USE OF THE FLEXTENSOR FOR PREVENTION, TRAINING AND REHABILITATION OF ATHLETES

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• INTRODUCTION: ELASTODYNAMIC WORK

Elastic resistance has certain features which distinguish it from all other types of resistance. In elastic systems, resistance is expressed by Hooke's law:

F=Kx, where the necessary force (***F***) is directly proportional to the product of the spring constant (***K***), which is a feature peculiar to the elastic, and the displacement of the spring's end from its equilibrium position (***x***). In other words, as the elastic is lengthened, the resistance increases linearly.

Therefore, in strengthening exercises with elastics, the maximum intensity of the load is equal to the final tension of the elastics themselves. This means that the “dosage” of the load in relation to the patient's articular capacity occurs automatically. In this respect, elastic load can be described as an effectively “accommodating” load.

Another way of looking at Hooke's law shows that exercise against elastic resistance occurs with linear load progression, so there is neither inertia to overcome when beginning, nor are there abrupt variations in the force following changes of the biomechanical levers' advantage.

Exercising without inertia from the load, as can easily be realized, means being able to develop higher execution speed and faster acceleration. This favors pliometric work and the always desirable capacity to exert a force in the shortest time possible.

These simple observations convince us of the effectiveness and utility of work with elastics, which tends to favor a modern approach to rehabilitation and training, based not only on strength and resistance but also – and especially – on coordination and neuromuscular control.

- **THE FLEXTENSOR**

The Flextensor is a thoroughly innovative tool designed to re-educate and train the lower limbs. It allows stimulation of muscles through strengthening analytical exercises which involve both the quadriceps femoris and the knee flexor muscles.

This device's innovative approach is linked to the use of elastic resistance which, as above-mentioned, differs from all other types of resistance.

This device has proven itself to be extremely useful as an aid both to therapists for re-education of lower limb traumas and to trainers for preparation programs.

The Flextensor, a device that can be easily used, offers many original features compared to traditional gym machines.

1. Smoother movements, thanks to the particular resistance offered by elastics which grows gradually as tension increases.

2. Excellent modulation of work loads, as tension is increased or reduced and elastics are added or removed.

3. Offers the chance to perform exercises with high angular speed.

This device allows eccentric and concentric exercises to be performed at speed, as well as isometric exercises, and above all it offers the possibility to reproduce functional movement like the alternate flexion and extension of the knee without constraints while still providing resistance in the same way that isokinetic machines do.

By suitably removing elastics, it is possible to choose to work selectively on flexion or tension.

In re-education and strengthening work with elastic resistance, the muscular groups working against the resistance are stimulated differently than they would be with traditional isotonic or isokinetic machines.

Basically, work with elastic resistance is unique because of the linear increase of resistance as tension in the elastic grows. This makes the Flextensor a device which completes the array of machines we have at our disposal without intending to replace them.

- **MODES OF OPERATION**

Operational Configurations

The device is designed to work on flexion and extension knee muscles in both legs at the same time.

The device may be set-up in one of two modes which create different types of elastic load and, by adding or removing elastics, greater or smaller loads.

a) Basic configuration. Only the frontal horizontal brace is fixed: it is connected to the frame and locked into place by tightening the knobs. The front elastics (55 cm in length) hook right in to the brace. The rear elastics (90 cm in length) hook on behind the back rest and pass through the two rollers under the seat.

Figure 1 – Flextensor's basic configuration

b) Complete configuration. A vertical brace with two rollers is added to the basic configuration and fixed using the screws supplied with the machine. The front elastics pass through the two above-mentioned rollers.

Figure 2 – Flextensor's complete configuration (with Upperflex)

Considering that the movements of greatest interest occur between the leg's stretch position and a femur-tibia angle of 90°, in the device's basic configuration the elastic load proves to be mainly concentric in extension and eccentric in flexion, while in its complete configuration concentric load is obtained also during flexion.

Resistance can also be increased or reduced by changing the number elastics.

Using both shoes and their elastic kits, it is possible to work with both lower limbs together, thanks to the double rollers which ensure that extension and flexion of the two limbs can occur at the same time.

In order to reduce the space taken up by the device when not in use, the frontal horizontal brace can be inserted behind the seat and locked onto the frame using the knobs, while the very narrow vertical brace may simply be leant against a wall.

Figure 3 – Flextensor's “extension” configuration

How to Position the Patient

- Let the patient sit down and make themselves comfortable, so that the popliteal fossa is resting firmly against the chair. The backrest may be adjusted to facilitate this; loosening the knobs allows the backrest to slide freely so that, once in the correct position, it can be locked into position again by tightening them.
- Fix the patient's thighs into place using the strap.
- Adjust the number of elastics for the flexors and quadriceps.
- Fix the patient's feet securely in the shoes.
- While exercising, the patient should keep their hands on the handles, their back straight and the abdominal muscles contracted in order to level out any lumbar lordosis and limit any kind of offset movements. When exercising intensely, if deemed necessary, the Velcro strap supplied with the device may be used to fix the patient's upper body to the backrest and give them extra support.

• THE FLEXTENSOR IN REHABILITATION

The Flextensor has proven itself a valid therapeutic aid for physiotherapists. It can be used starting from the very first rehabilitative stages to accompany the patient right up to their return to daily life.

This machine allows very easy switching from light loads with low joint impact, crucial in the first stages of rehabilitation, to heavy loads and high angular speed work, necessary in the final stages to ensure a full recovery.

Exercise Modes

Isometric Mode

When tackling the very first stage of muscle toning, a physiotherapist may choose from a wide range of exercises based on isometric contractions of one or more muscle groups. They can choose to opt for exercise requiring synergistic recruitment of agonist and antagonist muscles or of several agonist muscles in relation to a certain movement. The Flextensor is thus part of a group of therapeutic aids, and if used in isometric mode it can efficiently stimulate the flexion and extension knee muscles without running the risk of overloading and/or damaging the above-mentioned muscles, least of all the joint itself.

As mentioned earlier, the Flextensor offers resistance which increases linearly as the elastic is lengthened, without having to overcome any initial inertia. This, added to the possibility of changing the load from one to four elastics, offers patients the chance to perform work which is well tolerated and balanced in relation to their abilities and to observe any constraints in the active range of motion (ROM). Such constraints are typical in the first stage of rehabilitation, especially following surgery on the ligaments.

The device's basic configuration should be favored when the operator chooses to concentrate muscle toning work on the quadriceps femoris muscle.

Ideal progression goes from 10 up to 30 s resistance, which is usually longer than the contraction, while sets may progress from 10 to 20 units per rehabilitation session. In addition, the simple step of asking the patient to also contract the adductor muscles (for example by placing a small ball between the knees while exercising) creates greater stimulation of the vastus medialis obliquus (VMO) recruitment. Finally, the angles at which the knee is working can be set in advance within a range comprised between about 90° (flexion) to complete extension.

To reinforce the flexion muscles in the knee, the machine's complete configuration is recommended, with the same length and quantity of stimulation as described above. The freedom of movement granted by the restraining shoe and the stabilizing Velcro straps allows intra- and extra-rotation of the tibia in relation to the femur in order to create, respectively, greater activation of the medial flexor muscles or the femoral biceps.

Concentric Mode

By choosing one of Flextensor's two configurations based on which muscle area needs strengthening, it is possible to have the patient perform concentric movements against an elastic resistance. Of course, this type of contraction requires greater effort than an isometric contraction.

With modest elastic resistance, especially when treating direct or indirect trauma to muscles, exercise therapy with the Flextensor may be administered in the very first stages. This can be done by stimulating the damaged muscle and minimizing the risk of further injuring the tissue. Once the work load (one to four elastics) to be employed has been carefully chosen, the appropriate quantity of work should be decided on the basis of the patient's clinical condition.

Repetitions frequently fall within a range of 10 minimum up to a maximum of 20-30, while, as far as sets are concerned, working on 6 to 8 units is recommended. Rest time plays a key role, as it is calculated based on sets-repetitions-number of elastics in use, depending on whether the aim is greater muscle resistance (30-45 s rest, 1-2 elastics, 6-8 sets, >20 reps) or muscle strength (1'30 s rest, 3-4 elastics, 4-6 sets, 10-15 reps).

Elastodynamic Mode for Flexors and Extensors

This kind of exercise constitutes Flextensor's unique feature in rehabilitation. In fact, by hooking both the front and rear elastics in with the device in its basic configuration, the operator can have the patient perform flexion-extension movements of the knee, both against elastic resistance. This type of exercise is geared strongly towards neuromotor and coordination work, rather than simply offering toning stimuli. This mode, reserved for the patient's final recovery stages, increases their performance in terms of: muscle reactivity, joint fluidity, speed of and resistance to contraction, agonist-antagonist muscle coordination.

Exercises performed according to this mode, although stimulating and at the same time requiring advanced motor skills, have proven to be well tolerated and efficient both for active patients (athletes) and sedentary patients (non-athletes, amateur athletes).

Normal use requires two front elastics and two rear elastics, with exercise lasting 10 s: the therapist's aim is to guide the patient to being able to perform the exercise with maximum intensity, so they can establish a “record”, referring to the highest number of repetitions completed in the set time period. In this way, performance improvements in the short and long term can be monitored, at the same time motivating the patient by providing them with goals to meet/exceed.

The subjects we analyzed showed that athletes, both male and female, were able to complete 25 to 30 repetitions within 10 s, while for sedentary patients the number was usually lower than 20.

Without taking absolute values into account, since they are closely linked to factors such as sports activities carried out in the past, body weight, height, psychological aspects and competitiveness etc, what emerges is immediate improvement over 5 sets (spaced out by 40 s rests), underlined by the growing number of repetitions completed. This allows us to state that, even with the muscles tiring as the exercise is executed, neuromotor coordination is positively influenced and improves performance.

A rehabilitation protocol structured around six 10 s active sets and 40 s rest constitutes the starting point in order to subsequently be able to administer 10 sets scheduled in the same manner. If the aim is to stimulate toning more than coordination, the number of elastics may be increased up to 4 and an isometric hold of the knee's extension may be requested after the repetitions in each set are completed.

Moving on to some recommendations on the use of the Flextensor, by way of example we can analyze two of the most common orthopedic pathologies: **reconstruction of the anterior cruciate ligament and meniscectomy**.

The possibility to work with a knee joint range between 0 and around 100° enables the operator to administer exercises (following the guidelines described in the paragraph titled “Isometric Mode”) to patients who have undergone ACL reconstruction surgery even in relatively early stages of recovery.

Already 3-4 weeks after surgery, the therapist can have the patient begin isometric work for the quadriceps femoris muscle with the knee at various angles of flexion, taking care to avoid the first 30°.

After meniscectomy surgery, exercise can be carried out at all angles, and it is possible to introduce concentric mode exercise in the early stages.

In rehabilitation after ligament reconstruction, it is necessary to postpone the use of this mode until about two months after the surgical procedure in order to avoid excessive premature stimulation of the neo-ligament.

For the final stages of rehabilitation, after either kind of surgery, the use of the Flextensor is recommended until the patient's discharge following the guidelines of the elastodynamic mode for flexors and extensors in order to fully recover all the neuromotor skills necessary for optimal return to all daily or sports activities.

• THE FLEXTENSOR IN PREVENTION AND TRAINING

Any training program, whether it is designed for muscle recovery after injury or in preparation for the competitive season, is usually structured around several stages of activity aiming to reach certain goals. In individual sports, and even more so in team sports, the analysis of athletic performance leads to the development of several skills which, although very different, complement each other. By observing the different kinds of strength necessary in any sport, for example soccer, it is possible to realize how complete athletes' physical preparation must be. In fact, this sport requires all of the following kinds of strength: maximal strength, speed strength, explosive strength, strength endurance, dynamic strength and specific strength. Each involves different skills in the myotendinous structures and makes use of different metabolic or neuromuscular processes. Therefore, it is necessary to carefully consider the development of all these kinds of strength. In particular, aiming to transform maximal strength into dynamic strength appears to be crucial for all sport-specific movements on the playing field.

In relation to muscular strength, training protocols in the gym aim to limit the effects of atrophy due to immobilization and center around the recovery of neuromuscular and metabolic capacities. These exercises feature modest loads and high frequencies of nervous impulses to the muscle. Subsequently, training strives to increase maximal strength and trofism, using free weights, isotonic and isokinetic machines to this aim. When the injured limb's muscular strength deficit is 10% or less compared to the other limb, the training program continues also on the playing field, where the athletic side of physical recovery will be addressed by requiring expression of dynamic strength, speed strength, strength endurance and specific strength.

Considering the high angular speeds used during specific training of speed strength, special attention should be reserved to the choice of tools employed, seeking to work with devices capable of offering a good compromise between exercise intensity and correct execution technique. Most gyms offer isotonic machines with pulleys and elliptical movement systems that, although modern and compliant with joints' biomechanical requirements, rarely offer the chance to perform muscular actions at high angular speed without load peaks. The inertia due to mass and the overloads on the joints at the end of the single shortening cycles often give rise to problems for athletes as they carry out isotonic training for explosive strength. To avoid this, isokinetic machines have long been used, since their load is adapted to different lever ratios and resistance is accommodating; although this type of training is not well suited to all sports featuring accelerations of movement, like sprints, throws and jumps.

While performing isokinetic exercises, the flexion-extension movement of the knee loses its defining quality, as it is constrained to pre-established execution times; while in the sport-specific athletic movement different angular speeds are expressed at different degrees of movement.

With the analysis of the individual traits and limitations of the methods discussed, we have come to carry out training with elastic loads using the FLEXTENSOR, discovering this device to be a valid compromise between exercise intensity and the risk of overloading. This tool allows other training methods' defects to be compensated, not by actually replacing other devices, but by effectively acting as a link between training carried out in the gym (maximal strength) and specific ballistic training performed on the field (maximum dynamic strength). The aim is thus to use the FLEXTENSOR in combination with other machines and to maximize the expression of speed strength, resistance to speed strength, nervous activation, pre-stretch and the stretch-shortening cycles with controlled and restricted ballistic movements more similar to those of sport-specific movements.

Training with the Flextensor

High maximal strength levels are not always crucial requirements when aiming to obtain excellent athletic results. However, a significant maximal strength is key to the development of high levels of explosive strength.

Several factors significantly affect the expression of speed strength: the type of muscle fiber, the size of each muscle fiber and the tension it produces, the fiber's physiological condition (active rest, pre-stretch), its level of training, the number of fibers to which messages are sent and the influence of proprioceptors such as the Golgi corpuscles, muscle spindles and joint receptors.

In order to maximize the expression of speed strength, the unwanted effects of training methods for general strength cannot be disregarded. It has been proven that during training carried out with heavy loads and a large number of repetitions muscle work is executed by two types of muscle fiber (ST and FT), thus obtaining an increase in the area occupied by ST fibers, as well as their continuous recruitment. On the other hand, during quick movements the involvement of slow fibers (ST) can be negative, thus reducing the explosive strength performance (Komi et al). This observation highlights the very specific nature of training, so if in the maximal strength development stage the work were carried out with loads above 70% of maximum load (ML), in the speed strength development stage it would be appropriate to work with submaximal loads, with percentages varying between 20 and 50% of the ML (Hakkinen, Komi, Bosco) and movements performed at maximum speed. Single exercise time is usually less than 30 s (in function of the load percentages, the subject's resistance to fatigue, FT percentage) and rest time between 1 and 3 minutes (Mader 1983).

The nervous system also influences the speed of contraction. Through specific training of speed strength, the nervous system leads to changes in the relative curve of EMG activity as it moves to the left and shows a steeper increase of the tension which is exerted. A complete change occurs in the previous pattern of nervous activation when explosive tension is developed, as proven by Desmet, Godaux and Komi.

Other advantages of training with elastics loads:

- The possibility of working at high angular speeds, closer to those of sport-specific movements.
- Greater involvement of the muscle's elastic components.

- A more pronounced stretch-shortening cycle, more similar to sport-specific movements.
- Improvement of agonist and antagonist muscle synergy, which facilitates inter- and intramuscular coordination.

Angular Speed Assessment

This analysis begins with a comparison of the angular speeds used on different machines for training in the gym and the sport-specific movements of soccer. The first assessment was carried out on an isotonic machine such as the LEG EXTENSION by measuring the different angular speeds. We realized that by altering the time employed for execution of ten repetitions, where each repetition requires a cycle of 200° (100° flexion, 100° extension), angular speed remained very low, fluctuating between 80 and 130°/s. In this case, execution speed is considerably influenced by the type of machine as, with loads less than 50% of the maximum, detachment of the support base from the leg occurs in the final stage of extension due to inertia.

A preliminary conclusion may be derived by observing the angular speeds common in the general strength training period.

No. of repetitions	Total degrees (extension+flexion) per repetition	Total time in seconds	°/s (average)
10	200	15	133,3
10	200	16	125,0
10	200	17	117,6
10	200	18	111,1
10	200	19	105,3
10	200	20	100,0
10	200	21	95,2
10	200	22	90,9
10	200	23	87,0
10	200	24	83,3
10	200	25	80,0

The training technique most easily measurable in terms of angular speed remains of course the isokinetic machine, although with the drawback that, as well as offering less specific ballistic exercises, its maximum angular speeds peak at around 400°/s. Such values are certainly much higher that those obtained with isotonic methods but still far off the typical speeds expressed in soccer.

Studies carried out by the Concordia College Undergraduate Students on angular speeds of the knee during kicking report angular speeds between 540°/s for low level female athletes and 660°/s for high level female athletes. If we were to consider values for male subjects, they would most likely increase even further.

The final assessment was carried out on the FLEXTENSOR. An exercise lasting 10 s was carried out in which subjects were asked to perform as many repetitions as possible. Having assessed the degrees of work in a single stretch-shortening cycle to be 220°, we were able to assess angular speeds between 220 and 560°/s with a contrasting elastic resistance of 15 to 30 kg.

No. of reps in 60 s	No. of reps in 10 s	°/s (average)
66	11	242
72	12	264
78	13	286
84	14	308
90	15	330
96	16	352
102	17	374
108	18	396
114	19	418
120	20	440
126	21	462
132	22	484
138	23	506
144	24	528
150	25	550
156	26	572

Training Techniques

By way of introduction, we must say that training should always be developed around an athlete and adapted to each individual's subjective physiological traits.

With a machine like the FLEXTENSOR, work on power can be carried out by varying angular speed in relation to a specific work load. Recommended exercises vary, with sets lasting between 10 and 30 s and rest times between 30 and 90 s, depending on the kind of strength and metabolism resource that needs training.

Work load can vary based on the number of elastics, seeking out an intensity ranging from 25% to 50% of ML (calculated by direct or indirect method on an isotonic leg-extension machine). On the basis of the maximum load value obtained, the load equivalent to desired percentages (30-50%) can be calculated. The number of elastics may then be determined by considering them to be equivalent to about 5 kg each.

Example:

Maximum load on LEG-EXT equal to 45 kg (1RM)

30% of 45 kg is equal to 15 kg

15 kg is equal to 3 elastics (equivalent to 5 kg each).

- SPEED STRENGTH exercise -A-

  Anaerobic alactacid work

6 to 10 sets lasting 10 s in which to perform maximum possible number of repetitions. Estimated load around 50% (5 elastics if maximum load is close to 50 kg). Rest time roughly 90 s.

Maximum power also needs to be assessed by calculating the maximum number of repetitions and keeping the units of time and resistance constant. This allows the power percentage for all repetitions to be appraised. Percentages lower than 90% do not lead to significant improvement in performance. Therefore, required average power should be no less than 90%.

- SPEED STRENGTH exercise -B-

Mixed anaerobic alactacid-lactacid work (CP and glycolitic)

6 to 10 sets lasting 20 s in which to perform maximum possible number of repetitions. Estimated load around 30% (3 elastics if maximum load is close to 45 kg). Rest time roughly 90 s. Average power of the sets no less than 90%.

- SPEED STRENGTH RESISTANCE exercise -C-

  Anaerobic lactacid power work

10 sets lasting 30 s in which to perform maximum possible number of repetitions. Estimated load around 30% (3 elastics if maximum load is close to 45 kg). Rest time roughly 60 s. Average power ranging from 80 to 90% of maximum power.

- PLIOMETRIC exercise

This exercise requires the athlete to perform movements with reduced angles, using an elastic load which is unequally divided between flexors and extensors (e.g. 3 to 1 or 1 to 3). In this way, the muscles are trained to a more efficient stretch-shortening cycle through pliometric work carried out in open kinetic chain.

PLIOMETRY OF THE KNEE EXTENSOR MUSCLES:

-3 rear elastics – 1 front elastic

3 sets of 10 repetitions, angle between 0° and 30°

-3 rear elastics – 1 front elastic

3 sets of 10 repetitions, angle between 30° and 60°

-3 rear elastics – 1 front elastic

3 sets of 10 repetitions, angle between 60° and 90°.

PLIOMETRY OF THE KNEE FLEXION MUSCLES:

-1 rear elastic – 3 front elastics

3 sets of 10 repetitions, angle between 0° and 30°

-1 rear elastic – 3 front elastics

3 sets of 10 repetitions, angle between 30° and 60°

-1 rear elastic – 3 front elastics

3 sets of 10 repetitions, angle between 60° and 90°.

BIBLIOGRAPHY

- *Weineck J., 1992.202 – L'incremento della capacità specifica di prestazione.*

- *Bosco C., Komi PV– Mechanical characteristics and fiber composition of human leg extensor muscle. Eur. J. Appl. Physiol, 41:275-284, 1979.*

- *Bosco C. – La valutazione della forza con il test di Bosco. Società Stampa Sportiva, Roma, 1992.*

- *Bosco C. – La forza muscolare aspetti fisiologici ed applicazioni pratiche. Società Stampa Sportiva. Roma, 1997.*

- *Cometti G. – Les mèthodes modernes de musculation. Tome I :Donnèes theoriques. UFR STAPS Dijion, 1988.*

- *Costill DL, Coyle EF, Fink WF, Lesmes GR – Adaptations in skeletal muscle following strength training. J. Appl. Physiol. Respirat. Environ. 96-99, 1979.*

- *Komi, PV, Karlsson, J., Tesch, P., Suominen, H. & Heikkinen, E. (1982) Effects of heavy resistance and explosive type strength training methods on mechanical, functional and metabolic aspects of performance. In PV Komi (ed.) Exercise and Sport Biology, pp. 90-102. Human Kinetics, Champaign, Illinois.*

- *Hakkinen K., Komi PV, Alen M. (1985) Effect of explosive type strength training on isometric force and relaxation-time, electromyographic and muscle fibre characteristics of leg extensor muscle. Acta Physiol. Scand. 125: 587-600.*

- *Desmet J., Godaux L. – Ballistic contraction in man: Characteristic recruitment pattern of single motor units of the tibialis anterior muscle. J Phisiol. 264: 673-693, 1977.*

- *Mader A., Heck H., Liesen H., Hollmann W. – Simulative Berechnungen der dynamischen Änderungen von Phosphorylierungspotential, Laktatbildung und Laktatverteilung im Sprint. Dt Z Sportmed. 1983; 34: 14–22.*

- *Weineck J. – L' allenamento ottimale, Calzetti Mariucci Editori.*

- *Wilmore JH, Costill DL – Fisiologia dell'esercizio fisico e lo sport, Calzetti Mariucci Editori.*

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