

Module 3. Programming a Session

3.1 Analysis of the Variables that Influence Session Programming

3.1.1 Choice and Order of Exercises

There are many ways to catalog exercises from the possibilities offered by traditional strength training at the gym. Some of these are:

- According to the kinematic chain (open or closed).
- Push or pull.
- Monoarticular or bi-articular.
- Bilateral or unilateral.

The organization of exercises and the number of muscle groups used during a training session significantly affect the manifestation of strength. In scientific literature, for example, there are three basic types of routines:

- 1) Full body.
- 2) Divided into upper and lower body.
- 3) Routines divided by muscle group.

Full body routines involve performing exercises that stress all major muscle groups (doing one or two exercises per muscle group). One workout for the legs and another one for the muscles of the trunk and arms is performed for routines **divided into upper and lower body**. For routines divided by muscle group, two or more exercises are performed for specific muscles (for example: chest and triceps). Although all three types of routines are effective to improve strength; the first type is more related to strength training in team sports and that is why we will focus on its development. The remaining two types of routines are more related to hypertrophy sessions, characteristic of *body builders*.

It would seem that individual goals, available time, training frequency, and personal preferences determine the type of work to be done. The most significant difference among these routines lies in the magnitude of the specificity observed during each session: a muscle group is trained once or twice a week in routines divided by muscles, two to three times a week in upper/lower body routines and two to four times in full body routines.

The following are some recommendations on training with overload:

- Polyarticular or global exercises should be performed at the beginning of the session to obtain maximum benefits, since this is when the accumulated fatigue is minimal.



The inclusion of exercises such as cleans or power cleans requires additional time to learn the technique and it is important for the athlete to be rested to perform them.

- It is important to always perform polyarticular exercises before monoarticular exercises.
- As well as exercising large muscle groups before small ones.
- When the goal is to develop maximum muscle power, one should always do the most complex exercises first and then those that are technically simpler.
- It is important to rotate exercises for upper or lower body or those that are agonist/antagonist.
- The most intense exercises (close to rep maximum) should be done before less intense ones.

Unlike the previous ones, our proposal lies, as we saw in the approximation areas, in analyzing what the athlete needs, his strengths and weaknesses, and in applying this to a context according to the requirements of the sports actions. After having studied the motor pattern to be optimized, proposals for action will be created and included within an annual schedule.

Let's see an example applied to the handball shot:

In the following table we can see the percentages of maximum muscle activation in an overhead shot.



Table 1 Muscle Activity of the Shoulder according to the Overhead Shot Phase

Muscles	Early Setup (% MVIC)	Late Setup (% MVIC)	Arm acceleration (% MVIC)	Deceleration and follow-up (% MVIC)	Total shot (% MVIC)
Supraspinatus	45 ± 19	62 ± 20	65 ± 30	87 ± 43	65 ± 22
Infraspinatus	46 ± 17	67 ± 19	69 ± 29	86 ± 33	67 ± 21
Subscapularis	24 ± 15	41 ± 21	81 ± 34	95 ± 65	60 ± 28
Anterior deltoid	13 ± 9	40 ± 14	49 ± 14	43 ± 26	36 ± 9
Medial deltoid	21 ± 12	14 ± 14	24 ± 14	48 ± 19	27 ± 9
Posterior deltoid	11 ± 6	11 ± 15	32 ± 22	53 ± 25	27 ± 11
Pectoralis major	12 ± 14	51 ± 38	86 ± 33	79 ± 54	57 ± 27
Latissimus dorsi;	7 ± 3	18 ± 9	65 ± 30	72 ± 42	40 ± 12
Biceps brachii	12 ± 7	12 ± 10	11 ± 9	20 ± 18	14 ± 9

MVIC = Maximum Voluntary Isometric Contraction

Source: Adapted from Escamilla, & Andrews, 2009.

In the table we see the considerable activity of muscles that make up the rotator cuff (supraspinatus, infraspinatus and subscapular) and that act in deceleration and follow-up. Knowing this is particularly useful when designing exercises. Note the low activity of the medial deltoid throughout the entire performance compared to that of the medial pectoralis, the fundamental muscle when shooting. This tells us what actions we should encourage and strengthen for the athlete to optimize his shot and also to keep his shoulder healthy. In this case, *pull over* or similar exercises are a priority and, as complementary, those that strengthen braking actions, such as the eccentric rotation while the famous scaptions should not be part of a program to strengthen the shot action since its action is scarce and it is not related to the motion.

3.1.2 Volume

Before defining and delimiting the scope of the training volume, we need to understand the following concepts:

- A **rep** is the complete movement of an exercise. In traditional exercises, rep involves two phases: concentric, which overcomes a resistance, and eccentric, which yields. However, there are exercises in which only one of the phases can be developed (for example, in eccentric exercises), and there are more complex ones, which require the execution of several muscle actions and several motions (for example, a power start).



- A **set** is a group of reps performed continuously without stopping, that is, without rest. Although a set may consist of any number of reps, a range of 1 to 15 reps is typically used.
- A **rep maximum (1RM)** is the maximum resistance that can be mobilized to complete one rep of an exercise using the correct technique. However, if we use a lighter load and perform a set containing a maximum number of successive reps with the correct technique until we reach a state of fatigue, for example 12 reps, we call this "12 RM".
- A **training zone** is a range that generally includes performing three reps. For example (The zone comprising performance between 1-3 RM, 4-6 RM, 6-9 RM, 9-12 RM, and 12-15 RM). In these zones, the resistance used allows the person to reach the desired number of reps with relative ease or difficulty (close to muscle failure). For example: in a zone of 9-12 RM, an individual can perform nine reps without issues, but if he wants to do eleven or twelve, he will be very close to the muscle limit.
- Training **volume** refers to a *quantitative* aspect of work done by an athlete; it consists of the duration of the training in hours, the amount of kg lifted per session or training period, the number of exercises and sets per session, and the reps per exercise or training. Coaches should keep track of training volumes (total kg lifted per session) in order to plan future sessions.

This is a variable that becomes more important as the athlete approaches the high sports level, since the athlete's performance can be optimized with increased training volume. If the player adapts to higher workout volumes, he experiences better recovery between sets and training sessions (Bompa, T. & Buzzichelli, C., 2015). This is reflected in more work per training session and per week.

Increase in strength training volume depends on the athlete's biological characteristics, the requirements of the sport, and the importance of strength in that sport.

Regardless, dramatic increases in training volume can be detrimental to of the player's performance as it may result in fatigue and may increase the risk of injury; therefore a progressive plan is recommended to increase loads in which the player 's performance is monitored and significant decreases in his performance are avoided.

In traditional overload training (as at the gym), training volume is defined as the measure of the total amount of work performed during a session, week, month, or other training period (Fleck & Kraemer, 2014). The training frequency (number of workouts per week, month, or year), duration of training, number of sets, number of reps per set, and exercises performed have a direct impact on training volume.

The simplest method to estimate the volume is to count the number of reps done in a specific period of time (one week or one month of training), although it can also be estimated by the total number of kilograms used.

The volume calculation is useful to determine total training strain. In some cases there is a correlation between higher training volume and increased training results, such as hypertrophy, adipose tissue reduction, lean mass increase, and even driving *performance*. High training volumes can even determine a lesser loss of strength once training has stopped. Therefore, we must consider volume when developing training programs.



Training volume affects strength gains

Multi-set training programs are more effective at enhancing strength than individual set programs (Rhea, Alvar, Burkett, & Ball, 2003). Although increasing the number of sets is just one way to increase volume, increasing the frequency is a variable that can affect training volume. In order to analyze which of these two variables most affects strength gains, Candow & Burke (2007) conducted an investigation where two training groups were used; the first group performed a training session consisting of nine exercises for six weeks, three days a week, two sets of ten RMs were performed during the week, while the second group performed the same exercises, but only two days a week and three sets of ten reps, meaning the same weekly training volume where frequency was the only difference (three days of 2x10 RM vs. two days of 3x10 RM). The authors did not find significant differences in flat press or squatting RMs in any of the two training programs. They concluded that the total training volume is more important than other variables such as frequency or number of sets to maximize strength increases.

How to Calculate Volume

Volume is the quantitative element of training. As already stated above, it is the total work done per exercise, day, month, or unit of time (sets per reps per load).

Work = strength x distance.

If a subject is able to perform five reps of squats with 100 kg (220 lb) of weight and the distance covered by the bar in each rep is of 0.6 m (1.97 ft), then the work done by the individual is as follows: 100 kg x 0.6 m x 5 replicates = 300 kg-m

Estimating the work done during a strength training session is useful not only to determine the energy consumption, but also the stress generated by the workout.

From a practical point of view and especially with a large number of athletes, it is quite complicated to calculate the work, therefore, more efficient estimates can be made. For example, if the distance of the exercise remains constant, it is reasonable to estimate the work in a simpler way by calculating the volume of the load (reps per mass lifted). A secondary method is to estimate the training volume simply by adding the reps performed in a workout. Of these two methods, the first offers a more effective approximation than the second (Stone et al., 1999).



3.1.3 Intensity

Intensity is the qualitative aspect of an exercise. In weight training, it is estimated as a percentage of 1RM or the rep maximum done for any exercise.

In healthy young adults, the minimum intensity at which strength can be increased is between 60% and 65% of 1RM (Rhea et al., 2003). Working out in zones close to 80% of 1RM causes optimal strength gains in people with experience in overload training. The training of many reps and very light resistance (less than 30% of 1 RM) does not produce significant increases in strength. It is also very important to acknowledge that the maximum number of reps per set that increases strength varies from one exercise to another and from one muscle group to another. For example: at 60% of 1RM of leg press, the maximum number of reps recorded is 45.5, while the same intensity of a bicep *curl* only allows an average of 21.3 reps. It seems that when we use a percentage of 1RM, it is probable that a greater number of reps will be performed in exercises with the larger muscle groups and with trained people (Fleck, S.J. & Kraemer, W., 2014).

The amount of RM or RM zones can change from one exercise to another, among men and women, if we use free weights or training machines and also according to the level of training. There is a high variability in the number of possible reps at a percentage of 1 RM in all exercises. And it is also very important to note that there is great variability among individuals performing maximal reps in all exercises.

Unlike endurance training, strength exercise intensity cannot be controlled through heart rate (HR), as this is a poor indicator for intensity. HR is different depending on the strength training orientation, whether at intervals (the traditional form) or training in circuits. Deminice et al. (2011) analyzed the maximal HR obtained during a training session of three 10-RM sets with 90-second rests between sets and arms exercises at first and leg exercises later, which resulted in an average of 117 beats per minute (60% of the maximum HR), while performing the same exercises in the same order but in a circuit and with shorter rests had an average of 126 beats per minute (65% of the maximum HR). In both workouts, the same intensity, number of sets and reps were used. The difference in HR was due to the order of the exercises and the duration of the rest periods.

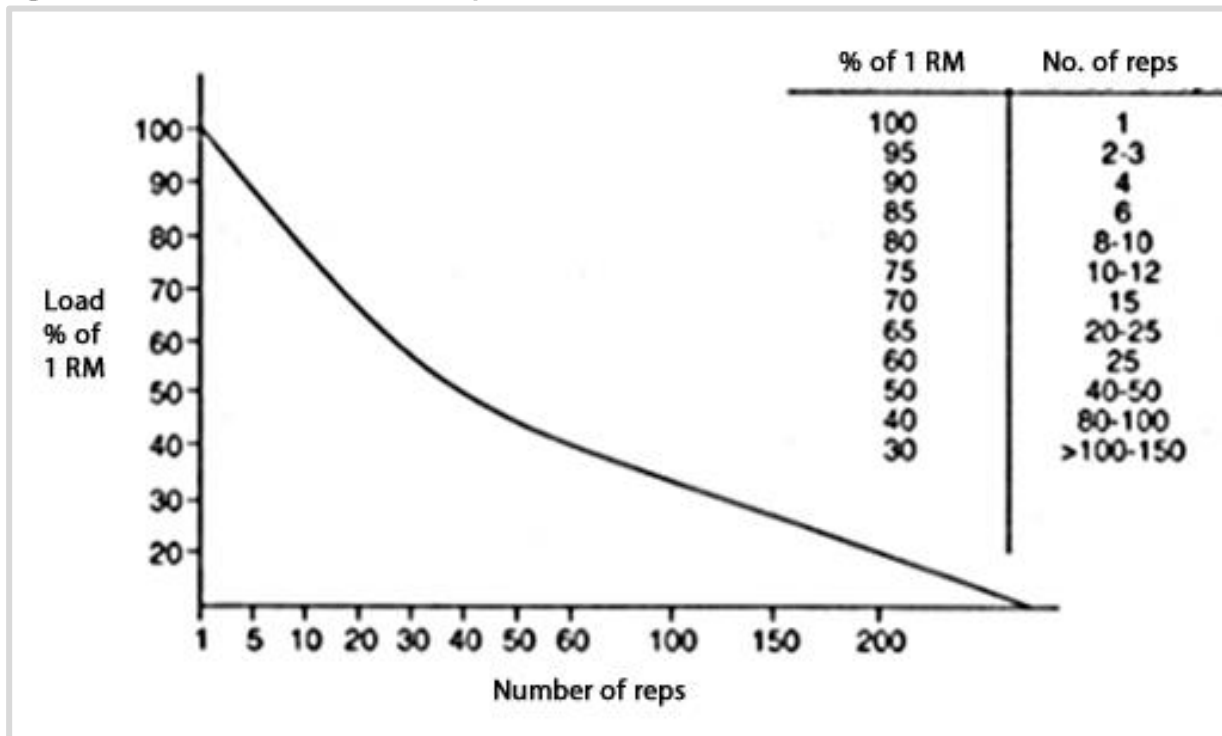


Table 2 Intensity and Load Values Used in Traditional Overload Strength Training

Value Intensity	Load	1 RM Percentage
1	Supramaximal	>105 %
2	Maximum	90-100 %
3	Heavy	80-90 %
4	Median	50-80 %
5	Low	30-50 %

Source: Adapted from Bompa, & Buzzichelli, 2015.

Figure 1: Load curve vs. Number of reps



Source: Adapted from Bompa, & Buzzichelli, 2015.

3.1.4 Frequency and Rests

The number of sets and reps and the total number of exercises done per session determine the training volume. The optimal training frequency refers to the number of workouts per week in which a certain muscle group is trained or a certain type of exercise is performed (Fleck, S.J. & Kraemer, W., 2014).

The study by Calder, A. W., Chilibeck, P. D., Webber, C. E., & Sale, D. G. (1994) is interesting to better understand the concept of frequency. The authors compared an upper and lower body routine with a full body routine in women during 20 weeks of training. Participants did the same exercises, sets, and reps per exercise, but those performing full body routines trained two days a week and those performing the split routine trained four times a week.



The volume reached was the same, the only thing that changed was the frequency, which was why the author did not find significant differences between both groups.

Even so, the optimal training frequency may be different between muscle groups or exercises. Comparisons of flat press and squats determine that three weekly sessions are more effective in improving strength than one or two sessions (Feigenbaum, M. S. & Pollock, M. L., 1997), whereas for lumbar extension, one weekly session is as effective as performing the same action two or three times a week (Graves et al., 1990). On the other hand, in trunk rotation, training two sessions a week provided the same results as three sessions, both being greater than a single session.

Tan (1999) proposes that the optimal frequency of overload training varies between three and five sessions a week. The author acknowledges that the upper body tends to respond better to higher training frequencies compared to the lower body. This is probably because small muscle groups also cause small increases in strength and need prolonged stimuli to make these gains meaningful.

The level of training is a very important factor to take into account to determine the number of sessions to be applied weekly. If the goal is to increase strength levels, we should design weeks with a frequency of three to five sessions, as we mentioned in the previous paragraph. If we want to maintain the acquired levels, one to two training sessions may be sufficient (Tan, B., 1999). It is important at this point to emphasize that highly trained athletes may require greater frequency, since others in the competitive period may need a less frequency due to the wear and tear generated by the competition.

Rests (Pauses)

Rests between sets, between exercises and between training sessions allow the athlete to recover and are a fundamental part of any successful training program. These periods are mostly determined by the purpose of the session. The magnitude of the rest affects the recovery and concentration of lactic acid in blood as well as the hormonal response to training (Fleck, S. J. & Kraemer, W., 2014). In general, if the goal is to increase maximum strength and/or muscle power, rests are long (from 2 to 5 minutes), loads are very high and 1 to 6 reps are performed per set at maximum strength and 2 to 5 if seeking power. If the goal is to develop muscle hypertrophy, periods of recovery between sets can be from 1 minute and a half to 60 seconds or even lower, and reps can vary from 10 to 15. For the development of muscle endurance a type of training in circuits is recommended in which recovery times are very short (less than 30 seconds), loads to be mobilized are relatively light and are performed in a range of 15 to 25 reps per set (Willardson, J. M., 2006).

A very important aspect to take into account when establishing rests is that the duration of the rest should not compromise the quality of the technical execution since high levels of fatigue cause a loss in the quality of the movement and, therefore, a potential risk of injury.

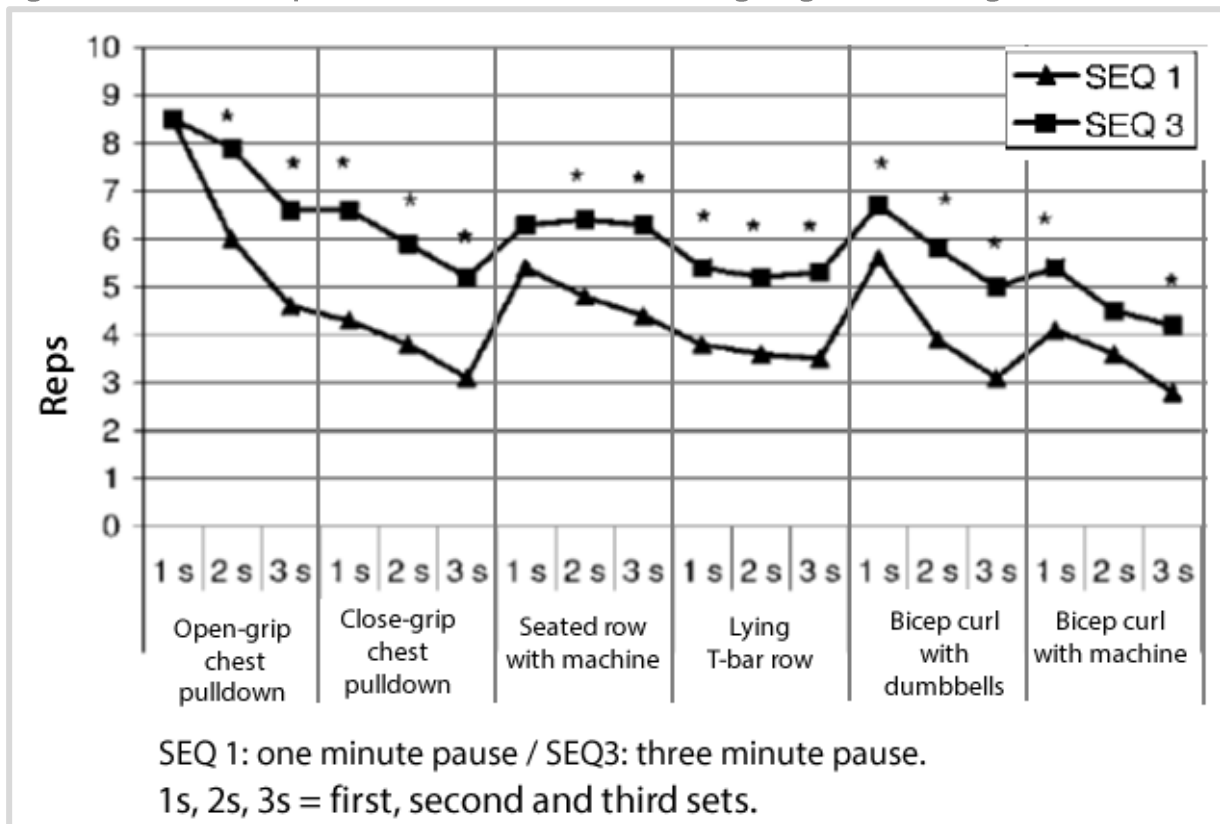
A very important indicator that more rest is needed is muscle pain. If during the following training session the athlete cannot perform as usual due to muscle pain, it is likely due to insufficient rest between sessions.



The duration of the rests depends on several factors: the load used, the speed employed, the speed of execution, the number of muscle groups involved, the level of training of the athlete and his weight, since heavier athletes take more time to recover than lighter ones.

Short rests between sets and exercises offer the advantage of completing a session in less time. On the other hand, the accumulated fatigue generates a significant reduction in the number of reps and, with this, smaller training volume. Miranda et al. (2007) analyzed the maximum number of possible reps at an intensity of 8 RM. In the following figure we can see how the three-minute rests allow more reps than the one-minute rests. The number of reps that can be done in successive sets decreases significantly with short pauses.

Figure 2: Number of Reps in Each Exercise Set of a Training Program with Long and Short Rests



Source: Miranda et al, 2007, p. 1034.



3.2 Training Monitoring

3.2.1 Technology Applied to Training Monitoring

In recent years, thanks to the phenomenon of globalization, resulting from the impressive technological evolution, ideas, concepts, objectives, and teaching and learning strategies have expanded, which not only affect society and activities of daily life, but also impact on sports and physical exercise (Bagnara, I., 2011). The latter are strongly influenced by technology, which has played a major role in the evolution of training in recent years.

The rise of science applied to sports training has generated the possibility of designing technological devices applied to sports. Currently, there are numerous implements designed to measure, plan and evaluate sports performance. These are devices that collect information on the intensity of training, the functional state the athlete is in, and the body's ability to adapt to training loads. The purpose of applying technology in sports reduces training programming errors and therefore reduces the number of injuries caused by the erroneous design of the tasks and their respective intensities.

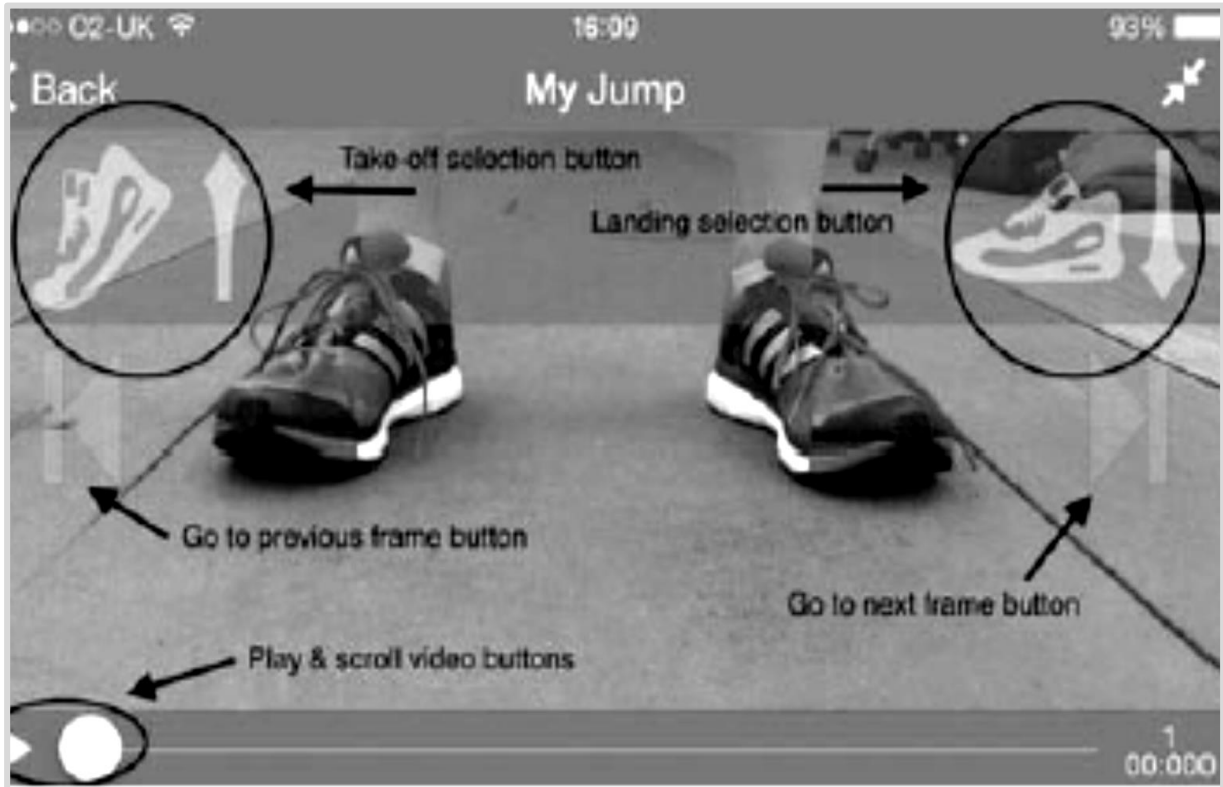
Nowadays, cell phones are a powerful tool to increase the quality of the training process. With no commercial interest, in the next few sentences we will analyze some applications and tools available to the trainer that allow him to raise the quality of his work. Since the use of state-of-the-art devices allows us to measure variables reliably, this can be very important both for designing new methods and training activities, as well as for disseminating scientifically-based information of higher quality to the various agents involved in sport.

My Jump

Vertical jump tests are among the most common means to assess physical aspects regardless of the sport or the population analyzed. The first jump tests were primarily designed to assess the strength of legs in sports such as basketball, volleyball, or soccer.



Figure 3: My Jump



Source: Balsalobre-Fernández, Glaister & Lockey (2015). p. 3.

Research by Balsalobre-Fernández, Glaister & Lockey (2015) analyzed the validity and reliability of a phone application to measure performance in a countermovement jump (CMJ). Compared to a power platform, the My Jump application was found to be valid and extremely reliable, especially considering that the device mentioned above is the one that is used *par excellence* in scientific research. However, the equation used by the application analyzes flight time squared, so higher flight times have a slightly higher measurement error (1.6 cm) relative to a strength platform. Either way, carrying cellphone in one's pocket can be a scientifically validated way of monitoring and assessing the explosive strength of the legs without the need to carry expensive equipment to training.

GPS Systems

Many people who watch first level team training ask themselves: what are those vests used by players? What are they for? These vests contain a **GPS (Global Positioning System)** which makes it possible for the player's location to be monitored by satellites; this device was initially designed for military purposes (Cummins, C. O'Connor, H. & West, C., 2013). In addition to GPS, these vests feature built-in accelerometers. Thus, through these instruments, primary variables such as speed, distance, acceleration and deceleration, impact, muscle fatigue index and racing exceeding 21 km/h, which is considered a *sprint* are controlled (Coutts, A. & Duffield, R., 2010). These accelerations and sprints are the most important data to assess the risks of injury. Another feature offered by these vests is the representation of a heat map to express where and how much the athlete runs.

Coaches seem to understand that, for the first time, they have all the technological tools to warn them of future injuries and also to quantify fatigue values or muscle wear and tear. Among other things, this helps them align the team for the next match and put their rotations into practice with the idea of reaching the end of competitions with more athletes and in better shape. Although they have the disadvantage that they cost a lot of money and the difficulty of implementing them in any institution, the use of these vests has become almost essential in world-class teams, not only soccer but also basketball, rugby, hockey, handball, etc.

Figure 4: GPS Systems



Source: [Untitled image on GPS 1 systems]. (Undated). Taken from: <http://goo.gl/4GvTCI>
[Untitled image of a GPS 2]. (Undated). Taken from: <http://goo.gl/EIRTMD>

Velocity Based Training (VBT) measured through linear encoders or accelerometers.

For decades, traditional training to increase neuromuscular performance measures (strength and power) consisted in working at different percentages of one rep maximum (1RM) and modifying variables such as the frequency and volume of training. However, nowadays, the proposal to use speed to achieve specific training goals has become more popular in scientific literature and in fitness centers (Mann, J. B., Ivey, P. A. & Sayers, S. P., 2015).

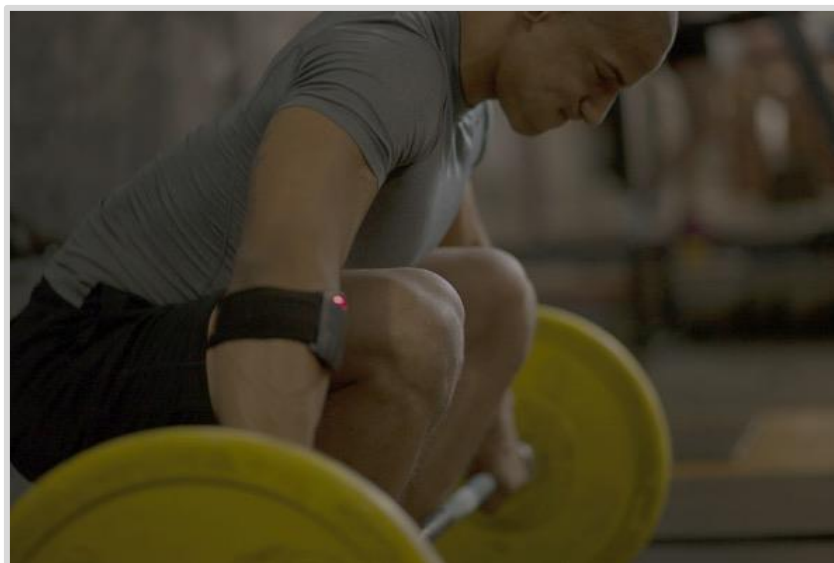
Figure 5: VBT



Source: [Untitled image on VBT]. (Undated). Taken from: <http://goo.gl/kuE4s2>

VBT is a method using accelerometers or linear encoders (see Figure 5) to measure the speed of the bar, dumbbell or other tools. Generally, the encoders work by converting a physical attribute (the position change of the cable attached to the rod, for example) into a set of digital pulses; usually, this device is connected to a personal computer with a software that interprets the data (Harris, N., Cronin, J. Taylor, K., Boris, & Sheppard, J., 2010). On the other hand, accelerometers are sensors that measure the inertial force generated in the three planes when a mass (the athlete's body or tool) is affected by a rate change (Boyd, L., Ball, K., & Aughey, R., 2011).

Figure 6: Accelerometer



Source: [Untitled image of an accelerometer]. (Undated). Taken from: <http://goo.gl/OjjZ7l>

There are different brand names for these accelerometers, some of which are: Tendo Units, Gym Aware, and Push Strength. Encoders use specific software, the brand names of which depend on their geographical location; some of the best known are: Muscledab, Win laborat, and Techfit. Thanks to these, trainers now have the ability to monitor, assess, and train athletes giving the coach instant and objective feedback of how training affects some variables of an athlete's performance.

There are several reasons why trainers should consider implementing the use of VBT:

- 1) **It makes it possible to identify the daily fluctuations as a result of stress, for example, and thus adjust loads:** since it is an average speed and not a percentage of 1RM, the athlete can use the appropriate load for a given day; this makes trainers and athletes rethink the notion of rep maximum value as constant and invariable.
- 2) **It makes it possible to recognize optimal speeds and loads in training to increase its specificity:** if a counter movement jump has a speed of 3.4 to 3.04 m/s (Cormie, P., & McBride, J.M., 2009) and in the weight room we do squats at a rate of 0.3 to 0.8 m/s throughout the year (Mann, J.B., et al., 2015), we are not adjusting exercises to the speed the motion of the sport requires.
- 3) **It gives the athlete and trainer immediate feedback,** which motivates the athlete and increases the quality of training.

On the other hand, the limitations this type of training has are:

- Accelerometers or encoders to measure speed can be costly for the trainer.
- They require the trainer to give up some control and give the athlete certain autonomy, as he can correctly select the loads and perform each rep at the maximum possible speed.
- Reviewing the data of some software packages can be complex and slow, which wastes training time.

3.2.2 What is the Core? A Proposal for Training

Core musculature is composed of 29 pairs of muscles that support the complex of the **hip-lumbar spine-pelvis region**. These muscles help stabilize the spine, pelvis, and the kinetic chains during functional motions. When this system works efficiently, the result is an optimal distribution of forces, adequate absorption of impact forces on the ground, an absence of excessive compression and translation, or shear forces on the joints involved in a particular chain of movement (Fredericson, M., & Moore, T., 2005). To summarize, core musculature plays an important role in:

- Trunk rotation.
- Transfer of force to limbs.
- Stability of the lumbar-pelvic region (Bliss L. S. y Teeple, P., 2005).

Considering the wide variety of existing motions in sports, players need to have sufficient strength in the hip and trunk to provide stability in all three planes of motion. This is



sufficient reason to consider that core stability plays a key role in preventing injuries (Leetun, Ireland, Willson, Ballantyne, & Davis, 2004).

Stability of the lumbar-pelvic region means the ability to prevent significant displacement of the spine and return to equilibrium after suffering a disturbance. Although the passive elements (bone and ligaments) contribute to a lesser extent, this stability is maintained dynamically by the muscles in the region (Wilson, J. D., Dougherty, C. P., Ireland, M. L., & Davis, I. M., 2005).

These muscles can be divided into two systems depending on whether they act as a stabilizer or as the primary action of the movement (see Table 3). Local muscles are characterized by being shorter, they are inserted directly into the vertebrae and generate enough force to stabilize the spine (Faries, M. D., & Greenwood, M., 2007). Within this group, it was confirmed that the transversus abdominis (TrA) is of great importance when verifying its activation 100 milliseconds before the start of the movement of the legs in a reaction test (Hagins, M., Adler, K., Cash, M., Daugherty, J., & Mitrani, G., 1999).

Table 3 Core Musculature

Core Musculature		
Local Muscles (Stabilizer System)		Global Muscles (Movement System)
Primary Stability	Secondary Stability	
<ul style="list-style-type: none"> • Transversus abdominis • Multifidus 	<ul style="list-style-type: none"> • Internal oblique • Medial fibers of the external oblique • Lumbar quadrate • Diaphragm • Pelvic floor • Iliocostalis and longissimus lumbar region 	<ul style="list-style-type: none"> • Rectus abdominis • Lateral fibers of the external oblique • Psoas major • Erector spinae • Iliocostalis (thoracic portion)

Source: Adapted from Faries & Greenwood, 2007. p. 12.

Multifidus and TrA are considered primary muscles as they do not generate movement of the spine, while the internal oblique, medial fibers of the external oblique, and lumbar quadrate, although their main task is to provide stability to the spine, play a secondary role in the movement thereof.

Muscles responsible for producing movement and torque in this region are called global. These have large levers which help them generate great speed, power, and force or torque motions that cover multiple planes while facing external loads that are transferred to the local musculature (Faries, M. D., & Greenwood, M., 2007).

As we emphasized before, it is very important to maintain the stability of this area of the body. Particularly if we consider the large compression forces acting on the lumbar discs in sports training and practice, where doing a half squat can represent a force of between six and ten times the body weight on the L4 and L5 vertebrae (Cappozzo, A., Felici, F., Figura, F., & Gazzani, F., 1985). This means that an athlete who weighs 90 kg (198 lb.) lifts a weight of 145 kg (319 lb.) while doing squats, applies a compression force of approximately 900 kg (1984 lb.) to his lumbar spine.

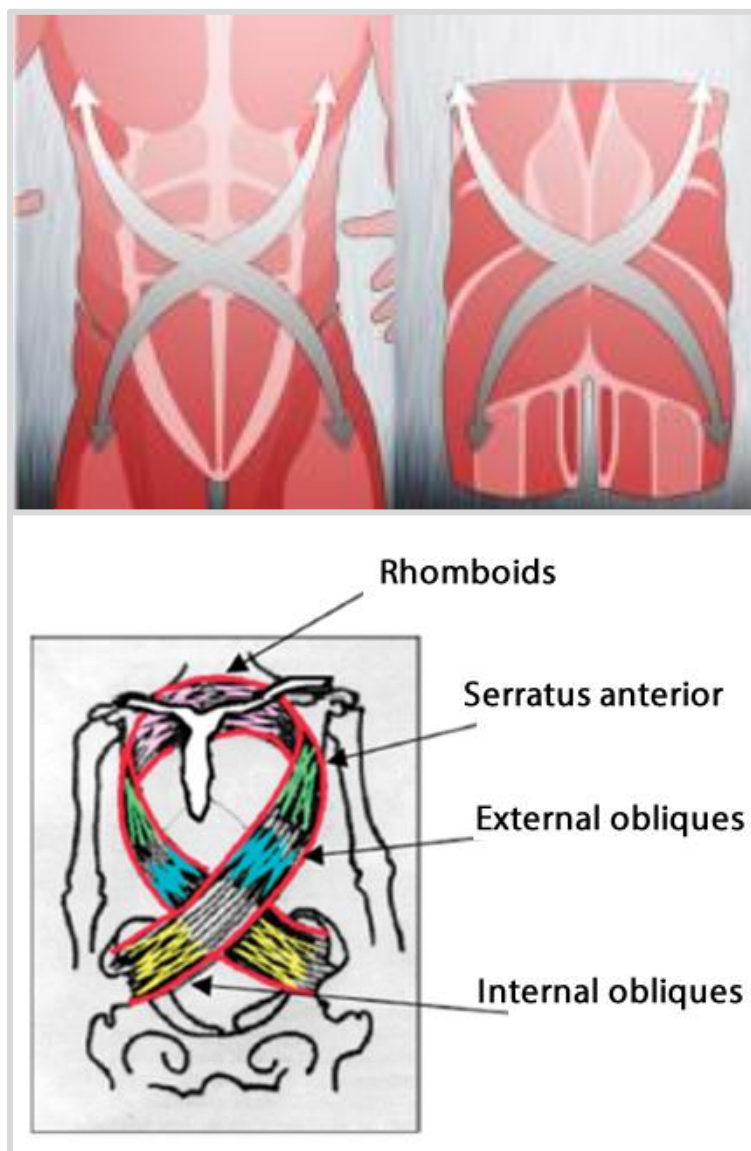


Transfer of Force from the Core to the Limbs - the Serape Effect

The **serape effect** was named thus after a traditional Mexican garment consisting of a band of fabric that goes behind the neck and crosses the front of the chest (see Figure 7).

This effect is a process by which the force generated on the trunk is transferred to the limbs. A great example of this is a jump shot in handball. The thing that is not visible is that the abdominal muscles, particularly the transverse muscles, are activated before the arm and leg movements. Consequently, while the athlete carries the ball behind his head, transverse becomes the first fixation of the body and the core generates the power that will be subsequently transferred to the shoulder, elbow, wrist, and finally the momentum of the ball.

Figure 7: Serape



Source: Santana, McGill, & Brown, 2015, p. 10; Santana, McGill, & Brown, 2015, p. 9.

Figure 8: Serape during Shot



Source: Santana, McGill, & Brown, 2015, p. 9; Santana, McGill, & Brown, 2015, p. 11.

How to Train the Core – Establishing a Progression

First of all, the **correct technique** is essential in this type of exercise because wrong execution puts the athlete at risk of injury. It is therefore necessary for the athlete to learn to activate local stabilizing muscles before producing more complex motions. Another important aspect to address is **diaphragmatic breathing**, as this muscle is the "ceiling" of the core and, when contracted, it increases intra-abdominal pressure and thus increases the stability of the lumbar-pelvic region (Cappozzo, A., Felici, F., Figura, F., & Gazzani, F., 1985).

Once the athlete is able to stabilize the lumbar-pelvic region from isometric exercises, McGill (2010) recommends incorporating the following exercises known to be the three most important exercises for core muscles:

- 1) **Curl-ups** for the rectus abdominis. The rectus is very active during the initial phase of lifting of the head, neck and shoulder, and the lumbar spine should be neutral.
- 2) **Side bridges** for oblique, transverse abdominis, latissimus dorsi, and lumbar quadratus. This exercise is very challenging for lateral oblique and rectus without generating high compression loads on the spine.
- 3) The **bird-dog** in quadruped position performing a knee extension and opposite elbow to stimulate the lower back extensors.

As these exercises progress, one can switch from a stable to an unstable surface using tools and adding complexity to these tasks.

To conclude this section, we summarize the proposal of Bliss and Teeple (2005) who established the following principles to be followed in relation to the progression:

- 1) Moving from stable to unstable surfaces and from static to dynamic.
- 2) Perform exercises in all three planes: sagittal, horizontal and transverse.
- 3) Incorporating proprioceptive and increasing difficulty elements (suspension training, physio balls, etc.)
- 4) Carry out explosive strength exercises, multijump, and sports specific motions tailored to the player's needs.

3.2.3 Warm-Up and Post-Activation Potentiation

Warm-up prior to competition or training is an activity included in sports. Trainers and athletes consider it essential in their quest to achieve optimal performance. However, these considerations have not always been well supported by substantial empirical evidence, so trainers reached conclusions about their warm-up practices and strategies based on trial and error (McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B., 2015). Due to this, extensive research has been conducted to determine the key elements in these tasks.

The objectives of proper and effective warm-up are:

- Socioaffective arousal (psychological aspects).
- Prevent muscle and joint injuries.
- Optimize performance through increased body temperature and increased metabolic and physiological reactions of the athlete's body.

According to Kirkendall (2014), the following components should not be missing from a warm-up prior to a sporting event:

- Aerobic activation of progressive intensity.
- Strength exercises for issue areas.
- Static and dynamic stability activities.



- Dynamic stretches.
- Agility and plyometrics tasks.
- Motor control activities related to the sport.

Among the physiological and neural mechanisms that have been discussed in the scientific literature regarding warm-up, are: increased muscle metabolism, increased oxygen consumption, and post activation potentiation (PAP). Among these, one of the physiological objectives pursued is increased body temperature, based on the increase of muscle metabolism and nerve conduction (see Table 4).

Table 4: Possible Effects of Warm-Up

Effects Related to Increased Temperature	Effects Not Related to Increased Temperature
Decreased muscle and joint viscoelastic resistance	Increased blood flow to muscles
Increased release of oxygen from hemoglobin and myoglobin	Elevated base oxygen consumption
Acceleration of metabolic reactions	Post-activation potentiation (PAP)
Increased nerve conduction speed	Psychological effects - social-emotional aspects.
Improvement in the body's thermoregulatory ability	

Source: Adapted from Bishop, 2003.

Traditionally, before matches, teams have always performed a sequence involving aerobic activation: running at low intensity, joint mobility exercises, and sport specific tasks with or without the ball. These warm-ups lasted on average 30 minutes with a transition of 12 minutes between the end of the warm-up and the beginning of the match. Likewise, in all sports it is common to have a half-time break of about 10 to 15 minutes between the first and second halves (Mc Gowan et al., 2015).

Warm-ups that include **small-sided games** (2 vs. 2, 3 vs. 3, 4 vs. 4, etc.) provide additional benefits over a generic activation, since they take precedence in neuromuscular activation and coordinative work (Gabbett, T. J., 2008). These games are designed to stimulate the specific needs of the sport, both technical and tactical components such as physiological aspects since sport-specific tasks such as passing, shooting, and ball control are repeated in the game. Zois, Bishop, Ball and Aughey (2011) found improvements in vertical jump, repeated sprints and agility in soccer players after implementing small-sided games (SSG) compared to a traditional warm-up.

When using SSG, it is recommended that they last less than 16 minutes and be carried out as close as possible to the match, preferably within less than ten minutes (McGowan et al., 2015). Another time for these interventions is during the break, which should last 3 to 7 minutes to maintain elevated body temperature and willingness of the athlete to continue performing during the second part of the game.



Post-activation potentiation (PAP)

Doing rep maximums or sets of an exercise or close to the maximum in order to increase strength/power in subsequent exercises is what is known as **post-activation potentiation (PAP)** (Seitz, L. B., & Haff, G. G., 2016). It has been proven that under these criteria, performing squats or power snatches can significantly increase subsequent performance in vertical and horizontal jumps or sprints of 10 and 40 m (10.28 - 43.22 yds).

The effects of PAP are divided into muscle and nerves. At the muscle level, it has been found that the rep maximums provoke a phosphorylation of myosin light chains, thereby increasing the sensitivity of the actin-myosin complex of the calcium that is released from the endoplasmic reticulum causing increased activity of cross-bridges (Tillin, M. N. A., & Bishop, D., 2009). On the other hand, in the central nervous system, effects would be related to the increased recruitment of high threshold motor units (MU), increased MU synchronization and lower activity of reciprocal inhibition reflex by antagonists Tillin, M. N. A., & Bishop, D., 2009).

The factors affecting the magnitude of PAP are:

- **The athlete's level of experience and strength:** stronger players have greater power than weaker players and are able to express this increase in less time (Seitz, L. B., de Villarreal, E. S., & Haff, G. G., 2014).
- **The type of potentiating exercise and its technique: three power snatches** at 90% of 1 RM can produce a more pronounced positive effect in 20 m (21.26 yd) sprints than three reps at 90% in squats; in addition, the depth of the squat can affect the level of PAP time (Seitz, L. B., de Villarreal, E. S., & Haff, G. G., 2014).
- **The rest between the execution of the potentiating exercise and powered activity:** it would seem that the benefits range from 5 to 18.5 minutes, although the best results are between 7 to 10 minutes (Wilson et al, 2013.)
- **The number of potentiating exercise sets:** there are greater effects when doing multiple sets rather than just one set (Wilson et al, 2013.).
- **The intensity to be used:** moderate loads of between 60% and 84% provide better results than very heavy loads (over 85%) or light loads (under 60%).
- **There seem to be no differences in gender.**

The exercises to be used, in addition to traditional exercises (squats, flat press) or weightlifting derivatives, may be progressive intensity multijump and medicine ball multi-throw, among others; all these exercises can be effective means to produce PAP and should be included in any competition preparation activity.



3.2.4 Fatigue and Recovery After a Session or Match

An extremely important factor in the performance of a sports team is the proper recovery of the state of fatigue after a game or training, especially in conditions under which athletes train and play sometimes on the same day, on successive days, or every other day, with little time to rest. It is worth noting that, if we can get athletes to recover faster from a state of fatigue, they will have a clear performance advantage compared to rivals who have not applied any recovery method. (Terrados, N., Calleja-González, J., & Schelling, X., 2011).

Según Terrados (2011): "Sports fatigue is a state in which the athlete is unable to maintain the expected level of performance or training." Two types can be distinguished:

- **Central Fatigue:** according to which the muscles are able to generate high power, but the nervous system blocks them, perhaps as a means of protecting them from injury (Bishop, D., 2003).
- **Peripheral Fatigue:** where muscle homeostasis has been disturbed, either metabolically or through tissue damage, to the point that the muscle is biochemically or biomechanically unable to respond effectively to the effort as when it is rested (Bishop, D., 2003).

Currently, and from a sports point of view, the main mechanisms of fatigue would be the following (Terrados, 2009):

- 1) Depletion of substrate stores.
- 2) Excess in accumulation of metabolites derived from the exercise.
- 3) Very high temperatures.
- 4) Muscle damage after a workout.
- 5) Changes in the immune system.
- 6) Hormonal variations.

In soccer at the international level, the number of matches per season, counting home and away matches and national representative events, is very high. During the 2009-2010 season, counting the FIFA World Cup, many Spanish players got to play up to 70 competitive matches. It is known that participation in a soccer match leads to a decrease in performance during the following hours and days caused by a state of acute fatigue. Andersson et al. (2008) found that elite soccer players need at least 72 hours to get their values of physical performance, inflammation and muscle damage back to those of the hours before the last game. At certain times of the season in which the competition schedule does not allow a rest, the team must play in two events in the same week and the time to recover after playing successive games can be 3 to 4 days, a period that may be insufficient for certain players in relation to the body's ability to restore homeostasis. As a result of the repetition of these events, the player can experience acute and chronic states of fatigue, which ultimately leads to a potential state of low performance and/or lesions.



Ekstrand, Waldén, & Hägglund (2004) found that those players with low performance in the soccer World Cup in 2002 had played an average of 12.5 matches in the ten weeks prior to the event. In contrast, those who showed a high level of play had played only 9 games in the same time. In addition to this, Dupont et al. (2010) found that players who play two matches a week and get between 72 and 96 hours' rest are 6.2 times more likely to be injured than soccer players who only play one match every seven days.

Competitive and training demands impose a substantial burden on the athlete; the musculoskeletal, nervous, immune and metabolic systems are highly affected to the point that recovery strategies after the match become necessary and are crucial in preparing the next match (Ascensão et al., 2008). Other factors need to be taken into account, such as mental preparation and pre-match travel as precursors of a state of fatigue; playing away, especially coupled with long trips and nights of rest in unfamiliar environments, has a negative impact on sleep quality and this can affect the players' performance (Bengtsson, H., Ekstrand, J., & Hägglund, M., 2013).

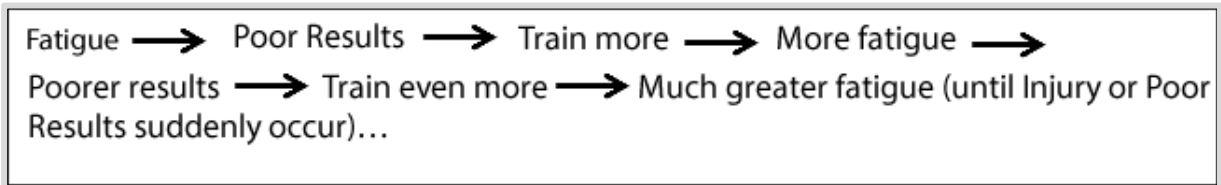
On the other hand, it is important to acknowledge that in team sports we should not only focus on the physiological etiology of fatigue. The detailed assessment of the influence of the location of the match, the level of the opponent, the score and the emergence of critical moments in the match on physical performance present, in team sports, a number of practical implications of great importance for trainers and physical trainers in the analysis of team fatigue (Lago Peñas, C. Martín Acero, R., Seirul-lo Vargas, F., Alcalde, J., y Hernández Moreno, J., 2011). First, it would be useful to incorporate in the post-match analysis of the team's physical performance, the specific characteristics of the situational variables that came up in the match, such as the influence of tactical and strategic factors, since a decrease in performance during a match may not just be the result of the players' physiological fatigue. Second, if the trainer or physical trainer is able to identify aspects of collective performance that are negatively influenced by some situational variable or critical moment, the causes of this deterioration can then be isolated and taken into account specifically in preparation of the following matches during training (Lago Peñas et al., 2011).

We must consider a very important aspect related to fatigue that has to do with several pathologies (some quite serious) that are concurrent to fatigue, but which must be distinguished from it. It is important to have a proper medical diagnosis so that low performance due to the onset of a disease is not confused with sports fatigue, as this could pose a serious misdiagnosis.

As we have seen, it is considered essential to know what type of fatigue the athlete is suffering from to help with his recovery. Thus, for example, it would not be effective to use strategies for rapid recovery of muscle glycogen if the athlete's fatigue is of a psychological nature. Without the correct analysis of the etiology of the loss of condition, we often fall into the following sequence of errors:



Figure 9: The Fatigue Cascade



Source: Adapted from Terrados (2012), unpublished notes.

That is why the correct quantification of training loads is essential. As we saw earlier, knowledge of a sport's fatigue mechanisms greatly helps plan training and recovery strategies for the athlete, which is important to maintain his state of health and help keep him in good shape. Both with regards to soccer and the rest of team sports, Nédélec (2013) refers to fatigue as a multifactorial phenomenon related to:

- Dehydration.
- Depletion of muscle glycogen deposits.
- Muscle damage.
- Stress and mental fatigue.

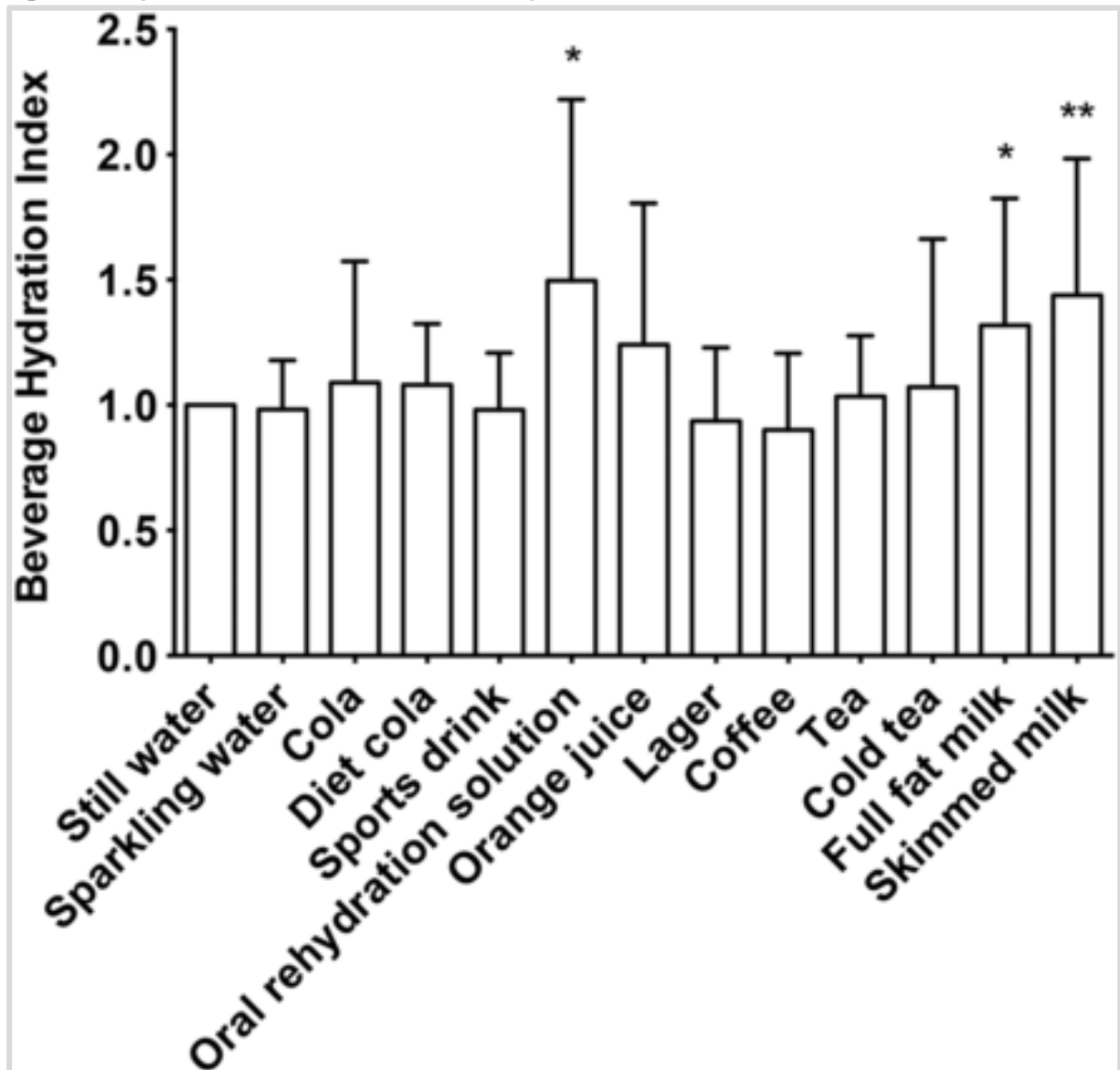
Therefore, the entire recovery process should aim to meet the demands of the athlete in the four recently mentioned factors, combined with what was previously discussed regarding the team's tactical -strategic issues.

Fatigue Recovery Strategies in Collective Sports

- 1) **Rehydration:** a 2% body weight decrease leads to a loss in performance, and 5% can cause cognitive disorders (Maughan, R. J., Merson, S. J., Broad, N. P., & Shirreffs, S. M., 2004). Immediately after exercise, athletes should drink enough carbohydrate drinks to replace fluid losses caused by exercise. These drinks should contain sodium and be close to between one and a half and twice the weight lost through sweat. Likewise, alcoholic drinks and coffee are discouraged in these periods due to their diuretic effect. The following chart is a comparison of the rate of hydration of 13 commercially available drinks.



Figure 10: Hydration Index of 13 Commercially Available Drinks



Source: Maughan et. al., 2016.

- 2) **Appropriate Nutritional Strategies:** consumption of high glycemic index carbohydrates and high biological value protein is key to replenishing glycogen deposits and optimizing muscle repair after damage induced by intense exercise. In addition, they should be consumed before the end of the competition. Furthermore, it is important to incorporate the consumption of foods containing high doses of Omega 3 fatty acids and antioxidants (Nédélec, M., 2013).
- 3) **Sleep (Quality and Quantity):** sleep is an essential part of the recovery process of the athlete, because sleep disturbances affect them negatively. Sleep is not only an important factor in muscle recovery, but also for mental fatigue. There are several recommendations such as: sleeping in a quiet environment, maintaining a stable temperature of approximately 18°C, wearing comfortable clothing, maintaining a previous routine, avoiding using tablets or phones with bright screens in bed, resting at least seven hours at night, ensuring the room is dark enough, listening to

quiet music and regulating the consumption of alcohol or caffeine, which can have a diuretic effect and can disrupt sleep (Nédélec, M., 2013).

- 4) **Cold Water Immersion** at a temperature between 9°C and 10°C for 10 to 20 minutes seems to be a useful strategy to quickly regain strength levels and reduce acute inflammation after the match. The benefits of this approach are more related to the temperature of the water than with hydrostatic pressure. Some research shows that 15 minutes in water at approximately 15°C reduces blood flow to the legs and arms, redirecting it from the periphery to the core and thereby increasing venous return and heart efficiency. It also limits acute inflammation caused by muscle damage and has a short analgesic effect due to the decrease in nerve conduction speed, the activity of muscle spindles, myotatic reflex, and muscle spasms (Nédélec, M., 2013).
- 5) **Massage and Other Means:** massage is a widely used tool despite the fact that its effectiveness on muscle function is unclear. It seems that the psychological effect of a sense of wellbeing in the individual is more important than the actual physiological facts (Bishop, D., 2003).
- 6) **Electrostimulation** and other means such as **active recovery, passive stretching,** and **compression garments** still lack scientific evidence to support their use, although this does not mean they are useless in recovery. Perhaps the protocols carried out in the scientific literature are not ideal for evaluating them or perhaps it is their placebo effect that increases the athlete's sense of wellbeing; therefore they should not be discarded (Nédélec, M., 2013).



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