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EDITORIAL MISSION STATEMENT

The editorial mission of the EWF – Scientific Magazine is to advance the knowledge of human movement based on the assumption that it is firstly, by any standard, the expression of muscular strength and secondly, a way of life and an ethical approach entrusted to professionals who not only are highly qualified, but also have full knowledge of the scientific facts, as well as being specifically competent. From its first issue, EWF – Scientific Magazine, has set itself the ambitious goal of bridging the gaps between the scientific laboratory and the operator on the field, enhancing both the practical experience of the coaches and the results of applied research. Consequently, the editorial rule will be a constant reference to practice and the publication of recommendations on how to apply the results of research to the practice of movement and sport.

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Carol Tarvis, 1992

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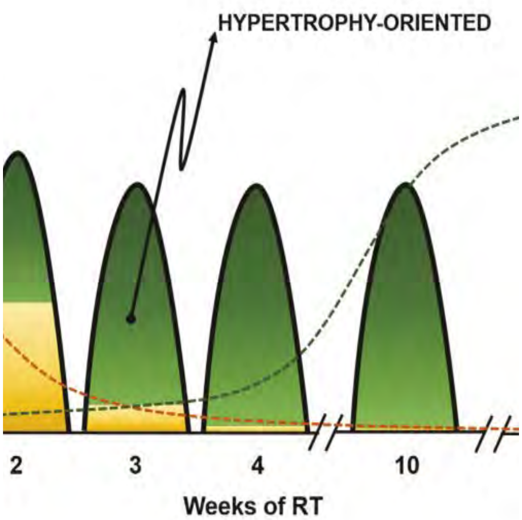

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EDITORIAL

What is trained today in weightlifting?

I ask those who read my editorials to be patient. You will no doubt have noticed that in an almost cadenced, cyclical and recurrent manner, I return to the subject of training and the process of training in particular. Time goes by and the appeal of this complex and highly articulated process leads me to reflect, lucky as I am perhaps, having the privilege of being able to attend national and international weightlifting competitions very frequently, competitions that represent the conclusion, the final act, of days, weeks and months of training, major and minor processes of preparation of a performance, which for various reasons are always exceptional regarding a determined subject.

I am very curious to understand what is behind a performance, be it positive or not, and what the elements are that have determined it. I am intrigued by the attitudes and approaches of the various coaches in achieving that type of performance and if I observe and note here and there most of the aspects that seem involved, one part of them alone does not allow you to fully complete the entire puzzle of the final performance. It is not merely a sum of things; it is not a predictable whole, it is not mathematics!

In competitions I often see attitudes and different approaches, which are rarely or perhaps never used in training, different in any case from commonly used routines. Let me give some examples: I have never seen any coach in training put a blanket or a towel on an athlete's shoulders between lifts. During regular training I have never seen a coach check an athlete's hydration level; I have never seen a coach massage an athlete before a maximum lift, let alone slap them or make them sniff salts before lifting or repeating a maximum lift. And yet a maximum lift is a maximum lift, whether it is in training or attempted in the competition: and still, the approaches are different.The determination of the coaches is different, the language is different. But are competitions so different to training? Let me be clearer: perhaps other things are done in competitions that require different behaviour than during training? If so, then we should reflect on what training actually means; and we must be aware that our reflections must be oriented towards understanding the different elements that make up competition, such as requiring different approaches, which in some cases, are never used in training.

Let's try to analyse these approaches from different points of view. Firstly: the psychological aspect. What can happen in an athlete's psyche if, during the most important event, when he/she should be aware of the progress made in training, the coach, in other words, the most important person there and then, sends a series of objectively very negative messages.

The messages say: ... I'm covering you because otherwise you'll get cold and if you get cold you won't be as good as I want ... the message is loud and clear!

I'm taking take care of you because you are unable to regulate your own body temperature; I'm telling you how hot you should be. In actual fact, all weightlifting competitions are held indoors, so is this type of attitude really necessary? Hydration. Rarely have I seen in training coaches worry about whether the athletes have hydrated enough before starting the workout. Many scientific studies demonstrate the value of this practice applied to strength training, which is hardly ever used, even on the days when the maximum lifts are scheduled. The message is more or less the following: ... I know when and how much you have to drink! In weightlifting competitions, there is the age-old habit of the "slapping" technique. Once again, this is used only in competitions and is actually devoid of any scientific or functional value (those who do it should have some knowledge of how the nervous system works, what a mechanoreceptor is, etc.), as well as being horrible to witness, when it comes to both male and female athletes.

A dreadful gesture on all fronts, but in particular for the intrinsic message this action conveys: I, as coach, can invade the personal space of an athlete, and can also slap him/her, because in competitions (there is no corresponding action during training) the athlete often becomes an instrument in the hands of the coaches. For years I have been insisting on the international scene that this practice be banned. Unfortunately, however, I have always come up against a brick wall. Another custom often noticed in competitions is that of coaches repeating all the technical and postural moves like a mantra before the athlete steps onto the platform and repeating them again, often shouting them, before the athlete starts the lift. This practice is also rarely seen in training. I wonder and I put the question to you: if before a lift a coach has to repeat what needs to be done, what use are the days, weeks and months of training? Shouldn't training prepare for competition? If so, why are certain things done in competitions that have no corresponding action in training?All the behaviours listed above demonstrate, that both those who endure them and those who exercise them, have indeed poor mental preparation for the competition. Competitions must be prepared mentally on a par with the physical preparation. Strategies to improve safety and, in particular, the independence of athletes must be adopted (coaches often enjoy treating the athletes as competition toys, the prevalence of the child within the adult) and this often means that the competition, therefore direct confrontation with adversaries, produces stress which, if not ably managed, transforms into uncontrollable anxiety.

In conclusion, I put the question to everyone: do coaches train mentally for training?

Antonio Urso
EWF President

NATURE OR NURTURE

GENDER VARIATIONS IN WEIGHTLIFTING TECHNIQUE

BY ANDREW CHARNIGA
www.sportivnypress.com


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SWEDEN

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INTRODUCTION

An important question of weightlifting sport science is whether there are gender differences in technique associated with physiological and biomechanical differences between the sexes. If such distinctions exist, do they involve actions the coach should teach the female athlete or eliminate; for instance, so as to conform to current thinking of correct technique?

"…*nature" refers to biological/genetic predispositions' impact on human traits, and nurture describes the influence of learning and other influences from one's environment.*"

NATURE OR NURTURE TECHNIQUE

Optimum parameters of weightlifting technique developed by the Soviet school of weightlifting have been forthcoming for males. Consequently, the question which should be asked are these parameters applicable to the female weightlifter? If so, then applying those male technique parameters would constitute 'nurturing' the female to perform the classic exercises like a man.

However, if the coach/teacher allows for "biological/genetic predispositions" gender differences in weightlifting mechanics emerge; not deficient, just different.

For instance, consider the graphics of joint angles and tracings of path of shoulder joints, barbell center of mass (BCM), common center of mass (CCM) and body center of mass for two female lifters. Those three points of balance lie almost in the same vertical plane over the pelvis for the female graphic on the left; whereas, the same three points in the figure on the right do not; they are all in front of the pelvis. The alignment of the three points in the figure on the left are closer in conformity to the classic Soviet model; the alignment on the right are completely removed from what would be considered the optimum; even practical.

The female athlete on the left has been taught to perform the classic exercises step by step; a nurtured technique. The result is a slow, mechanical, inefficient, a nurturing of technique. Conversely, the athlete on the right is elite; expressing a natural predisposition to move the body in such a manner as to achieve a positive outcome i.e., a technique of nature. She is not focused on raising the barbell within specified parameters.

CRITICAL PARAMETERS OF TECHNICAL PROFICIENCY

Soviet era research established numerous parameters of technique such as barbell speed, trajectory, height of lifting, optimum joint angles, and so forth.

The most informative parameters of technical efficiency in the classic weightlifting exercises are:

- a low height of lifting;
- a high speed descent;
- an efficient expression of muscle power, i.e., the force of muscle contraction less resistance of muscle antagonists and elasticity of muscles, tendons and ligaments (Sokolov, 1982; Falameyev, 1980);
- balance/equilibrium.

Of the four parameters listed above the first two are quantifiable: the maximum height of lifting and the speed of descent under the barbell. The efficiency of muscle power is only to be guessed; the quality of balance/equilibrium is likewise, not easily quantifiable.

The first three parameters are interconnected, interdependent and inter – conditional the same quality: the speed of muscle relaxation.

A successful lift with a minimum height of lifting is not possible in either snatch or clean unless the lifter drops under the barbell very fast; which in its turn is not feasible unless the weightlifter is able relax muscles extremely fast. An efficient expression of muscle power is only possible when internal resistance from unnecessary tension of muscle antagonists is minimal. Furthermore, suppleness is likewise inextricably linked with muscle relaxation in minimizing internal resistance to movement.

The quality of balance/equilibrium is a critical skill; not just the balancing of a barbell in the squat position of the snatch. The complexity of equilibrium grows from the instant of barbell separation from the platform; forcing the weightlifter to cope with a ever growing toppling over force as the barbell rises; while at the same time lifting with maximum force.The disposition of the three points in the figure one are a reflection of the athletes effort to generate power while overcoming the toppling over force of the barbell pulling the body forward.

Considering those enumerated critical skills connected with mechanically efficient technique; biological differences between the sexes can be observed in the variations of the approach to raising a barbell. These variations in turn are connected with some distinct gender differences.

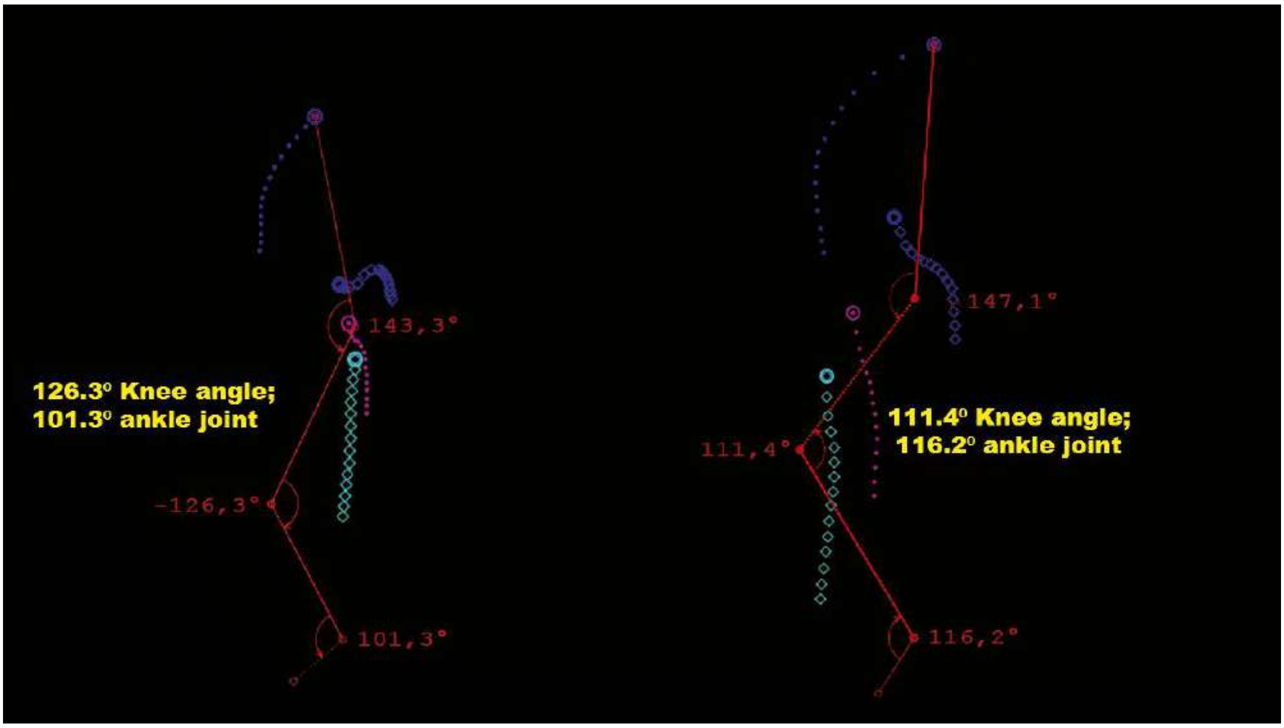

FIGURE 1: GRAPHIC DEPICTION OF TWO FEMALE LIFTERS. Ankle, knee and hip angles are depicted along with tracing of three points: green – barbell center of mass (COM); red – common COM (center of mass of body and barbell as a single unit); blue – COM of the body. On the left a 'nurture' and on the right a 'nature' technique. (graphics Todd Lyons)

Contrasting of gender differences (male/female):

- higher levels of testosterone/ females only 10% of males;
- more muscle mass, less fat mass/ less muscle mass, higher fat mass;
- greater relative upper body strength/less relative upper body strength;
- higher center of mass/lower center of mass;
- less natural mobility in joints/ greater natural mobility;
- higher muscle tonus/lower muscle tonus;
- naturally higher aggressiveness/low aggressiveness.

GENDER VARIATIONS IN THE CLEAN AND JERK

The clean and jerk consists of two exercises in one: an energy sapping lift to the chest requiring mostly power; a lift from the chest requiring more skill than power. Some gender differences can be observed in the performance of this complexity.

Ivanov (1977), studied the connection between the "time of readiness", the time of pausing in the starting position before beginning the jerk and successful attempts with near maximum and maximum weights of 1,690 weightlifters of the USSR. He analyzed a possible dependence between successful/unsuccessful jerk attempts of 978 weightlifters and the time of recovery from the squat. In both circumstances the longer the time of readiness and/or, the time to recover from the squat the more likely the athlete was unable to jerk the barbell.

However, the author concluded the time of recovery from the squat had a greater effect than the time of readiness on whether the jerk was successful. Longer recovery times from the squat were more likely to result in a missed jerk from the chest.

These data was obtained from an era before women weightlifters. The author believed the oscillation of the barbell in the start position had some influence on the time of readiness. Longer times were recorded with heavier weights because the heavier barbell takes longer to stop oscillating, i.e., the athlete would wait until vibration of the barbell to lessen.

The time to recover from the squat, in effect the time of straining, had the most influence on the athlete's ability to jerk the barbell. So, a longer time of straining would more likely result in a missed jerk from the chest than a longer time of resting in the starting position of the jerk.

The greater negative influence of prolonged straining versus a prolonged 'resting' in the start position of the jerk of course applied only to male weightlifters.

The perspective of this rather obscure research is unique. Ivanov attempted to quantify the effect of straining on the expression another physiological quality coordination/skill. Which, in this case the coordination/skill, follows the the prolonged straining in the same exercise. It is common knowledge (Kanyevsky, 2007) a successful jerk from the chest with a given weight requires less power than needed to clean it. So, the effect of an energy sapping clean on the lower power, but higher skill jerk to follow; is a question of human physiology with broader implications beyond weightlifting.

THE FEMALE WEIGHTLIFTER'S 'DOLGA GATOVITSA' AN EFFECT OF PROLONGED STRAINING

Practical experience, extensive observations of international and local competitions reveal a tendency of a longer time of readiness in the start position of female weightlifters. Furthermore, unlike the male weightlifter, the time of straining to recover from the squat need not affect a female's ability to successfully jerk the barbell as much as it would a male lifter. This is especially evident when contrasting the jerk attempts of male and female lifters who expended near exhausting effort to recover from the squat.

More often than not, males who take a longer time to stand, i.e., undergo prolonged straining, will immediately attempt to jerk the barbell. They will not pause long enough to regather, to release unnecessary muscle tension, to balance the body – barbell system before beginning jerk proper. Perhaps the perceived exertion of the recovery from the squat triggers a reflexive response from the male lifter to begin the jerk while there is still energy available to jerk the barbell. This 'rush to lift' precludes sufficient time to relax excess muscle tension; to balance the athlete – barbell system.

Three videos illustrate this circumstance. In the first video a female lifter takes a rather prolonged time of readiness, a 'dolga gatovitsa' (literally, Russian for 'a long time to get ready',) after a very difficult and prolonged straining to stand from the squat. The same circumstance occurs in video 2. The woman takes a rather long time of readiness; especially when added to the prolonged time to stand from the squat.

In video 3 the male lifter begins to jerk the barbell rather soon after struggling to stand; this lack of readiness sends the weight forward out of control. These differences in reaction to straining are subtle, not mutually exclusive; yet nonetheless, distinct.

1 – https://youtu.be/oiuv29Y1-28
2 – https://youtu.be/x-MsvbK9w1A
3 – https://youtu.be/tBA1EsN9aP8
4 – https://youtu.be/e29vv3rhY-k

Whatever the mechanism, counter-intuitively, females are more likely (but not exclusively) to respond to an energy sapping clean by waiting longer in the start. Waiting longer before jerking would seem to sap more energy; leaving little power in the tank to jerk the barbell. However, in most cases their 'Dolga Gatovitsa' is not energy sapping; but an effective prerequisite to successfully jerk the barbell.

This phenomena in all probability is connected with the physiological and psychological make up of the female weightlifter. Anecdotal evidence indicates females tend to be more energy efficient at straining than males. And, this feature could explain why prolonged (straining) recovery from the squat is neither physically nor psychologically as taxing for females as males, i.e., a quality of nature.

On the other hand females who have been taught to approach weightlifting aggressively, that is to say, from a male perspective; are more likely to expend more energy in standing from the squat and take less time to regather in preparation to jerk, i.e., a quality of nurture.

The female weightlifter's energy expenditure from prolonged straining may not be perceived to be so taxing as to preclude her from jerking the barbell due to lack of energy; as it is for the male weightlifter.

For instance, observations of rapid, discrete changes of facial expression (Charniga, 2016) in females which coincide with changes in mechanical advantage of the weightlifting exercises shows females, especially elite and the super elite, will instinctively 'dial down' superfluous muscle tension in order to perform the exercises with greater mechanical efficiency.

Consider the super elite female straining to stand in figure 2. The relaxed features, as though somnambulate, coincide with a knee angle of approximately 90°. This is the most difficult segment of the squat when the force arm of gravity is greatest, i.e., where one would expect the strain to be reflected on the young woman's face. Although difficult to quantify, this phenomena of relaxed straining can only be interpreted as mechanical efficiency.

SOME GENDER VARIANCES IN MOVEMENT

"*In almost every domain of life, men are considered the normal human being , and women are considered "abnormal" , deficient because they are different from men*."

Carol Tarvis, 1992

Considering the list of gender differences above males have some exclusive advantages in weightlifting. Consequently, means for the female weightlifter to circumvent such male advantages of greater muscle mass, high serum testosterone, lower fat mass and the like, are to make use of the natural gifts of suppleness, joint mobility and greater elasticity in overcoming mechanical difficulty in the classic exercises. Evidence is to be found in the female weightlifter's movements outside accepted norms of linear symmetry. For instance, many elite females pull and recover from the squat with a distinct shifting of the knees inward (varus) and or outward (valgus); covered in other essays (Charniga, 2015;2019). The bowing of the knees outside the linear line of the foot typically coincide with the most difficult segments of the exercises; the joint angles of 80 – 100° and the like.

FIGURE 2: Somnabulate super elite female, facial muscles relaxed; straining to stand as knee angles reach 90°, the most difficult segment of the exercise. Charniga photo

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Other movement variations involve effective utilization of inertia and elastic energy in lieu of a total reliance on muscle force.

For instance, generally there are two ways athletes assume the start position for the jerk. The first is to begin the half squat with the knees locked or a knee angle about 180°; the other is with knees slightly flexed. In either case the lifter begins the half squat by flexing knees from either of these static dispositions.

A variation outside the norm is illustrated in the video 4: **https://youtu.be/e29vv3rhY-k**. The woman assumes the start for the jerk from a brief static, flexed knee position. Instead of flexing knees further to squat, she begins by rapidly straightening the knees; then proceeds to perform the half squat. This preliminary straight – to – bend squatting gets the barbell moving (inertia); bending the bar as the legs straighten; which in turn, will recoil as she bends into the half squat; contributing to an even greater bend and accumulation of strain energy. Furthermore, the rapid straightening of the knees facilitates the knee bend by rapidly stretching the bi - articular muscles which flex the knees; thereby utilizing the energy of recoil from soft tissues.

The peculiarity of this woman's technique, effectively using what Nicolai Bernstein called the "free forces" is a classic example of someone getting the most out of her body; above and beyond mere muscle contraction:

"*The movement of the body is more economical, and consequently, more rational, the greater degree to which the organism utilizes the reactive and external forces and the less reliance on recruiting active muscles*".

N. A. Bernstein, 1947

QUESTIONS OF BALANCE

"*Complex systems are full of inter-dependencies— hard to detect— and nonlinear responses.*"

Nasim Taleb, 2012

Of the four critical parameters of proficient technique, balance/equilibrium is interconnected, interdependent and inter-conditional to the other three. The effectiveness of a low height of lifting, a high speed of descent under the barbell and a rapid relaxation of muscles are facilitated by the athlete's ability to balance the athlete barbell system in the receiving position of the exercises.

Balance/equilibrium is complicated, as already noted, by the rising general center of mass of the athlete barbell as a single unit. Balance/equilibrium in the fore aft (sagittal plane) direction is likewise a complex problem. A select few males are champions utilizing the inefficient squat jerk technique; yet many lesser lifters copy this technique. This despite the fact that those who manage to become champions stumble about the platform lucky to succeed with usually less than 50% of their jerks; many, often are lucky to make one.
So, it should not come as a surprise that very, very few females; certainly no champions at the international level; jerk with the squat technique. Balance/equilibrium in the sagittal plane is too complex, either with a quarter squat bend; or, worse yet a full squat under the barbell.

FIGURE 3: Super elite female jerks record weight with a wide split to counterbalance the athlete – barbell unit in the fore – aft plane; while lowering center of mass for better equilibrium. Charniga photo.

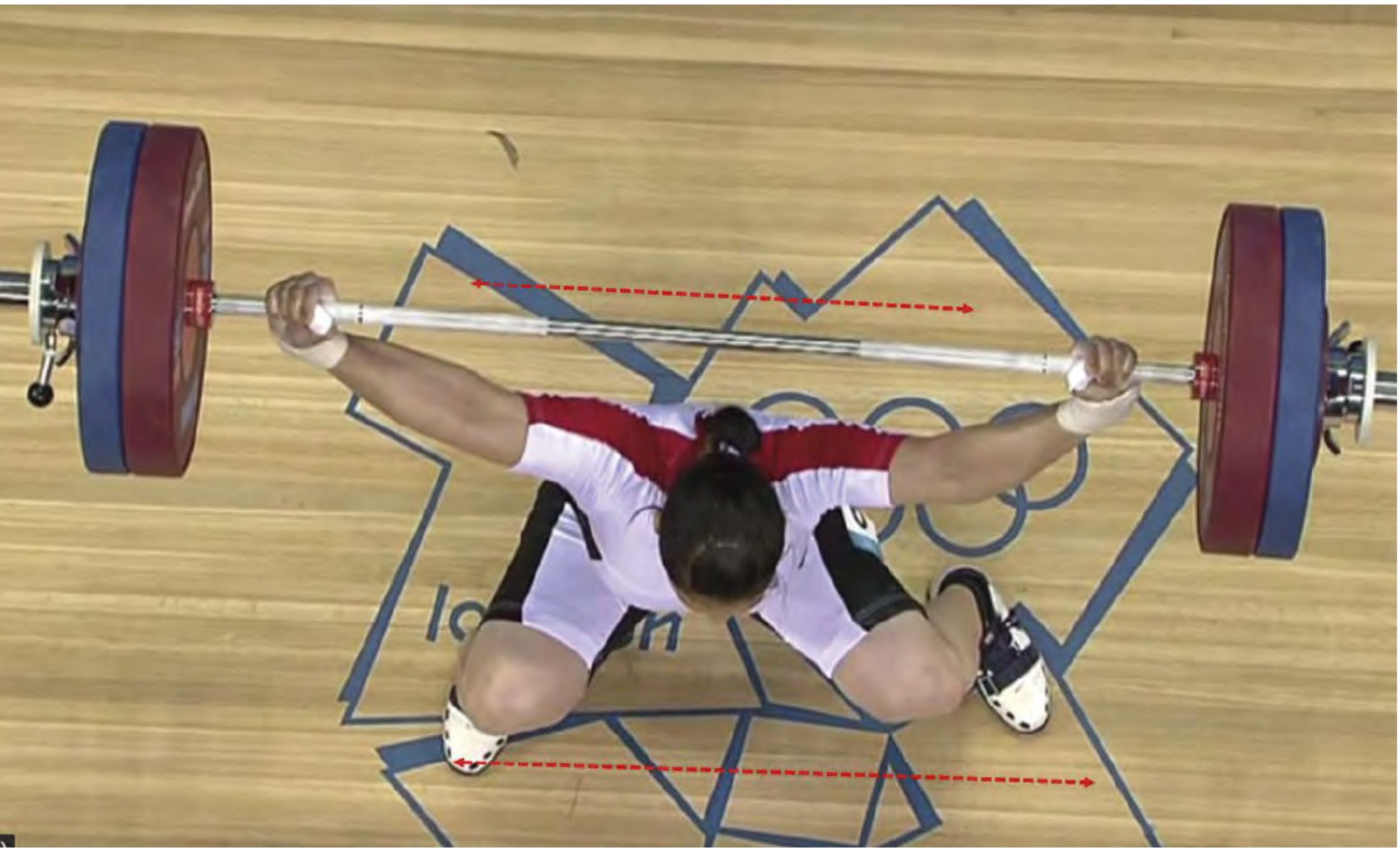

FIGURE 4: Elite female lifter shifted feet asymmetrically in the squat; in order to lower center of mass and increase the area of balance in the sagittal plane.

So, it should go without saying that scissoring under the barbell in the jerk is the most effective technique due to the largest area balance in the fore aft plane; coupled with a reasonably low center of mass of athlete – barbell.

Females typically have a higher success rate in both classic exercises in competition. Consequently, almost universal adoption of the scissors jerk technique is consistent with the female weightlifter's greater overall psychological stability as reflected in a higher success rate in comparison with males (see figure 3).

Generally balance/equilibrium is perceived as primarily active. Weightlifters are already active with regards to balance/equilibrium with precise placement of hands on the bar, spacing and disposition of feet, and so forth. That said, females are more likely than males to be reactive in seeking balance/equilibrium.

For instance, an example of reactive movement to drop fast and very low under the barbell is illustrated in figure 4. The lifter hopped backwards while shifting her feet to the side asymmetrically. The left foot is situated behind the horizontal line of the barbell and her right foot. This asymmetry of the feet is reactive action. It occurs in the act of straining to lift a maximum weight; necessitated by a high speed of muscle relaxation to drop low very fast and quickly achieve equilibrium.

A simple argument can be made the foot asymmetry increases the area of balance in the sagittal plane similar to a split disposition of the feet in the jerk. It is reactive; nature and not nurture, because the athlete is moving the body outside any feasible ability for conscious control.

For instance, estimated two thirds of all female lifters at 2013 Chinese National Games hopped backwards into the squat for snatch; with asymmetrical foot placement.

Furthermore, many elite females drop fast under the barbell without flexing the hips to assist the speed of descent (Charniga, "Variations in the jump under the barbell in the snatch and the clean") . This is further indicative of low overall muscle tonus and a natural ability to relax muscles fast, i.e, a technique of nature.

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CONCLUSIONS

Gender differences, however, subtle need to be taken into account in the learning/training of weightlifters. If a coach prepares a female weightlifter from a male perspective there is a risk the strengths of the female athlete will be ignored. The coach may endeavor to decide the female weightlifter's movements conform to generally accepted parameters; which have been handed down for decades as appropriate for male weightlifters. That would be the nurture approach.

A nature approach would allow the female weightlifter perform the classic exercises in conformity with the strengths inherent to the athlete's Biology: low overall muscle tension, larger mobility in joints, ability to reflexively relax muscles fast; utilize inertia, elastic energy, and so forth.

Consequently, the coach needs to cognizant of the technique peculiarities of the female athlete such as a more effective utilization of calf muscles and less reliance on the back (an Asian pull technique) an asymmetrical placement of the feet in squat, bowing the legs in and out during the pull, a longer time of readiness in the jerk a 'dolga gatovitsa', a mechanically efficient expression of muscle power by means of relaxation of unnecessary tension in antagonists and a greater reliance on utilizing elastic energy from tendons and ligaments.

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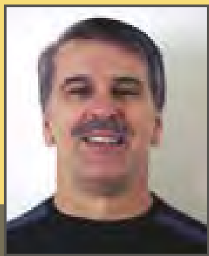

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POSTURE

SOME SIGNIFICANT ASPECTS

BY ANTONIO URSO

THE CONCEPT OF POSTURE

It is difficult to give a sweeping definition of posture, and this is because of the multifactorial processes that regulate the statics and dynamics of the human body: for this reason there are as many different definitions as there are schools of thought and approaches to this topic. Many definitions are closely related to the perspective with which this phenomenon has been studied: from biomechanics or the nervous or psychological system. Among the various definitions, the most interesting, or at least the one that contains the most identifying elements, is that provided by Dr. Fabio Scoppa (2005): (1) "… By posture we understand the position of the body in space and the spatial relationship between the skeletal segments, whose purpose is to maintain balance (antigravity function), both in static and dynamic conditions, which contribute to neurophysiological, biomechanical, psychoemotional and relational factors, also linked to the evolution of the species". In 2000 (2), Gagey affirmed with authority that: "… posture is closely linked to emotions to the point of being the expression itself for the outside world, not only through facial and gestural mimicry, but also through the disposition of the body as a whole".

Scoppa also stated in 1998 (3) that the development of personality goes hand in hand with the development of the body structure, so that the habitually assumed posture faithfully reflects the person's dominant character traits. Even in the case of idiopathic scoliosis, it is possible to establish this type of relationship, as during evolution certain psychophysiopathological mechanisms may be capable of disrupting the spinal balance and triggering the dysmorphic process.

POSTURE REGULATING MECHANISMS

Therefore, what are the posture regulating mechanisms and, in particular, how do they interact with each other? The brain, at various levels, registers:

- The spatial configuration of the organism;
- The structure of musculoskeletal structures and internal organs;
- The vital biochemical parameters;
- Mechanical and biochemical variations related to behaviours and events. In turn, "the images of the body, represented in the maps, are capable of exerting a constant influence on that same body from which they originate".
- Brain maps are also a source of emotions and feelings (starting from primordial ones) which are then processed and modulated by the psychic dimension of the autobiographical self (Damasio) (4).

From this consideration of Damasio, it is clear that postural regulation must be inserted in a concept of a complex system. In this case, a system is a set whose elements are connected by relationships. While the whole is defined by the list of its elements, the system is defined not only by its elements but also by the relationships between them (5). The predictable behaviour of this system does not depend on the characteristics of its components, but on the form of the relationships that connect them. From the above, it is clear that a system implies an oriented succession of events. The relationships are oriented in so far as the behaviour of the system depends on the inputs and outputs (afferents or efferences). In this way two fundamental systems can be schematized:

- a static system;
- a dynamic system.

Both systems must work in order to guarantee the three fundamental aspects incorporated in the concept of ergonomics, namely:

- balance;
- economy;
- comfort.

To achieve these aspects, optimal control of strength is required (in this case functional rather than maximal expression), capable of integrating the above elements in a balanced mind-body condition. Ergonomic posture cannot disregard the psychological state of the moment. In other words, ergonomic posture cannot disregard the following basic conditions, in which it is contextualized and which in turn it integrates:

- consistent body image
- harmonious coordination of vestibule - oculo - motor
- optimized foot support
- optimized occlusal support
- functional vertebral structure
- functional femual-ileo-sacral structure
- functional humeral-scapular-thoracic structure

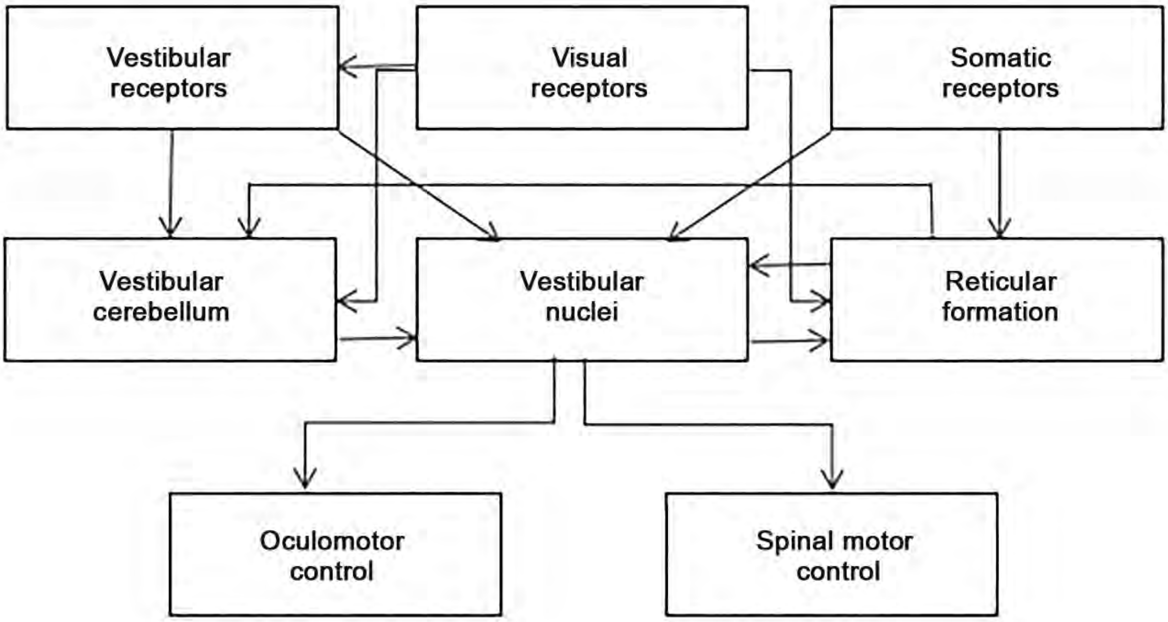

FIGURE 1: NEURAL PATHWAYS OF BALANCE AND ORIENTATION. Above are the three input modes of the receptors that transmit impulses to three CNS processing units: the vestibule-cerebellum which is located just behind the brain, the vestibular nuclei and the reticular formation whose neurons are both located in the bulb of the medulla oblongata. After the receptor information has been processed, the vestibular nuclei transmit the signals both at the exit of the motor ocular control and at that of the motor spinal control. Motor ocular control is responsible for eye movements, while spinal-motor control is responsible for contractions in the neck, limbs and muscles of the body. A secondary pathway that goes to the thalamus and cerebral cortex can be activated whenever stimulation of the vestibular apparatus gives rise to sensations of movement or the need for orientation

- balanced positioning of the girdles and head with respect to the gravity axis
- consistent activation pulses of the straightening and opening functional circuits, in other words for external extension and rotation
- balanced tensional organization of all functional circuits
- tonic-emotional balance.

A careful analysis of the points listed above highlights the concepts of globality and functional integration as fundamental pillars of posture.

Upright posture, which is measured in this work, manifests itself according to a precise vertical alignment of skeletal landmarks and constitutes the indispensable basis for the ergonomic use of the body in various contexts. The interaction of these conditions determines important changes in physiological postural ergonomics which, over time, become permanent variations of postural patterns as they modify the related postural motor enneagrams in the SNC. The twelve points listed above draw out the concepts of globality and functional integration as fundamental pillars of posture.

On the concept of verticality, the gene-culture co-evolution model, proposed by many anthropological studies as an interpretation of the current form, affects the evolution of behaviours, relationships and communication, but also intervenes in determining and fixing important variations of its morphofunctional configuration (6).

1. Scoppa F. Scoliosi idiopatica: dalla biomeccanica alla psicofisiologia, in: Caradonna D (Ed.), Argomenti di posturologia. Atti del II Congresso Mondiale di Posturologia – Fiuggi. GSC Editrice, Bologna 1998; pp.125-52.
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4. Damasio A. Il sé viene alla mente, Adelphi, Milano (2012)
5. Massara G, Pacini T, Vella G, Ergonomia del sistema posturale, Maparrese Editore S.R.L. – Roma (2008)
6. It is necessary to distinguish standing stationary posture from preparatory posture for the variation of dissipative action parameters, functional stability, homeostasis, tensegrity, readiness and ergonomic performance.

MORPHOFUNCTIONAL ASPECTS

In humans, the skeletal districts most subjected to variations and adaptations mainly concern the structures and reciprocal relationships of:

- astragalus - calcaneus
- lumbar spine - pelvis
- rib - thorax
- cervical spine - skull - jaw

The human morphofunctional conformation is configured as a dissipative structure. In fact, it involves the need for a continuous homeostatic energy flow to maintain its steady state which is characterized by an oscillating postural system, in other words, "functional instability" as a fundamental condition for its maintenance. It apparently behaves like a spinning top, pressing on a fixed point with oscillations of the longitudinal axis of the body around the gravity axis.

The oscillations as a whole are supported by a cybernetic control system, that is, by the ability to independently make certain choices based on the information collected (7).

THE NEUROMUSCULAR SYSTEM

Orthostatism is regulated by tonic postural activity in order to maintain the centre of gravity within its polygon support; the body constantly oscillates thanks to the intervention of postural reflexes that oppose the action of the force of gravity. This is enabled by the motor system of the esteroreceptors, tonic and tonic-phasic muscles that fix the joints aided by the flexor muscles (antagonist muscles).

Basic postural tone is, on the other hand, the state of permanent and involuntary muscle contraction that fights against gravity. In this respect, neuromuscular systems act in the form of feedback. The main feedback comes from the oculomotor, vestibular and medullary systems.

a) Oculomotor feedback

the ocular muscles are connected through their receptors with the complex of oculomotor nuclei III - IV - VI to the ascending and descending reticular substance. The coordination of the two oculomotor nuclei is ensured by the posterior longitudinal band. The latter is connected to the spinal nerve XI which innervates the sternocleidomastoid and trapezius muscles, creating the oculocephalic reflex (8);

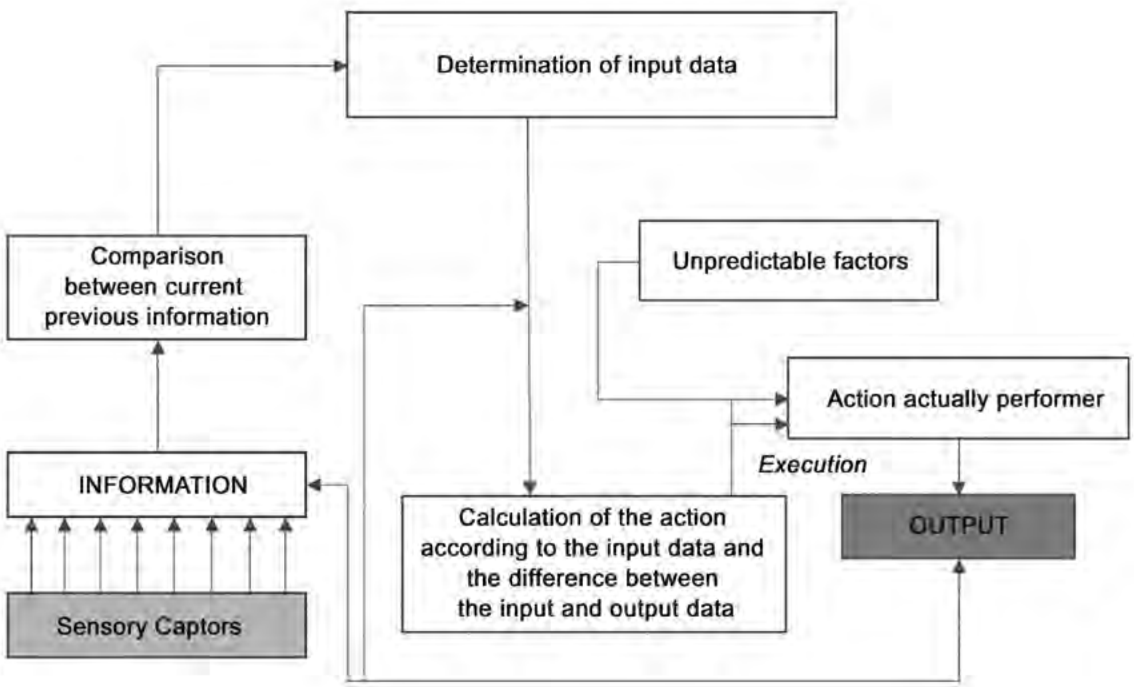

FIGURE 2: CYBERNETIC CIRCUIT. A cybernetic system is a control system (postural in this case) characterized by the ability to independently make certain choices based on the information collected. These act on four fundamental blocks of action: memory - decision - execution - feedback.

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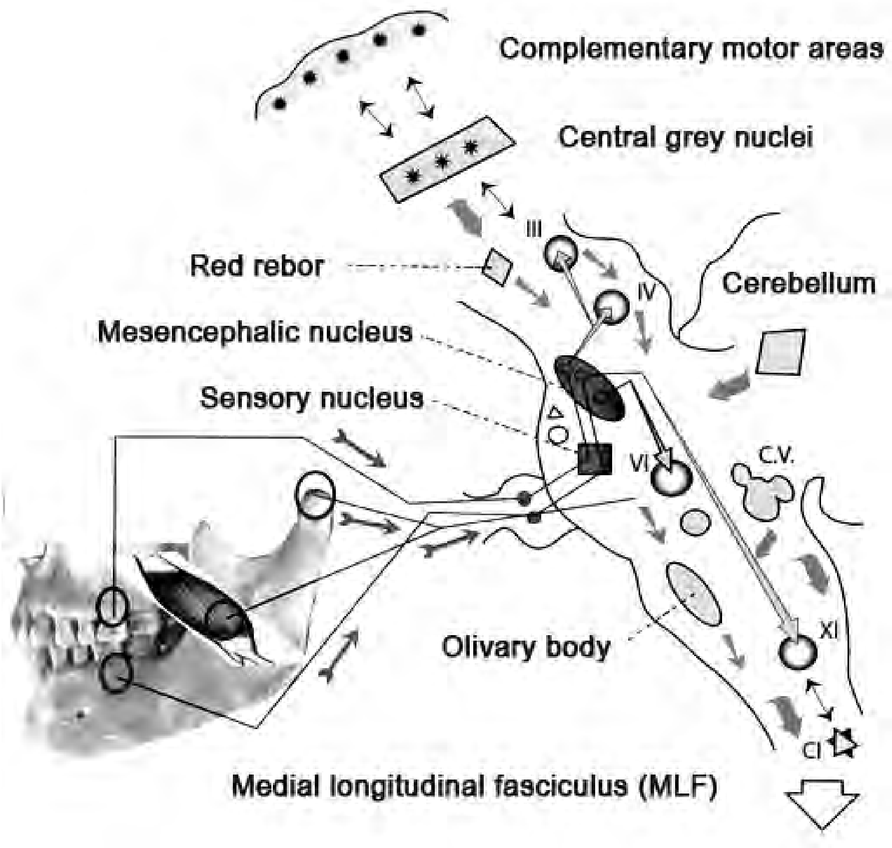

FIGURE 3: Trigeminal interferences

7. Passive muscle stretching causes a tonic reaction and the adequate stimulus for this specific reflex, called myotatic or stretch-reflex. Through this reflex, the muscles organized in functional chains use the skeleton as the fulcrum and by means of different power take-off points they create a head-foot coordination capable of ensuring the right muscle tone through the intelligent dialogue of the muscles with gravity, which it is concretized by means of the myotatic or stretch-reflex reflex guaranteeing an effective tension-structural hold.
8. Da Meyer J. – Baron J.B. – Le processus impliqués dans le régulations posturales. Eléments de neurophysiologies des comportaments moteurs – Azemar&Rippol. Insep Publication 1982.
9. The works of Finnish academic Jami in 1997 show that the Golgi tendon organ is sensitive to muscle tension of 0.1 g and does not respond to an identical mechanical stimulus (non-linearity).

b) Vestibular feedback

At the level of the inner ear there are receptors (ciliary cells) which send information to the reticular formation through the vestibular nuclei located at the level of the pontine-nuclei passage. Adaptation is ensured by the vestibular and reticular pathways;

c) Bone marrow feedback

Through neuromuscular spindles, Golgi receptors, mechanoreceptors, joint, skin and visceral receptors, information passes through the posterior horn of the spinal cord to the cerebellum and cortex. The various bone marrow neurons are equipped with a "memory" for both automatisms and learning.To these feedback systems are added what in posturology are called receptors (or modulators), in other words, the sense organs that collect environmental and somatic information, taking into consideration in this case the proprioceptive and exteroceptive sensory receptors:

- **Vestibular receptors** - provide information from the labyrinth and vestibule. All this information is connected to the movements of the head: linear (otolic macules of the saccule and of the utricle) and angular (domes of the semicircular canals) accelerations. This information is associated with the acoustic information coming from the cochlea (VIII cranial nerve);

- **Visual receptors** - there are two types: cones for viewing colours and rods for perceiving light intensity. They join into a single cranial nerve, the second (optic nerve).

- **Proprioceptive receptors** - the neuromuscular spindles and Golgi tendon organs located in series with the muscle fibres, formed by nerve strings wrapped in a connective capsule are located in the muscle-tendon passage area (9), provide information on the static and dynamic responses of the muscles and on the tensions exerted on the tendons. The information on the joint position and the direction of movement are connected to

The official journal of the European Weightlifting Federation

"SPINO-BULBO-THALAMOCORTICAL PATHWAY = MEDIAL LEMNISCUS = DORSAL COLUMN PATHWAY"

the joint mechanoreceptors that contribute to kinaesthesia.

- **Cutaneous exteroreceptors** Are sensitive to touch, pressure and movement (Ruffini Pacinian and Wagner-Meissner corpuscles as well as Merkel cells,). Their task is to participate in the "information pool" that receives the tonic-postural system. They are divided into free endings, which pain information through nociceptors; complex non-encapsulated endings sensitive to touch and light pressure; complex encapsulated endings.

ASCENDING PATHWAYS OF PERIPHERAL SENSITIZATION

The spino-bulbo-thalamocortical pathway transmits **epicritic tactile** sensitivity and **conscious proprioceptive sensitivity of the trunk and limbs** to the cerebral cortex at the level of the primary sensory area located in the parietal lobe of the cerebral hemisphere.

- It **originates** in the **spinal ganglia**, which are made up of **T-neurons** (or sensory protoneurons) which have neurites that divide each into a peripheral fibre that stretches to the periphery, ending in a sensory corpuscle, and in a central fibre that enters the spinal cord.
- the **central fibres of the "T" neurons** enter the spinal cord at the level of the posterior lateral sulcus as posterior root fibres. They then arrive at the root zone of the spinal cord where each of them divides into an ascending branch and a descending branch.
  - the **descending branches** form the **oval area of Flechsig** and the **comma tract of Schultze** destined for the posterior horn of the spinal cord;
  - the **ascending branches** form the **tract of Goll** (fibres born from the spinal ganglia between the 1st coccygeal and the 5th thoracic) and the **tract of Burdach** (fibres born from the spinal ganglia between the 4th thoracic and 1st cervical). The Goll and Burdach tracts ascend along the posterior column of the spinal cord and arrive in the lower part of the **medulla oblongata** ending in the **nucleus of the gracil fasciculus** and in the **nucleus of the cuneatic fasciculus** respectively.
- from the nuclei of the gracile and cuneate fascicles the path continues with a single bundle: the **medial lemniscus**. Immediately after its origin, the medial lemniscus crosses with the heterolateral bundle at the front of the central canal, then folds upwards and ascends until it reaches and ends in the **posterior ventral nucleus of the thalamus**.
- the posterior ventral nucleus of the thalamus gives rise to the **thalamo-cortical fibres** that become part of the **sensory radiation** that belongs to the cerebral cortex of the two upper thirds of the ascending parietal convolution of the **cerebral hemisphere, seat of the primary sensory area (areas 3, 1, 2)** (site of the somatotopic sensory representation of the trunk and limbs).

Spino-thalamocortical pathway =spinal lemniscus pathway.
The spino-thalamocortical pathway transmits the impulses of protopathic tactile sensitivity and the thermal and pain sensitivity of the trunk and limbs to the cerebral cortex of the primary sensory area of the parietal lobe of the cerebral hemisphere.

- it originates in the spinal ganglia. The fibres originating from the T neurons of the spinal ganglia penetrate the spinal cord as posterior root fibres, and make up the Lissauer dorsolateral tract at the level of the Lissauer marginal zone and constitute the longitudinal tract of the posterior horn at the level of Waldeyer's zonal layer. The fibres of these two tracts enter the posterior horn of the spinal cord where in part they go directly to the nucleus of the head of the posterior horn = the nucleus proprius of the posterior horn and in part make an intermediate step in the nucleus of the gelatinous substance of Rolando and then they too proceed to nucleus of the head of the posterior horn;

- fibres originate from the nucleus of the head of the posterior horn which intersect on the median line within the spinal cord grey matter and proceed to the anterior and lateral heterolateral columns where they form respectively the anterior spinothalamic tract which is protopathic tactile sensitive and the lateral spinothalamic tract which is thermal and pain sensitive;
- the anterior and lateral spino-thalamic bundles go up the spinal cord side by side and, together with the spino-tectal bundle, form the spinal lemniscus;
- the spinal lemniscus extends along the medulla oblongata, the pontine tegmentum and the mesencephalic tegmentum: the spinotectal tract inserts into the quadrigeminal lamina,

10. Korbinian Brodmann (Liggersdorf, 17 November 1868 - Munich, 22 August 1918) was a German neurologist who became famous for his subdivision of the cerebral cortex into 52 regions, distinguished by cytoarchitecture characteristics. Still today it refers to its topography in anatomical-functional studies, with the acronym BA ("Brodmann's area", or "Brodmann area"). In the years following his work, some of these areas assumed importance for the possible localization (or polarization) of some mental functions; for example the areas of Brodmann 41 and 42 of the temporal lobe (related to some auditory functions), areas 1, 2 and 3, in the post-central gyrus of the parietal lobe (somatosensory system), areas 17 and 18 of the occipital lobe (deputies to some functions of the visual system.

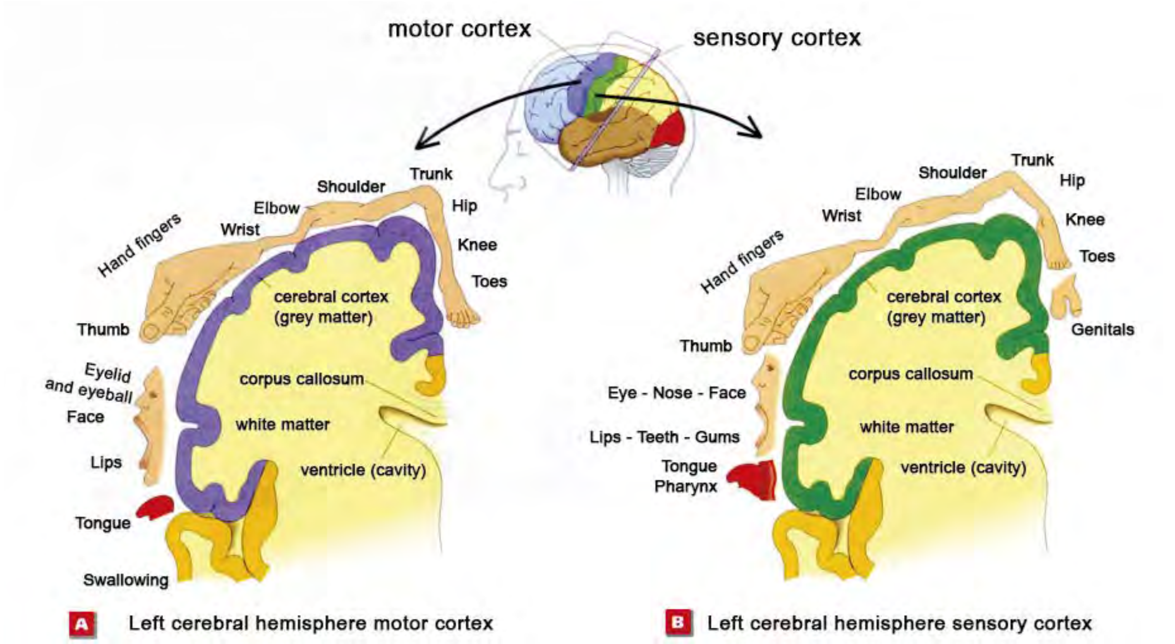

FIGURE 4: The sensory or sesticetic or somatosensory homunculus (10) represents the somatotopic organization of the somatosensitive (cutaneous) afferents of all districts of the body to the postcentral (or post-rolandic) circumvolution, just behind the Rolandic fissure, in the S-I area of the parietal lobe. The term homunculus is called as such as the representation of the human body appears grotesque and disproportionate: in fact, some regions, in particular the hand, foot and mouth, are enlarged: this is because the size of a region is proportional to the number of skin receptors present. Localization of the somatosensory homunculus: the S-I area consists of at least three different areas, each of which represents a different somatosensory function. They are, in antero-posterior sense, the areas 3, 1, 2 according to Brodmann, each of which represents an independent homunculus sensory towards the adjacent areas. Area 3 is believed necessary for the global recognition of an object, area 1 for detecting the roughness of a surface and area 2 for detecting the shape. The highly detailed map of the human motor cortex was developed in the 20th century by Canadian scholar, Wilder Penfield.

while the anterior and lateral spinothalamic tracts reach and end in the posterior ventral nucleus of the thalamus;

- from the posterior ventral nucleus of the thalamus arise the thalamo-cortical fibres that enter the sensory radiation and reach the cerebral cortex of the upper two thirds of the ascending parietal convolution, seat of the primary sensory area (areas 3, 1, 2) (site of the somatotopic sensory representation of the trunk and limbs).

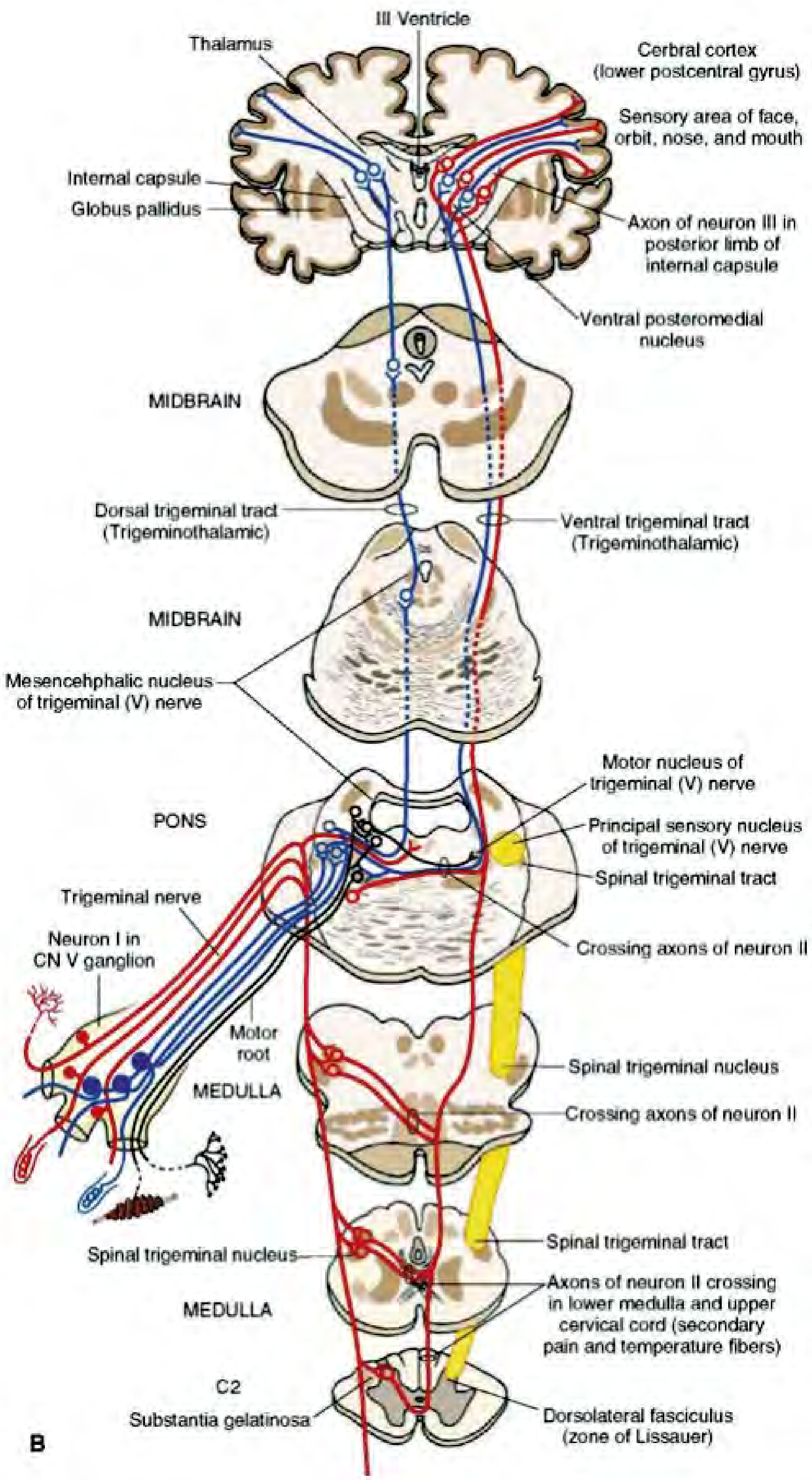

FIGURE 5: The spinal sensitive pathways afferent to the cerebral cortex are the spino-bulb-thalamocortical pathway and the spino-thalamocortical pathway.

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KNOWLEDGE FRONTIERS

THE CONCEPTS OF MECHANO-BIOLOGY APPLIED TO STRENGTH TRAINING

PART TWO

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BACKGROUND

The execution of complex movements, as are sports movements and the exercises deriving from them, mechanically stimulates muscle tissue for total anatomical remodeling, found on five different dimensional scales:

1) molecular,
2) subcellular,
3) cellular,
4) tissue,
5) organic[1].

Each intense muscle contraction triggers, at the molecular level (1), the aggregation of atoms to stretch, thicken, stiffen and strengthen the weaker contractile and connective protofilaments present in sarcomeres, the main functional units of muscle cells[2]. The formation of new protein molecules leads, at the subcellular level (2), to the regeneration, replication and repositioning of sarcomeres in the myofibrillar plasma. The space that the reorganization of the sarcomeral units requires, at the cellular level (3), stimulates the increase in the number and volume of muscle fibres.

The morphological and architectural variations of the myofibres produce, at the tissue level (4), a change in the shape and orientation of the muscle fascias with respect to the tendon junction to which they are connected3 and, at an organic level (5), a change in the direction of the forces that the muscle bellies project onto the bone levers. Each of these phases of the anatomical adaptation process is therefore fundamental in order to make the muscles capable of shortening with more force (activating more molecular bridges in the unit of time), greater speed (improving the sliding of the protofilaments on a subcellular scale), more resistance to tractions (increasing the density of cellular compounds) and better efficiency in producing mechanical power (reducing the friction present in the muscle tissue in contraction) and moving joint levers (making movements with less energy expenditure). The mechanical stimulations, obtained from training and physical therapy protocols, are distributed on all five levels, from the macroscopic (systemic) to the microscopic (molecular) scale, by means of the living matrix[4]. This fundamental system of regulation of vital functions consists of an intricate network of bone, cartilaginous, ligamentous, tendinous, myofascial, muscular, myofibrillary, sarcomeral, cellular and molecular connections[5], which the human body possesses to transfer, from one constituent parts to another, any cellular signal and to activate, at a distance, a specific genetic transcription6. The methods in which genetic transcriptions are activated through the living matrix, in the muscles and other tissues of the human organism, are studied in mechanobiology[7].

Although the study of human biomechanics continues to spark great interest in the field of scientific research applied to sport and movement, more modern mechanobiological investigations into osteo-articular and muscle-tendon systems outline even newer features of the complex organic response to the mechanical stresses that physical exercise produces. The results of biomechanical research and those of mechanobiological investigations, with reference to the mechanical properties of muscle cells, are therefore complementa-

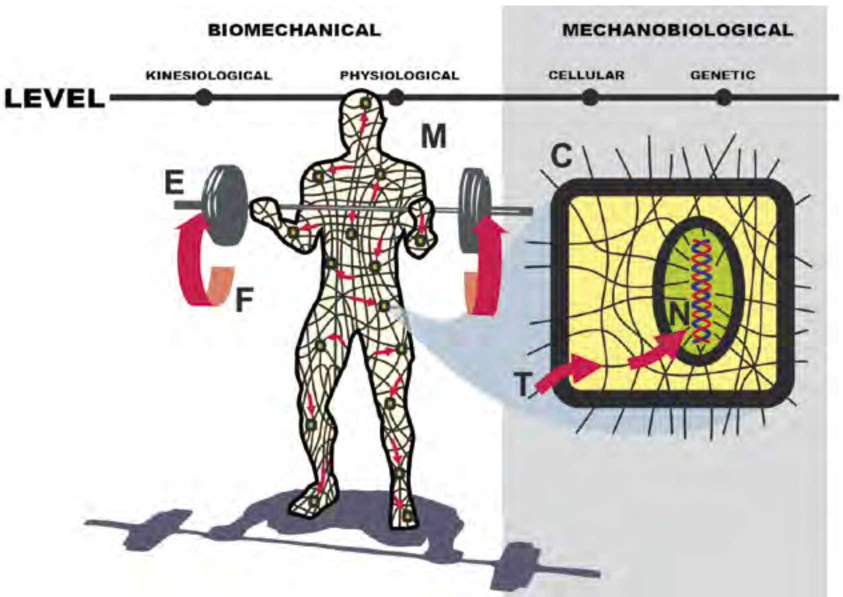

FIGURE No. 1 LIVING MATRIX. This consists of an intricate network of fundamental connections that regulate the vital functions of the human organism at the BIOMECHANICAL and MECHANOBIOLOGICAL level. The Living Matrix receives the mechanical stresses (F) produced by physical exercise (E). The stimuli received at the KINESIOLOGICAL level are redistributed, at the PHYSIOLOGICAL level, between the various tissues that make up the organism (M). The mechanical stimulus, at CELL level, places some cellular components under tension (T) which, at GENETIC level, initiate a process of molecular synthesis (N).

ry: if the former study the biological causes of the production of muscle strength, the latter analyze the effects of anatomical adaptation (Figure 1).

INTRODUCTION

According to the principles of mechanobiology, the mechanical parameters of the strength, length and speed of muscle contraction vary in relation to the type of adaptation that the muscles undergo with exercise8. This concept is well known to all athletes who want to continuously improve the mechanical responses of their muscles in training, and then succeed in competitions to express their maximum strength potential. In fact, any training protocol that inappropriately modifies the way in which an athlete delivers muscle power, in terms of time, intensity and joint angles, inevitably alters the entire process of technical improvement and expected performance. Considering that high levels of muscle power are as much required in competitive performances in which rapid and explosive movements are performed, as in those in which a certain distance must be covered in the shortest possible time, the primary interest of research applied to sport remains to investigate how training programmes affect the production of muscle strength, speed and power.

Scientific knowledge on the biomechanical parameters of the strength, length and speed of muscle contraction is continuously being studied. Its theoretical foundations are based, historically, on mathematical models obtained with experiments carried out in controlled situations, involving few and isolated muscle sections of reduced size, in-site and in-vitro, whose real applications lead to indeterminate solutions. However, thanks to the most innovative three-dimensional ultrasound investigations and the reconstruction of muscle contraction in virtual reality, it is currently possible to observe, in vivo, the effects that training has on the mechanical and architectural properties of muscles[3].

THE SUBJECT OF THE ARTICLE

Knowing the variation of the shape and the direction of the forces of a muscle in contraction allows us to understand, therefore, its possibilities of intervention in the realization of sports movements and in its training modalities9. Coaches, movement instructors, athletic and physical trainers, when creating training plans for their athletes, students, clients, tend to erroneously overlook the effects of muscle adaptation to physical exercise. A sports training programme must always begin with a careful biomechanical study of the execution technique of the athletic movement and must continue with a mechanobiological understanding of its practice.

From a biomechanical point of view, in the different phases of athletic movements, the amplitudes to be covered with the joints, the accelerations to be achieved with the body segments and the inertia to be contrasted with the weight masses must be evaluated. From a mechanobiological point of view, on the other hand, it is essential to understand which exercises and operational strategies to adopt - and which to avoid - to obtain an anatomical remodeling of muscle tissues that effectively satisfies the biomechanical characteristics of the sports movement being perfected.

This article aims to describe the changes in the mechanical and architectural properties of the muscles involved in exercises for the strength development, in line with the results of the most updated biomechanical and mechanobiological research applied to the sports training sector and physical preparation.

THE MECHANICAL PROPERTIES OF MUSCLE FIBRES

The function of muscle fibres is to shorten under control of the nervous system, to move the body levers and overcome environmental constraints through the production of force. Whenever a muscle fibre is activated in the absence of external resistances that curb its shortening, its contraction will therefore take place at maximum speed. On the other hand, if the muscle fibre counteracts substantial peripheral forces, its shortening will be slow and intense. This myofibrillar dynamic is described by two relationships:

1) the Force-Length relationship (F-L), which represents the trend of the force peaks produced according to the degree of shortening or elongation achieved;
2) the Force-Velocity relationship (F-V), which represents the variations in the speed of contraction, or stretching, which occur at different levels of pre-tension.

F-L relationship. Muscle fibres produce force through four main sarcomere components: the acto-myosin complex, the endosarcomeric matrix, the exosarcomeric matrix, the sarcoplasmic gel. The first two components generate force in the presence of a nerve stimulus whereas the second

two demonstrate their strength potential even when the fibre is not active.

In the presence of calcium ions and phosphates, the ends of the sarcomeres are pulled towards the centre of the muscle fibre by the fast and repeated anchoring that occurs between the mobile terminals of the myosin protofilaments and the protein propellers of the actin. The force produced by this acto-myosin complex therefore depends on how long the overlap stretch between the thick myosin and the thin actin filaments is.

The **endosarcomeric matrix** is mainly composed of the network of titin and nebulin filaments present in the sarcomeres of a muscle fibre. Titin is a large protein filament which, in the presence of calcium ions, is capable of wrapping around actinic helices and neutralizing the external resistances that oppose the myofibrillary contraction[10]. Nebulin, on the other hand, tightens around the helices of the actins with the function of pulling the ends of the sarcomeres during contraction[11]. The typical encapsulated conformation (the titin filaments intertwine to form a thick spiral), which the endosarcomeric matrix takes by wrapping the whole of the sarcomeres of the same muscle fibre[12], makes the entire muscle fibre resistant to stretching and disintegration by traction.

The **exosarcomeric matrix** of a muscle fibre originates from the coating and connecting filaments of the acto-myosin complexes, on which they wind themselves sideways just as a spindle of yarn rolls up on its spool. The containing force produced by the exosarcomeric matrix provides the muscle fibre wth resistance to elongation, stability to compression and deformability to flexion[13]. This force occurs in two passive components and, therefore, independent of the nervous stimulus. The first, concentric and compression, occurs when the myofibrillary elongation reaches the structural limit. The second, eccentric and expansion, intervenes, however, when the pressure of the sarcoplasmic gel rises excessively in cases where the shortening reaches maximum levels.

Sarcoplasmic gel (or sarcoplasma) is the dense aqueous solution, contained in the sarcomeres, where ions and energy substances useful for myofibrillary contractile activity circulate continuously. In conditions of rest, i.e. in the absence of internal calcium ions, sarcoplasm always guarantees perfect alignment between the free terminals of the myosin and the active sites of the actin. Furthermore, its high viscosity produces passive resistance which protects the sarcomeral protein filaments from possible structural damage due to maximum compression and expansion. In conditions of myocellular activity, the flow of calcium ions that crosses it increases its convective motions, reduces its viscosity and amplifies its mechanical advantage useful for the sliding of the acto-myosin complex. However, the shortening and stretching of the muscle fibres both produce an increase in the internal pressure of the sarcoplasma[14].

The myofibrillar shortening leads it to compress longitudinally and develops, internally, a pressure directed radially towards the myofibrillar membrane. This eccentric pressure moves the protofilaments of the myosin from the helixes of the actins and reduces the possibility of generating contractile force[15]. The myofibrillar stretch, on the other hand, transversely compresses the sarcoplasmic gel, which develops an internal pressure directed radially towards the central axis. This concentric pressure presses the free terminals of the myosin against the actin polymers, limiting their flow[15].

In 1998, R.L. Lieber and J. Friden, professors from the University of California, observed in vivo the sliding of the acto-myosin complex of the extensor muscles of the wrist of twelve volunteers. A laser microscope was inserted in the forearm through a small surgical incision. The results of the experiments of the two American researchers confirmed the mathematical model of the F-L relationship studied sixty years earlier, in-vitro, by the British Nobel Prize winner, A.V. Hill16, a pioneer of neuromuscular physiology applied to sport[17]. From this model it can be seen that, by changing the length of a sarcomere, from a condition of maximum shortening to one of maximum elongation, the contraction force produced by a neurostimulation (or an electrostimulation) follows a **parabolic course** (minimum at the limit lengths and maximum at intermediate lengths), in perfect dependence on the degree of overlap of the myosin and actin filaments. However, Hill's mathematical model describes the F-L curve in relation to the acto-myosin complex only. To have a more complete interpretation of the phenomenon of myofibrillary contraction, the force contributions of the acto-myosinic bonds must be added to those coming from the endosarcomeral matrix, from the exosarcomeral matrix and from the sarcoplasmic gel (Figure 2). In fact, the endosarcomeral matrix elevates the levels of contractile force when the sarcomere is in elongation, the exosarcomeral matrix allows the sarcomere to express the maximum levels of force for a wider variation of the length of the myofibre, the sarcoplasmic gel produces force peaks higher when the sarcomere activates at an intermediate length.

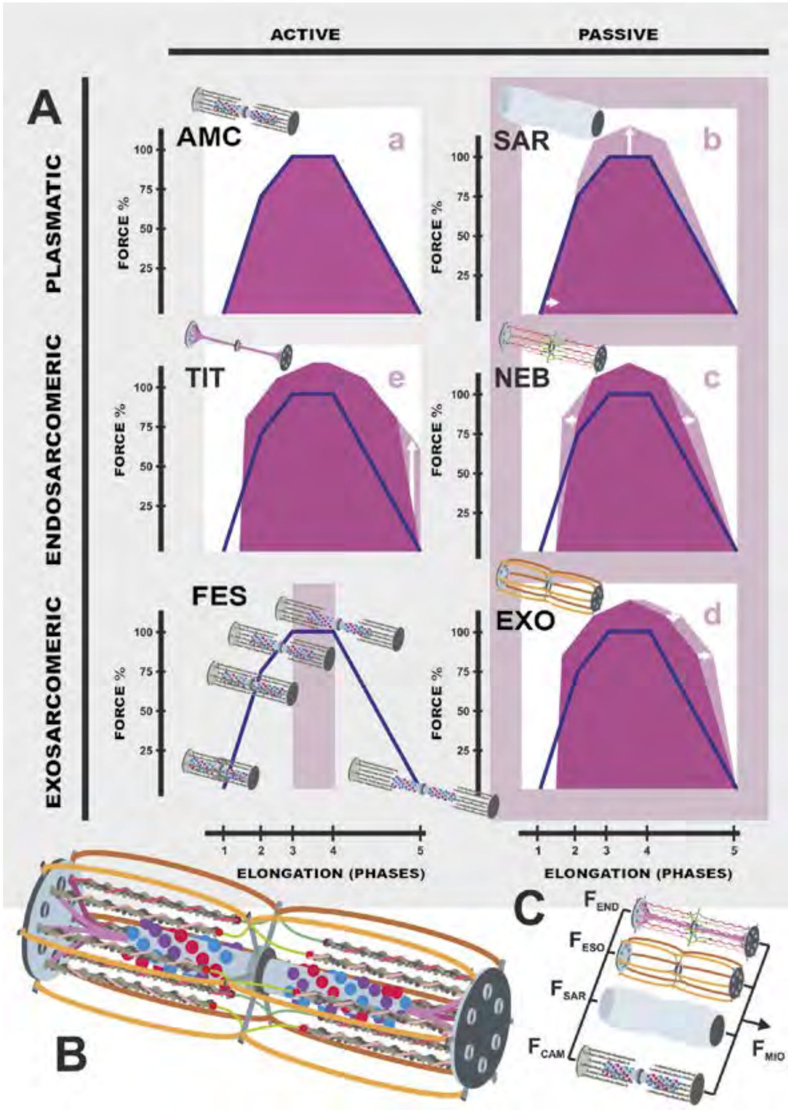

Figure No. 2 F-L Parabola. Contributions of the different sarcomeral components (PLASMATIC, ENDOSARCOMERIC, EXOSARCOMERIC) on the production of strength, during the contraction of muscle fibre (A). The ACTIVE sarcomeral components produce strength only in the presence of calcium ions, the PASSIVE ones always. The force-elongation curve of the sarcomere follows five different phases (FAS). At each phase, the acto-myosin complex (AMC) produces a certain level of force (curve a). The contribution of sarcoplasma (SAR) increases the peak of force in the central phases of sarcomeral shortening (curve b). The nebulin complex (NEB) anticipates and delays the phases in which the sarcomere reaches its maximum strength levels (curve c). The exosarcomeric cytoskeleton (EXO) prolongs the maximum strength values in the phases in which the sarcomere stretches excessively (curve d). Even the titin complex, if activated by suitable levels of calcium ions, contributes to this effect (curve e). Sarcomere is a complex biological structure (B) in which the contractile force (C) is the resultant (FMIO) of the individual contributions of its acto-myosinic components (FAMC), sarcoplasmic (FSAR), exosarcomeric (FEXO) and endosarcomeric (FEND).

F-V relationship. To understand how the speed with which the transmissions of force between myosin and actin occur characterizes the intensity of the contraction, we can use for example the anecdote of the thirsty pilgrim who, after many hours of walking in the sun, arrives at a very deep and narrow well. The sign says: "drinkable water". Next to the well, there is a large bucket, wider than it is high, tied to a long and thick rope. The man is dying of thirst so he throws the bucket into the well, fills it with water and starts pulling. Immediately he realizes that the more the recovery speed increases, the more he loses his grip, the rope jerks, the bucket starts to sway, fall and empty. Even when he lowers the rope to the bottom he realizes that the more the bucket is empty, the greater the risk that it will go down quickly and break against the walls of the well or the surface of the water. On the other hand, if the bucket is fuller, it will have a faster, smoother and safer journey to the bottom. So, after a few attempts, the pilgrim learns that, if he wants to pull up an overflowing load, he must hold the rope in his hands for longer, slowly bend his arms and quickly alternate his grip. Only in this way will the rope remain taut and the ascent of the heavy bucket be vertical and constant. The F-V relationship of muscle contraction thus finds its explanation by comparing the pilgrim's hands, which alternately grasp the rope, with the cyclic sliding of the acto-myosinic bridges of a myofibril. Therefore, as in the case in which the pilgrim cannot pull a very heavy bucket quickly, in a muscle fibre that contracts concentrically, a greater shortening speed corresponds to a lower production of force. Conversely, as in the pilgrim's case where it is easier to send a half-full bucket to the bottom of the well, in a muscle fibre that contracts in an eccentric way, the more traction force that extends it, the faster its elongation will be.

As velocity increases, therefore, the F-V relationship shows a sudden drop, with a **hyperbolic trend** of force. Two reasons explain this trend:

1) the acto-myosinic bridges follow one another so quickly as to cause a reduction in their residence time and, in association, in their contribution of force;
2) the strong ionic currents that flow into the sarcomere, during a maximal contractile stimulus, make the convective motions of the plasma inside it turbulent, increasing its viscosity and the direct friction action on the sliding protofilaments. It would therefore seem that during maximum contraction, the muscle fibre behaves more like a hydraulic piston, whose resistance is greater with the increase of the compression speed, as opposed to a spring shock absorber, whose elastic response increases with the increase of the compression force[18].

The mathematical model representing the F-V relationship was first outlined in 1935 by two American physiologists, W.O. Fenn and B.S. Marsh19 and perfected three years later by A.V. Hill16. For more than eighty years the

results of Prof. Hill's research, not yet refuted, demonstrate how a stretching muscle produces a force far beyond that necessary to maintain a maximum load. In this case, the overvoltages that a muscle could produce to resist elongation reach estimates equal to 110-180% of its maximum isometric force[20]. This consideration supports the practice, widespread in the sports training sector, of developing muscle strength by carrying out exercises in which the muscles must stretch quickly and with maximum loads[21]. However, recent analyzes of the literature have shown that the muscle mechanics studied by Prof. Hill correctly predicts the myofibrillar contraction rate in the range of force values between 50% and 80% of the isometric maximum load[22]. With values below and above this range, the contraction rate is respectively overestimated and underestimated. Therefore, the common use of calculating the highest peak of muscle power by moving a load equal to 30% of the isometric ceiling[23] and with a contraction speed equal to a means of that maximum[24,25] is based on purely theoretical approximations. In the practice of strength sports such as powerlifting, for example, the maximum power peak is reached by moving a load close to 50% of the isometric ceiling at a speed that is about a third of the maximum (reachable in the absence of external resistances)[26] and, with an overload close to 80% of the isometric ceiling, at a speed that is about a fifth of the maximum value[27].

Furthermore, based on the pre-stretching conditions that can occur with each new contraction, a muscle fibre can exhibit a different F-V[18] relationship. The example of a single-speed tractor pulling a trailer can help understand this phenomenon. If the trailer is almost empty, the tractor speed increases linearly based on how much the farmer presses the acceleration pedal.

Instead, the more the trailer is loaded, the less the tractor speed will change linearly with the accelerator pressure and the more time it will take for the farmer to bring the tractor to the optimum pace. Therefore, just as the tractor accelerates differently in relation to the load to be towed, the muscle fibre contracts with different speed variations, depending on the degree of pre-tension present at the moment of the nervous stimulus.

This deduction is possible by comparing the contractile force of the muscle fibre with the power of the tractor engine, the intensity of the nervous stimulus with the pressure of the acceleration pedal and the tension at the ends of the fibre before the contraction with the weight of the trailer being towed. In practice, in wanting to perform the same exercise with increasing overloads, each muscle fibre recruited will be subjected to increasing pre-stretching conditions and will respond with increasing internal resistances and diminishing contraction speeds.

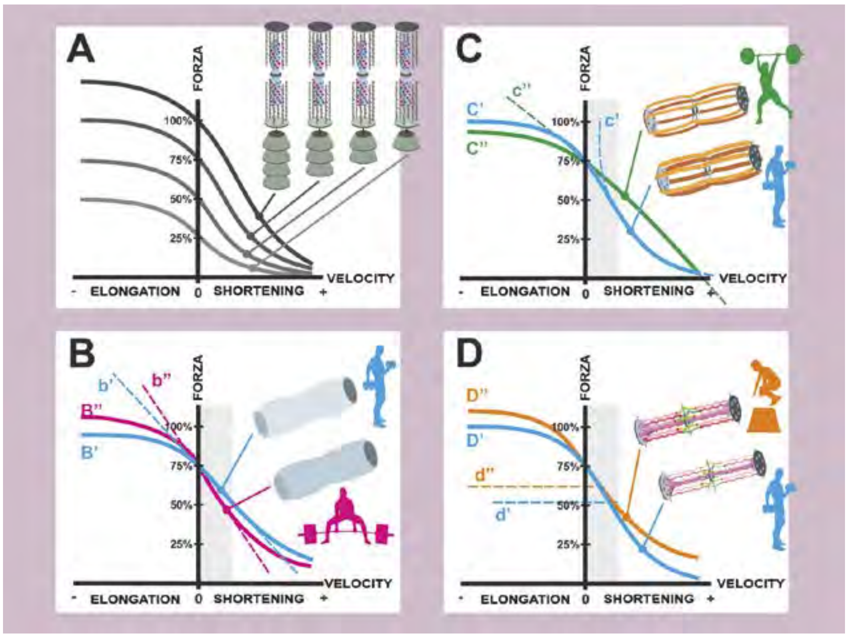

Figure No. 3 F-V Hyperbola. At different levels of pretension (A), the contraction of the sarcomere manifests a variation in the production of force and speed of shortening. Exercises with maximum overloads, if compared with those with a reduced load (B), alter the F-V curve (from B 'to B"). They increase the density of the sarcoplasma, which creates sarcomeral rigidity in lengthening and prolonging the shortening times (from b' to b"). Even explosive exercises, if compared with those with a reduced load (C), contribute to changing the F-V curve (from C' to C"). They reduce the resistances produced by myofibrillary passive structures, showing less rigidity in elongation and more speed in shortening (from c' to c"). Finally, as in previous comparisons, training with plyometric exercises (D) brings about a change in the F-V curve (from D' to D"). Their practice strengthens the nebulin-titin complex placed inside the sarcomere, raising the F-V curve and, with it, the resistance to elongation and the shortening speed (from d' to d").

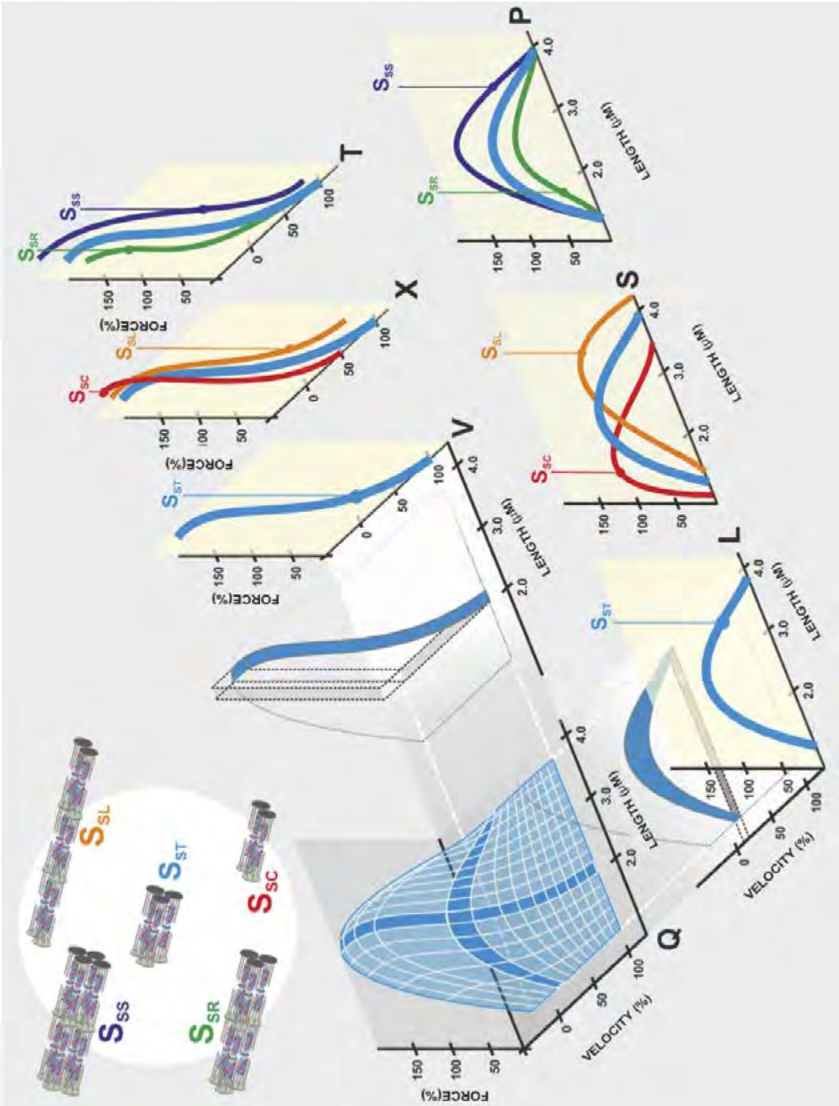

Figure No. 4 Myofibrillary mechanobiology. Overall, the biomechanical properties of muscle fibres can be represented by the Force-Length-Velocity curve (graph Q). This curve is obtained by superimposing the Force-Velocity hyperbolic curve (graph V) with the Force-Length parabolic curve (graph L) and defines the level of force and velocity that a muscle fibre can develop when it starts to contract starting from a specific pre-stretching condition. From a mechanobiological point of view, if a fibre receives a biological signal that leads to the modification of its sarcomeral kit (SST), its mechanical properties of strength, length and velocity would change. With the stimuli of an intense training programme for the development of maximum strength, the number of parallel sarcomeres of the myofibril could first increase (Sss), and then decrease after a rest period (SSR). As a consequence, the myofibrillary contractile force will increase during the training period and decrease, passing to the detraining period (graph P). Furthermore, if more parallel sarcomeres are produced, it will be possible to generate more force at reduced speeds (graph T). With stimuli from an explosive force development programme, the number of sarcomeres in the series of myofibrilla may also initially increase (SSL), and then decrease in a subsequent discharge phase (SSC). In this new training period, the fibre will become stronger during stretching (graph S) and will have higher contraction speeds at lower loads (graph X).

The change in the curvilinear course of the F-V relationship in relation to the degree of pre-tension is due both to the mechanical power of the acto-myosin complex, and to the joint visco-elastic responses of the exosarcomeral matrix, the endosarcomeral matrix and the sarcoplasmic gel. The more numerous, heavy and elastic the free terminals of the myosin, the thicker the spiraling meshes of the titins, the denser the embryos of the sarcomeric coating filaments, the lower the viscosity of the sarcoplasma, the more the activated muscle fibre is quick to contract under pre-tension (Figure 3).

Training with overloads, through its mechanobiological responses, can reshape the myofibrillary mechanical properties and alter the F-L and F-V relationships of the entire muscular bellies (Figure 4). For example, training with squats and a barbell loaded with 90% of the maximum weight usable for a single repetition on the shoulders, tends to develop mainly muscle strength. On the contrary, performing a series of jumps with overloads, performing jump squats with a barbell loaded at 30% of the single maximum repetition, increases the extension speed of the lower limbs[28].

THE ARCHITECTURAL PROPERTIES OF MUSCLE FIBRES

The architectural properties of muscle fibres are characterized by the parameters of length, thickness and angle of pennation[29]. The length and thickness of a muscle fibre depend respectively on its number of sarcomeres in series and in parallel. The angle of pennation, on the other hand, represents the degree of three-dimensional inclination with which the muscle fibre is positioned with respect to the shortening axis of the entire muscle belly. These three architectural properties mutually influence the contributions of force and speed that a myofibre is able to direct towards the ends of the muscular belly in which it is placed[30]. In absolute terms, contraction force of a muscle fibre originates from the total number of sarcomeres present in it, while contraction speed derives from the length of its sarcomeral queues, since more sarcomeres in series lead to higher values of contraction speed29. As the angle of pennation increases, however, the force produced by the myofibrillar contraction tends to divide in two directions, one parallel and one transverse to the shortening axis of the entire muscle belly[30]. As a result, a muscle fibre is capable of pulling the myotendinous and aponeurotic junctions with which it connects, only when it is aligned or running parallel to it[29,30]. In the extreme case in which the muscle fibre aligns perpendicularly to the longitudinal axis of the muscle, its strength and its speed of contraction would continue to stiffen the muscle, but would no longer serve to shorten it[31]. Therefore, depending on its angle of pennation, a muscle fibre can perform a traction or stabilization function of a muscle-tendon end. In this regard, it is interesting to point out that, during the movement (or maintenance of the position) of one or more anatomical segments of the human body, the muscles contract until the angle of their fibres' penetration reaches an optimal amplitude[32]. In practice, the one in which the activated muscle fascias pull and stabilize the joint levers as required by the action.

The directions of the myofibres follow the longitudinal development of the characteristic striations of the muscular bellies which, from a biomechanical point of view, correspond to the lines of contraction of the muscle. Thanks to avant-garde technology, it has been possible to use magnetic resonance images to associate, in virtual reality conditions, the architectural properties with the mechanical properties of the muscle fibres of the shoulder[33], pelvis and lower limbs[34]. These studies have shown that, in-vivo and in-site, the variation in the angle of the muscle fibres' pennation occurs to obtain a quadruple conservative advantage of the functionality of the muscles.

The first is structural (1): through the variation of the curvature of the streaks, the volumetric integrity of the muscle masses during contraction is preserved.

The second is anatomical (2): the inclination of the muscle fascias with respect to the action line of the tendons increases the number of fibres that can be inserted on the surface unit of the myotendinous junction.

The third is mechanical (3): thanks to the geometric variation of the contraction lines, the angular momentum produced by the shortening of the entire muscle is kept constant.

The fourth is functional (4): the variation in the angle of the pennation, which occurs during myofibrillar contraction, produces a pair of forces capable of traction and, at the same time, of stabilizing the sections of tendons to be moved.

It is understood that the movement of the joints consents a change in the shape (not the volume) of the muscle masses, the cleavage of the streaks, the alignment of the contraction lines, the directions of the muscle fibres and obtain the levels of strength and speed required by the fibres muscle recruited to perform movement (Figure 5).

The results of some tests on muscle force, cross checked with those of ultrasound surveys carried out on different categories of high level sportsmen such as bodybuilders, rugby players and weightlifters, have shown that strength and power training increases the angle of muscle fibre of the quadriceps. Although investigations of bodybuilders have shown that excessive angle of pennation is associated with the reduction of muscle contraction speed levels, in rugby players and weightlifters the results are conflicting.

Weightlifers and rugby players have muscle contraction speeds higher than those of bodybuilders, although the muscle fibres of rugby players have a similar angle to that of bodybuilders35 and the that of weightlifters is even higher[36].

A confounding factor of these comparisons between different strength athletes is the morphological evaluation of the same anatomical area. Different sports require different workouts. In fact, it would seem that the angle of pennation and the cross sections of the muscular bellies change according to the mechanical stimulus received. For example, the hypertrophic stimulus is not evenly distributed over the entire muscle belly, but only affects those parts of the muscle masses, proximal or distal, which have been involved in training. Depending on the exercise performed, individual areas of the muscular bellies can change shape, cleavage of muscle streaks, angles of fibre penetration, intensify the function of joint stabilizers (expressing themselves with stronger contractions), or that of actuators of the joint levers (expressing themselves with faster contractions). In fact, a spinter's quadriceps undergo hypertrophy more in the areas proximal to the hip than those of cyclists who, due to the difference in technical movement, increase their volume in the distal area around the knee[37].

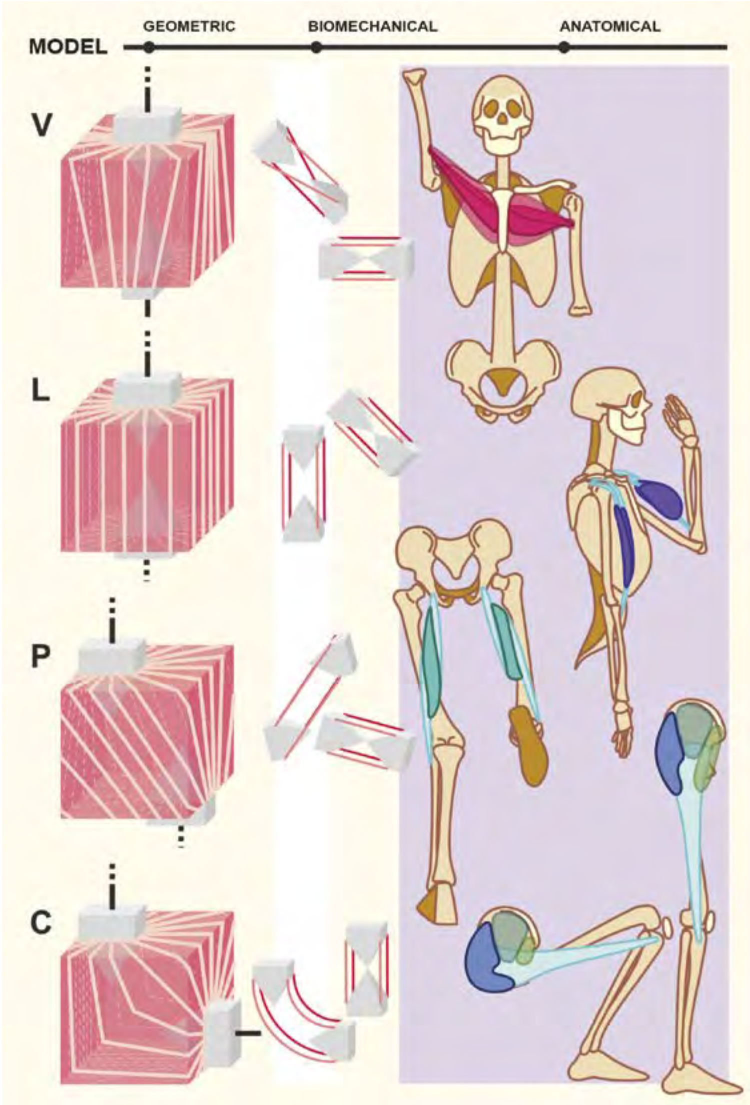

Figure No. 5 Angles of Pennation models. By means of the three-dimensional digitization processes of the anatomical parts making up the human body, on a microscopic scale, it was possible to model the inclination of the myofibres in the muscle bellies. Four models were designed: Fan (F), Linear (L), Pennate (P) and Curve (C). Each model describes, at a GEOMETRIC level, a specific arrangement of muscle fibres which, at a BIOMECHANICAL level, is able to twist (F), move closer (L), translate (P) or rotate (C) the tendon heads together (the pyramid-like wedges in the graphic representations of the models). In this way, it is possible to perform, at an ANATOMICAL level, all the innumerable joint movements that the muscles can perform.

The viscosity properties of the connective tissue make it rigid when stretched at high speeds, and plastic, when traction occurs at reduced speeds. A connective tissue that displays rigidity in a specific direction deflects the inclination of the contracted myofibres in another direction. A plastic connective tissue, on the other hand, absorbs the forces produced by the contraction of the neighbouring myofibres and dissipates them and deforms. Furthermore, if the connective tissue is interposed mainly between the muscle fibres and the muscle-tendon junction, then it will mainly direct the muscle force towards the joint levers. If the connective tissue is more dispersed among the muscle fascias, then it will compact the muscle masses with reduced mechanical performance on the tendon[39]. Therefore, as observed in bodybuilders[40], a maximally hypertrophied muscle belly, consisting of a high number of fibres that insert themselves on the myotendinous junctions in parallel and with a high angle of penetration, is internally crossed by a thick intertwining of connective tissue. The maximal force produced by such voluminous muscles tends to dissipate mainly in the lining connective tissue and partially head towards the tendons. This would partly explain the limit of bodybuilders' expression of strength. Ultimately, it is possible to say that exercises with overloads develop the connective structures in a different way, according to the methodology adopted[41]. Exercises that aim to increase muscle strength reshape muscle tissues by increasing the number of contractile units in parallel, the connective tissue of which makes them mechanically independent[37]. Exercises aimed at developing speed, on the other hand, produce an anatomical adaptation by the proliferation of those contractile units which, arranged in series, are wrapped in a connective tissue that mechanically binds them together[37]. In this regard, it was observed that an 8-week 15 s sprint programme at maximum speed, alternating with 5 min of active recovery, allowed the detection of an increase in intermiofibrillary connective (desmin) proteins, whose specific function is to join the sarcomeres[42] in series.

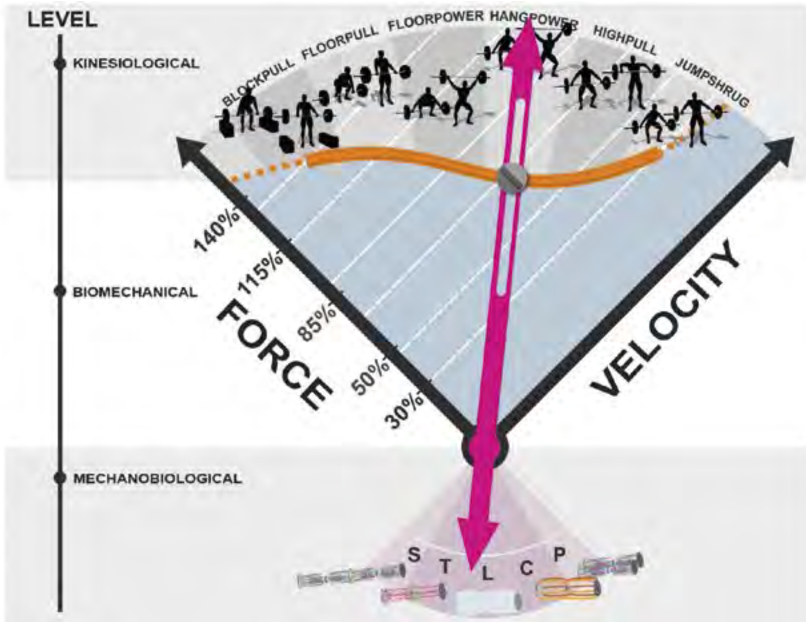

Figure No. 6 Biomechanical and Mechanobiological Parameters of Weightlifting Exercises. KINESIOLOGICAL level. Six different types of exercises that are used by Olympic weightlifters. BLOCKPULL: exercises in which the barbell is raised on blocks. FLOORPULL: exercises in which the barbell is lifted off the ground. FLOORPOWER: exercises in which the barbell is lifted off the ground and supported with bent legs. HANGPOWER: exercises in which the barbell is pulled from the height of the thighs and locked with bent legs. HIGHPULL: exercises in which the barbell is pulled upwards using legs and arms simultaneously. JUMPSHRUG: exercises in which a short jump is performed keeping the barbell at the level of the groin. BIOMECHANICAL level. For each of these exercises it is possible to express certain levels of strength and speed. MECHANOBIOLOGICAL level. In addition, the faster you go from the types of exercises in which high loads are used to those performed at maximum speed, the more the mechanobiological response of the organism will change by moving from the replication of the sarcomeres in parallel (P), towards the development of the connective (C), the increase in sarcoplasmic density (L), the reinforcement of the elastic elements of myofibres (T) and, finally, the replication of sarcomeres in series (S).

Further investigations of muscle architecture have observed that the belly of a muscle compresses in different directions depending on the intensity of contraction[30]. When a muscle contracts with intensities close to 80% of the ceiling, it undergoes a greater variation in the angle of its fibres; it shortens slowly and tends to expand in width (on the mediolateral axis, which crosses it transversely). Vice versa, a muscle that contracts without significant pre-tensioning, with an intensity lower than 20% of the ceiling, slightly varies the pennation angles of its fibres and tends to contract at high speeds, mainly increasing in thickness (on the dorsoventral axis, which it crosses it from the depth to the surface). The first analyzes of this phenomenon were carried out on the siren lacertina, a marine salamander with two short upper limbs in place of the pectoral fins and with a pulmonary branch of the gills. The muscles of this amphibian have such a regular architecture that for biologists it is an excellent example on which to study the contribution that connective tissue has on the change in shape and function of muscles when they contract at different speeds[38].

PRACTICAL IMPLICATIONS

Satisfying the primary need of all athletes whose imperative is to increase muscle power, in theory, means moving Hill's hyperbolic curve up and to the left of the F-V plane and, in practice, to be able to perform technical movements simultaneously expressing increasingly higher peaks of force and velocity. In a context of physical preparation, for example, we now know that Olympic weightlifting exercises are excellent means of training to develop strength and speed of the muscles of the lower limbs[43].

The mechanical stimuli produced by the pushing, squatting and countermovement actions produced by weightlifting exercises can be programmed to modify the extremities of the F-V curves (Figure 6).

In an annual programme organized to develop muscle power, for example, three distinct phases are carried out, through which the biomechanical parameters of strength and speed are modified while specific mechanobiological responses are sought. Generally, the first phase of the annual programme is to develop maximal strength, in order to fulfill two purposes. The first, of a biomechanical nature, aimed at improving the technical quality of execution, at the elevation of the acceleration peaks in the specific joint angles of the sports discipline practiced and at prolonging the time in which it is possible to train with overloads[43]. The second, which is mechanobiological, in anticipation of an increase in muscle volume and mass, of the reorganization of the connective tissue that surrounds the myofibres, of the reinforcement of the tendons and ligaments, of the search for the optimal angle of pennation to be able to simultaneously express stability and joint speed during movement. In the second phase of the annual programme, specific training sessions for the development of absolute strength alternate with sessions that train explosive strength and speed. This intermediate phase is structured to simultaneously achieve four objectives, two biomechanical ones - to increase the maximum value of muscle strength (1), to shorten the time required to reach the peak of strength (2) - and two mechanobiological ones - to increase the number of sarcomeres in series and in parallel (1), to improve the elastic potential of the tendons and connective tissue. The first biomechanical objective, to increase the maximum muscle strength values, and the first mechanobiological objective, to increase the number of sarcomeres arranged in parallel and to improve the connective elastic restitution, are obtained on the days in which the

variations of the technical exercises take place which expect to lift up to 140% of the maximum load[43]. The second biomechanical objective, to increase the rapidity of expression of maximum force, and the remaining mechanobiological objectives, to increase the number of sarcomeres in series and improve the elastic restitution of the tendon, can be reached in the sessions programmed with explosive exercises, carried out with fast counter-movements and loads reduced, not exceeding 60% of the ceiling. The third and final phase of the annual programme is structured by combining, in individual sessions, high-load exercises with low-load exercises[37,44], trying to exploit the post activation potentiation (PAP). This physiological phenomenon is found when a muscle produces a strong explosive contraction immediately after recovering from a brief discharge of maximum mechanical stimulation. Recent studies have observed that during training with overloads, 6 minutes after three short (3s) maximal isometric contractions, the angle of pennation of the muscle fibres is reduced, the tendons are more stretched and, consequently, the expression of muscle strength becomes more explosive45. From a biomechanical point of view, performing combinations of exercises with maximum loads and explosive exercises, interspersed with a prolonged (6 minutes) passive recovery time, allows to simultaneously increase the parameters of strength and speed[46]. From a mechanobiological point of view, it would seem that PAP originates from the viscoelasticity of the interfibrillary connective tissue, whose plastic deformation, under maximal mechanical stimuli, consents between the second and sixth minute of the passive rest phase, a change in the alignment of the muscle myofibres involved in maximal efforts[45].

CONCLUSIONS

Since the biomechanical properties produced on the microscopic (sarcomeral) scale are reflected on those found on the macroscopic (organic) scale[47], the three-dimensional F-V-L curve remains the most important mathematical model of muscle functions known to date[48]. Through its application, the concepts related to the mechanical properties of muscle fibres can be transferred, in practice: in a certain pre-stretching condition, the production of strength and speed during muscle contraction changes. All exercises with overloads, including the same exercises carried out at different loads, differ from each other in terms of specific myofibrillary pre-stretching conditions, tendon tensions, pennation angles, joint levers, productions of strength, power and speed. Each exercise therefore corresponds to a distinct mechanical stress, capable of initiating a specific

genetic response. The order and the execution methods of the exercises present in a competitive programme create a sequence of ideal adaptations to the development of athletic qualities. Knowing how to choose the exercises is of fundamental importance to meet the demands of the desired levels of sports performance. Lastly, knowing how to correctly choose the exercises and methods to be used involves knowing the effects they have on the adaptation responses of the muscles. The study of mechanobiology in the sports training sector can help make this choice.

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DOMS

DELAYED ONSET MUSCLE SORENESS. DEFINITION AND CLASSIFICATION

BY MICHELE CASTELLANO VITATERNA

We have all experienced the unpleasant sensation of feeling pain when getting out of the car, going down the stairs, the difficulty of getting up off a chair or moving about normally after an intense workout. This type of pain is called Delayed Onset Muscle Soreness (DOMS) and is also known as EIMD. Those who have been training for a sufficiently long period of time have probably experienced it. Some athletes perceive this pain as an indicator of success, of good training, but let's have a look at what scientific evidence affirms.

WHAT ARE DOMS

It basically represents muscle pain after a training session.
It's necessary to make a distinction between two types of soreness:

1) Acute Onset Muscle Soreness. The soreness, which generally manifests as a burning sensation, makes its appearance during, or immediately after training. Possible causes are an accumulation of post-training metabolites or tissue oedema caused by the displacement of blood plasma into muscle tissue following exercise. It is a phenomenon of short duration (the breakdown of lactic acid takes place in an hour after the end of physical exercise) which occurs without generating any delayed and persistent pain.
2) Delayed Onset Muscle Soreness. An athlete usually perceives this some hours after finishing physical exercise (of any type) and it is described as the consequence of mechanical and/or metabolic stress[18].

Scientifically speaking[15], DOMS are (mainly) a muscular problem (Type 1B fibres), whose pain usually occurs at rest, some hours after sports activity (8 hours after training, with peaks of 48-72 hours, even if the exact time may vary), making the whole muscle rigid on palpation: DOMS may cause a decrease in the movement space of the relative joint. This, however, is nothing to worry about.

"It is not muscle damage that causes pain, so much so that medical investigations do not show muscle injuries after exercise" [22,23,29]

A series of Japanese studies[50-53] claims that pain is related to neurotrophic factors: substances secreted by muscle cells that increase nerve sensitization. This theory is still being tested exclusively on lab rats. It would not be the first time, as is also the case with Manual Therapy, that the modifications produced by therapeutic interventions constitute a stimulation of the Central Nervous System, such as in articular manipulations. In the past it was believed that there was a "realignment" of the bone heads, while today the reflection effect that this manoeuvre generates is clearer.
Returning to the Japanese rats, researchers have showed that the development of DOMS was "completely suppressed" by some drugs.
Known as "COX-2 inhibitors", these drugs specifically block neurotrophic growth factors and are very powerful NSAIDs with alleged very serious side effects.
The latest studies[72] concur with these "neurological" definitions of DOMS.
It is also interesting to note the very practical and not very "academic" explanation of the DOMS reported in a study[83], reformulated in the conclusions below.
The mystery remains.

WHAT GENERATES DOMS?

The exact causes are unknown, there are, however, reasonable hypotheses:

1) **eccentric contractions**;
2) **genetics**, since it is a common observation that sensitivity and intensity vary considerably from one person to another;
3) it may be aggravated by other **physical or metabolic stress**;
4) the **fear** of pain may allow to predict how invasive the DOMS will actually be.

Regarding **eccentric contractions**, observe the image below to better understand what happens after the application of an extended protocol of these exercises. As can be seen, in the representation on the left, the muscle fibre appears to be haphazard, while the right one appears as "ordered". Most studies examining these fibres, to study DOMS, use untrained subjects who perform large amounts of eccentric work,

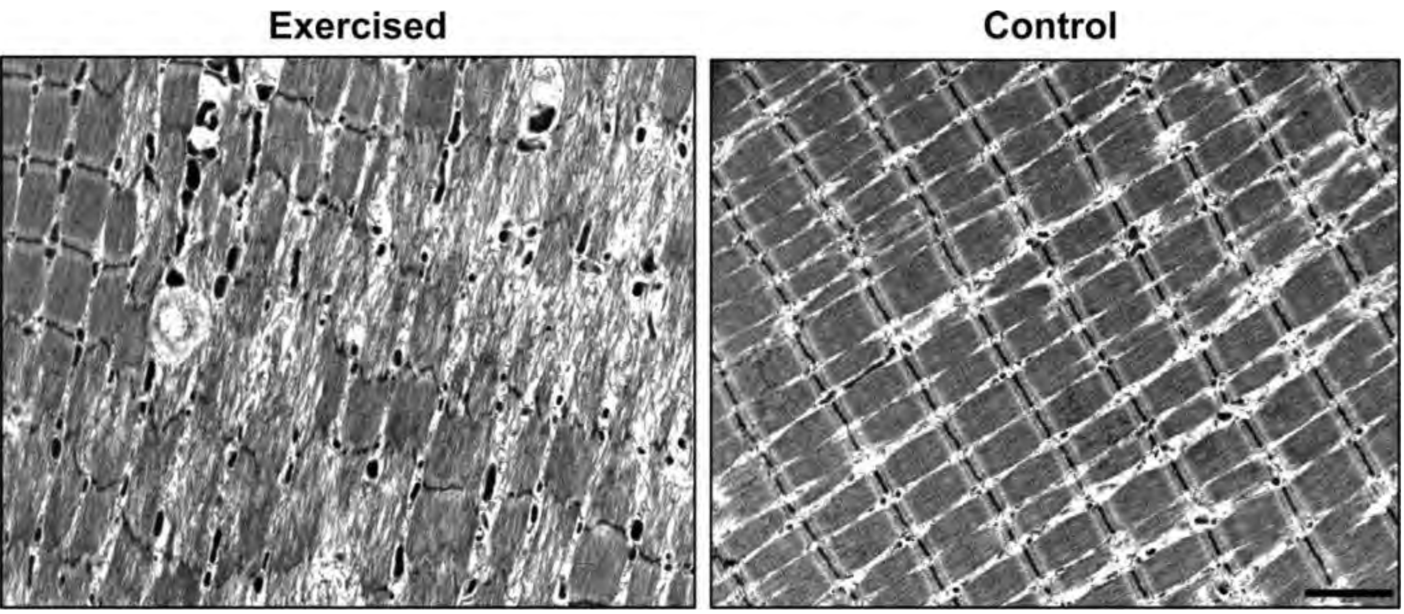

FIGURE 1: Note how during eccentric exercise there are actual modifications of the histology of the muscle fibre[73]

which is unfamiliar to them. This model is unlikely to represent most people who train. However, it gives an idea of what happens in the muscle. These types of contractions cause stress to the membrane of muscle cells and trigger a "local inflammatory response"; the latter determines the formation of metabolic waste products (metabolites) that act on the nerve endings, giving rise to the perceived painful sensations. The metabolites also increase vascular permeability and determine a mobilization of neutrophils (a type of white blood cell) towards the area affected by the lesion; neutrophils generate free radicals and this contributes to further damage to cell membranes. In these circumstances, swelling is also often present, a condition that contributes to aggravating painful sensations.
The pain is due to the release of muscle substrates in the space where the nociceptors are located[7].
Another stimulus that induces DOMS during exercise is **metabolic stress**.

"**Lactic acid does not cause DOMS.**"[24,25]
It is good to remember that after high intensity exercise, rest will be enough to bring the blood lactate values back to basal levels within the normal time intervals between training sessions. However, there is some evidence that lactic acid may contribute to the appearance of DOMS[2,19] because metabolic stress, during exercise, can cause structural changes in the cell membrane (sarcolemma), causing various elements to succeed in enter the cell[3], thus favouring a "local inflammatory response".

"**No inflammation occurs during DOMS**"[22,23,26-29]

To study this concept in more depth, the downhill run (an eccentric exercise par excellence) was chosen[22] to reproduce DOMS and the outcome was that this exercise did not cause inflammation of the skeletal muscles 48 hours after exercise, despite the onset of symptoms and the increase of CPK (creatine phosphokinase) also called CK (creatine kinase). It is necessary to bear in mind that inflammation is the hallmark of tissue damage, so this evidence tends to suggest that muscles

are not damaged by intense recruitment.
It is also believed[23] that physical exercise can induce DOMS by activating the inflammatory factors present in the epimysium. The latter are molecules that mediate inflammatory processes and represent the "metabolites" (products of metabolism). Activating them does not necessarily mean that an inflammatory process occurs, only that they could be implicated in the generation of pain produced by DOMS. Therefore, these pains may be related to molecules present before exercise, rather than after, or more likely, a combination of molecules present before and after, which suggests that "metabolic stress" is almost certainly much more complex than finding a molecule, or even a set of molecules, that cause pain after intense training. It is much more likely to depend on several variables over time, which also means that more studies are needed to clarify the concept of "metabolic stress".

In brief: the immune system perceives a given stimulus as offensive and therefore stimulates a local and non-systemic response (inflammation). In subsequent training sessions an adaptation of the organism to this type of stimulus is created[28].

The **fear** of pain was evaluated[17] in 126 courageous volunteers who underwent a workout with a high number of eccentric contractions in order to prepare them for DOMS. Before this experiment, they were given a test about "the expectation of fear" regarding what awaited them. This study showed that fear of pain before a potentially invasive event can predict recovery time. In other words: r**ecovery time is also influenced by the fear of pain**.

The above can occur in experienced and unskilled athletes. What determines the appearance of DOMS is subjecting the body to a change in the training stimulus. Studies[1] show that DOMS are not limited to any particular muscle group and some individuals tend to experience them more in some specific muscle areas.
It is interesting to note that there is no difference in the typology of DOMS among the genders[4]. It is also important to remember that the severity of pain is not related to the extension of "muscle damage" induced by the exercise[17].

DOMS DOES NOT MEAN GREATER MUSCLE GROWTH

Some studies show the presence of DOMS after long distance running, which indicates that it does not occur exclusively during training with overloads. This should act as an eye-opener about DOMS as an ineffective indicator for monitoring muscle growth, since running causes minimal hypertrophy.
There is evidence to show that DOMS can negatively affect training sessions, altering motor models in training sessions that take place after it has arisen. Thus, DOMS could actually hinder compliance with so-called sports programming. In addition, intense DOMS can reduce strength capacity by up to 50%[6]. This causes functional deficits[5] which can impair a certain level of training, hindering long-term muscle growth.

To conclude this section, we should specify that the increase in muscle volume that is perceived after a workout is the result of the accumulation, inside the cells, of proteins and plasma. The result is oedema in the muscles, with significant swelling that lasts about 48 hours after exercise.

DOMS IS NOT DANGEROUS

It is important to remember that exercising with DOMS does not seem to worsen "muscle damage"[7], but it can interfere with the recovery process. In extreme cases, exercise-induced muscle damage can cause rhabdomyolysis, a serious condition that can lead to kidney failure.

DOMS is a mild form of metabolic poisoning called "rhabdomyolysis". True rhabdomyolysis is a medical emergency during which the kidneys are damaged by myoglobin, produced by real muscle injuries. Myoglobin itself is not dangerous, but when it reacts with other acidic components of urine it causes kidney damage measured through CPK> 20,000 U / L.

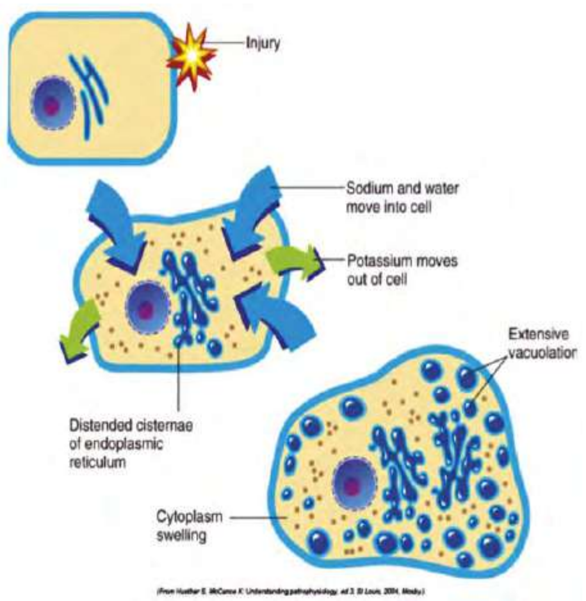

FIGURE 2: In this image, the term "injury" refers to any traumatic event suffered by the cell. Should one of the conditions described above occur, the cell will swell, creating the cascade process described in reference article 12.

FIGURE 3: Urine from a person with rhabdomyolysis showing the characteristic brown discoloration caused by myoglobin. Unless your urine is of this color after a workout or manual therapy treatment you have nothing to worry about.

CPK is the measure that indicates that some form of muscular injury has occurred following which this enzyme is released into the blood.

As mentioned before, many physical and metabolic stresses, including intense physical exercise, cause lighter rhabdomyolysis states. There are also other studies[21] documenting numerous events of rhabdomyolysis caused by extreme sports practices in amateur athletes, also called "white-collar rhabdomyolysis" or during military training[74] or by careless practices of ventilated saunas[75].
It is therefore important to pay the utmost attention when training an athlete with a new load programme.

HOW TO REDUCE DOMS

One of the best ways to reduce the risk of DOMS is to advance slowly in the application of each new exercise programme, establishing a reduced intensity for the first training period. This "preparation" phase allows the body to adapt to a greater intensity which will be gradually introduced. In sports, there are various strategies which have been more or less scientifically validated. The following section will explore them in detail.
For convenience's sake, they have been divided as follows:

Motor strategies:
1) Stretching;
2) active recovery;
3) warm-up;
4) quality of sleep.

Physical strategies:
1) Massage;
2) electrotherapies;
3) ultrasound;
4) hyperbaric therapy;
5) compression clothing;
6) cryotherapy;
7) ice baths;
8) contrast bath therapy;
9) heat.

Chemical strategies:
1) 1. Supplements/nutrition:
   a) caffeine;
   b) taurine;
   c) omega 3 fatty acids;
   d) curcumin;
   e) vitamin D deficiency;
   f) anti-oxidants (cherry, blackcurrant and pomegranate juice);
   g) glutamine and arginine;
   h) monohydrate creatine;
   i) increasing hydration.

NSAIDs

Motor strategies

The importance of warming up adequately before a sports performance is a universally known fact. In the case of DOMS, it is probably the only time that this wise practice does not provide any added value. Various forms of **warm-up**[34] have been studied in association with other strategies (massage and stretching), producing only small improvements on the prevention of DOMS. However, it was not possible to establish which is the most effective method.

Active recovery, with light loads, seems to be a more suitable strategy60,9 for improving the symptoms (temporary analgesic effect) determined by DOMS, but still scientifically ineffective.

As regards **stretching**[35,36,66] there is a Cochrane review [a Cochrane review is a systematic review of the literature available on a certain topic, Ed.] which states that in relation to the DOMS it is a useless practice, both before and after training.

Sleep quality is another often forgotten component. The scientific relationship68 between insomnia and pain is very intense.
Therefore, another component to be taken into consideration before developing complex rehabilitation plans without rational support is to improve sleep.

PHYSICAL STRATEGIES

As regards DOMS prevention and treatment strategies, reviews[30,31] of past years have highlighted how cryotherapy, stretching, homeopathy, various modalities of ultrasound and electric current have not produced any relief of the pain caused by DOMS.

Over time, **massage therapy** did not reveal evidence[43,31,60,82] of efficacy, if not to a small extent, and the same results[77] were also found for other forms of manual skills. The improvements[81] observed by patients are related to the perception of pain and not to the improvement of functionality. As we know, pain is mediated by bio-psycho-social factors and therefore a single change in these factors does not testify that there has been an actual decrease in DOMS. The evidence supporting this thesis was based on studies[8,61-66,88] that showed how massage reduced inflammation and promoted muscle recovery. The shortcomings of these studies, however, are represented by methodological defects, by bias: scarcity of samples, entropy of variables, minimal and undefined changes over time and above all, the defect known as the "funnel plot"[87]. Nonetheless, self-massage can be an advantageous, economic and relatively risk-free practice.

For the sake of clarity, I refer to a 2018 study[66], which is a systematic review treated with meta-analysis (even if discredited

for the reasons explained above). The conclusions of the study: **active recovery, massage, compression clothing, ice baths, contrast bath therapy and cryotherapy** have all had positive effects on perceived muscle pain. In stark contrast, however, to what has just been declared, a 2006 review[76] denies the effectiveness of the same strategies. In the same way, another previous review[80] does not find any connection with the use of heat or cold to favour recovery from DOMS.
This review explains the possible effects of using temperature therapies, supporting their use, for now, with an empirical approach.

Contrast therapy has little evidence[89,90] to support it, but there is something to it. A reasonable practice involves a tank with water at a temperature of 10-15°C and another at 38-40°C. The immersion times are 2-7' with a number of cycles from 3-7.

Heat therapy does not benefit from much research either[54,55] however, the data so far are encouraging and support its use. The administration of heat is mainly via saunas (also infrared) and **steam baths**.

Advanced cryotherapy exposes athletes to cold and dry air below -100°C for 2-4 minutes in a specific room. A recent Cochrane review[14] found that there is insufficient evidence to claim that cryotherapy can reduce DOMS or improve recovery. In addition, the review does not report evidence of the possible risks of this therapy.

As for **ice baths**, a Cochrane[85] review denies its effectiveness as a form of recovery, while a subsequent review[84] reports good data regarding "the perception of fatigue". This parameter is not very reliable, for the same reasons as massage therapy, since pain is the result of a bio-psycho-social process. The water temperature of 10°C, or in any case in a range between 5°C and 13°C, examined by the aforementioned studies, confirmed a significant result in favour of cooling.

The suggested cooling time to relieve subjective symptoms is 13 minutes (range: 10 to 24 minutes). Finally, there is a need to investigate the side effects that such practices could have, since other studies speak of possible risks[38,39].

Compression clothing are not supported by many scientific findings[91,92,9]3 and the few studies on the subject are contradictory.

Other physical treatments without scientific evidence include:

- **ultrasound**[32,33];
- **electrotherapy**[66] such as (TENS)[40] and microcurrents[41];
- the effectiveness of **hyperbaric therapy** has recently been definitively refuted[66] by a Cochrane review[69].

Supplements/nutrition

The subject of supplements, and more generally that of nutrition, is an interesting and still debated topic. The purpose of this overview is far from exhausting the topic and will touch on the more popular supplements.

Caffeine is known to increase alertness and endurance. Interestingly, recent studies[13,71,72,86] report that caffeine has the ability to reduce DOMS. Through the administration of a dosage equal to 5 mg/kg of body weight, a beneficial effect of caffeine on pain was found. For example, a male of approximately 84 kg should take about 420 mg of caffeine (one hour before training). But this is an exaggerated amount! A can of Red Bull contains about 85 mg of the substance and therefore no supplement contains a similar amount. Caffeine is an adenosine antagonist because it blocks receptors, with a consequent reduction in pain levels (it directly affects the central nervous system).

Taurine has multiple biological functions. In the same can of Red Bull, mentioned above, there are about 1,000 mg of taurine. Clarification: a supplement of up to 3,000 mg per day of taurine is considered safe. A 21-day, double-blind trial[10] of males measured the effects of 50 mg of taurine (20 times less than the content of a Red Bull) after 7 days of eccentric exercise.

Researchers found a reduction in DOMS markers and oxidative stress after exercise; however, there was no effect on inflammatory markers. A recent review also reports other dosages86.

Omega-3 fatty acids are found in fish. Research[71] has shown positive signs about its use especially on the recovery of strength and range of motion. This is presumably due to the decrease in pro-inflammatory factors such as IL-6 and TNF-alpha. The recommended dose[71] is approximately 2g/day.

Curcumin is an extract of turmeric used as a spice in Indian cuisine. It exerts powerful anti-inflammatory effects, although, as explained above, inflammation may not be a decisive factor in the appearance of DOMS. Despite the complexity of the matter, recent studies[57] have found a reduction in pain and less loss of strength following the intake of curcumin. Furthermore, in a review[71] it is recommended to use it with doses of 5g/day. In another more recent review[86], other doses are reported.

Vitamin D deficiency has become more common in the West than previously thought[59,67]. Vitamin D deficiency is related to DOMS[86], as both reveal a similar symptomatology. This deficiency exacerbates the symptomatology of DOMS. Therefore, in the case of very long and/or disproportionate muscle recovery, it is rational to investigate the deficiency of this vitamin. In addition, a recent review[71] demonstrates an improvement in the adaptive response to training after sun exposure. Another review86 reports various supplementary values.

For **antioxidants** it is interesting to read the findings of a Cochrane review[70]: "*Taking dietary antioxidants in the form of supplements does not result in a clinically relevant reduction in muscle pain after exercise until 6 or 24, 48, 72 and 96 hours after the exercise.*"

Other reviews[71,79,86] on the subject, on the other hand, establish benefits for recovery. Another chapter yet to be written. Despite the ominous premise, here is what other reviews report.

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According to the latter[42,77], cherry juice can have a beneficial effect on recovery but not on pain and the recommended dose[71] would be about 250-350ml (30ml if concentrated) twice a day for 4-5 days before a sporting event or for 2-3 consecutive days to encourage recovery.

Blackcurrant juice appears to be useful86 in doses of 473 ml twice a day. The effect of **pomegranate juice** was studied[86,87] on professional weightlifters, who took 750 ml/day and 500 ml an hour before training and found a better subjective and objective recovery.

Research is extremely inadequate on **glutamine** and **arginine** based supplements.

Creatine monohydrate is a naturally occurring nutrient, consumed in the diet and synthesized in the body. The recommended supplement dose[71], in order to improve recovery, is 20 g/day for 5 days, followed by 3-5 g/day to increase and maintain high creatine levels in the body. Another review[86] reports various doses.

Increasing hydration is a practice that, although supported by common sense, does not find much research[86] in relation to DOMS.

NSAIDs

Oral NSAIDs have proven effective[44,45] in the reduction of pain only and not on prevention, nor on improving muscle function and reducing inflammation markers. There may be a small improvement in healing time.

I found a very interesting study[47] which experimented with a belief in the world of marathons that ibuprofen has a preventive function on the DOMS of ultra marathon runners. The results are extremely contrary to previous opinions, so much so that another scientific article[48] used previous research (together with back pain), as an example to measure how difficult it is to encourage people to accept new scientific evidence, since, despite evident negative results, when athletes were asked: "would you continue to use this drug?", almost all of them provided an affirmative answer. An interesting article that focuses on beliefs.

The official journal of the European Weightlifting Federation

ANTI-INFLAMMATORY DRUGS FOR HEALING

The role of inflammation in DOMS is extremely unclear. As reported in the previously referred to trial[28], inflammation increases as pain diminishes an extremely strange discovery that opens a Pandora's Box on the complexity of muscle recovery. A systematic review[49] treated with recent meta-analysis, the first of its kind, concluded that NSAIDs can bring little improvement to muscle recovery.
In general, it can therefore be said that:
"To date, solid and consistent treatment for DOMS[43] has not been established."

CONCLUSIONS

It is now clear that, given that the causes are still unknown, even more so are the strategies for improving this particular condition. Therefore, there is not even a classification system that can provide the severity of the symptoms with a value. It is up to the practitioner, with theory and practice, to perceive what type of symptomatology it is.
Assuming that a truly valid strategy for recovery has not yet been found, some scientific evidence is more encouraging than others.
The most valid scientific strategies are: hot/cold therapy and heat, the integration of curcumin, caffeine, fatty acids (omega-3), monohydrate creatine and taurine; in addition, improving sleep quality is one of the most valid strategies.

Not unequivocal results concern massage therapy, NSAIDs and active recovery.

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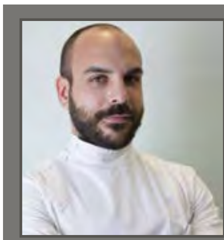

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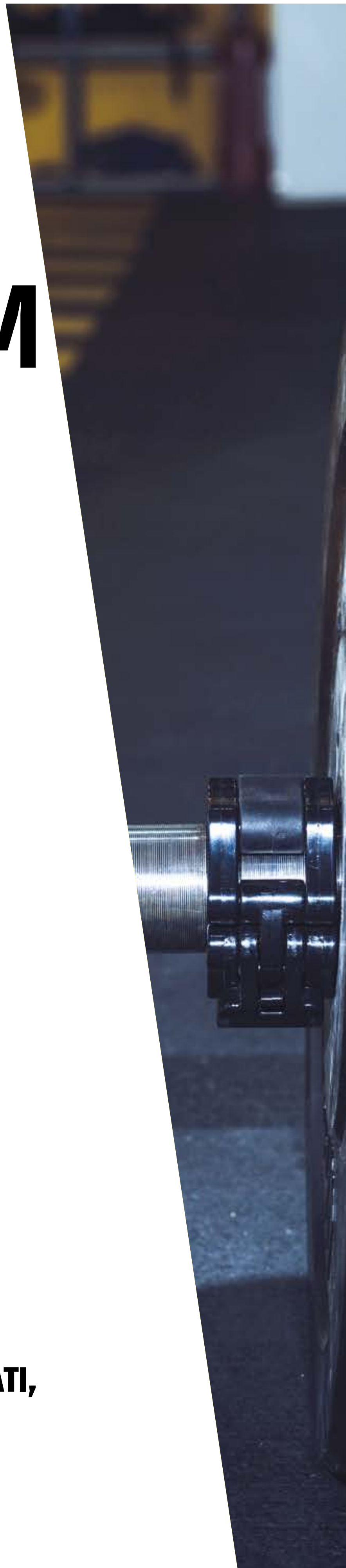
AUTONOMIC NERVOUS SYSTEM RESPONSES TO STRENGTH TRAINING IN TOP-LEVEL WEIGHT LIFTERS



BY FERDINANDO IELLAMO, DANIELA LUCINI, MAURIZIO VOLTERRANI, MAURIZIO CASASCO, ANNAMARIA SALVATI, ANTONIO GIANFELICI, ALESSIA DI GIANFRANCESCO, ANTONIO URSO, VINCENZO MANZI

INTRODUCTION

Searching for minimally invasive, minimally disturbing indicators of training status in athletes has been always a matter of interest in exercise physiology and sports medi- cine. To this aim, several variables have been monitored, mostly related to adaptive changes in the neuroendocrine system and particularly heart rate (HR), because HR rep- resents one of the most accessible, noninvasive and lowcost physiological measures in sports medicine. In this context, spectral analysis of short-term HR variability (HRV) has been shown to be capable to detect the com- plex adaptational changes in sympatho-vagal control attending physical training.

Indeed, we and other groups reported the feasibility and reliability of HRV in monitoring autonomic nervous system (ANS) changes with training in healthy subjects (Iwasaki et al. 2003; Okazaki et al. 2005) cardiac patients (Iellamo et al. 2013) and athletes (Iellamo et al. 2002, 2004; Manzi et al. 2009).

However, most of the studies performed so far, investigated ANS changes occurring with endurance, aerobic training, and showed a dose–response relationship of ANS responses to training, best described by a second- order regression model (Iwasaki et al. 2003; Okazaki et al. 2005; Manzi et al. 2009; Iellamo et al. 2013) with different and reciprocal shapes for parasympathetic and sympa- thetic indicators.

Aerobic exercises consist of activities performed for prolonged periods that involve large muscles masses (e.g., running and cycling). Aerobic exercise induces many physiological adaptations, mediated at both central and peripheral sites (Wilmore et al. 2008). The main metabolic adaptations to aerobic exercise at muscular level are a slower consumption of muscle glycogen, a larger reli- ance on fat oxidation, and less lactate production during exercise at a given intensity (Wilmore et al. 2008).

To what extent adaptations in ANS regulation observed in endurance athletes extend to markedly different exer- cise training modes, for example, strength training, has been much less investigated.

Strength training is a type of physical exercise that provides meaningful functional benefits to the health and athletic performance, including muscle hypertrophy and, possibly, hyperplasia (Folland and Williams 2007; Roberts et al. 2015). Traditionally strength training programs consist of exercises with resistance or added weight, comprising repetitions before muscle exhaustion and in weight lifters include to a large extent, olympic lifts (snatch, clean and jerk), powerlifts etc (see Methods).

To the best of our knowledge, no study has analyzed the relationship between training load and ANS parameters in high-level strength-trained athletes.

In the present investigation, we assessed the changes in cardiac ANS parameters with training load in weight lif- ters of the national Italian team preparing for the Euro- pean Championship 2016 and tested the hypothesis that changes in ANS with weight-lifting-specific training are different from those described with endurance training, being therefore sport-specific.

METHODS

This study was conducted on the entire group of weight lift athletes of the National Italian Team over the season culminating with the Rio de Janeiro 2016 Olympic Games. All athletes had been previously screened for cardiovascular or metabolic diseases that could contraindicate participation in agonistic competitions.

Subjects

Nine healthy, trained, weight lifters (5 males and 4 females, age 20 to 39 years, of weight class from 48 Kg to 70 Kg, with at least 6 years of high-level competitions (all had participated to international competitions and medal winners) volunteered to participate in the study.

All subjects provided informed written consent to the experimental procedures after the possible benefits and risks of partici- pation were explained to them. The study protocol was approved by Institutional Review Board of Sports Medi- cine Institute CONI and followed the guidelines laid down by the World Medical Assembly Declaration of Helsinki.

Experimental protocol

Before the beginning of the study, all the athletes abstained from vigorous efforts for 4 weeks to avoid possible effects over the experimental intervention; thus, for the purpose of this study, at this time they were considered as (partially) detrained and underwent the baseline recording sessions. Thereafter, each athlete was investigated on three subsequent occasions during the season, according to the training periodization by the coach. The last assessment was performed just before the European Championship 2016, where athletes competed to obtain the pass for the Rio de Janeiro 2016 Olympic Games. All the recording sessions were performed early in the morning after an overnight fasting, before breakfast.

No one athlete was considered overtrained at the time of the recording sessions, based on the lack of the following signs: an inability to sustain the usual training program and the presence of symptoms, such as increased feelings of fatigue during daily training routine, sleeping disorders, apathy, or restlessness. No athlete was taking drugs at the time of the recording sessions. This was monitored by the physician's team.

Training protocol and training load calculation

The subject trained about 18 times a week (3 sessions/day, 6 days a week), according to their individual program. Training routine consisted of different weight exercises: olympic lifts (snatch, clean and jerk), powerlifts, pulling exercises, and squat lifts, for a total of 90–100 repetitions per day. The average intensity of all strength exercises var- ied from 70% to 95% of 1-repetition maximum (1 RM). The training parameters, that is, the volume and intensity of the different types of exercise were recorded during the whole experimental period. The training volume used in the training load calculation, was the total training time, while the intensity was the percentage of 1-RM. Therefore, training load (TL) was calculated as follows:

TL arbitrary units;
AU volume min
X intensity %1RM:

The sum from all sessions for each given training cycle provided the total training load for that cycle. All sessions were supervised by the coach to monitor the appropriate amount of exercises.

Autonomic nervous system assessment

The continuous ECG signal was obtained with a modified C5 lead, connecting the electrodes to an analog preampli- fier (BT 16 plus, Marazza, Monza, Italy). Respiratory sig- nal was recorded with a piezoelectric thoracic belt. The analog signals were connected to an A/D board inserted in a personal computer, sampled at 250 Hz, and stored on the hard disk for subsequent analyses. These signals were used to assess autonomic function. Athletes did not perform strenuous physical activities in the 20 h before recordings. All the recordings were performed in a room at ambient temperature (22–24°C) in the Sports Medicine Institute CONI of Rome. After instrumentation, the sub- jects lay supine for 15 min before experiments to relax in the room made dark and noiseless; thereafter, continuous ECG data acquisition was performed for 10 min.

Power spectral analysis

A purposely developed software (Heartscope, ver.1.6,
A.M.P.S. llc, New York) (Badilini et al. 2005) was used to identify the peak of R wave on ECG. The software con- structs automatically time series of RR intervals and respi- ratory activity (RESP) with low operator-analysis interaction. Spontaneous variability of RR interval and RESP was evaluated by means of power spectral analysis using an autoregressive algorithm, as previously described (Pagani et al. 1986, 1997; Manzi et al. 2009). Briefly, the harmonic components of RR interval were evaluated by the autoregressive method. Components in the frequency band from 0.03 to 0.15 Hz were considered low frequency (LF), and those in the range from 0.15 to 0.4 Hz, were considered high frequency (HF). The LF component of RR interval (when expressed in normalized units) is con- sidered to be an expression of mainly cardiac efferent sympathetic regulation, whereas the HF component of RR interval variability is considered to be an expression of cardiac

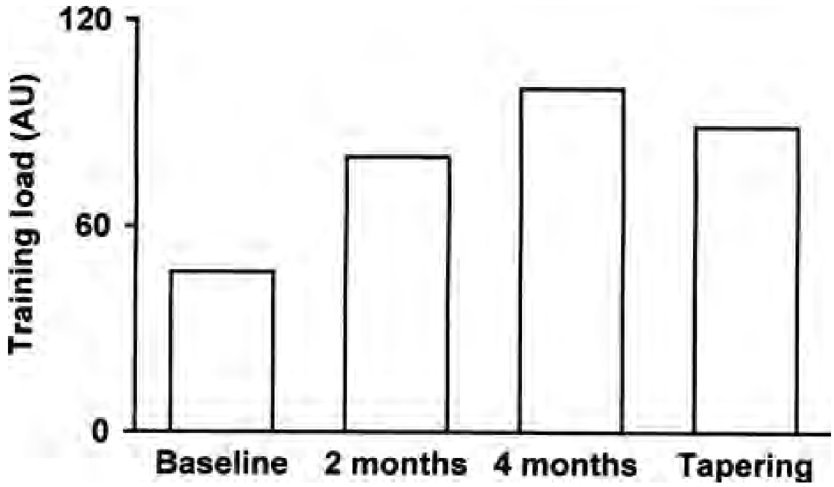


FIGURE 1: Time course changes in training load during the competitive season.

vagal modulation (Pagani et al. 1986, 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Iellamo et al. 2001). Oscillations slower than 0.03 Hz were considered as very low frequency compo- nents (i.e., DC noise). Spectral analysis of the respiratory signal was performed on the signal sampled once for every cardiac cycle. Respiratory spectra were used to assess the main respiratory frequency. The power density of each spectral component was calculated both in abso- lute values and normalized units (n.u.), computed as the ratio of the absolute power of either HF or LF to the total power, less the very-low-frequency component if present, and multiplying this ratio by 100 (Pagani et al. 1986). The use of normalized units is crucial in order to obtain valuable information as to the oscillatory cardiac modula- tion, because of the high interindividual variability in R-R interval total variance and DC noise (Pagani et al. 1986, 1997; Iellamo et al. 2001) and possible redundancy of indices (Lucini et al. 2018).

Statistics

The significance of differences in the ANS parameters among the different recording sessions was evaluated by analysis of variance (ANOVA) for repeated measures. Effect size (g2) was also calculated according to Cohen (1988) and values of 0.01, 0.06, and >0.14 were inter- preted as small, medium and large, respectively. To express the dose–response relationship between the training stimulus and changes in autonomic cardiac regulation indexes, correlations between the training load and auto- nomic cardiac regulation indexes at baseline and at the different times during the training season were estimated from a second-order regression, accordingly to previous studies (Iwasaki et al. 2003; Okazaki et al. 2005; Manzi et al. 2009). Differences were considered statistically significant when P 0.05. A commercial package (SPSS, version 20.0 for Windows; Chicago, IL) was used for all statistical calculations. The results are expressed as mean SEM.

RESULTS

TL progressively increased during the season then decreased during the tapering period of the European Championship (Fig. 1). Baseline heart rate (HR) and systolic and diastolic arterial pressure were 62 ± 1.3 b/min, 100 ± 14 mmHg, and 65 ± 8 mmHg, respectively, and did not change significantly throughout the study, as did breathing frequency, that ranged from 0.29 to 0.27 Hz.

Spectral analysis of HRV

The LF power of R-R interval variability (normalized units) showed an increase with the increase in TL and then a decrease, as did the LF/HF ratio.

The HF component of R-R interval variability (normalized units) showed a reciprocal pattern, with a decrease as TL progressed, fol- lowed by an increase. The same occurred for R-R interval. Although the mean changes at the group level in all indexes of autonomic cardiovascular regulation were not statistically significant (P>0.05), the effect size calculated using partial eta squared were moderate or large (RRMean, g2 = 0.087; RR LFnu, g2 = 0.226; HFnu, g2 = 0.177; RR LF/HF, g2 = 0.133). As shown in Figure 2, the ANS parameters as well as R-R interval were significantly and very highly correlated with the dose of exercise with a second-order regression model (r2 ranged from 0.96 to 0.99; P < 0.001), with different and reciprocal shapes for parasympathetic and sympathetic indicators. HFNU and R-R interval (and total variance as well), resembled an U- shaped curve with a maximum at the highest TL, whereas LFNU and LF/HF ratio resembled a bell-shaped curve with a minimum at the highest TL. Of the nine athletes competing at the European Cham- pionship, four won medals that were spread across weights categories and sex. Two female athletes won a sil- ver and a bronze medal while two male athletes won a gold and silver medal, respectively.

DISCUSSION

The main and novel finding of the present investigation is that cardiac ANS adaptations to strength training in top-level weight lift athletes are dose-related on individual basis, and are substantially different from those observed in endurance-trained athletes, showing a progressive shift toward a parasympathetic predominance as training load approached the maximum.

Hence, ANS adaptations to training in top-level athletes appear to be mainly sport- specific and not generalized.

ANS adaptations to training

We recently reported consistent data on the dependence of ANS adaptations upon TL, on an individual basis, in endurance sports (Manzi et al. 2009; Iellamo et al. 2013). Specifically, indexes of parasympathetic cardiac regulation showed a bell-shaped curve with a minimum at the high- est training load, whereas indexes of sympathetic cardiac regulation resembled an U-shaped curve with a maximum at the highest training load (Manzi et al. 2009; Iellamo et al. 2013) (Fig. 3). As TL approached the maximum there is an increase in the LF component of HRV and in the LF/HF ratio and a decrease in the HF component of HRV and baroreflex sensitivity (BRS) (Manzi et al. 2009) (Fig. 3), in keeping with previous studies suggesting that the magnitude of training load alters cardiac autonomic modulation in a direction that would be consistent with a sympathetic predominance (Pichot et al. 2000; Portier et al. 2001; Iellamo et al. 2002, 2004).

The results of the present investigation in weight-lifting world-class athletes, that experience markedly different training routines in comparison to endurance-trained ath- letes, are at variance with the above findings, even though they confirm the nonlinear dose–response relationship between the exercise training stimulus and dynamic regu- lation of HR.

This concept would be supported by the finding that individual dose–response changes were detected across athletes of different sex, age and weight categories (ranging from 48 to 85 kg), hence experiencing different absolute TL but the same relative TL.

Overall, it does appear that cardiac ANS adaptations are strongly dependant, on an individual basis, on the type of training being performed and, therefore, are dependent to a large extent on sport-specific training practises. To our knowl- edge, this is the first study to have addressed ANS adapta- tions to strength training in weight-lifting world-class athletes during a whole season culminating with a high demanding competition.

In our study no significant differences in ANS parame- ters with variations in TL have been detected on a group level. The more likely explanation for the discrepancy in ANS parameters on individual versus group level, is the large inter-individual difference in HRV parameters at baseline and throughout the study, along with weight cat- egory, age, and sex differences between athletes, which prevented the detection of significant differences in mean values with TL variations and the small sample size. This explanation would be supported by a previous study by Manzi et al (Manzi et al. 2009) showing the same occur- rence, that is, discrepancy in ANS parameters on individ- ual versus group level, in endurance athletes [and in cardiac patients as well (Iellamo et al. 2013)].

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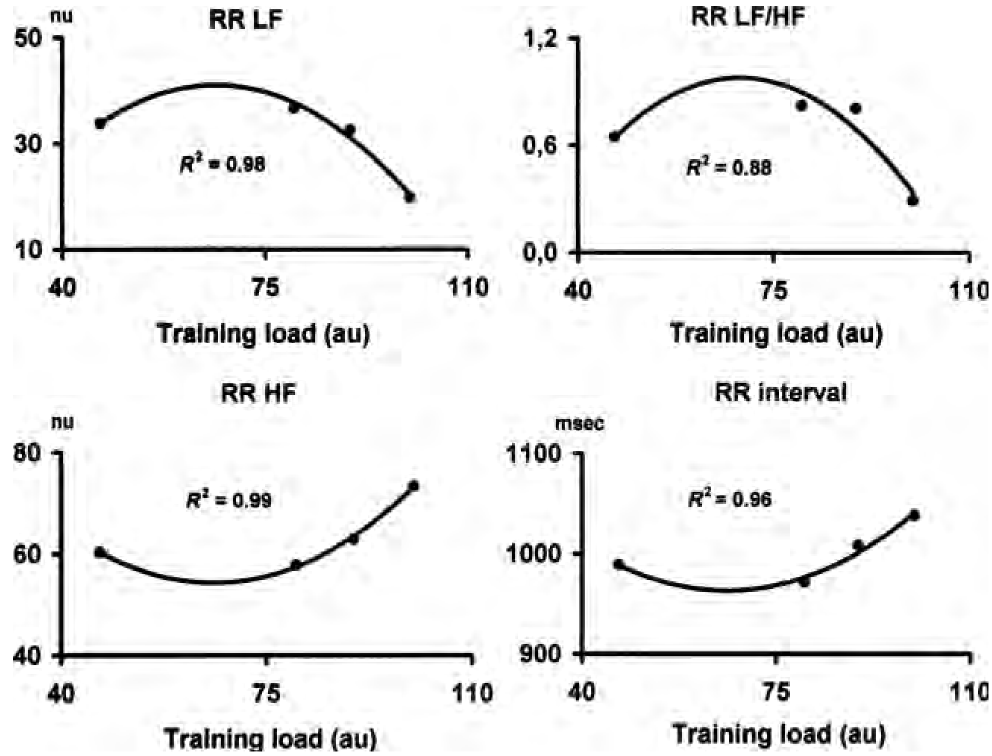

FIGURE 2: Dose–response relationship between training load and autonomic cardiac indexes. HF, High-frequency; LF, Low-frequency components of R-R interval variability; LF/HF, Low- to High-frequency ratio in R-R interval variability; NU, normalized units. Entries represent mean values SEM for nine athletes.

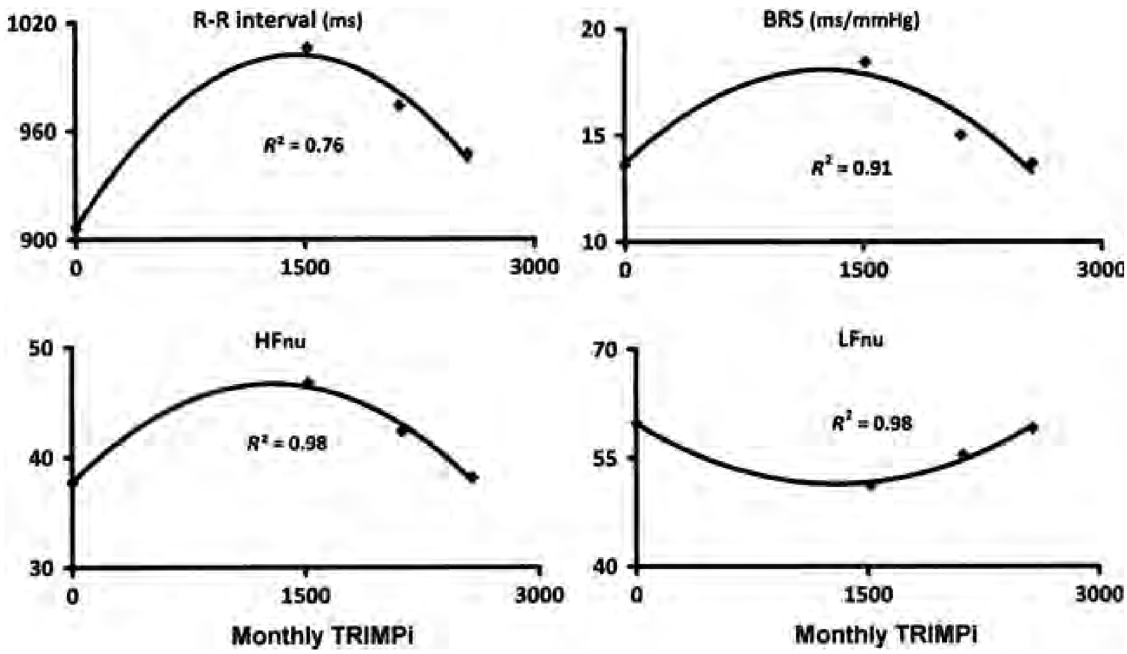

FIGURE 3: Dose–response relationship between exercise intensity/volume (monthly TRIMPi) and autonomic cardiovascular indexes. BRS, Baroreflex Sensitivity, HF, High-frequency and LF Low-frequency components of R-R interval variability, NU, normalized units. Entries represent median values for eight athletes. Used by permission from Manzi et al. (2009).

It thus appears that to adequately examine the relation between ANS and physical training, it is necessary to account for the relative degree of effort expended by each athlete individually, in addition to training specificity. Regrettably, our results cannot be directly compared to previous investigations in top-level athletes addressing the link between ANS changes and long-term strength

training programs in the preparation for a competition. Current knowledge regarding the link between ANS changes and weight training is lacking, since long-term HRV-monitored studies have mainly addressed endurance training.

As far as resistance training is concerned, available data, not obtained in elite athletes, collectively would indicate that this type of exercise does not affect resting HRV in healthy young and older individuals (Kingsley and Fig- ueroa, 2016; Bhati et al. 2018).

A strength of the present investigation is the repeated measurement of ANS parameters during the training period, which could have improved our comprehension of the link between changes in training load and changes in cardiac autonomic regulation, although the mechanism(s) underlying this effect were not examined as a part of this study and need to be defined.

The opposite changes in ANS parameters with changes in TL between endurance (Iwasaki et al. 2003; Manzi et al. 2009; Iellamo et al. 2013) and strength training (present study) might be ascribed to differences in the single exercise routines during the training sessions, with endurance exercises requiring a more prolonged cardiac demand, implying a greater sympathetic activation, in comparison to the much shorter, although intense, requirements of weight-lifting exercise routines.

Limitations

The main limitation of the present investigation is the small sample size, which, unfortunately, is a common and unavoidable characteristic of studies carried out in ath- letes of top-class level. Similarly, we performed a four point assessment that could be perceived as few. However, it is highly difficult to have national-class athletes avail- able for more frequent assessments over the whole year. On the other hand, most studies in this field performed only two assessments (i.e., before and after training) thus precluding an accurate delineation of the link between serial changes in training load and changes in cardiac ANS regulation and a dose–response analysis. The strong correlation between ANS parameters and training load (r2 ranging from 0.89 to 0.99) also argues against a chance effect. In addition, we could not discriminate between male and female athletes, because of the small number of athletes of both sexes. Again, however, the strong consis- tency of our data on individual dose–response relationships would argue for sex-independent ANS adaptations, although this point should be confirmed. Finally, the study lacks a control group that did not exercise. However, within the framework of the present investigation, this would be more a theoretical rather than an actual limitation. Indeed, it would be hard to hypothesize dose-response training-related changes in ANS, as those observed in our study, in subjects who do not undergo exercising training. Indeed, there would be virtually no rationale to investigate the relationship between ANS adaptations and training in nonexercising individuals.

We should also mention that we used an indirect method to assess changes in autonomic function.

Although this procedure stimulated strong debates in the literature (Eckberg, 1997; Malliani et al. 1998), nev- ertheless several studies have affirmed that spectral analysis of HRV is a simple way to extract the information embedded in the frequency code characterizing neural cardiovascular regulation (Pagani et al. 1986, 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Iellamo et al. 2001). Indeed, the issue of the validity of the spectral analysis approach was addressed by experiments in humans (Pagani et al. 1997) in whom direct recordings of muscle sympathetic nerve activity were performed during various states of autonomic regulation, as produced by graded infusions of vasodilators and vasoconstrictors.

The presence of similar, coherent oscillations at LF in nerve activity, R-R intervals, and systolic arterial pressure (SAP) variabilities at various levels of induced pressure changes, provides support for the use of LFR-R (in n.u.) as an index of mainly sympathetic modulation of the sinoatrial node. The lack of LF oscillations in the R-R interval [and SAP variability as well, which reflects vascular efferent sympa- thetic regulation (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Pagani et al. 1997)] in tetraplegic patients who lack the ability to modulate sympathetic nerve traffic to the heart and vasculature (Iellamo et al. 2001) provides further experimental sup- port to the above concept.

In conclusion, the results of this study indicate that in weight-lifting-trained world-class athletes there is a curvi- linear dose–response relationship between training load and ANS functioning parameters, on an individual basis, as previously reported in endurance-trained athletes. At variance with endurance-trained athletes, however, in weight-lifting-trained athletes ANS adaptations go in an opposite direction with an increase in vagal and a recip- rocal decrease in sympathetic indicators with the progres- sion of training load (compare Figs. 2 and 3).
The study confirms that monitoring of HRV might have practical in addition to physiological implications, in that it could provide additional information useful to assess the dynamics of training in weightlifters during the training period and before competition through a simple, noninvasive, and minimally time-consuming approach.

CONFLICT OF INTEREST

None declared.

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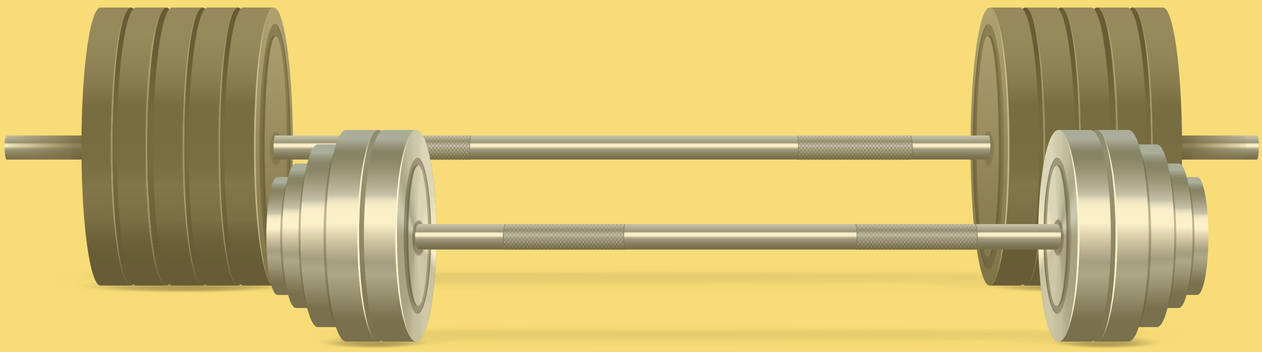


MECHANISMS REGULATING MUSCULAR HYPERTROPHY

BY CARLO MENGHINI, LUCA RIVA, MAURO ROCCA

Skeletal muscle is a plastic fabric that adapts quickly to its mechanical environment. An increased load on the muscle, in the form of exercising with overloads, stimulates an increase in strength and muscle mass. The increase in muscle mass mainly occurs due to the growth of existing cells; this process is called muscular hypertrophy [1].

Very often this term takes on a negative connotation, most likely due to the stereotypes represented by individuals who aim to increase muscle mass, and by some extreme practices used. It is not uncom-mon for the phrase "increase in muscle mass" to immediately bring to mind the image of a questiona-ble exasperation of this concept, potentially creating an "undesirable" effect for those not related to this practice. Only a small number of athletes train with the aim of increasing muscle mass, although there is much scientific evidence regarding its benefits on longevity and quality of life[1], [2].

Perhaps, not much importance is given to this type of training, also due to the lack of knowledge of the phenomena that describe it, often based on word of mouth, or on the opinion of some presumed experts in the field. In recent years, scientific evidence on hypertrophy has significantly increased, in an effort to identify the processes that underlie it and their integration into practical application. These processes are actually very complex and still not fully explained. Learning them correctly, based on what is de-scribed in the literature, helps us avoid the confusion of concepts and some misleading interpretations and consequent incorrect methodologies, used for this type of training.

The regulation of the size of the muscle tissue is dictated by the evolution of the protein balance (NPB), which corresponds to the algebraic subtraction (NPB = MPS-MPB) between synthesis (MPS) and protein degradation (MPB) [3], [4]. A positive protein balance will result in muscular hy-pertrophy, whereas a negative protein balance results in muscular atrophy [1]. A close relationship be-tween muscular hypertrophy, the evolution of the protein balance and mTORC1 activity (complex 1 of the target of rapamycin for mammals) was demonstrated starting from 1999 [5].

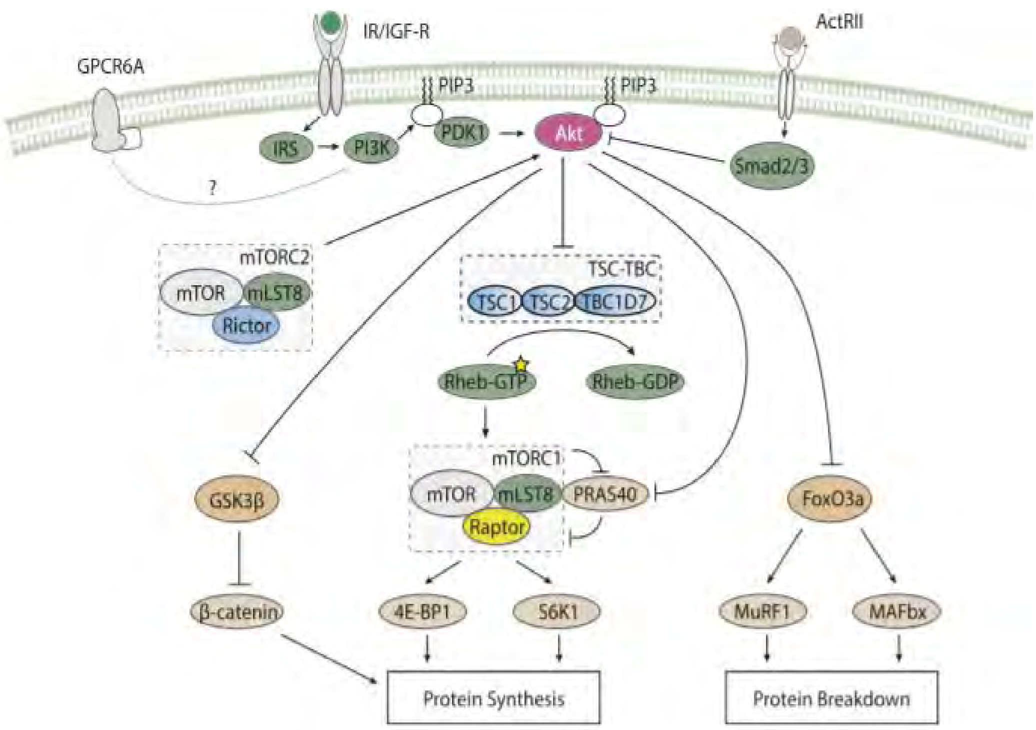


FIGURE 1: Regulation of mTOR by growth factors and associated signalling pathways. Bond, P. Regulation of mTORC1 by growth factors, energy status, amino acids and mechanical stimuli at a glance. J. Int. Soc. Sports Nutr. 13, (2016).

Since then, the knowledge of the signals that influence muscle hypertrophy has evolved considerably. We now know that mTOR is a conservative and evolutionary protein kinase capable of transmitting information from nutrients, growth factors and mechanical loading to drive protein synthesis and cell growth.
Its importance in regulating muscle mass is also demonstrated by the fact that its inhibition halts the increase in protein synthesis, blocking the hypertrophic response, while its over-regulation leads to an increase in muscle mass. The mTOR forms complexes, called mTORC1 and mTORC2, with other proteins which dictate its location, activity and targets. The first complex deals with the control of cell size. Its activation causes the phosphorylation of some substrates, the activation of its downstream ef-fectors, such as p70S6K. The latter is a ribosomal protein kinase involved in ribosome biogenesis, which causes the translation of mRNA into proteins, leading to the synthesis of new proteins and muscle mass [6].

In addition to mTOR there seem to be other pathways that regulate hypertrophy. Cells recognise and respond to cellular stimuli via different signalling cascades, including the MAPK protein kinase group (mitogen-activated protein kinase): this group is made up of sub-groups, which, with different ac-tions, regulate different cellular activities, from gene expression to differentiation and apoptosis [7], [8]. It appears that some MAPK subgroups are responsible for stimulating protein synthesis in a manner dependent or independent of mTOR stimulation, indicating their contribution in different stag-es leading to the stimulation of protein synthesis. These complexes are stimulated in response to cellu-lar stress, oxidative stress, cytokine release and growth factors [6], [9], [10]. So, as we will see, from a more metabolic than mechanical stress. Some of these complexes seem to be particularly sensitive to eccentric contractions [11].

The stimulation of these pathways appears to be provoked by different mechanisms: In 2010, Schoen-feld identified three main mechanisms that induce adaptations in hypertrophy, such as mechanical ten-sion, metabolic stress and muscle damage [9]. Indeed, by observing these three mechanisms and their role in the growth of muscle mass, it is possible to understand the relationship between the cellular mechanisms that occur within the muscle and the variables that determine training for the development of muscle mass, both in the short term, and in the long term. Knowledge of these mechanisms had ex-panded over the years.

This article represents a review of recent literature on the mechanisms that in-duce muscle mass growth, which will be further investigated in a later article.

MECHANICAL TENSION

The mechanism recognised as the main regulator of muscle mass is mechanical tension. This can simply be defined as the load distributed on the muscle. The basic idea is that the application of a cer-tain load on the muscle involves muscular hypertrophy, while the absence of load results in muscular atrophy [9], [10]. Skeletal muscle is a tissue born to respond to mechanical stimulation, in fact, there are mediators sensitive to mechanical stimulation. Mechanical tension begins with a phenomenon called mechanotransduction, where mechanical energy is converted into chemical signals that mediate anabolic and catabolic pathways with the aim of bringing the protein balance in favour of synthesis with respect to degradation [12]. It appears that the stimulation of mTOR given by the load occurs mainly due to two mechanisms. The first mechanism is similar to that of growth factors (IGF-1), while the second occurs thanks to the interaction with phosphatidic acid (PA). One of the substances capable of activating mTOR according to this process is phosphatidic acid (PA), a lipid messenger that plays a signalling role in various systems, whose activation influences the response of mTOR. PA is fundamental in the stimulation of mTOR deriving from the load [13] and is recognised as the main muscular mechanic transducer [10]. Another mechanism that performs the function of mechani-cal transduction is represented by FAK

(Focal Adhesion Kinase) in the FA complex, which are pro-teins associated to the cytoskeleton, responsible for the transduction of the mechanical stimulus in bio-logical processes [14]. These latter complexes were reputed to be able to stimulate hypertrophy through stimulation of the MAPK pathway [15]. It is very important to understand how to interpret the mechanical tension acting on the muscle. The latter could be measured in several ways: in the single repetition, in the entire workout or over weeks. In a later paper, we will try to answer these questions, using what research has recently tried to clarify.

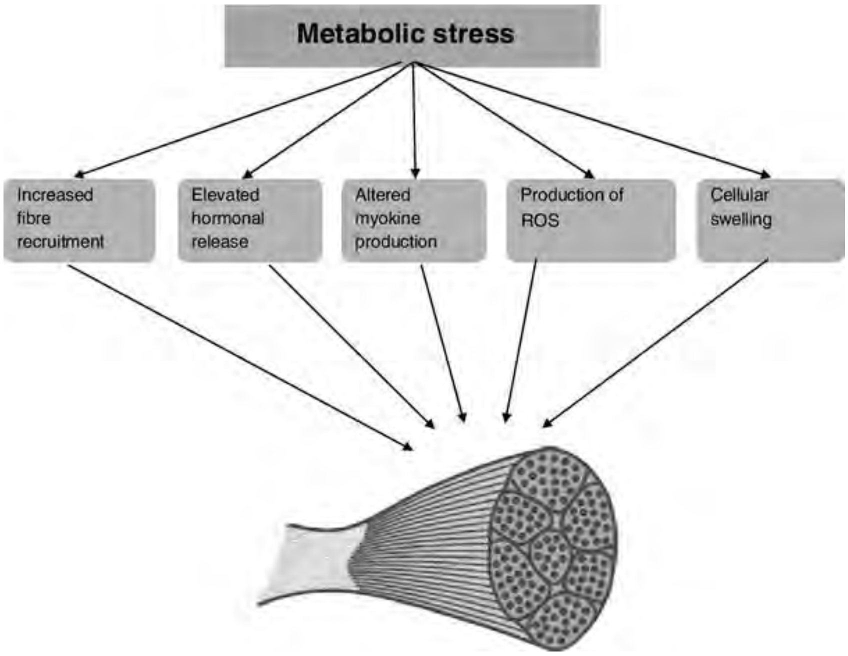


FIGURE 2: Events characterizing metabolic stress. B. J. Schoenfeld, 'The mechanisms of muscle hypertrophy and their application to resistance training', J. Strength Cond. Res., Vol. 24, no. 10, pp. 2857–2872, Oct. 2010.

METABOLIC STRESS

Metabolic stress is a physiological process that takes place during exercise, in response to conditions of the depletion of energy stocks. This process causes the accumulation of metabolites such as lactate, inorganic phosphate (Pi) and hydrogen ions (H +) in muscle cells. Metabolic stress has a significant impact on the hormonal release of cytokines, pro-inflammatory myokines and ROS (reactive oxygen species or free radicals), emphasising the establishment of phenomena such as hypoxia or cellular swelling [17].

Most of the components of metabolic stress are capable of stimulating the anatomical signals for the growth of muscle mass, mainly through the MAPK pathway, or are able, as in the case of hypoxia, to emphasise muscle recruitment and use of anaerobic metabolism [9].

Scientific evidence shows that the load, the number of repetitions, recovery between sets, the time un-der tension and failure, are important factors in inducing the accumulation of metabolites. In fact, a low recovery time between sets (<60s) and medium-high loads and repetitions (70% 1RM, 10 rep), cause a greater release of metabolites into the blood stream, compared to longer recoveries (> 60s) and higher loads and lower repetitions (4-6 rep, 85% 1RM) [16]. The fact that the accumulation of metab-olites leads to a marked stimulation of the MAPK path, has led to believe that this cascade is not de-pendent on the mechanical load. Consequently the hypertrophy, according to these protocols, can oc-cur due to metabolic sensors rather than mechanical ones.

In fact, many studies show that relatively low loads, especially if brought to failure or implementing methods such as BFR (blood flow restriction) training, where the application of an elastic obstructs the blood flow, or otherwise a slow and prolonged phase of muscle contraction in both the eccentric and concentric phase [29] causes the accumulation of metabolites), lead to a similar hypertrophy when compared to medium-high loads, despite the low mechanical tension [18].

Unfortunately, the studies that investigate the relationship between metabolites and muscle mass pro-vide information on the production of metabolites associated with the load, in other words, the me-chanical tension associated with metabolic stress but not the single role of metabolites in stimulating the growth of muscle mass. Recently, some researchers have succeeded in isolating the effect of me-tabolites on muscle mass growth. The authors compared the same training protocol in two groups. Subsequently to the protocol carried out, in one group they applied an obstructive elastic (BFR) in the trained muscle, so as to increase the accumulation of metabolites and maximise the metabolic stress in a single group, while maintaining the same mechanical tension. After 8 weeks, muscle mass was measured but no difference was found between the groups [20]. The same results are reported by oth-er evidence [19]. It therefore appears that the accumulation of metabolites alone, without muscle contraction and mechanical tension, has no additive effect in stimulating hypertrophy [17].

It would probably be more legitimate to think that the effect of metabolic stress is to be understood more as permissive and consequential to the contractions, rather than a cause of hypertrophy stimula-tion. It must also be noted that through their ability to increase muscle recruitment, even with low loads, or to stimulate hypertrophy through different routes, the accumulation of metabolites allows to reach hypertrophy without using high loads, with similar results, sacrificing time. This means that the use of protocols with the aim of stimulating metabolic stress could be very useful in conditions where the use of high loads is not possible or different adaptations are sought from those obtained with high loads, while wanting to maintain or emphasise the results in hypertrophy

MUSCLE DAMAGE

One of the first studies on exercise-induced muscle damage (EIMD) dates back to the early 1900s, when Houg described muscle damage as an injury resulting from lacerations and inflammations of muscle, connective or nervous tissue [21], [22]. Even after many studies on muscle damage, few have investigated its influence on the growth of muscle mass; only a little clarity has been made recently [23]. Exercise-induced muscle damage occurs after the execution of non-regular or unusual exercises, following eccentric contractions or excessive training volume. Its size is modulated by the type, vol-ume, intensity and duration of the exercise [24], [25]. The symptoms of EIMD are a reduced ability to generate strength, a reduction in the range of movement, DOMS (delayed onset muscle soreness) and an increase in physiological stress. Other effects subsequent to EIMD may be an increase in cell swelling, release of pro-inflammatory molecules and ROS [26], [27].

There are several theories according to which EIMD would lead to an increase in muscle mass, both in the technical field and that of research.

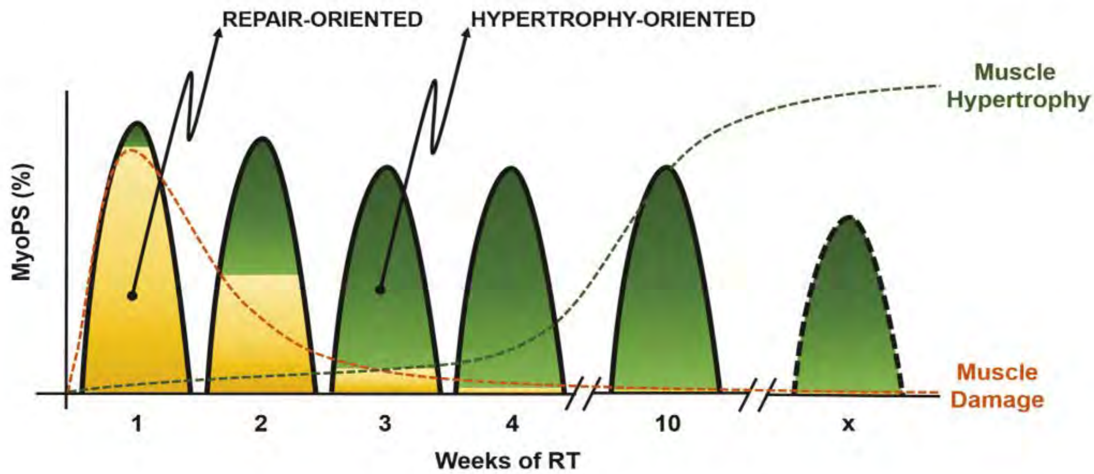


FIGURE 3: Trends in protein synthesis, muscle damage and muscle mass in 10 weeks of training. F. Damas et al., 'Resistance training induced changes in integrated myofibrillar protein synthesis are related to hypertrophy only after attenuation of muscle damage', J. Physiol., Vol. 594, no. 18, pp. 5209–5222, Sep. 2016.

The common belief is that, by increasing the lacerations of muscle fibres, inflammation and cellular stress, the body implements an adaptive and super-compensatory response, not only returning the muscle tissue to previous conditions, but increasing it further. In 2016, Damas et al. investigated the relationship between muscle damage, protein synthesis and hypertrophy in several weeks of training. During the study, muscle biopsies were taken to detect muscle damage and hypertrophy. The study was conducted on untrained subjects, in order to elicit obvious muscle damage and assess its progression over time, in relation to muscle mass and protein synthesis. In the first weeks, the researchers saw a noticeable increase in protein synthesis, which co-incided with the highest levels of EIMD. A correlation between protein synthesis and muscle damage was found, indicating its marked effect in stimulating protein synthesis.

Unfortunately, this increase in protein synthesis in the first few weeks did not seem to coincide with increases in muscle mass, showing no correlation between the two variables. This is because our body is able to direct protein synthesis where it is needed. In this case, the increased protein synthesis elicit-ed by muscle damage was directed to the waxed muscle fibres, with the aim of repairing them and not further increasing their mass. In fact, in conjunction with the decrease in muscle damage in the fol-low-ing weeks, a direct correlation between protein synthesis and growth of muscle mass can be seen, which indicates the direction of protein synthesis for the growth of muscle tissue [27]. Another study demonstrates that, if muscle damage is provoked in the same training protocol, this does not lead to advantages in increasing muscle mass [28].

The evidence we have today shows us that muscle damage has no influence on muscle mass growth but may be necessary to support future adaptations. In fact, it could be required to prepare the remod-elling of the muscle and its architecture to withstand subsequent training sessions, which could trans-late into better workouts and gains in muscle mass [23].

LOAD INTENSITY AND TRAINING VOLUME

In the previous parts, we talked about the importance of interpreting the load that is distributed on the muscle. For example, we can interpret mechanical tension as the amount of load imposed on the muscle during a repetition (load intensity), or the total load used during the entire training session or in the various training sessions (training volume).

Given the importance of mechanical tension in hypertrophy, medium-high loads (> 70% 1RM) are usually recommended to maximize adaptations. These recommendations are based on the belief that medium-high loads are necessary to recruit high-threshold fibres, previously believed to be primarily responsible for maximizing muscle adaptations in hypertrophy [30]. In fact, lower loads (<50% 1RM) usually give on average lower electromyographic signals (EMG) [31]. This could lead to the supposition that there is an advantage in the use of medium-high loads in stimulating muscle growth, given the greater muscle activation and muscle recruitment estimated by EMG.

Very often, the variables that we wish to extrapolate from EMG are used as a surrogate to extrapolate a possible causal link with the results in strength and hypertrophy. Sometimes, however, these conclusions may be unfounded and unmotivated, mainly because of the complicated nature of EMGs and the lack of longitudinal studies that provide a causative relationship.

The evidence available so far indicates that, failing to estimate the contribution of passive mechanisms, the type of recruitment or peripheral influences [32], electromyographic traces can give us certain results only in terms of muscle arousal, not to be confused with muscle recruitment [33]. For instance, it appears that with the use of light loads there is a temporary recruitment and de-recruitment of muscle fibres to maintain the same production of strength over time, altering the EMG results [34]. We could, perhaps, draw some conclusions, but they should be applied with caution.

To understand if the load intensity and therefore also the EMG signals deriving from it affect hypertrophy, in 2017 Schoenfeld et al. performed a meta-analysis to identify the differences in strength and hypertrophy between low (<60% 1RM, > 15RM) and high loads (> 60% 1RM, <15RM), in protocols performed to muscle failure [5]. 21 studies were identified, with quality ranging from good to excellent (5.6 PEDro scale), of which 10 measured hypertrophy.

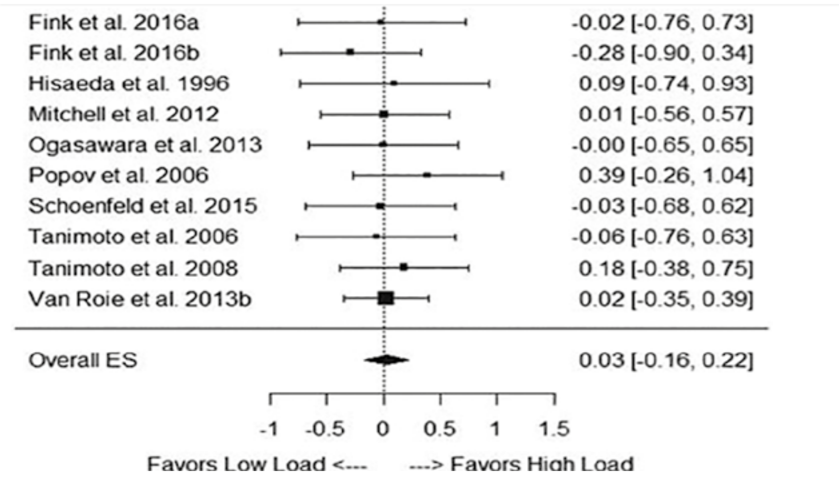


FIGURE 4: Effect Size tra tutti gli studi esaminati in massa muscolare tra alti e bassi carichi. B. J. Schoenfeld, J. Grgic, D. Ogborn, and J. W. Krieger, 'Strength and Hypertrophy Adaptations Between Low- vs. High-Load Resistance Training: A Systematic Review and Meta-analysis', J. Strength Cond. Res., vol. 31, no. 12, pp. 3508–3523, Dec. 2017

The studies analyzed showed similar hypertrophy results between different load intensities, with greater increases in strength for heavy loads, as could be expected. It should be said that most of the included studies were done on untrained subjects, but the same results were replicated also in well trained subjects [35].

Therefore, it appears that it is possible to achieve similar hypertrophy with different load intensities and different EMG signals. The intensity of the load is probably not the main predictor of hypertrophy, but up to a certain point. In fact, it seems that excessively low loads (<20% 1RM) are not capable of leading to the same hypertrophy as heavier loads (> 40% 1RM), even if at equal volume, demonstrating a minimum load intensity limit to be used in training directed to the growth of muscle mass [36]. [An interesting note by the authors of this paper, which, in our opinion, goes precisely in the direction of a fundamental principle to be observed in proposing physical workloads: before choosing the minimum volume deemed effective, it is always essential to choose the minimum work intensity. This applies both to the sprinter and the marathon runner! Astute readers will understand its strategic significance.]

In most cases, the variable in common between the protocols examined is the training volume. When the latter is equated between two protocols, we usually observe similar results in the growth of muscle mass, regardless of the other variables, especially in protocols performed to failure [35], [37]. The training volume is commonly defined as the product between the sets, the repetitions and the load, or it can be simply estimated by the sets (6-20 rep) [38] and is to be calculated by muscle group and on a daily, weekly, monthly basis, and so on [39], [40].

This could lead us to speculate that mechanical tension should be understood as the total overload on the muscle in training sessions, rather than referring only to the load intensity. The most recent evidence indicates that the volume has a dose-dependent relationship with the stimulation of protein synthesis [41] and with the growth of muscle mass, in other words, an increase in the weekly volume corresponds to an increase in muscle mass over the course of several weeks of training [42], [43].

This relationship, however, seems to have a certain limit, beyond which, greater increases in volume do not create greater increases in muscle mass [39], [43]. This can be explained by a study that over 6 weeks, 2 times a week, compared a 5x10 and a 10x10 (German Volume Training) with the same load, noting that the first group achieved greater gains in strength and hypertrophy than the second, despite having performed with roughly half the volume [44]. The probable cause of this relationship is thought to be due to the excessive fatigue accumulated by an excessive training volume. An increased risk of injury is also to be taken into consideration.

Theoretically we think of the existence of an optimal volume to maximize results, which could vary from subject to subject and also in the same subject, for example between the various stages of training or between the various muscle groups [61]. For the moment, it would appear that a good starting volume is 10 weekly sets per muscle group, but this number is really to be taken with a pinch of salt given the different volumes needed for different states of training, population and other characteristics described above [54]. The volume also appears to have a dose-dependent relationship with health [39].

Having reached the conclusion that training volume is the main variable of training that influences the growth of muscle mass, all strategies that lead to an increase in volume over time, in the right dose, are to be implemented in a programme aimed at the growth of muscle tissue.

Beyond this, it must be said that the volume of training performed must be carried out at a certain perceived effort, which does not necessarily have to be to failure [31], but close to it (> 7 RPE [38]), and where the execution of the exercises it is carried out at a certain range of movement (ROM), time under tension (TUT) and execution technique. For example, exercises performed with a large ROM cause greater increases in strength and muscle mass than the same protocol, at a lower ROM but with almost double the load [45] - [48]. It would most likely be appropriate to understand ROM as an integral part of the training volume, representing the extent of the load distribution over the muscle length. Furthermore, the methods that include the use of medium-high loads and medium repetitions, for example 6-12 repetitions at 60-70% 1RM, would represent a more efficient way to accumulate volume at a certain intensity of effort, simultaneously leading to a greater stimulation of muscle strength.

TYPES OF CONTRACTION

The regulation of muscle tissue could also be influenced by the type of contraction. We can distinguish two types of mechanical tension, one active, given by muscle contraction (concentric phase) and one passive, characterized by a state of muscle elongation, where eccentric contraction reflects both, as the muscle is elongated and in partial contraction [49].

It is a common belief that eccentric contraction causes greater hypertrophy than concentric contraction. For example, some researchers [50] have recently compared the two muscle contractions observing a greater stimulation of FAK in eccentric contractions and a greater stimulation of the MAPK pathway [51]. Furthermore, eccentric contraction is capable of causing major muscle damage [52].

The most recent meta-analysis available [53] sought to investigate the differences in muscle mass growth only between the concentric and eccentric contractions on 15 studies, with a minimum duration of 6 weeks and where the included measurements were the most precise that we now have.

The result was a slight ES (effect size) of advantage of the eccentric contractions compared to the concentric ones in the stimulation of hypertrophy, which did not reach statistical significance Unfortunately, or fortunately, in eccentric contraction it is possible to develop a force greater than 20-50% compared to concentric contraction and in most studies, the repetitions performed were equated, without taking into account the load. Most likely, the load raised in the eccentric phases was greater, leading to slightly advantageous results in the growth of muscle mass due to the greater training volume.

The previously cited studies of Franchi et al. [50], [51], [54] sought to investigate the difference in protein synthesis, muscle mass, FAK, MAPK and muscle architecture between the two types of contraction after several weeks of training. At the end of the protocols, no differences were identified between the methods of contraction on the growth of muscle mass or on the stimulation of protein synthesis, even if the load used in the eccentric contractions was 1.2 times that of the concentric ones.

However, there are several interesting things to extrapolate from the studies. It appears that eccentric contraction has been able to increase muscle mass in several points compared to concentric contraction. This is also explained by a marked elevation of FAK (4 times) in the distal sites of the muscle under consideration. This process is called regional hypertrophy, which is a different increase in muscle mass in various points of the muscle. In addition to this, eccentric contraction has further increased the length of the muscle fascicles, while concentric contraction has shown a greater increase in the pennation angle of the muscle.

This does not indicate an advantage given by eccentric contractions in the stimulation of muscle mass, but indicates the need to integrate both contractions in the right dose and work at different angles of movement to stimulate muscle growth throughout the stomach.

THE HORMONAL HYPOTHESIS

Hormonal release is also a potential influencing mechanism on hypertrophy, considered crucial by many coaches to induce the growth of muscle mass, leading to careful research towards training protocols that have an emphasis on acute hormonal release. In fact, the endocrine system plays a massive role in regulating muscle mass. Hormones such as testosterone, GH, insulin, IGF-1 (insulin-like growth factor) and cortisol have indeed a marked influence on the growth of muscle tissue [55]. For example, GH is capable of stimulating IGF-1, especially in MGF form, potentially increasing the stimulation of mTOR and the hypertrophic response induced by training [56].

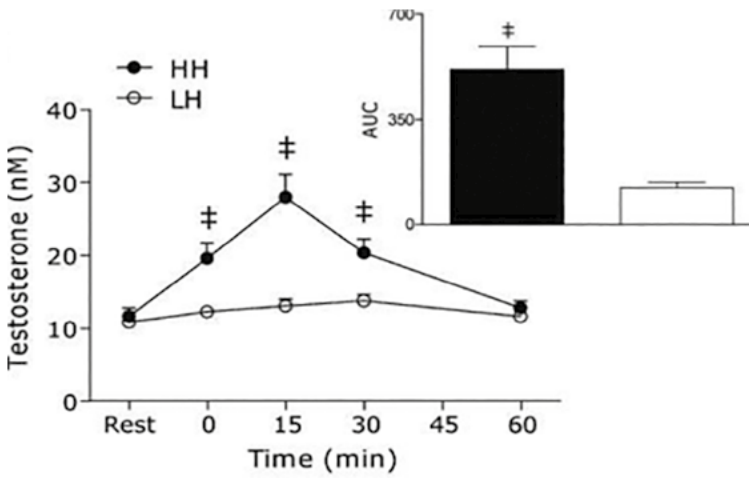


FIGURE 5: Variations in Testosterone between the two protocols indicated as low hormone (LH) and high hormone (HH). D. W. D. West et al., 'Resistance exercise-induced increases in putative anabolic hormones do not enhance muscle protein synthesis or intracellular signalling in young men', J. Physiol., vol. 587, no. Pt 21, pp. 5239–5247, Nov. 2009

In addition, the direct relationship of testosterone with hypertrophy is by now established, having a dose-dependent relationship with it, especially as regards exogenous administration. Testosterone also appears to have a dose-dependent relationship with the stimulation of satellite cells and therefore of myonuclei, both believed to be the main cause of differences in muscle mass gains among subjects [65]. In fact, several studies give a positive correlation between post-exercise increases of GH and testosterone with the increase in muscle mass [55], [57].

The reduction in recovery times, the increase in training volume and the stimulation of large muscle masses seem to vary the acute hormonal response, potentially explaining an advantage in the hormonal response of protocols that include these characteristics [55], [58] - [60]. West et al. tried to test the idea of acute hormonal elevation caused by the stimulation of large muscle masses by measuring the protein synthesis response between two training protocols for the biceps, where one group performed a similar protocol also for the lower limbs, with the aim to increase the acute hormonal response as much as possible. In the experimental group, the involvement of the muscles of the lower limbs led to significant increases in the release of lactate, GH, IGF-1 and testosterone compared to the other group.

The response in protein synthesis (both myofibrillary and mixed) did not seem to differ between the two protocols [59], the same group of researchers reproduced the same experiment by measuring the growth of muscle mass after 15 weeks, noting any differences between the two protocols [61]. It appears that the higher acute hormonal elevations in response to certain types of protocols are simply not so high as to replicate the exogenous dosages and consequently incapable of inducing short and long term advantages in stimulating protein synthesis and mass muscle.

REST TIMES

Very often we ask ourselves what is the optimal recovery time between one set and another. In gyms, individuals rest about 1 minute or as little as possible, the aim being to stimulate a further increase in muscle mass or "weight loss", it is thought due to the greater hormonal elevations or accumulation of metabolites. In fact, there seems to be a close relationship between the reduction of rest times, a greater hormonal release and the accumulation of metabolites. To further see if acute hormonal elevations or the accumulation of metabolites influence the hypertrophic response, we will be able to observe the difference between low or high recovery time protocols.

Recently, the difference in muscle mass gains between two protocols with equal volume was examined, but where rest times differed from 1 to 3 minutes, in trained subjects. At the end of the study duration (8 weeks), greater gains in mass and muscle strength were found in favour of the group that trained with longer rest times [62].

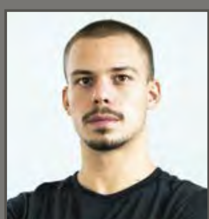
In addition, two recent meta-analyzes achieved the same results, showing higher increases in muscle mass in protocols with longer rest times (> 60s) than in the short ones (<60s) [63], [64]. Therefore, even if with short rest times we have a greater acute hormonal response, especially for GH, these acute hormonal variations do not seem to lead to advantages in stimulating hypertrophy [58], [60], [65]. The advantage of implementing longer rest times between the sets is given by the ability to increase the re-synthesis of energy supplies and reduce the fatigue accumulated in the previous sets, allowing the execution of a greater volume of load in the training session. Considering the relationship between the training volume and the growth of muscle mass, it is necessary to give priority to this variable when developing a programme with the aim of developing hypertrophy.

CONCLUSION

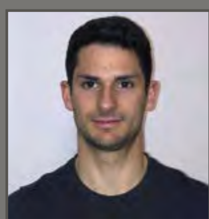
With a brief analysis of only some of the aspects that can affect muscle growth, it seems clear that everything that includes specific training goes well beyond the simplifications sometimes abused in this field. If you want to maximize the hypertrophic stimulus, it requires a different method of approach to the problem rather than the simple prescription of an exercise or a training volume.

Therefore, a working method that can integrate and manage training variables over time is necessary in order to obtain a complete training stimulus that includes the right doses of mechanical tension, metabolic stress and muscle damage. It is necessary to plan and periodize the training aimed at hypertrophy, with the clearest vision on how every aspect of training can affect the main variables of hypertrophic development.

Carlo Menghini



Luca Riva



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Spanish resumenes

NATURALEZA O EDUCACIÓN: VARIACIONES EN LA TÉCNICA DE LEVANTAMIENTO DE PESAS SEGÚN EL GÉNERO.
Andrew Charniga
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 4-13
El autor aborda la temática de las variaciones en la técnica de levantamiento de pesas según el género. Una cuestión importante de la ciencia deportiva del levantamiento de pesas es la posible existencia de diferencias en la técnica según el género derivadas de las diferencias fisiológicas y biomecánicas entre los sexos. En caso de que existan estas diferencias, ¿debería el entrenador enseñar a la atleta a adoptar las medidas necesarias o por el contrario a eliminarlas con el objetivo, por ejemplo, de adaptarse al pensamiento actual de la técnica correcta?

LA POSTURA. ALGUNOS ASPECTOS IMPORTANTES.
Antonio Urso
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 14-23
Se trata de una revisión del significado y de los mecanismos que regulan la postura del ser humano, de los aspectos morfofuncionales que esta conlleva y del sistema neuromuscular comprometido. Un párrafo sumamente interesante es el dedicado por el autor a las vías ascendentes de la sensibilidad periférica.

FRONTERAS DE LOS CONOCIMIENTOS. CONCEPTOS DE MECANOBIOLOGÍA APLICADOS AL ENTRENAMIENTO DE LA FUERZA (SEGUNDA PARTE).
Donato Formicola
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 24-39
Los ejercicios con sobrecargas estimulan un proceso de adaptación anatómica que afecta a la totalidad del organismo humano. A través de una compleja red de interconexiones, los esfuerzos mecánicos que sufren los tejidos por la práctica del entrenamiento, llegan a las células musculares y las inducen a modificar su conjunto molecular para producir unas contracciones cada vez más fuertes y rápidas. Todos los deportistas, con independencia del tipo de deporte, intentan aumentar la fuerza y la velocidad de contracción de los músculos.

El estudio de programas de entrenamiento destinados al aumento de estos dos parámetros biomecánicos fundamentales significa, para los técnicos deportivos, los fisioterapeutas, los preparadores atléticos y los físicos, saber elegir qué ejercicios inducen, en el organismo de sus atletas, alumnos y clientes, unas respuestas mecanobiológicas concretas. En este artículo se analizarán las características arquitectónicas de las células musculares que influyen en su producción de fuerza y velocidad. Además, con la exposición de los resultados de las últimas investigaciones científicas, se utilizarán los principios de la mecanobiología para describir los cambios morfológicos de las estructuras contráctiles y conectivas de los músculos cuando estos se ven implicados en ejercicios para el desarrollo de la fuerza. Por último se examinarán las fases de un programa anual de entrenamiento con las sobrecargas y se procederá a su definición en términos biomecánicos y mecanobiológicos. Los primeros, para identificar los efectos que el plan de entrenamiento a largo plazo debe ejercer en el rendimiento deportivo. Los segundos, para determinar los procesos de remodelación morfológica que se producen en el cuerpo de un atleta durante la práctica del entrenamiento.
Saber elegir correctamente los ejercicios y los métodos que deben utilizarse en una programación concreta de alta competición, exige conocer los efectos que estos producen en las respuestas de adaptación de los músculos. El estudio de la mecanobiología puede ayudar a resolver esta elección.

DMAT. DOLOR MUSCULAR DE APARICIÓN TARDÍA. SIGNIFICADO Y CLASIFICACIÓN.
Michele Castellano Vitaterna
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 40-55
El autor define el significado del DMAT y clasifica dicha manifestación desde el punto de vista de la etiología y desde el punto de vista de sus manifestaciones y de su evolución natural.
Aborda el tema de las estrategias de gestión del DMAT, subdivididas en motoras, físicas y químicas, a las que pasa revista y de las cuales describe los beneficios y las ventajas, así como en caso de que se produzca, su inutilidad; asimismo, intenta aclarar muchos posibles equívocos y reconoce en el recurso a medios de entrenamiento basados sobre todo en contracciones excéntricas, una de las posibles causas principales del DMAT.

RESPUESTAS DEL SISTEMA NERVIOSO AUTÓNOMO AL ENTRENAMIENTO DE FUERZA EN LEVANTADORES DE PESAS DE ALTO NIVEL .
Ferdinando Iellamo , Daniela Lucini, Maurizio Volterrani, Maurizio Casasco, Annamaria Salvati, Antonio Gianfelici, Alessia Di Gianfrancesco, Antonio Urso & Vincenzo Manzi
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 56-65
En los atletas, el análisis espectral de la variabilidad de la frecuencia cardíaca (VFC) ha demostrado su capacidad para detectar cambios adaptativos en el control simpático-vagal durante el entrenamiento físico. Hasta ahora, los estudios investigaban los cambios que se producían en el sistema nervioso autónomo (SNA) con el entrenamiento de resistencia, mientras que las adaptaciones a unas modalidades de ejercicio marcadamente distintas como, por ejemplo, el entrenamiento de fuerza, no habían sido nunca investigadas. Evaluamos los cambios en los parámetros cardiacos del SNA durante el entrenamiento a largo plazo en los levantadores de pesas del equipo italiano durante la fase de preparación para el Campeonato de Europa, en el que los atletas competían para obtener el pase a los Juegos Olímpicos. Estudiamos a nueve atletas que entrenaban 3 sesiones al día, 6 días a la semana. La intensidad de los ejercicios de fuerza experimentaba una variación del 70 % al 95 % 1 RM. La carga de entrenamiento (TL) se calculó como sigue: intensidad 9 volumen (mín) (%1RM). Todos los parámetros del SNA estuvieron considerable y altamente correlacionados a nivel individual con la dosis de ejercicio con un modelo de regresión de segundo orden (r^2 entre 0,96 y 0,99; $P < 0,001$). El componente de baja frecuencia (LF) de la VFC y la relación LF/HF mostraron un aumento inicial con la progresión de la TL y posteriormente un descenso, al estilo de una curva acampanada con un mínimo a la TL más elevada. El componente de alta frecuencia (HF) de la VFC y el intervalo R-R mostraron un patrón recíproco, con un descenso inicial con la progresión de la TL seguido de un aumento, al estilo de una curva en forma de U con un máximo a la TL más elevada. Estas adaptaciones se revelaron contrapuestas a las observadas anteriormente en los atletas de resistencia. Estos resultados sugieren que en los levantadores de pesas olímpicos, las adaptaciones del SNA al entrenamiento están relacionadas con la dosis individual y que las adaptaciones del SNA dependen principalmente del tipo de deporte.

LOS MECANISMOS QUE REGULAN LA HIPERTROFIA MUSCULAR.
Carlo Menghini, Luca Riva, Mauro Rocca
SM (ing), nº 14, año V, septiembre-diciembre 2019, págs. 66-78
Los autores han analizado la teoría de los tres mecanismos que inducen el desarrollo de la masa muscular teniendo en cuenta el papel sumamente importante de la tensión mecánica en la estimulación de la masa muscular, la cual representa la base para inducir las adaptaciones deseadas por los atletas, e investigan en profundidad dichos mecanismos estudiados mediante el examen de algunas de las variables del entrenamiento que las caracterizan, entre otras, la influencia de las hormonas en el crecimiento del tejido muscular.

Russian resumenes

ПРИРОДА ИЛИ ВОСПИТАНИЕ: ГЕНДЕРНЫЕ ВАРИАЦИИ (РАЗЛИЧИЯ) В ТЕХНИКЕ ТЯЖЕЛОЙ АТЛЕТИКИ

Andrew Charniga

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 4-13

Автор рассматриват проблематику гендерных вариаций в технике тяжёлой атлетики. Важная проблема этого вида спорта заключается в том существуют ли гендерные различия в технике, связанные с физиологическими и биомеханическими различиями между полами. Если такие различия существуют, должен ли тренер научить спортсменок их устранить для того чтобы соответствовать настоящему представлению о правильной технике.

ОСАНКА. НЕКОТОРЫЕ ВАЖНЫЕ АСПЕКТЫ

Antonio Urso

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 14-23

Статья представляет собой обзор посвящённый значению и механизмам регулирующим осанку человека, морфологическим аспектам лежащим в её основе и задействованной нервно-мышечной системе. Очень интересный параграф посвящён Автором восходящим путям переферической чуствительности.

ГРАНИЦЫ ЗНАНИЙ: ПОНЯТИЯ «МЕХАНОБИОЛОГИИ», ПРИМЕНЯЕМЫЕ К СИЛОВОЙ ТРЕНИРОВКЕ. ВТОРАЯ ЧАСТЬ.

Donato Formicola

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 24-39

Упражнения с отягощениями стимулируют анатомический процесс адаптации затрагивающий весь организм человека. Механические напряжения, вызванные тренировкой в мышечных тканях, достигают через сложную сеть взаимосвязей мышечные клетки и «заставляют» их модифицировать свой молекулярный состав, провоцируя всё более сильные и быстрые сокращения. Спортсмены всех видов спорта стараются повысить силу и скорость мышечных сокращений. Изучение тренировочных программ направленных на совершенствование этих двух основных биомеханических параметров означает для сропртивных тренеров, для работников фитнеса, для тренероа по физической и атлетической подготовке, уметь выбирать упражнения которые приводят к специфическим механическим и биологическим реакциям организма спортсменов, учеников и клиентов. В данной статье анализируются «архитектурные» характеристики мышечных клеток которые влияют на производство силы и скорости. Кроме того, представляя результаты самых свременных исследований, используются принципы механобиологии для описания морфологических изменений сократительных и соединительных структур мышц участвующих в выполнении упражнений направленных на развитие силы. Наконец, в статье анализируются фазы годовой тренировки с отягощениями, определяя их с биомеханической и механобиологической точки зрения. С биомеханической точки зрения: для определения эффекта продолжительной тренировки на спортивную производительность. С механобиологической точки зрения: для выявления какие процессы морфологического ремоделирования происходят в организме спортсмена во время тренировки.

Умение правильно выбрать упражнения и методы для реализации конкретной соревновательной программы предусматривает знание их влияния на адаптационые реакции мышц. Изучение механобиологии может помочь зделать правильный выбор.

ДОМС (DOMS, DELAYED ONSET MUSCLE SORENESS). СИНДРОМ ОТСРОЧЕННОЙ МЫШЕЧНОЙ БОЛИ. ЗНАЧЕНИЕ И ХАРАКТЕРИСТИКА. ПЕРВАЯ ЧАСТЬ

Michele Castellano Vitaterna

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 40-55

Автор определяет значение понятия ДОМС (DOMS) и определяет это явление как с точки зрения этиологии так и со стороны манифестаций и естественной эволюции этого явления. Автор рассматривает тему стратегий контролирования явления ДОМС, подразделяя их на двигательные, физические и химические, анализируя их положительный эффект и преимущества, а так же, при необходимости, бесполезность; старается освободить исследования в этой области от возможных недоразумений и признаёт то что одна из основных возможных причин ДОМС заключяется в использовании в тренировке средств базирующихся прежде всего на эксцентрических сокращениях.

РЕАКЦИЯ АВТОНОМНОЙ НЕРВНОЙ СИСТЕМЫ НА ТРЕНИРОВКУ СИЛЫ У ТЯЖЁЛОАТЛЕТОВ ОЧЕНЬ ВЫСОКОГО УРОВНЯ

Ferdinando Iellamo , Daniela Lucini, Maurizio Volterrani, Maurizio Casasco, Annamaria Salvati, Antonio Gianfelici, Alessia Di Gianfrancesco, Antonio Urso & Vincenzo Manzi

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 56-65

Спектральный анализ изменчивости (вариабильности) сердечного ритма, HR (HRV) может показать что у спортсменов при физичекой тренировке присходят адаптационные изменения в симпато-вагальном контроле. До настоящего времени исследования были направлены на изучение изменений автономной нервной системы (ANS) вызванные тренировкой на выносливость, тогда как адаптация на другие методы тренировки, как например, на силовую тренировку, никогда не исследовались. Авторы оценили изменения параметров анатомии нервной системы вызванные продолжительной тренировкой у тяжёлоатлетов итальянской команды во время подготовки к Чемпионату Европы, результаты участия в котором были важны для получения права участвовать в Олимпийских играх. В исследовании участвовало девять спортсменов. Спортсмены проводили три тренировки в день шесть раз в неделю. Интенсивность силовых упражнений варьировалась от 70% до 95% от 1RM. Тренировочная нагрузка (TL) расчитывалась таким образом: объём (минуты), 9 интенсивность от 1RM. Все параметры ANS были значительно и высоко связаны, на индивидуальной основе, с дозой упражнений согласно модели регрессии второго порядка (r2 варьировался от 0.96 до 0.99; $P < 0.001$). Низкочастотный компонент (LF) HRV и отношение LF/ HF показал первоначальное увеличение с прогрессией TL а затем уменьшение напоминающее «колоколобразную» кривую с минимумом при самом высоком значении TL. Высокочастотный компонент (HF) HRV и интервал R-R показал картину с начальным снижением и потом с прогрессией TL с последующим увеличением напоминающим U-образную кривую с максимумом при самом высоком значении TL. Этот тип адаптации был противоположным тому который ранее наблюдался при тренировке на выносливость. Данные результаты показывают что у тяжёлоатлетов олимпийского уровня адаптация ANS зависит от дозы упражнений на индивидуальной основе и главным образом от специфики спорта.

МЕХАНИЗМЫ РЕГУЛИРУЮЩИЕ МЫШЕЧНУЮ ГИПЕРТРОФИЮ

Carlo Menghini, Luca Riva, Mauro Rocca

SM (Eng), nº 14, anno V, settembre-dicembre 2019, pp . 66-78

Авторы анализируют теорию трёх механизмов приводящих к развитию мышечной массы, подчёркивая особенно важную роль которую играет механическое напряжение для стимуляции мышечной массы представляющую основу для развития адаптации к которой стремяться спортсмены и глубоко исследуя изученные вышеупомянутые механизмы, анализируя некоторые «переменные» тренировки характеризующие, среди прочего, влияние гормонов на рост мышечной ткани.

ELEIKO
RAISE THE BAR