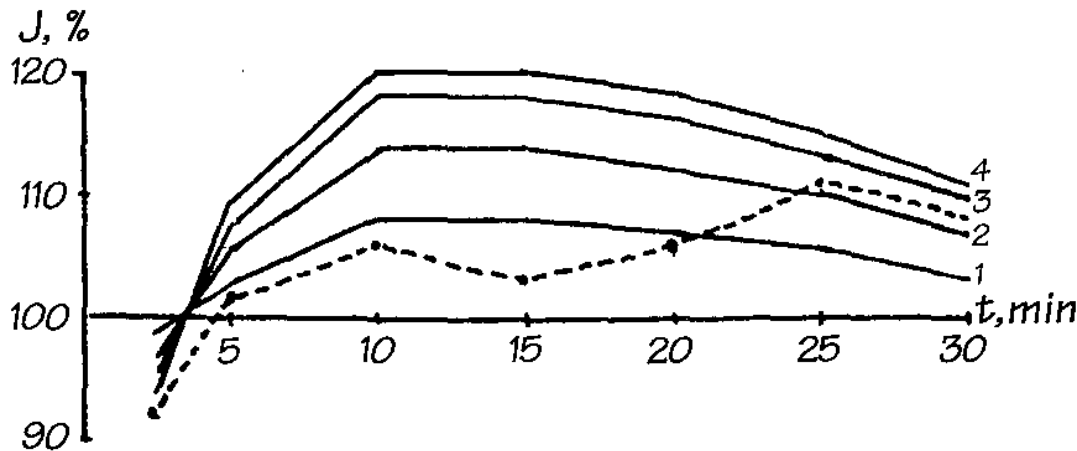
4.5. USING THE DEPTH JUMP ACCORDING TO Y.VERKHOSHANSKY



The forth experiment of Y. Verkhoshansky (1986):



During the third experiment, it was verified that the athletes were able to increase the height of the Depth jump only until the 10th repetition. So, the optimal number of Depth jumps in one series is 10. To verify the optimal number of series, 5 groups of athletes carried out training sessions with 1, 2, 3, 4 and 5 series of 10 Depth Jumps. Explosive strength of each athlete was measured in UDS test before and after the training sessions: every 5 minutes in a period of 30 minutes, when the athletes didn't perform any muscular work



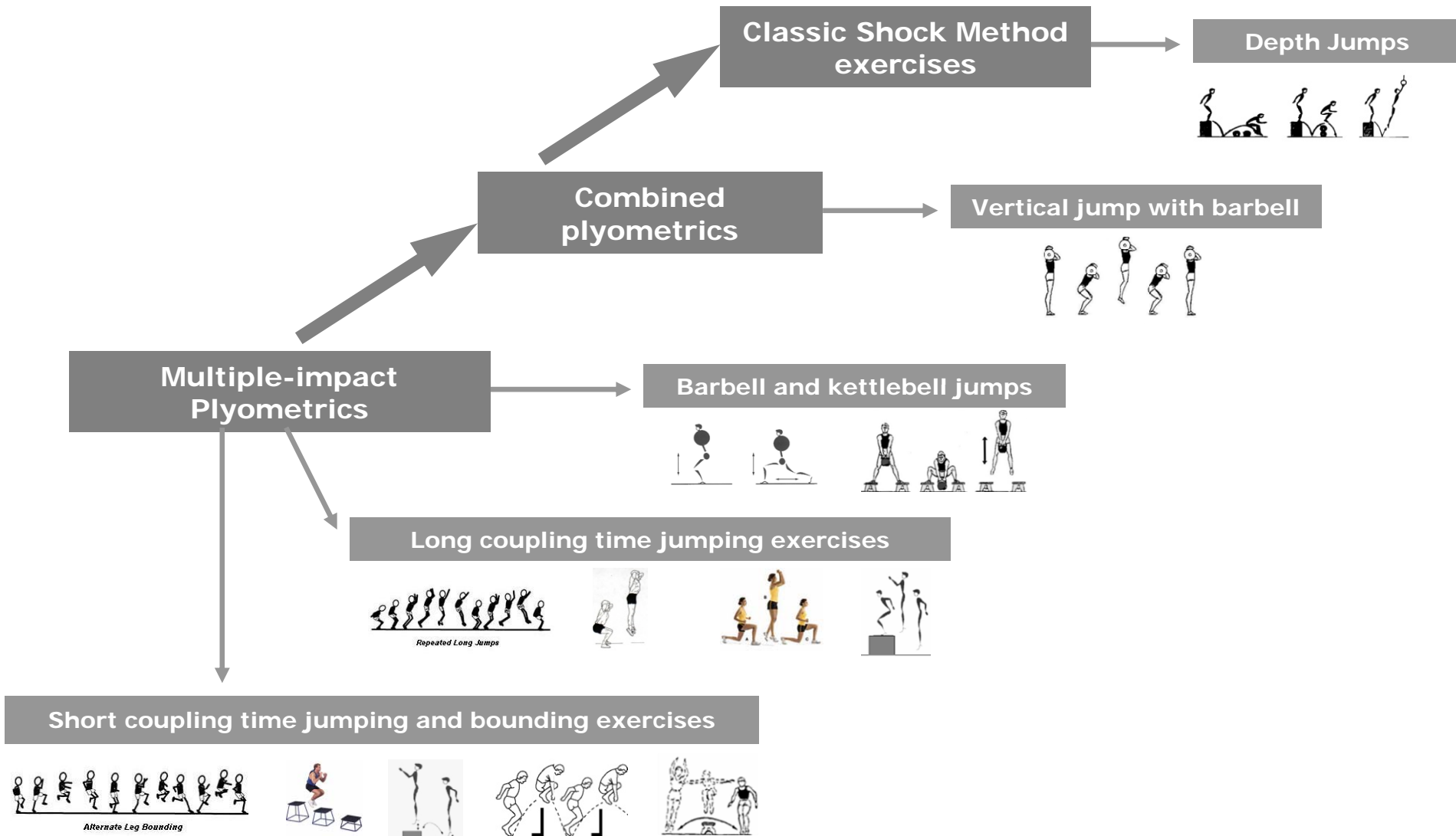
Trends of the explosive strength of one (1), two (2), three (3), four (4) and five (dotted line) series of aloft jumps.

In the groups that used 1, 2, 3 and 4 series of Depth jumps, the greatest increase in the level of explosive strength was observed 10 minutes after the training sessions. In the group, which used 4 series of Depth Jumps, the level of this increase was greatest. In the group that used 5 series of Depth jump, the maximal level of the Explosive strength increase was observed only 25 minutes after the training session and this level was lower than the maximal level of the group that used only 3 series of Depth jump.

4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF TAKE-OFF MOVEMENT

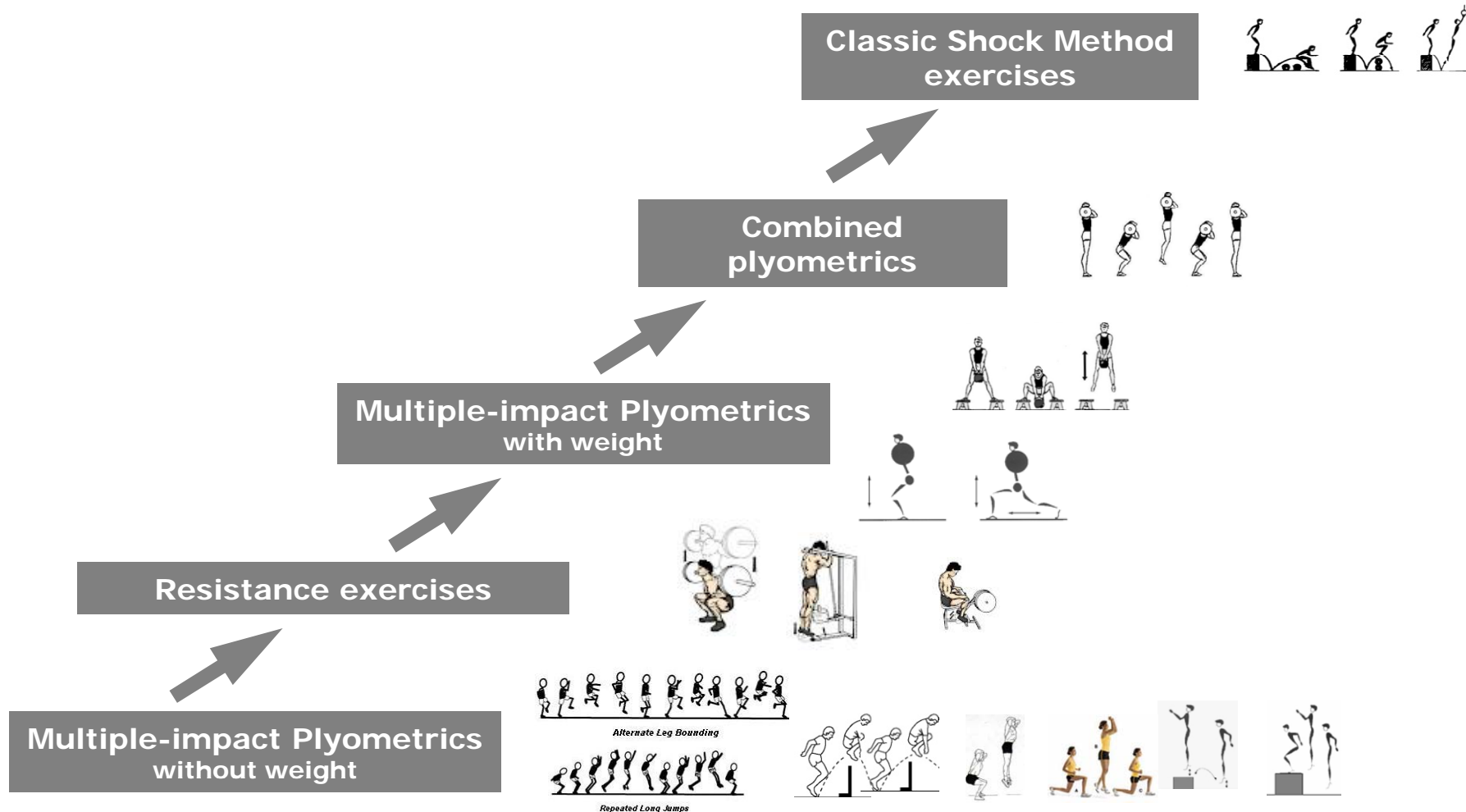
Case 1°: Specific movement with a relatively low level of external resistance



4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF TAKE-OFF MOVEMENT

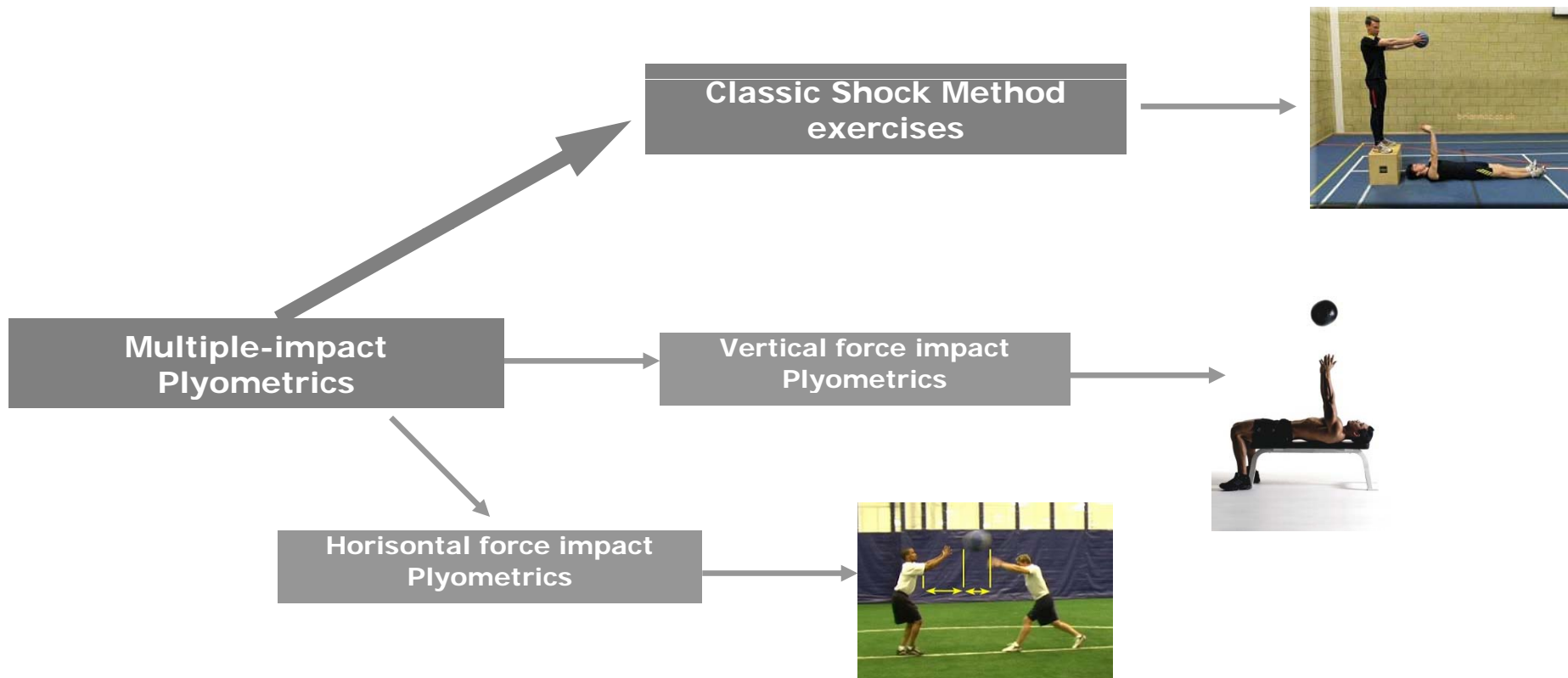
Case 2°: Specific movement with a high level of external resistance



4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT IN PUSHING MOVEMENT

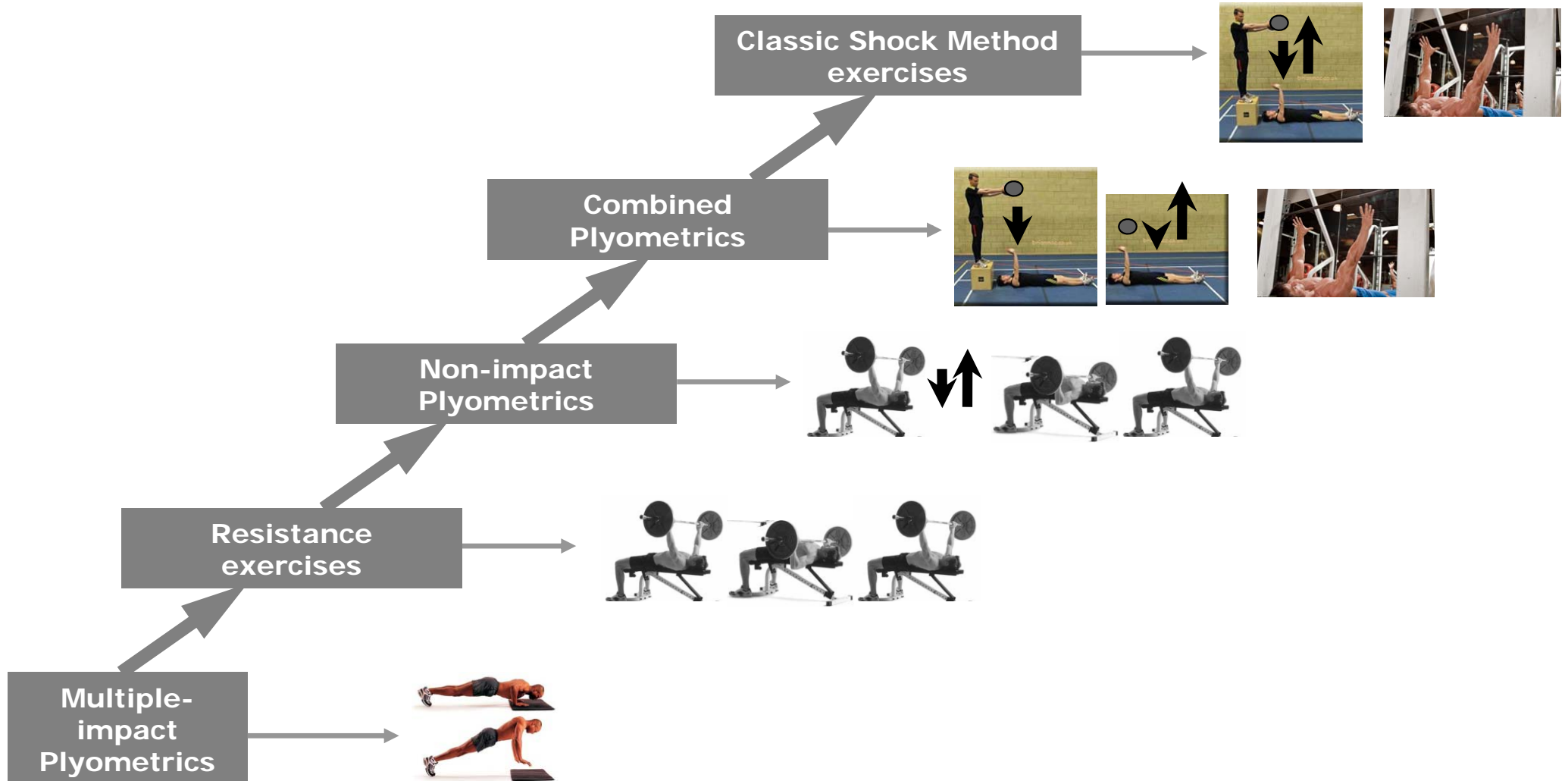
Case 1°: Specific movement with a low level of external resistance



4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT IN PUSHING MOVEMENT

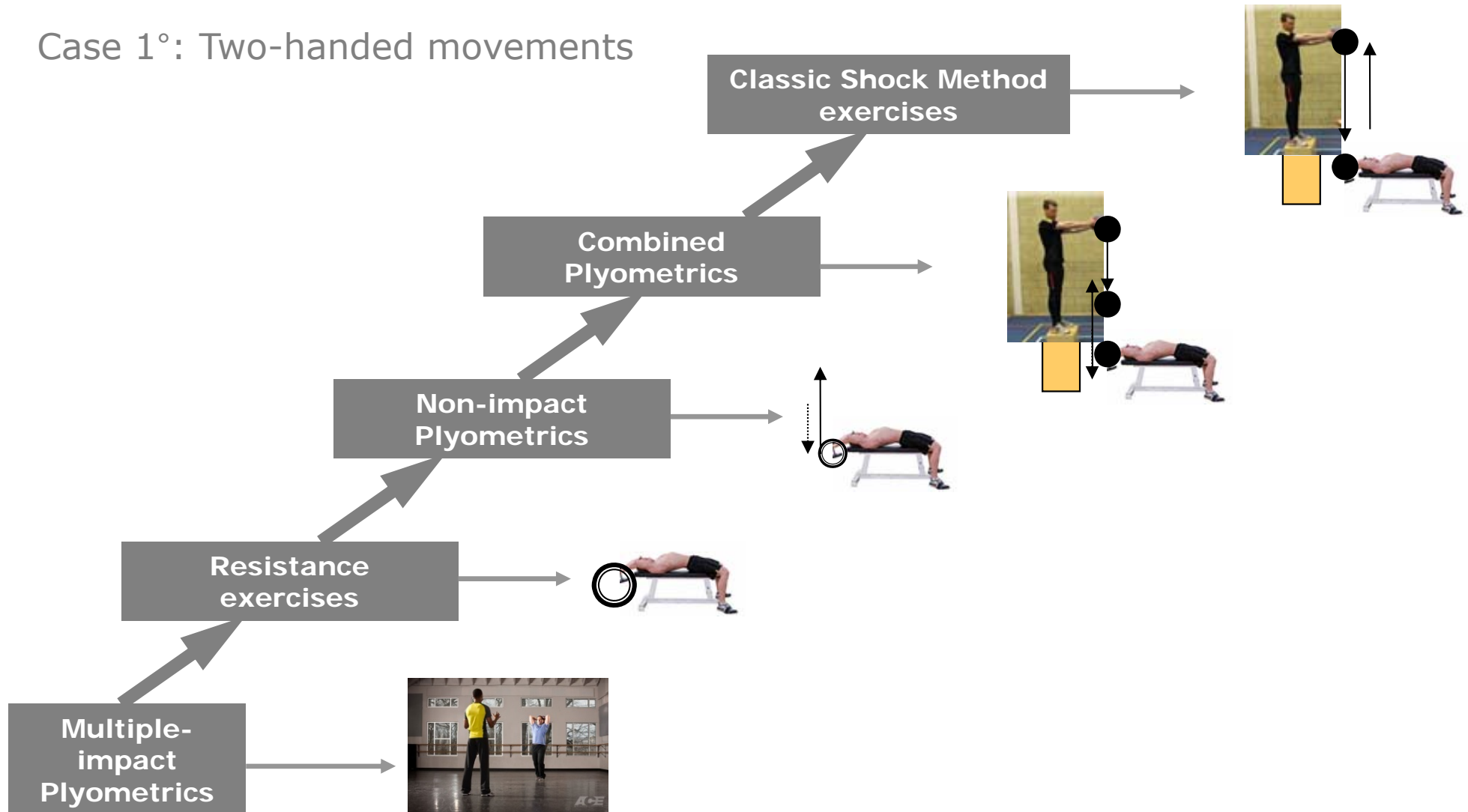
Case 2°: Specific movement with a high level of external resistance



4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF OVERHEAD MOVEMENTS

Case 1°: Two-handed movements

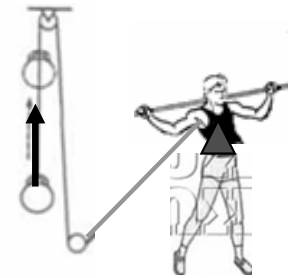
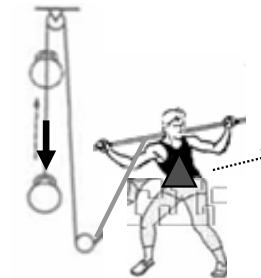
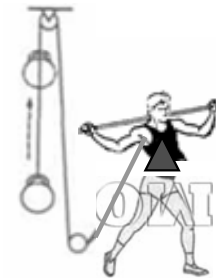
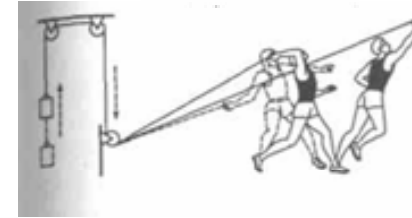
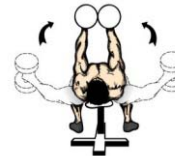
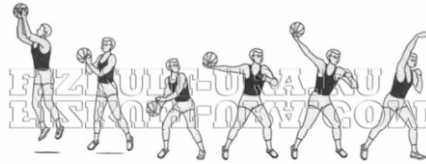
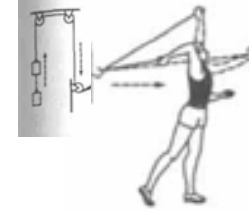
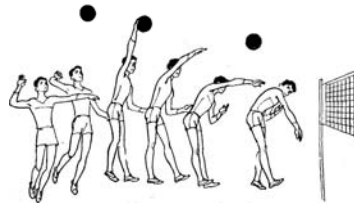


4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF OVERHEAD MOVEMENTS

Case 2°: One-handed movements

Phase 1°: resistance exercises

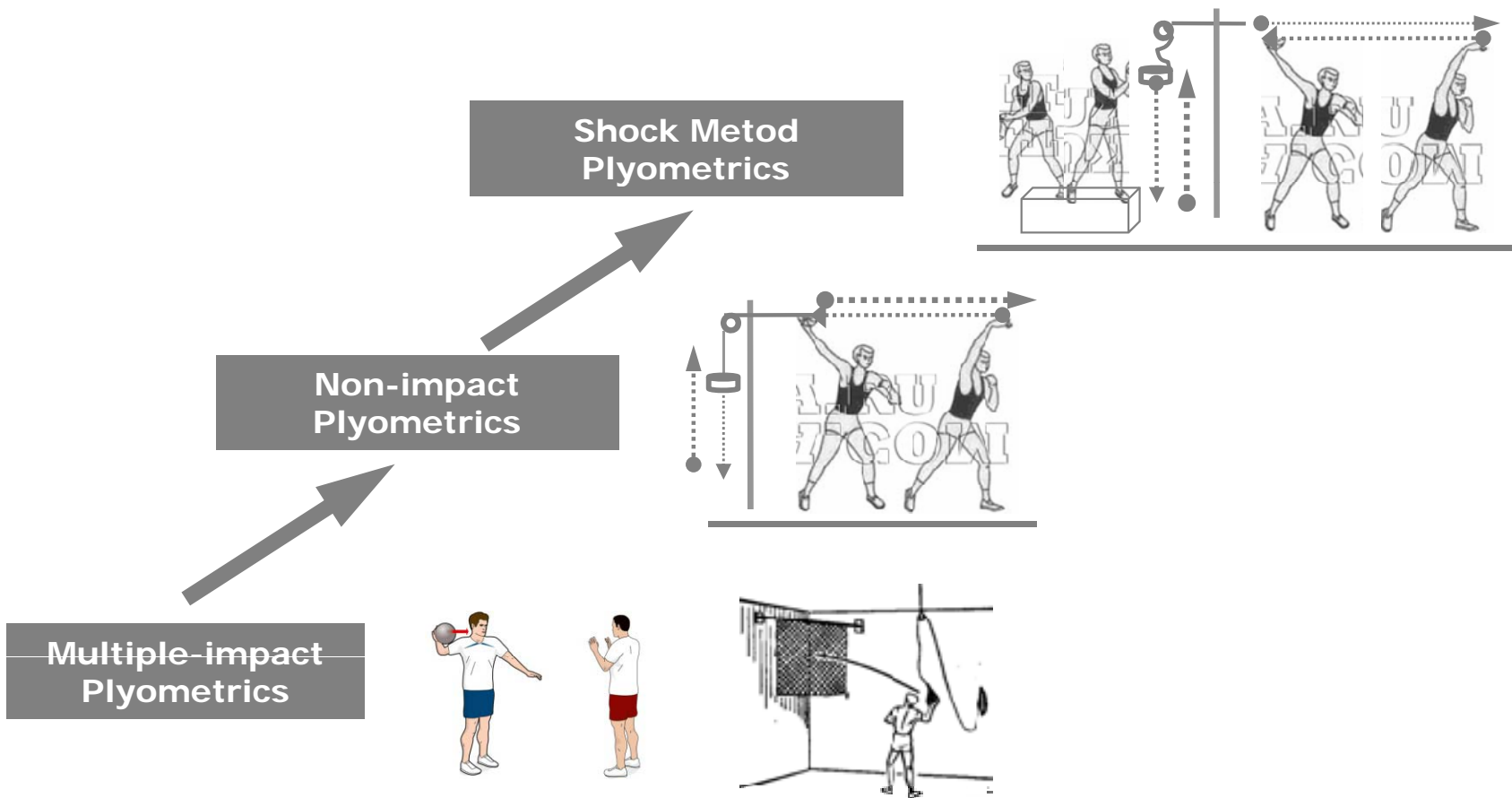


4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF OVERHEAD MOVEMENTS

Case 2°: One-handed movements

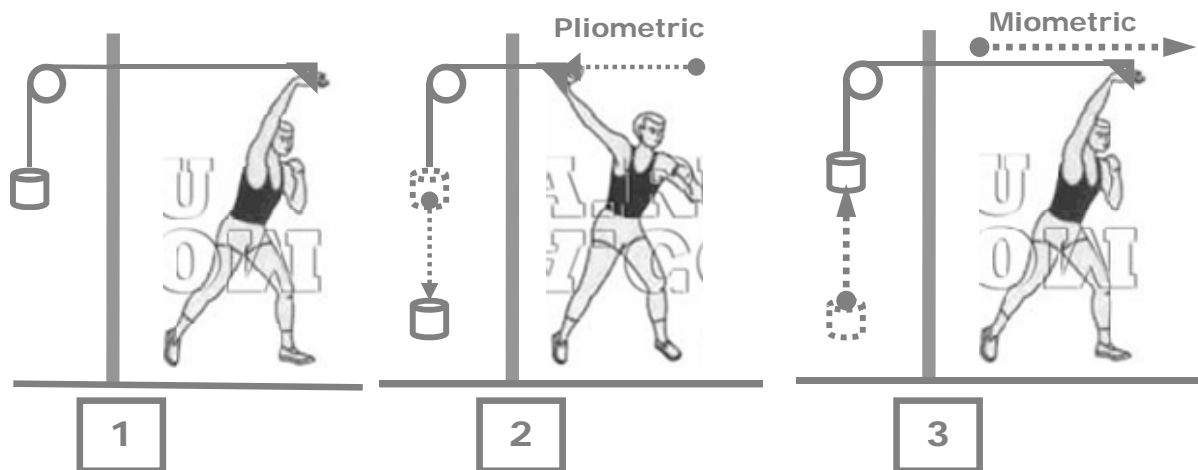
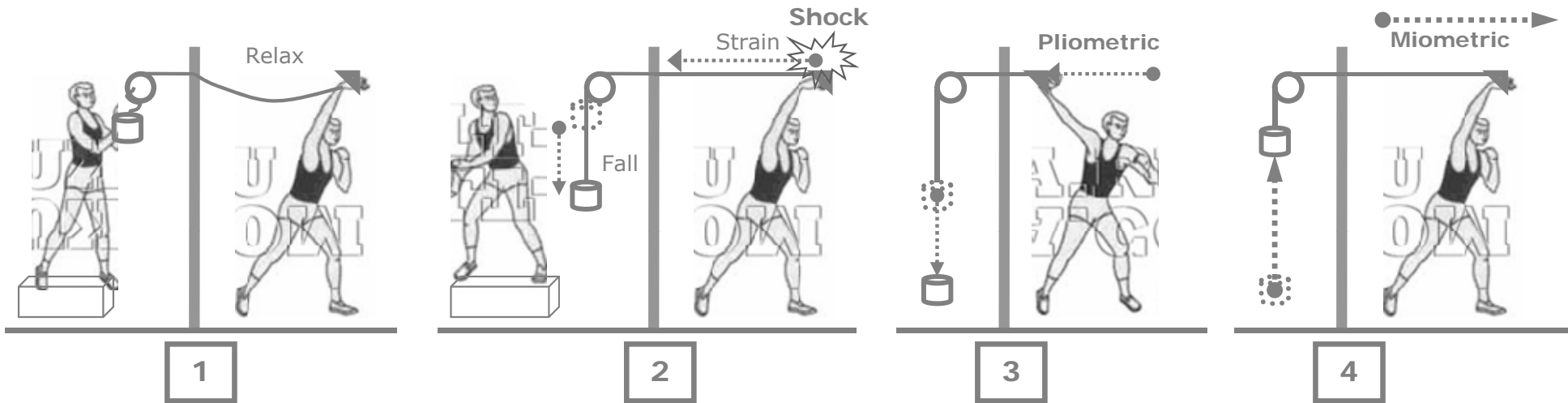
Phase 2°: Plyometrics



4.6. PROGRESSING PLYOMETRIC EXERCISES DURING THE PREPARATION PERIOD

INCREASING THE POWER OUTPUT OF OVERHEAD MOVEMENTS

The end of phase 2°: from non-impact to impact Plyometrics



Impact plyometric
(Shock method) exercise

Non-impact
plyometric exercise

Life is 'trying things to see if they work.'

Ray Bradbury

Creativity is just connecting things.

Steve Jobs

Being a creative coach means trying new training methods to see if they are effective and integrating them in a training system

Thank you for your attention