MODULE 1: Strength Evaluation in Team Sports

UNIT 1.1 Strength Evaluation in Team Sports

1.1.1 The Concept of Strength Related to the Field of Sports

Mechanically, force is defined as any action by a material body on another capable of causing changes in the state of rest or movement. The human being can move, oppose external loads and adapt to the environment due to its ability to generate strength from its muscle mass. Therefore, from a physiological point of view, muscular strength constitutes a key neuromotor capacity that can occur in different forms depending on the individual conditions and objectives in which each exercise is performed. In fact, different values of muscular force can exist according to the type of action performed (dynamic or isometric), the velocity, the weight moved or the mechanical characteristics of each exercise (Knuttgen and Kraemer, 1987, in Naclerio, 2011).

In most sports settings, strength is applied to accelerate, decelerate or to oppose the loads determined by the body itself, an implement or the action of an adversary, performing fundamentally dynamic actions where the resistance to be overcome is constant or isoinertial. Therefore, and given the great importance of muscular strength on sports performance and on health, the assessment protocols and criteria that are most commonly used for assessing levels of strength in dynamic isoinertial movements, will be analyzed. These are a key tool for properly diagnosing, programming and controlling strength training sessions (Naclerio, 2011).

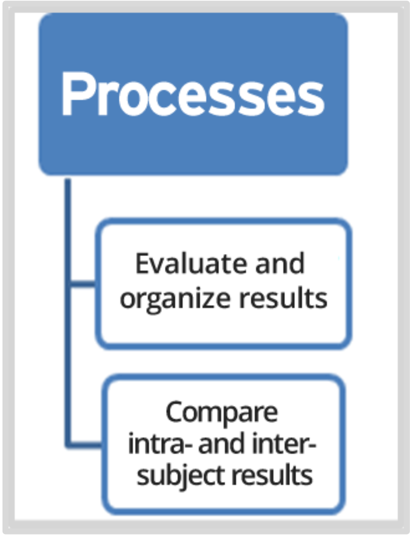
1.1.2 Strength Assessment: Concepts and Objectives

The objective of this development is that the professional involved with training that is oriented toward strength (neuromuscular) training is able to manage a basic strength evaluation methodology - within sport at various skill levels - that would enable the professional to carry out two very important processes (Figure 1).

The professional must:

- Assess and organize the results.
- Compare them both intrasubject and intersubject.

Figure 1: Processes to be Performed by the Professional in the Context of Strength Assessments in Sport



Source: Prepared by the author.

This is why the classification of values obtained in the tests should be intrasubject and intersubject. In other words, when we have subjects with different characteristics within a team, the tests are used to check on the evolution of the player himself (intrasubject); but they can also establish groups of players with similar characteristics in order to determine relationships and comparisons (intersubjects).

In the context of the processes mentioned above (assess and sort results, and compare intrasubject and intersubjects), it will be very important to take the following considerations into account:

- The conditional tests should not be used as predictors of performance, but as indicators and predictors for the control and progress of the player's physical condition.
- Internal load data would be needed to understand the internal condition of the player and be able to make a plan or proposal for training loads.
- It is interesting to monitor in order to get as close as possible to the athlete's condition. Therefore, both external and internal load data should be considered, so that the view of the exercise professional making the assessment reflects as closely as possible the athlete's current condition and fitness.

Therefore, the strength evaluation, which forms a part of training monitoring, may seek objectives such as those presented by González Badillo and Rivas Serna (2002):

1) Oversee the training process as well as changes in performance.

2) Assess the relevance of strength and power on the specific performance area.
3) Define the strength and power needs.
4) Define the athlete's profile: strengths and weaknesses.
5) Verify the relationship between progress in strength and power and the specific performance: the relationship between the changes.
6) Predict outcomes.
7) Prescribe the most appropriate training, depending on:

    a. The needs for strength and power in the sport as well as the subject's own needs.
    b. The results of tests carried out so far.
    c. Assessment of the influence of strength and power over other qualities.
    d. Differentiate between athletes from the same level as well as different sports levels.
    e. Contribute toward the identification of talents. (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

All training including strength evaluation as well as its monitoring, is a complex and multifactorial process that involves obtaining an amount of information that is key for sports training. It cannot be otherwise.

Training control cannot be confined to a single parameter, e.g. the value of 1RM (as will be discussed later). However, when the training is oriented toward healthy fitness, we should rethink the intended objectives, making them not so complex initially, and obtaining data that is relevant to the overseeing and prescription of training for that purpose.

Coinciding with the contribution made by Heredia Elvar (2005), the current approach in programs oriented toward neuromuscular fitness should consider a series of prerequisites in advance. In so doing, it must:

1) Help to determine the neuromuscular training area or zone in which the subject is going to develop the program (depending on the phase).
2) Ensure a direct transfer between the data obtained and its application to the training prescription.
3) Avoid situations involving potential risk of injury, ensuring safe and correct execution.
4) Allow progress between measurements to be checked and, logically, the assessment of the effects of the training. For this case, it is equally important to obtain feedback as positive reinforcement for the athlete. (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

The following aspects must be considered within a neuromuscular fitness program, in accordance with the structure of the FC Barcelona performance area (Seirul·lo Vargas, F., 2013):

1. Ensure healthy joint stability and control for the human athlete. Coadjuvant work.
2. Ensure variability in the proposals with regard to load levels and articulation ranges. Coadjuvant or optimizing work.
3. Interrelate the conditional structure with the rest of the structures to optimize the complex system (i.e. the human athlete). Optimizing work.

Before developing the proposed strength evaluation, and following González Badillo and Gorostiaga Ayestarán (1996), we will make a brief review of the methods for measuring strength and its manifestations. We would like to keep in mind an approach that is more applicable to sports training, considering the existing measurement methods according to the type of muscle activation measured:

- Measurements in Isokinetic (Concentric-Eccentric) activations.
- Measurements in isometric activations.
- Measurements in isoinertial activations (free weights), with or without additional measurement instruments and jumps (intense SSC) (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

It is important to point out that these measurements give us information about the athlete's (or player's) physical condition, but we cannot extrapolate this data to relate it with sporting performance.

1.1.3 Measurements in Isokinetic Activations

Isokinetic dynamometers have been used in rehabilitation—especially on the knee—as a means of performing both concentric and eccentric dynamic exercises. These make it possible to work all the strength potential of the muscle, in all degrees throughout the arc of movement (González Moro, 2004 as cited in Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

"Isokinetic exercise can be used to quantify the capacity of a group of muscles to generate a force or torsional moment and as a form of exercise to restore strength levels after an injury, or simply as training" (Tlatoa Ramirez, 2014).

It is important to understand that this type of test is performed during a rehabilitation stage in order to help resolve a particular problem. If these tests are performed with a healthy athlete and produce asymmetric values between limbs or warning signs, several other parameters must be taken into account before concluding that the athlete needs to improve or change some strength levels.

It must be understood that the athlete (or player) creates compensations in order to adapt to an environment that, by definition, generates decompensations, but these do not always have to be injurious. In case they are not injurious, that decompensation must be understood as the athlete's adaptation to his environment, since, if his motor structure is altered via external adaptations, he runs the risk of altering his proprioceptive information and modifying patterns that cause mismatches, and that this in turn, ends up having a negative effect on the player and his performance as an individual within the team.

Some of the features of this type of measurement are:

- The velocity of movement of the activated body segments remains constant.
- They allow us to assess movements in rotation, which in many cases are not quantifiable by other types of dynamometers.
- The resistance generated by the dynamometer is of the same order of magnitude as the muscular force applied throughout the range of movement.
- It allows optimal loads to be used on the muscles and the force (torque in joint movements) to be assessed in dynamic conditions.
- It is useful in injury recovery and rehabilitation. It is of little use for sports training since isokinetic movements are almost never found in any sports discipline.

The main components of isokinetic dynamometers are (Gonzalez Moro, 2004):

Table 1: Main Variables to Take into Account in Isokinetic Dynamometry (González Moro, 2004)

Variable	Characteristics
Speed of Motion	Slow speeds (up to 60%) Fast speeds (above 180%)
Range of Motion	Established for each joint and motion. Limited by specific pathology.
Type of Contractions	Concentric. Eccentric
Workout Pace	Continuous. Superimposed or contraction to contraction

Source: Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006.

Table 2: Physical Quantities Used in Isokinetic Dynamometry (Gonzalez Moro, 2004)

Force (newton)	Product of the mass displaced by the acquired acceleration. What the muscle actually does.
Moment (newton x meter)	When force is exerted along an axis of rotation. It is the torsional moment and indicates the external result.
Work (joules)	Force exerted by the distance of displacement. It is the transferred energy. Graphically, it is represented as the area under the moment curve.
Power (watts)	It is the work done over time. Useful for repetitive tasks.

Source: Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006.

The most commonly used units in isokinetic assessment are those derived from the torsional moment. They can be expressed as the mean moment throughout the range of movement; the maximum moment reached and the angular position of the path in which the maximum moment is exercised. The moment of each angle can be studied by obtaining the specific angular moments (González Moro, 2004).

Moments or forces performed can be expressed individually or in relation to the antagonist muscle groups. This allows to obtain the torque ratios of the hip, knee and shoulder flexors/extensors or the torque ratios of the external rotators/internal rotators of the shoulder. This way of expressing results allows us to detect possible strength deficits and muscular imbalances (Gonzalez Moro, 2004).

The main **advantages** of isokinetic assessment are (González Badillo and Rivas, 2002; González Moro, 2004):

- It allows us to compare agonist and antagonist muscles.

- It allows measurement of isometric, concentric and eccentric actions.
- It is possible to compare limbs with each other (e.g. imbalances), bilateral discrepancies, as well as assessing general muscular weaknesses, local atrophy and areas of weakness.

According to P. Kannus (1994 cited by Gonzalez and Rivas, 2002), the main **disadvantage** of these isokinetic measurements is that it is an unnatural movement. In addition to and in light of numerous studies (Gleeson and Mercer, 1996 cited by Gorostiaga and Rivas, 2002), isokinetic measurements must be carefully taken (i.e. for the impact on the data due to significant levels of measurement errors, depending on the measurement angle, less reliability in relation to higher velocities, etc.).

In addition, there are two major drawbacks for not assessing that option as plausible for use by the trainer:

- The validity of this diagnosis, at the specific level—whether for a movement in our daily lives or when practicing a sport—since it is virtually impossible to maintain a constant speed of movement via the axis of a given joint. As previously mentioned, this test is to be taken into account within the rehabilitation stage; it can serve as a guide, but never as the sole parameter to take into account.
- Its enormous cost and the need for preparation by the personnel in charge. (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

1.1.4 Measurements in Isometric Activations

Isometric force is described as the force or maximum torque produced by a peak voluntary isometric contraction (Mac Dougall, Wenger and Green, 1995). We can also say that it relates to application of a maximum voluntary muscle activation against an insurmountable resistance (Gonzalez Badillo and Gorostiaga Ayestarán, 1995).

Remember that these measurements are still part of the monitoring of the player as an individual (adjuvant training).

Specially designed equipment can be used for their evaluation, including dynamometers that are currently on the market or that are made-to-order. There are other, more economical adapted procedures which can also be used. Among the former are the dynamometers, strength platforms and isokinetic machines. In the second case, free weights are used, with progressive loads, until an impossible-to-mobilize resistance is reached. The former offer greater precision, but the use of free weights is more economical.

With regard to equipment or instruments that we will need to evaluate, Avis et al. (1985) and Secher (1975) recommend building a structure that allows for the evaluation of the specific movement pattern of the sport (if the subjects being evaluated are athletes), in order to respect the principle of specificity (to be clear on this point, it is very difficult to adhere to this principle of specificity when this, in terms of sport as a whole, by concept, is the variability of the game itself, where a technical-tactical situation is never repeated exactly during the competition). Thus, the structure would need to be equipped with a force transducer (load cell) that features an effort indicator. The readout apparatus can be an oscilloscope or a high precision graphical register. Currently, the analysis of the force or torque signal is performed through specific software and provides, in graphical form, the maximum force or torque values as well as values related to the rate or speed of development (Viitasalo, Saukkonen and Komi, 1980).

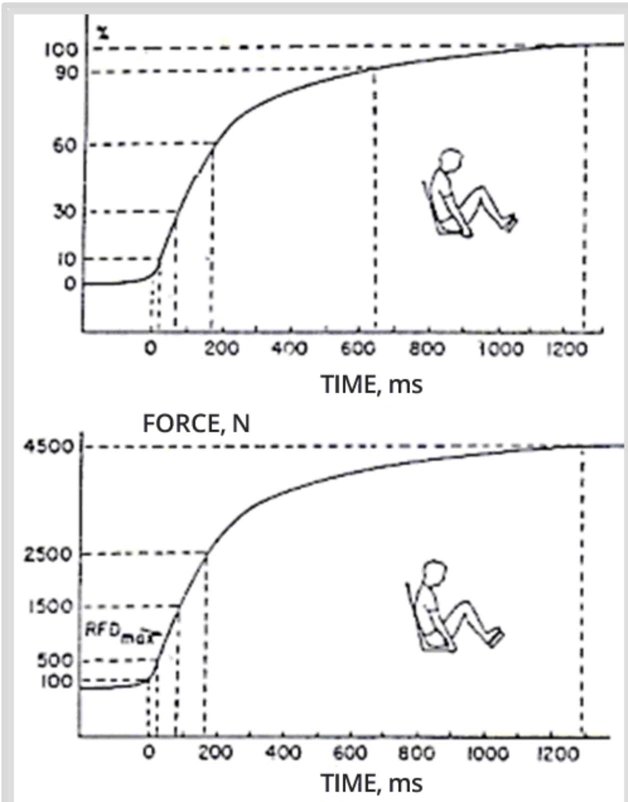
With regard to equipment calibration, Mac Dougall, Wenger and Green (1995) propose calibration with familiar weights. They state that the calibration must be performed across the entire working range of the instrument. Systematic calibration during a period of time will help establish the stability of the system, and will indicate the ideal calibration frequency. It is advisable to perform a calibration before each assessment session, especially when a lot of time has passed between one session and the next.
The key measurements in the isometric test are:

- **a)** The maximum force or torque.
- **b)** The rate or speed of force development
- **c)** The rate or speed of muscle relaxation.

a) Measurement of Maximum Force or Torque

Force is measured as maximum force (Newtons, or N), or as the maximum (Newton per meter, or N/m) torque (torsional moment) developed during a maximum voluntary contraction (Figure 2).

Figure 2: Force and Time Curve During a Maximum Voluntary Isometric Contraction



Source: González Badillo, J. J., y Ribas Serna, J. (2002) [Gonzalez Badillo, J. J., and Ribas Serna, J. (2002)]

The implementation of the test can be performed:

- With a progressive activation or contraction until reaching peak force.
- With a very fast muscular activation or contraction, trying to reach the maximum force in the shortest possible time.

For the measurement of the maximum force or torque, both forms can be used, but some authors, like Mac Dougall, Wenger and Green (1995), propose that the contraction must last long enough for the subject to be able to reach maximum force.

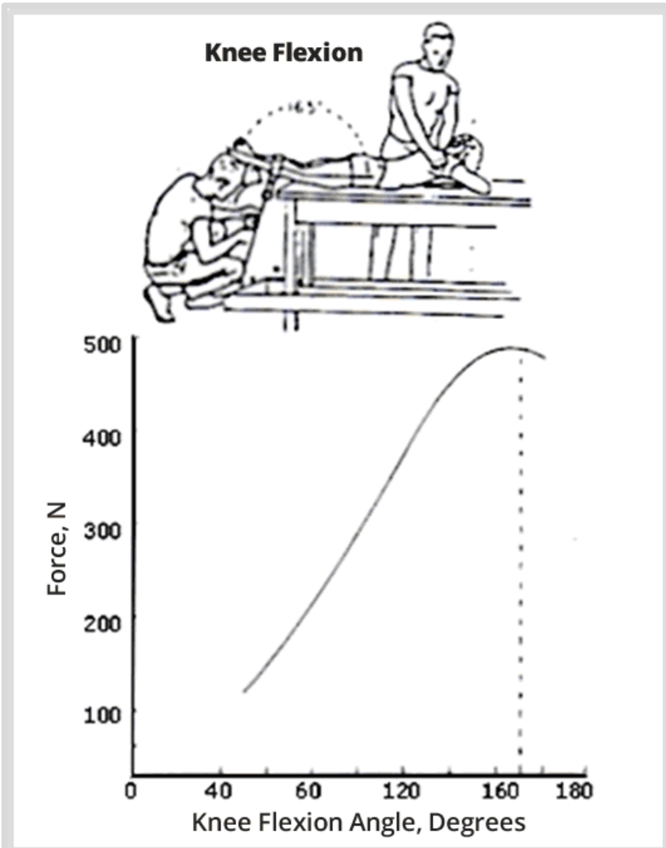
The time required to reach the maximum force depends on several elements (the adaptability of the evaluation program, the angle of movement evaluated, the characteristics of the subjects, the instructions they receive, etc.). In general, any subject can achieve the maximum force with contractions lasting 5 seconds (Hood and Forward, 1965). Therefore, the assessment protocols include contractions that last between two to five seconds (Andersen and Henckel, 1987).

It must be taken into account that, although it may take up to 5 seconds to reach the maximum strength, 90% of the maximum strength is often reached in less than 2 seconds (Hakkinen, Komi and Alén, 1985). González Badillo y Gorostiaga Ayestarán (1995) [Gonzalez Badillo and Gorostiaga Ayestarán (1995)] recommended contraction durations of between 3 to 5 seconds, repeated two to five times, and then, from these, taking the best result. It is important to keep in mind that once the maximum force is reached, it could only be maintained for a maximum period of 1 second (Hislop, 1963).

With respect to the rest periods between the various attempts, periods ranging from 15 and 20 seconds have been used (Tornvall, 1963), up to a total of 5 minutes (Viitasalo, Saukkonen and Komi, 1980). Shorter times lead to fatigue after two or three repetitions (Hood and Forward, 1965), so rest periods of 90 seconds seem to be the most suitable (Murria et al, 1977 in Mac Dougall, Wenger and Green, 1995). Mac Dougall, Wenger and Green (1995) propose pauses of one minute between repetitions.

Standardization of body position for the assessment is totally necessary. In the evaluation of a single joint, it is necessary to standardize the articulation angle of the test movement and the articulation angles of the adjacent body parts (Lunnen, Yack and Leveau, 1981). For example, in a knee flexion strength test, it is necessary to standardize the angle of the knee joint because the force can vary significantly over the degree of mobility (Figure 3).

Figure 3: Isometric Force Curve



Source: MacDougall, Wenger and Green, 1995

The image shows how joint position influences the isometric force of the knee flexor muscles. It is very important to standardize the angles of articulation in the isometric force measurement (Prentice, 1990, in MacDougall, Wenger and Green, 1995).

In the case of Figure 3, the flexion torque will be affected by the angle of the hip, depending on whether the subject is lying face up or face down (Houtz et al., 1957)**.** Another factor of influence has to do with whether one uses a manual restraint (to do this, there must be a correlation between gages, i.e., correlation intra and inter gages) or straps.

There is no strict rule regarding the optimal position for the test movements for one or several joints; a given motion may be ideal for one particular sport. However, it is clear that the selected protocol has to be repeated, without difficulty, every time one performs the test (Mac Dougall, Wenger and Green, 1995).

b) Measurement of the Rate or Speed of the Force Development (Force-Time Curve)

The rate (RFD) or the speed (SFD) of the force development is a measure of the pace at which force or torque develops. The units are in newton per second (N.s-1) and newton per meter per second (N.m.s-1) respectively.

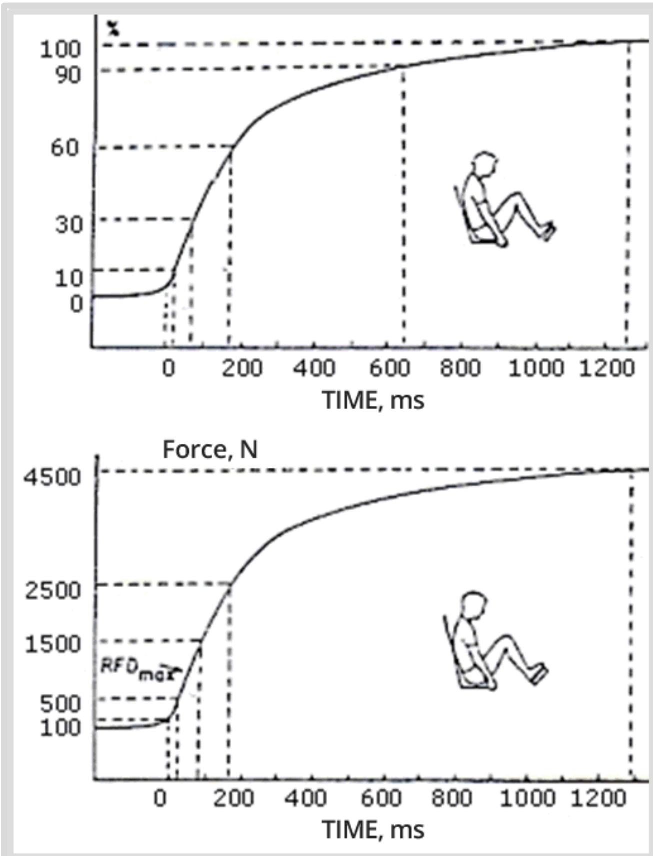
The most commonly used method to measure the RFD or SFD is to divide the peak force (PF) collected in a force-time record, by the time taken to reach the PF. The calculated value will be the mean RFD during contraction.

According to Mac Dougall, Wenger and Green (1995), this approach has at least four drawbacks:

- The first is that it is difficult to determine the precise moment in which the force departs from the base line.
- The second is that, if the force log shows a uniform progression toward the maximum (as in Figure 4), it is difficult to determine the precise point at which it reaches the PF (i.e. the moment when the peak force value is reached).
- The third is that, near the PF, irregular force readings usually appear (with dips and bumps). For example, at 800 ms, a PF of 95% can be consistently achieved. However, in an inconsistent log, the real maximum can take place in the first second of a contraction, and drop to a third in the following contraction, varying the mean RFD considerably.
- The fourth is that the calculation of the mean RFD does not produce the instantaneous peak RFD (for example, during a period of five seconds).

The first three drawbacks can be overcome by setting an arbitrary starting point (for example, 10% of the PF) on the baseline, and an end point (for example, 90% of the PF) below the PF level, where the contraction is still uniform (Figure 4).

Figure 4: Measurement of the Rate of Force Development (RFD)

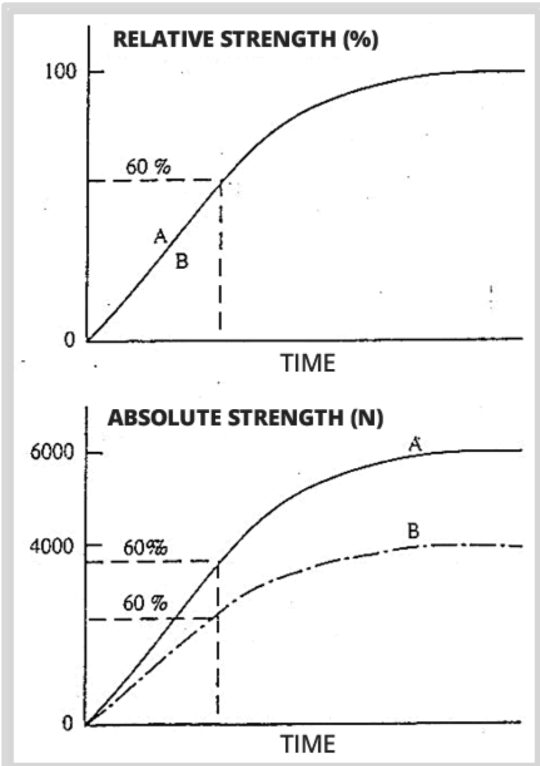


Source: Gonzalez Badillo, J. J., and Ribas Serna, J. (2002)

In Figure 4, the RFD is measured as the elapsed time from 10% to 30%, 60% and 90% of the peak force (PF). In Figure 5, the absolute RFD is measured as the time elapsed from an absolute force of 100 N to forces of 500, 1,500 and 2,500 N. The maximum RFD is determined through computer analysis of the force-time signal and takes place at 30% of the PF (Vitasalo, Saukkonen and Komi, 1980, and Hakkinen, Alen and Komi, 1984, in MacDougall, Wenger and Green, 1995).

Alén, Hakkinen and Komi (1984) have measured the time from 10% of PF to 30%, 60% and 90% of PF (100% maximum voluntary contraction). Following this method, the RFD is inferred from the attempts needed to reach the different percentages, and not through the calculation of the mean RFD during the different periods. However, although two athletes may reach 60% of the PF at the same time, one can be stronger than the other. Distinctions can be made between the two athletes by including in the analysis the attempts that were necessary for achieving various levels of absolute force (Alén, Hakkinen and Komi 1984) (Figure 5).

Figure 5: Rate of Force Development (RFD) in Two Athletes (A and B) Who Had Similar Relative Force-Time Readings



Source: Alén, Hakkinen and Komi, 1984.

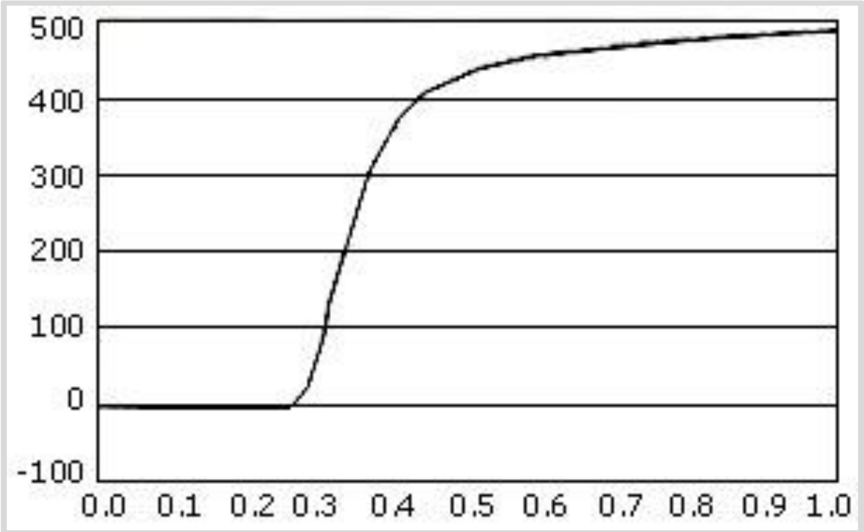
With regard to absolute force, however, athlete A displayed a greater force at 60% of PF. The evaluation took into account records of absolute and relative force-times (Mac Dougall, Wenger and Green, 1995).

With regard to the fourth drawback, the peak RFD is currently calculated by the same software that detects the largest increase of force during intervals of short duration (e.g. five seconds) (Viitasalo, Hakkinen and Komi, 1981), presenting it as the peak RFD. For example, in the study of Viitasalo, Hakkinen and Komi, P.V., (1981), in a unilateral knee extension, the peak RFD was 7,410 N.S-1 (mean) and took place at 31% of PF, which turned out to be 699 N. Likewise, one would also have to protocolize what time band is used to determine the peak RFD.

In the force-time analysis (Figure 6), it is very important to include measurements of the contraction at the beginning (for example, 30% of PF) and at the end (for example, 90% of PF) because the necessities of a sport and the effects of training may be specific to a particular phase of the contraction (Alén, Hakkinen and Komi, 1984; Hakkinen, Komi and Alén, 1985; Thorstensson, Karlson, Vitasalo, Luhtanen and Komi, 1976).

The increase of the force per unit of time (RFD) up to 70% is a way to measure explosive strength. This percentage of maximum isometric force is reached within a time near 100 or 120 ms. Thus, Gorostiaga Ayestarán and Gonzalez Badillo (1995) suggest, in the measurement of RFD, that the increase of force per unit of time will be measured in 100 ms. This would allow us to take this result as a measure of explosive strength or of the rate of strength development (RFD) (Gonzalez Badillo and Gorostiaga Ayestarán, 1995).

Figure 6: Force-Time Curve for Obtaining the RFD (Gorostiaga Ayestarán and Gonzalez Badillo, 1995)



Source: Gonzalez Badillo and Gorostiaga Ayestarán, 1995

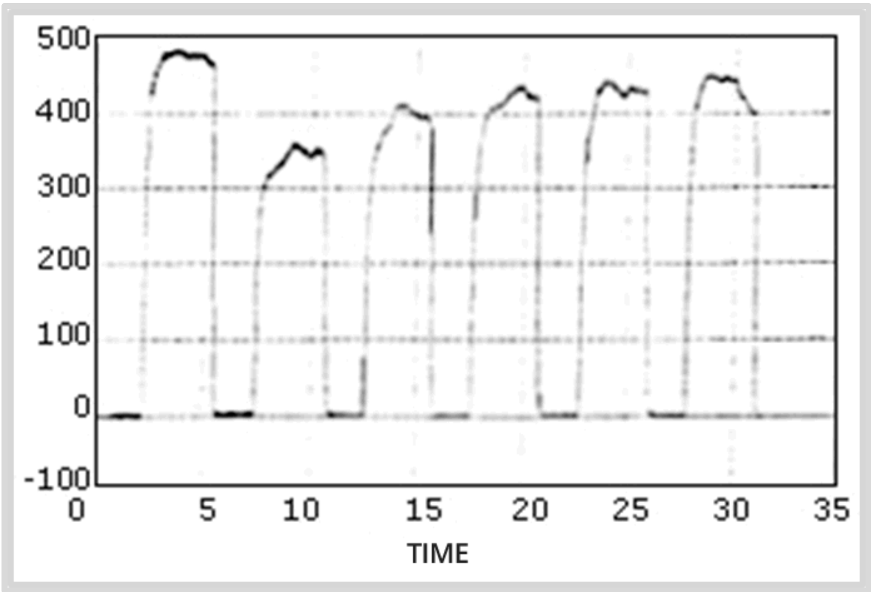
In general, the consulted literature on the RFD agrees with the estimation that, the maximum isometric force occurs when approximately 30% of the maximum isometric force is developed.

The recommendations regarding the position of the subject for measurement of maximum isometric force are fully applicable to RFD measurement.

With regard to the number of tests, some prior warm-up contractions must be carried out and, followed by three to five tests (Hakkinen, Komi and Kauhanen, 1986). Fatigue may have a significant effect on the RFD (Royce, 1962; Viitasalo and Komi, 1981) and, therefore, the rest periods between one repetition and another should be at least one minute (Mac Dougall, Wenger and Green, 1995), although, sometimes, breaks of five minutes were prescribed (Viitasalo, Saukkonen and Komi, 1980, in Mac Dougall, Wenger and Green, 1995).

González Badillo and Gorostiaga Ayestarán (1995) concluded, after having worked on measuring hand pressure strength (i.e. hand grip), that a recovery time of one minute between different attempts is sufficient in order to allow maximum strength to be determined for each one. The maximum force peak was reached by two seconds and was maintained for a very short time (Figure 7).

Figure 7: Force-Time Curves from a Maximum Isometric Strength Test with Three Attempts Separated by a Recovery Time of One Minute (González Badillo and Gorostiaga Ayestarán, 1995)



Source: González Badillo and Gorostiaga Ayestarán, 1995.

c) Measurement of the Rate or Velocity of Relaxation

The relaxation rate is not usually measured on a regular basis like the RFD, but it can provide very useful information on sports movements that require a prompt suspension of the contraction. The procedures described for the RFD can be applied to this measurement.

The maximum rate of relaxation can be measured in the same way as the time it takes to reach determined percentages or absolute PF values during the relaxation phase. For example, relaxation times from 85% to 60%, 30% and 10% have been measured (Alén, Hakkinen and Komi, 1984; Hakkinen, Alén and Komi, 1984). In the isometric extension of the knee, the maximum RFD of 7,410 N.s-1 occurred at 31% of the PF while the maximum rate of relaxation of 7,040 N.s-1 occurred at 58% of the PF (Vitasalo, Saukkonen and Komi, 1980).

An important contribution of Hakkinen and Myllylä (1990) is that the relaxation time increases, i.e. relaxation is slower after fatigue. As stated earlier, relaxation time is very important among those sports that require a quick interruption of the contraction.

For carrying out these types of tests with the best possible reliability and accuracy, a force "transducer" (load cells) would be required and, if possible, support from IT with respect to data collection and subsequent processing. Regardless of the software being used, it will be important to know which variables are being monitored and where they come from.

The value of the isometric measurements raises some issues that should be considered as potential disadvantages for their application in sports training programs:

- Their application must be performed in the angle in which peak force occurs on the specific gesture that is intended to be assessed. This implies a relationship in dynamic performance, which is questionable. In addition, there seems to be little relation between the neuromuscular, structural and mechanical adaptations between static and dynamic exercises (González and Rivas, 2002).
- It is widely accepted and documented that (isometric) exercises with a high static component are contraindicated for people with cardiovascular disease, essentially due to the high increase of systolic blood pressure that is generated and to their potential as inducers of ischemia during the exertion (Pate et al., 1991; Jiménez, 2003). (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

This is not usually the case for athletes, but it is necessary to point out this disadvantage.

UNIT 1.2 Assessing Strength in Different Manifestations

1.2.1 Measurements in Isoinertial Activations (Free Weights) in (Concentric) Miometric Action and (SSC Intense) Jumps with and without Technology

Strength measurement using free weights (and initially without technology) is perhaps the simplest, cheapest and most common system to measure strength, although it can only provide us information on maximum dynamic force values expressed in displaced kilograms (Gonzalez and Rivas, 2002). The simplest example is obtaining the value of 1 RM (repetition maximum) in an exercise. We could also obtain the value of this RM through the use of different formulas.

Factors that should be taken into account in the estimation of the RM (from Tous, 2000; Weir et al., 1994; Kraemer, Fry, 1991; Brown and Weir, 2001; Heredia et al., 2005; González Badillo and Ribas Serna, 2002; Jiménez, 2003)

- Familiarization: it will be necessary for the subjects to have contact with the equipment to be used at least one session before assessing the RM.). (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

In case of training in team sports—these being less injurious and posing less risk of injury—in the coadjuvant workout sessions (i.e. training to improve the player's condition) it is recommended to manage workouts in which the intensity is controlled by the nature of the effort; in other words, working with a load that can be close to the maximum or far off the maximum. This requires the player to become familiar with the material and exercises proposed for his or her development.

In exercises proposed to optimize the structures of the player (i.e. optimizing training), these are not classified by load intensity, but by areas of work, where the variety of repetitions is high within the session volume, and preferential simulator situations are undertaken, accentuating a series of structures in each activity.

- Select the exercises that are going to be trained the most, or that possess greater specificity and/or functionality. In this case, if exercises with free weights or machines are chosen, we must ensure that they are directed toward the large muscle groups. According to Kannus (1994), performing tests using machines results in a very specific movement, which generally is not a natural movement. This is why the results obtained would not be applicable to the actions that involve a complete multijoint kinetic chain (González Badillo and Ribas Serna, 2002). (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

In the case of team sports, if we are talking about monitoring all players' exercises, we must monitor exercises of a general nature that allow each player to be monitored. If, on the other hand, we are talking about rehabilitation, we must monitor exercises organized by the medical staff to recuperate the injured structure so that the player is able to return to competition with confidence.

- Within the same assessment session, do not perform more than two to three exercises. In the same session, avoid testing muscles that act as synergists in other movements or exercises to be assessed.
- Use subject-matter experts. Let's keep in mind that there will be an important influence on the learning variable within the assessment of subjects that start training. Such an assessment would not be very necessary when we know that the first (mainly neural) adaptations are produced with very low loads (with estimated resistances of 45-50%, and even lower), which also allow adequate learning of the correct technique for performing the exercises (Feigenbaum, Pollock, 1999; Jiménez, 2003).
- The recovery interval between sets must not be less than one minute or more than five (Weir et al., 1994).
- The optimum number of one-repetition sets to determine maximum strength should not exceed three or five (Kraemer, Fry, 1991).
- Reliability: two attempts should be made on two different days in order to obtain data that is as reliable as possible and to avoid large variability in the measurements.
- Warm up of five to ten repetitions at 40-60% of maximum perceived exertion.
- Rest for one minute, and perform light stretches, carry out three to five repetitions at 60-80% of the maximum perceived exertion.
- The next step will take the subject near the subject's perceived 1RM. The weight will then be increased and the subject will attempt a repetition. If this is achieved, a rest period of three to five minutes will be granted, after which the weight will continue to be increased until it is no longer possible to lift it.
- The value of 1RM will correspond to the weight of the last successful lift.

- It is important to establish a constant communication with subjects being assessed, asking them about their feelings as well as their own estimate regarding how close they are to their 1RM.
- Proper balanced tonic postural ability (BTPA) (Heredia et al., 2005) must be maintained while carrying out the test.
- Caution is advised when interpreting the obtained data (Brown and Weir, 2001), since there are many factors that can influence its manifestation.
- The tests must be applied at the appropriate time and the results obtained must have an application in the training process.
- It is recommended to divide the number of kilograms lifted by the body weight in order to obtain the strength relative to weight and in order to perform interindividual measurements.

Table 3: 1RM Direct Determination Protocol (Jiménez, 2005)

Direct 1RM determination protocol			
Phase	**Goal**	**Means**	**Time**
1	General warm-up	Cardiovascular and joint mobility and flexibility exercises	5 to 10 minutes
2	Specific and applied phase	6 to 8 repetitions with 40% - 60% of the supposed maximum weight	Resting one minute
3	Specific joint preparation	3 to 5 repetitions with 70% - 80% of theoretical estimated weight and with increasing speed	Pause for 3 minutes
4	Specific neuromuscular preparation	Weight increase, close to maximum (85 to 90% of the estimated or theoretical weight), performing 2 repetitions	Rest for 3 to 5 minutes
5	Maximal neuromuscular activation	With a weight close to 95% of the theoretical weight, the subject is instructed to perform one repetition	Rest for 1 to 2 minutes
6	Search for maximum weight	Applying a load at 100% and determining the maximum weight (1RM) 3 to 5 attempts until the maximum is precise	3 to 5 minutes resting time between attempts

Source: Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006.

In case it is necessary to use the RM, a progressive load test can be performed. Alternatively, any (linear or exponential) formula can be used to find the value of this RM (Tous, 2000).

Table 4: Formulas to Estimate the Value of 1RM

Brzycki (1993)
1RM = Weight lifted %1RM = 1.278 – (2.78 reps until failure) (Remember that it appears to be most accurate when less than 10 repetitions are performed)
Wilday (1998) Epley (1985)
1RM = (weight lifted x 0.3333 x reps until failure) + weight lifted (Much more accurate when more than 10 repetitions are performed)
Lander (1985)
%1RM = 01.3 –(2.67123 reps until failure)
O'Connor et al (1989)
%1RM = 0.025 (weight x reps until failure) + weight lifted

Source: Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006.

While it is true that for sports performance, the test with free weights can get us quite close to the actual competitive situation, this information is insufficient and must be made completed. This is why some interesting instruments have been designed for the technician that will provide us with more information (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

It is true that monitoring everything that the player does can give us some information about the external load that that player perceives during a session, day or microcycle. But with this information, we cannot claim that the tests or controls are what allows us to get closer to the real competition and predict the player's performance.

Controlling the player's load allows us to modulate his exposure time and training type, with the goal that the player is always available so that all of his structures (bioenergetic, conditional, emotive/volitional, socio-affective, coordination, cognitive and mental) allow for an inter-relationship between them that optimizes his own system. Nevertheless, we will never be able to propose more tests than training itself or competition that allows us to assess its performance.

The technological revolution of strength training evaluation and monitoring can be applied to any manifestation of strength. The parameters that this technology offers us for strength evaluations are velocity, acceleration, time to reach maximum speed, time to reach maximum acceleration; mean strength, maximum strength, time to reach maximum strength; mean power, maximum power, time to reach maximum power and maximum angle (Pérez, 2004). (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

These strength parameters (m • a) allow us to monitor the player's characteristics in a given context away from competition. This can help to give us an idea of his or her physical condition, understanding this state as something individual and not collective. Moreover, it allows us to monitor and improve one of the structures, but for optimizing the system, it is necessary to determine the interrelationship of all structures via preferred situations that simulate the competition.

Linear Encoders (we can find two devices provided by the data cited above: the Ergopower (Bosco System), and Realpower (Globus)) have an electronic measurement system based on the linear encoder that can be adapted and applied to any bodybuilder machine that uses the force of gravity as external resistance. The bio-robot measures and records the velocity of displacement as a function of time. In this way, it can display all the derived parameters such as velocity, acceleration, power, work, etc.

The MuscleLab system designed by the team led by Dr. Carmelo Bosco, or in its microMuscleLab Power version, will allow the accurate measurement of power (W), force (N), mechanical work (kJ), velocity (m/s), peak velocity, time (s) and load displacement (cm). This implies operating at a higher level of knowledge of the neuromuscular involvements; by monitoring these parameters, we will be able to understand the status of the subject's conditional structure.

To obtain data on the results of the parameters of a movement made with bodybuilding equipment or a free weight, the motion sensor is connected from MuscleLab to the load to be displaced. The equipment will record the displacement as a function of time and all derived parameters are calculated automatically: Velocity (m/s), angular velocity (rad/s), force, power, time etc. can be seen in a numerical or graphical form. Calculate the load of 1RM. Load-body weight relationship. Provides custom equations of the force-velocity and load-velocity curves. To get more information, goniometers, EMG, or accelerometers incorporated in the equipment can be used, which also include a biofeedback system that allows optimizing the efficiency of strength training (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

1.2.2 Strength Assessments in Sports Training: Initial Reflections

As we have explained, one of the key factors that will directly determine the assessment of strength, in this case in the field of sports training, is training load. The determination of the strength training load (in this case with resistances, on anisometric-concentric activations with free weights or machines), implies the attempt to define the load intensity parameter. The intensity is the qualitative aspect of training, which is the degree of exertion required by an exercise (González and Gorostiaga, 1996). (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

The qualitative aspect of training is the level of the relationship that exists between the different structures and allows the evolution of the human athlete's system regarding its preparation for competition.

The maximum intensity could be expressed by the weight used and compared with the % of this weight in relation to the maximum in exercise. Using the % of 1 RM (repetition maximum) as an expression of training intensity is very frequent and practical. According to this statement, this would mean that if the athlete performs a 1RM bench press test, for example, and in that test, he is able to do one repetition (no more) of 100 kg, he would be working with an intensity of 80% when working with 80 kg. (Heredia Elvar, Chulvi Medrano, Ramón and Pomar, 2006).

Table 5: Strength Training: Load Control Parameters (Isidro, Heredia, Pinsach and Ramon, 2006)

Strength Assessment and its Applications in Sports Training and Health	
Strength: Load control parameters	
Volume	On its own it is not particularly relevant, however acquires value when linked to intensity values. This is the global quantitative average of different training loads that develop during a session, micro, meso or macrocycle. **VOLUME INDICATORS** Repetitions – Sets – Tonnage (disuse)
Intensity	Qualitative aspects of the load. **INTENSITY INDICATORS** Average weight – intensity area – average relative intensity
Effort Nature	**Number of repetitions that are not performed in each exercise/set**
Density Recovery	**Recovery time** between sessions, micro and mesocycles. **Resting time** between sets (micropause) and exercises (macropause)
Exercise and Type of Resistance	Exercises with localized, general and specific effects. Types of resistance/load. Body weight (autoload), free weight (dumbbells-bars), machines (fixed, variable, adapted and inertia resistance), ballasted equipment.
Type of Execution	Determines **the execution method of said exercise** (speed, stability and ROM)

Source: Adapted from Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

As we shall see, even while doing a 1RM test, and estimating the maximum weight that we could move in that exercise at "that" moment we could establish the dynamic of the training intensity, the estimated intensity (for example 60%) does not always correspond to the subject's maximum potential. Other factors, such as, for example, execution speed, will also be determinants. When the resistance (this term is a lot more appropriate) used is equal to or greater than 90% 1RM, the execution speed has to be the maximum speed possible since speed cannot be regulated with these percentages. However, with % lower than 85-90%, performing the movement at maximum speed or not, can be extremely important. (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

It is interesting to begin to monitor the loads a player can do at different speeds (machines that allow control and monitoring of isokinetic character), as well as controlling speed parameters, before exercises, with the same load, on machines which offer different capabilities (pneumatic, rotational inertia, isotonic, variable resistance).

We must consider several issues with regards to using formulas to estimate of the value of 1 RM. In fact, when neither the weight nor the number of repetitions per set have been the maximum possible, one should be careful not to go too far from the intended purpose. Taking into account that (from Gonzalez Badillo, 1997):

- Knowing what percentage represents a load (weight) in accordance with the repetitions one can do with it. To have a pretty rough idea, numerous formulas are proposed to find the value of 1RD and the % that a weight represents based on the repetitions achieved. But, one should be careful in case of applying this to all exercises. Gonzalez Badillo (1997) only exposes a correlation between predictors (maximum number of repetitions performed with the corresponding weight), and the criterion (1RD or % of 1RD) of 0.99 in bench pressing, and 0.96 in squat. The formula described by Brzycki (1993), shows reduced accuracy after 10-12 repetitions – others such as Welday (1988) and Epley (1985) appear to be more precise when doing more than 10 repetitions–. The use of these, both in training and testing, is more reliable when the number of repetitions is between 2 and 10 (Gonzalez Badillo, 1997; Tous, 1999).
- Training objectives need to be very clear. To do this, it is necessary to have the competition needs clearly identified.
- Know that, according to these objectives and strength needs, the same number of repetitions/sets should represent a different load/effort.
- The degree of effort required is related to the number of repetitions not done (type of exertion) in each sets with regard to the maximum possible.
- Know the effect of each number of repetitions per set in relation to the effort required (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

1.2.3 The RM for Strength Training Load Determination: Use, Problems and Proposals

Could we actually say that, through a 1RM test, we know the subject's "true peak capacity" for this exercise? Or, on the other hand, will there be some variables that directly influence how that 1RM value corresponds to the current situation of the subject's performance on that particular day, and in a given psycho-biological situation? Are measurements of the value obtained, and its possible applications, truly valuable in relation to the cost/benefit? Let's look at this for a moment (Heredia et al., 2005):

- Several authors talk about the need to take into account that inexperienced subjects experience significant improvements in their strength values in successive test sessions simply because of their familiarization with the test, the equipment and the type of muscular action requested (Kroll, 1962; Reinking et al., 1996; cited by Brown and Weir, 2001; Jiménez, 2004).
- This only determines the performance capability in miometric actions (concentric) and not information on the pliometric capacity (Jiménez, 2004).
- The value obtained in 1RM is limited per point of lower mechanical efficiency throughout the ROM (sticking point) (McArdle et al, 1996; Jiménez, 2004).
- They depend on the individual's psycho-biological situation on that day and at that time.
- Incorrect 1RM measurement. For example, if the average movement speed value is measured during a bench press, and it is equal to or greater than 0.3 m s (1 ft/s)[1], the RM measured will be below the real value, which could mean that, from there, training will tend to be carried out with resistance below those theoretically programmed.

In general, we could consider the initial proposal of discouraging or limiting maximum strength testing (other values or parameters used to determine the exercise intensity in strength training may be more useful). For example, institutions such as the American Academy of Pediatrics and the National Strength and Conditioning Association (in Garcia Manso, 1996) recommend the use of 10 RM and/or the use of formulas, normally linear ones (Brzycki, 1993, Epley, 1985; Lander, 1985, O'Connor et al. 1989 in Tous, 2000).

In this regard, it would be necessary to reiterate some issues:

- A loss of reliability after 10-15 repetitions (depending on the test) is documented (as indicated above), which could lead us to a poor 1 RM estimate of the actual ability of the subject.
- How does fatigue influence 1RM? It is very important to understand that this factor will affect the result in the formula-based 1RM estimate test (more so when a higher number of repetitions are performed).
- The execution speed factor is decisive in this case, and even more important when more repetitions are done to determine the value of RM.

In this regard, from the proposal given by Gonzalez Badillo (1996) (in Heredia et al., 2006), we understand that the application of alternatives to the traditional concept of RM is much more useful and, possibly, accurate. Just like considering the type of the effort (Gonzalez Badillo, 1997) and execution speed as complementary means to control the training intensity, focused, of course, on the individual control of the subject.

The **nature of the exertion** is determined by the number of repetitions we do or do not do in one set. Therefore, for example, it is not the same scheduling a test for 3 repetitions per set when 6 (submaximal nature of the exertion) could be done, as performing the maximum number of repetitions with a load (maximal nature of the exertion).

If the nature of the exertion is maximum (maximum number of repetitions in one set), the maximum force will work at the expense of functional (repetitions of 1 to 3, for example) or structural (with repetitions of 8 to 10) adaptations. Although we must be aware of the state of the subject and control the values of internal and external load, proposing exercises at pure peak strength can pose a risk to the joints, and perhaps there will be no benefit for the cost (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

Table 6: Definition and Classification of the Type of Exertion (Gorostiaga Ayestarán and Gonzalez Badillo, 1995; Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

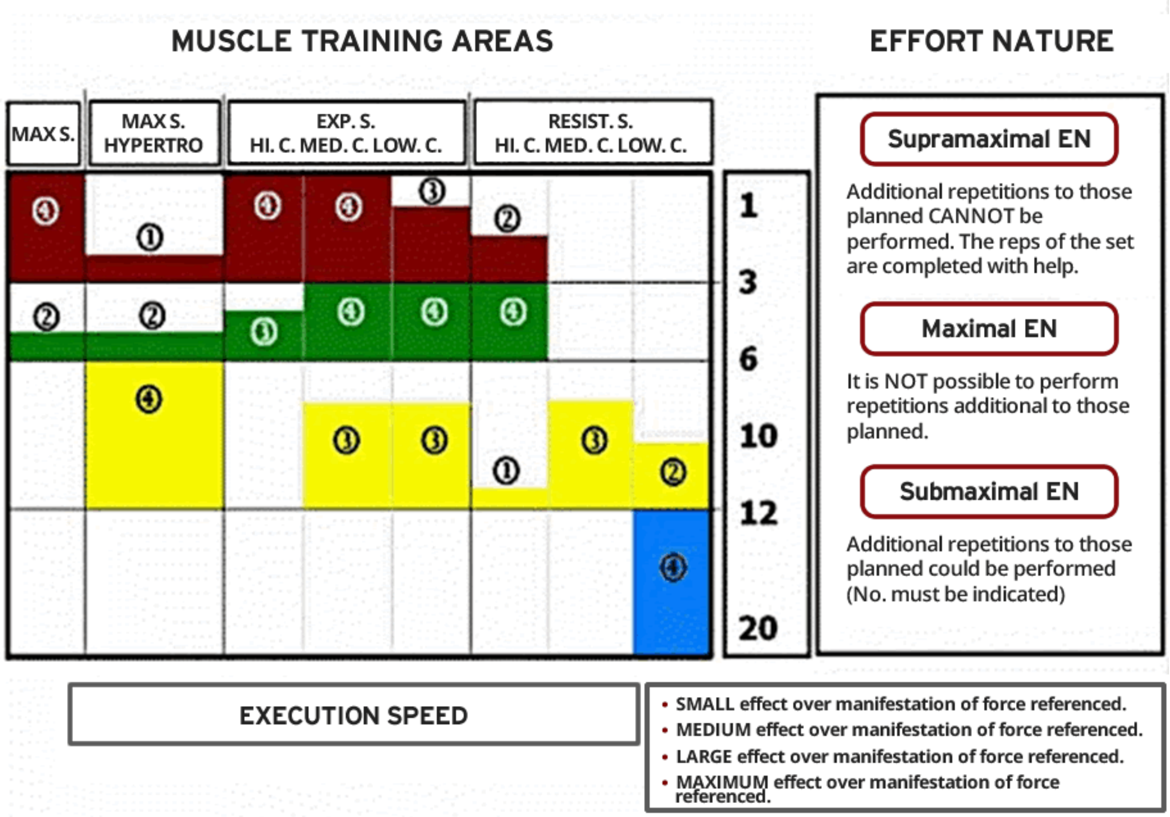
	Maximal Exertion (MaxE). It is not possible to carry out any more than the planned repetitions.
Nature of the	**Sub-Maximal Exertion (SubE).**

Exertion	More than the planned repetitions can be performed.
	Supra-Maximal Exertion (SupraE). Complete more repetitions than possible (with help).

Source: Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

It is well documented that, on the basis that if we do "x" number of repetitions per set, and no more, we are influencing a particular demonstration of strength and achieving a range of effects at a nervous or structural level, etc. (Gonzalez and Gorostiaga, 1996). Knowing this, we could establish the intensity on the basis of the determination of muscle training bands (repetitions/sets) along with determining the type of exertion (and its influence on the alleged demonstration of force: it may emphasize, minimize or neutralize such influence), without forgetting the importance of execution speed on such effects (this approach is set on the basis of a peak speed for the load being referred to and high peak speed can be determinant in the demonstrations of neural type peak-force (intramuscular coordination), and explosive demonstrations with different load types (Figure 8)).

Figure 8: Definition of Muscle Training Bands or Areas (Isidro, Heredia, Pinsach and Ramon, 2006)



Source: Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

The use of the Perceived Exertion Scales (Robertson et al, 2003) is widely documented and constitutes a valuable tool for the couch. The OMNI-resistance scale (0-10) would have advantages in perceiving the exertion intensity in intermittent activities, such as force training (Day et al, 2004; Pincivero et al, 2003; Naclerio in Jiménez, 2004). The use of this scale seems to require a period of adaptation and learning with appropriate instructions on its implementation (Glass and Satanon, 2004; Noble and Robertson, 1996; Naclerio in Jiménez, 2004). It has been estimated to take between 8 and 12 sessions, where the subject must become familiar with the use of the scale (Naclerio in Jiménez, 2004). (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006).

Estimate of 1 RM based on movement speed

With regard to the evaluation of muscular strength in athletes, Naclerio (2011) proposes the possibility of measuring the speed during the execution of a submaximal test and, knowing the mobilized weight, estimating the 1 RM value in certain exercises used for strength training.

Naclerio (2011) cites some studies that have described a linear, inverse and very high (r2= -0.83 to 0.99) relationship between the mobilized weight and the reached speed. This relationship would make it possible to analyze the variations of the muscular performance and estimate the value of maximum force due to the speed being inverse to the weight used (Kellis et al., 2005; Rhamani et al., 2002)

This prediction model takes the speed as an independent variable (predictor), and the mobilized load as a dependent variable (predicted). It is based on the following assumptions:

- The relationship between 1RM % and speed reached in an exercise is directly proportional.
- Variations of the maximum speed reached with low and moderate weights indicate the modifications of the weight used (1RM %).

Dr. Naclerio, along with his team at Universidad Europea de Madrid [European University of Madrid], developed 1 RM prediction equations in exercises with free weights (bench press and half squat) from the vertical velocity of the bar used by athletes (Naclerio, 2011).
Table 7 shows the prediction equation recommended for different groups of athletes:

Table 7: Equations to Predict 1RM from Vertical Speed

Sample	Parallel Squat with Free Bar	Bench press with free bar
Males (20-35 years old), fire department candidates	1RM=kg/(1.145+(-0.495)v) r^2=0.835	1RM=kg/(1.082+(-0.607)v) r^2=0.90
Males (14-16 years old) trained in explosive strength	1RM=kg/(1.094+(-0.388)v) r^2=0.86	1RM=kg/(1.050+(-0.517)v) r^2=0.94
Women (14-16 years old) trained in explosive strength	1RM=kg/(1.139+(-0.445)v) r^2=0.82	1RM=kg/(1.056+(-0.604)v) r^2=0.97

Source: Naclerio F., 2011.

So if the coach has equipment that allows him to measure the vertical velocity of the implement (linear speed transducer), he will be able to get a fairly accurate 1RM value, and tell the athlete to do only a sets of two or three repetitions with the maximum possible speed and with the normal training weight, or a moderate overload (50-70 % of estimated 1 RM) (Naclerio, 2011). This methodology allows a continuous control of the fluctuations of force values and, therefore, allows permanently updating load levels in each training, adjusted according to the state of each athlete prior to the start of each session (Naclerio, 2011).

We believe that Naclerio's proposal can be very useful to estimate the maximum load to be mobilized (1 RM) without exposing the individual in question to the 1RM test (remember that this test requires a high level of motivation and concentration, and since it is at maximum level, it is stressful for each evaluated subject). It also allows relating the moved load to the speed and acceleration, making it possible to detect important changes with the work objectives designed to maintain or improve the relationship of force and speed of the individual in the training program. Finally, the possibility of monitoring training from checks that can be carried out by successively applying these test, is interesting to generate relevant variations in the contributing training load.

Calculation of average execution velocity

In many cases, the devices to measure speed and acceleration of the training implements are not available, therefore checking these variables cannot be done, neglecting and abandoning the objective. Therefore, the speed of performing force exercises is often the less controlled variable and, possibly, the most influential when it comes to causing one or another to adapt (Tous, 1999).

In the case where there is no speed control device (linear encoder), average speed may be calculated through a less accurate system. The average execution speed is calculated by multiplying the number of repetitions that the subject is able to do by the total displacement in each repetition, and dividing this product by the block of time to be checked or evaluated (Tous, 1999).

It has been recommended for this type of check for the block of time to be about 5 seconds long, so as not to over-influence the reaction time, since fatigue could influence the execution (manifesting a higher standard deviation) when using a longer period of time. This test presents an important constraint when measuring the speed at higher loads at 85% of 1 RM (5 RM), therefore it should be done using lower loads at this percentage (Tous, 1999).

A practical situation is proposed (Test W5) (Tous, 1999):

- Exercise: force on a level bench.
- Distance traversed by the bar: 35 cm (13.8 in) (70 cm [27.6 in] total distance traversed by the concentric and eccentric movement).
- Total distanced traversed by the bar: 0.70 meters (2.3 ft).
- Execution time: 5 seconds.
- Instructions: do the highest number of repetitions possible within 5 seconds.
- Test result: 5 repetitions in 5 seconds.

Using the results, we get the average speed as follows:

- Average speed = (Number of reps. done x total displacement in meters [feet]) / block of time in seconds.
- Average speed = (5 x 0.70 m [2.3 ft]) / 5s
- Average speed = 0.70 m (2.3 ft)/s

One possibility is to repeat this test with other loads. Speed-load curves that would, perhaps, show important information on the state of the subject could be performed (Tous, 1999).

Evaluation of force in an eccentric system

The maximum eccentric force is estimated on the basis of the highest load (weight) the subject can resist, in a specific muscle group and exercise, during the eccentric phase of muscle contraction.

Although the studies related to electromyography surely can do more to help measure the level of muscular activation in exercises in eccentric systems, Naclerio (2011) states that there are few studies where the maximum weight that can be endured during the eccentric phase of the movement is measured, and, up until now, there is no standard criterion related to the movement speed that should be used to measure that force value. Hollander (2007) proposes determining the eccentric 1 RM when a minimum rhythm of 3 seconds cannot be tolerated while performing the eccentric phase of an exercise.

Hollander (2007) observed a great variability in the maximum eccentric weight analyzed in six force exercises.

The values of eccentric force can overcome the concentric force from 10% to 60% in men and 20% to 46% in women. The differences were greater in the exercises for upper limbs. On the other hand, Meylan (2008) recommends evaluating in eccentric systems in order to be able to identify the eccentric workloads and not determining these on the basis of results with a predominantly concentric speed test.

The agonist-antagonist relationship

This index compares the level of force demonstration between the agonist and antagonist muscles in different muscular contraction systems. Generally, the agonist (concentric)/antagonist (concentric) relationship has been used as reference (Figures 3 and 4) (Zatsiorsky, 1995; Verkhoshansky,).

Data provided by various researchers (Heyward, 2008) gives us guidance to evaluate the agonist-antagonist concentric force relationship (Table 8).

Table 8: Agonist-Antagonist Concentric Force or Agonist-Antagonist Muscular Balance Relationship (Heyward, 2008)

Joint	Movement	Relationship - Balance
Ankle	Plantar Flexion – Dorsal Flexion	3 : 1
Ankle	Inversion – Eversion	1 : 1
Knee	Flexion – Extension	2 : 3
Hip	Extension – Flexion	1 : 1
Lumbar Spine	Flexion – Extension	1 : 1
Elbow	Flexion – Extension	1 : 1
Shoulder	Flexion – Extension	2 : 3
Shoulder	Internal Rotation – External Rotation	3 : 2

Source: Heyward, 2008

Some studies have linked the incidence of ligament or muscle injuries to imbalances between the levels of strength produced around a specific joint core. As for the knee, it has been indicated that the reduced strength of the back musculature (flexor) with respect to the front (extender) of the thigh may mean predisposition to injury of the back musculature (Orchard et al., 1997).

> However, there are other studies where this relationship has not been found (Bennell et al., 1998, Newton et al., 2006), and they even question whether there is a significant cause and effect association between the imbalances in the strength of the front and back musculature of the thigh and the incidence of injuries.
>
> The contradiction between the different studies has been attributed to lack of specificity in the means used to measure strength (isokinetic machines) or the exercises used to perform these measurements (open chain exercises such as leg flexing and extending) (Newton et al., 2006). (Naclerio, 2011).

Either way, although the isokinetic tests do not include the specific muscular action regime of the majority of the sporting gestures, taking into account what Lehance (2009) stated, there would be a risk of ligament injury (ACL) or muscle injury (back of the thigh) if the traditional relationship (hamstring concentric force in respect to the concentric force of the quadriceps) is <0.47. Note that the optimum ratio is 0.66.

A limiting element of this index is that the assessment is performed (as with the previous) with free weights or variable resistance machines (gravitational or inertial action). Therefore, they could not provide more data or precision.

Another element to be taken into account is the speed at which the valuation is performed. It will be rather low due to the maximum force level being evaluated between agonist and antagonist (over and beyond the type of dominant system). This means that this index could only be taken into account as an element to verify the limiting factors (related to maximum force). However, it should be clarified that these values must be understood as valid references for studies on populations with different characteristics than those of the elite athlete population.

It is possible that an elite player has some of the previous values altered. However, this does not automatically mean that they have to be classified as a player with a risk of an injury. Of course, these are aspects to be taken into account when analyzing the real state in which the player is studied, and the rest of the parameters that can be controlled (internal and external load of the player). The purpose is to see whether these alterations in strength levels are a result of competition, and if the adjustments that the same player makes to be more efficient involve alarming values or indicators that cause overloads and, therefore, increase the risk of injury.

The injuries that occur unexpectedly through impacts and contusions are largely inevitable. However, force ratios and joint kinesiological parameters must be controlled to prevent injury due to overload.

Figure 9: 5 RMS test for right quadriceps, in OKC exercise, concentric regime

Source: Self preparation.

Figure 10: 5 RMS test of right hamstrings, in OKC exercise, concentric regime

Source: Self preparation.

Force difference (contralateral agonist-agonist relationship)

This index shows the force level produced by the mobilized weight (Kg) in an exercise that preferably allows isolating a specific muscle group. Usually, the exercise used is single-joint open kinetic chain (OKC), and evaluates the peak force (with a 1 RM test or several peak repetition test).

The objective of this test is to compare the force between contralateral agonists in a same regime of muscular contraction and at a similar rate.

The optimum ratio must be close to 1 (+/- 5 %) (Steel, 2007). This balance is considered acceptable when the difference in force between the agonist and contralateral agonist muscle is less than or equal to 10%. Although, generally in sports as a whole, the player generates greater imbalances with the objective of adapting to the competition, which, by itself, generates imbalances.

Newton et al. (2006), indicated that the difference between the forces transmitted through the left and right lower limbs must not exceed 10%. However, other studies have indicated that the risk limit is around 15% (Impellizzeri et al., 2007). A positive aspect of this assessment is its ability to isolate a muscle group and compare it to the contralateral side without participation or assistance from others. The disadvantage is that this form of evaluation corresponds to kinematic torque, while in sports activities, kinematic chain would be better due to simultaneous or sequential integration of different core joints in sport movement. It is also possible that, if an attempt is made to correct these deficits, there could be a change in proprioceptive scheme of motor control that can affect efficiency in the competition. For this reason, its use would restrict some phases of rehabilitation, such as controlling the decrease of force difference among muscles, adding more data to integration of information in the sport rehabilitation process. Within the post-injury rehabilitation phase, it is interesting to have pre-injury values to attempt to go back to these values during the rehabilitation period, until the athlete is able to compete again.
However, there is a possibility of evaluating the force difference among muscle groups that work, simultaneously or sequentially, through kinematic chain exercises, which can be multi-joint closed kinetic chain exercises (CKC). Therefore, it would be interesting to have CKC exercise data and values.

The problem here is that, in the case of the lower body, in order to assess a limiting capacity such as peak force, the exercises must use machines that maintain stability (horizontal press, press at 45°, Hack machine), since using free weights (1-leg squat, lunges) and one foot as support puts balance at risk, which limits the possibility of developing significant force levels (Naclerio, 2011).

Figure 11: 5 RMs testing of right quadriceps, in OKC exercise

Source: Self preparation.

Figure 12: 5 RMs testing of left quadriceps, in OKC exercise

Source: Self preparation.

1.2.4 Evaluation of the Stretch-Shortening Cycle (SSC). Evaluation of Explosive Strength Through Jumping Ability

Another interesting way of evaluating strength and its indicators is by using jumps. If the jump is done on a contact platform connected to a timer (for example, Ergojump, Bosco System, those made by Globus, or the Chronojump contact platform software; a free software suggestion), when properly implemented, it is possible to know the flight time and, therefore, the height reached, by the athlete's center of mass:

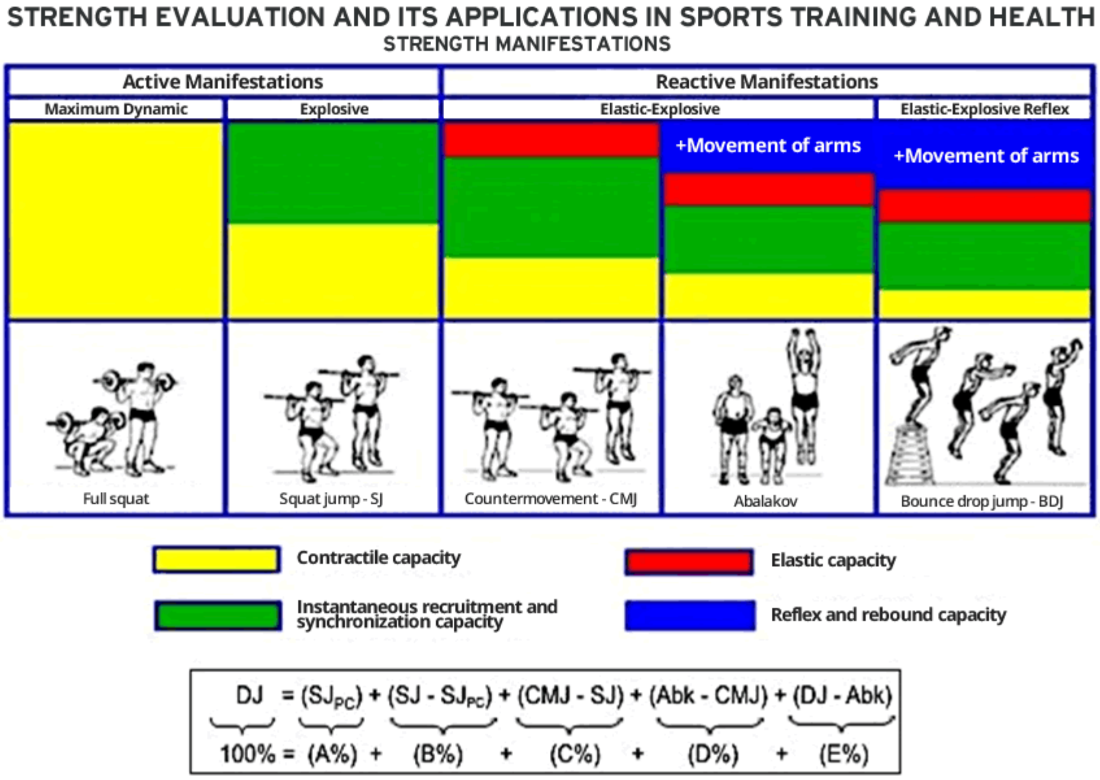
$$Hv = \frac{Tv^2 . g}{8}$$

Where Hv is the height, in meters, reached by the athlete's center of mass, Tv is the flight time, in seconds, and g is the acceleration of gravity (9.81 m s-2 average).

This will allow us to establish the influence of the contractile components, recruitment and synchronization, arm movement use index, neuromuscular reactivity and elasticity, and, with this data, establish the profile of these capabilities and relate it to a particular profile in relation to the sport specialties, as well as help us determine which factors deserve priority in the training strategy (Vélez, 1997).

This type of assessment is difficult to implement (due to its usefulness) in health oriented fitness programs, given the relative value and little transfer of information that these tests provide (Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

Figure 13: Manifestations of Strength and Assessment of Jumping Ability (Vittori, 1990; Gorostiaga Ayestarán and Gonzalez Badillo, 1995)



$$DJ = (SJ_{PC}) + (SJ - SJ_{PC}) + (CMJ - SJ) + (Abk - CMJ) + (DJ - Abk)$$
$$100\% = (A\%) + (B\%) + (C\%) + (D\%) + (E\%)$$

Source: Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

Figure 14: Evaluation of Active and Reactive Manifestations of Strength: Lower Limb/Jumps (Vittori, 1990; Gorostiaga Ayestarán and Gonzalez Badillo, 1995).

Source: Heredia Elvar, Chulvi Medrano, Ramon and Pomar, 2006.

Test on contact platform (SJ, RJ, CMJ, 10 and 30 seconds test, DJ, etc.)

The level of active and reactive explosive strength of the athlete's lower body can be assessed through standardized tests that include a battery of Bosco tests, requiring the use of a contact platform, or classic jump tests. The tools needed to carry it out are a tape measure, chalk and a wall, or, even better, a tape measure and a jump box.

Explosive strength can be estimated from the athlete's ability to jump.

In this case, initially, we proceed to describe the execution of explosive and reactive force testing using a contact platform.

The contact platform allows us to obtain the flight time, in milliseconds, when the subject performs a particular jump. Then, the flight time is converted to centimeters and we get the data that may be compared to new tests or reference tables, if desirable.

The contact platform also allows us to obtain, for certain jump types *(drop jump)*, the jump contact time. This indirectly shows how quickly the subject applied force against the ground.

Bosco's tests and some other tests include jumps introduced by Palazzi. These are:

1) *Squat Jump* (SJ) or jump, without a counter movement, from a static ½ squat.
2) *Counter movement jump* (CMJ)
3) *Rocket jump* (RJ) or jump from a deep flexion.
4) *Drop jump* (DJ) or jump and dropping from variable heights (20 to 100 cm).
5) CMJ reactive or continuous jumps, with a duration ranging from 5 to 60 seconds (preferably 5 to 15 seconds).
6) *Squat Jump* while lifting variable loads (20-100 kg [44-220 lbs] with the bar over the shoulders) and particularly with loads similar to body weight (SJbw).
7) Reactive or continuous jumps with rigid knees, with a duration from 5 to 7 seconds, with or without clearing obstacles, and with or without arm support.

The conventional jumps that can be performed without the contact platform are:

1) *Jump and reach test* (Abalakov or CMJ test with arm boost).
2) *Maximum jump* (MJ)
3) Long jump or horizontal jump tests.

1. *Squat Jump*

The squat jump execution method is the following:

- **a-** Sole of the foot in contact with the platform.
- **b-** Knee angle at 90°.
- **c-** Hands on hips and straight trunk.
- **d-** Knee angle at takeoff = 180°.
- **e-** Drop with hyper-extended feet.

In this test, the subject must perform a vertical jump, starting from the ½ squat position (flexed knee at 90°), with a straight or rather neutral trunk, with hands on hips.

The subject must perform the test without making a downward counter-movement; i.e. the jump from the stopped position must be carried out without using the arms.

The force application time is often very short (between 280 - 320 ms), which will greatly depend on having subjects with a high or low percentage of fast twitch (FT) muscle fibers. If the subject possesses a higher percentage of FT, the force will be applied in less time [approximately 280 ms (milliseconds)], but if the individual has a higher percentage of ST, the force will be applied in a more prolonged period of time (about 320 ms).

The subject must maintain the ½ squat position for 4"-5" to get rid of most of the elastic energy accumulated while bending.

Figure 15: Squat Jump (SJ)

Source: http://goo.gl/XaRWM0

SJ characteristics

- Examined characteristic: explosive strength (Bosco and Komi, 1979), nervous recruitment capability (Bosco and Viitasalo, 1982), the expression of a high percentage of FT (Bosco and Komi, 1979).
- Activation mode: concentric work (positive).
- Relationship to other parameters: correlation with sprint (r =-0.63) (Bosco and Komi, 1983), Abalakov test, Seargent test, standing long jump, with peak force recorded in Cybex machines at a speed of 4.2 rad/s.

Table 9 shows reference data for Squat Jump (SJ) from athletes at the international level.

Table 9: Squat Jump Reference. Male athletes (Bosco, 1994)

Sport	SJ (cm)
Rugby	34.5
Jockey (Norway)	35.6
Football	37.2
Handball (Italy)	37.5
Jockey (Italy)	38.2
Football (Norway)	38.2
Baseball (Finland)	39
Soccer (Italy)	40.6
Volleyball (Finland)	41
Volleyball (Italy)	41.7
Volleyball (USSR)	43.5
Volleyball (Norway)	47
Marathon	23
800-1500 m	34
400 m	40.5
100-200 m	45.5
Long jump	46
High jump	46.5
110 m hurdles	51.5
Shot put	56.5
Ski jump toboggan	49.5
Tennis (Italy)	36.5
Fencing	41.5
Wrestling	37

Source: Bosco, 1994.

The data shown in Table 10 makes it possible to relate the SJ value obtained by the subject with the predominance of FT fibers in the muscles of the lower body.

Table 10: Relationship between SJ Value and FT Fibers (Bosco, 1994)

Predominance of FT fibers	SJ (cm)
> 60 %	> 36.7
< 40 %	< 33.8

Source: Bosco, 1994.

Squat jump variant: 1-leg squat jump

This variant of the squat jump consists of the execution of the squat jump with only one leg. To do so, the traditional SJ execution is respected, but it is performed first with one leg (two to three attempts), and then with the other (two to three attempts). This method for performing the SJ is used frequently to analyze whether a healthy athlete has a balanced level of explosive strength (with active or purely concentric form) in both legs, as well as subjects who are carrying out an injury recovery program; the progress of the injured leg's explosive strength needs to be analyzed with respect to the healthy leg.

2. Counter Movement Jump (CMJ)

The method for performing the CMJ is as follows:

- **a-** Sole of the foot in contact with the contact platform.
- **b-** Hands on hips and trunk straight in the upright position.
- **c-** Perform a 90° counter-movement (suggested, but this is adaptable to each subject, as long as it is close to this angle) and jump.
- **d-** Angle of the knee on takeoff=180°.
- **e-** Landing with the feet hyperextended.

In the counter movement jump test (CMJ), the action of jumping upwards is performed with the help of the stretch-shortening cycle (SSC).

Due to the fact that the downward movement is performed with a very modest acceleration and the extensors are activated only at the time of the movement inversion, we can claim that the stretching of the elastic elements and the consequent reuse of elastic energy is limited. Therefore, the improvement of the involvement with regard to the SJ is also due to the use of the stretch / myotatic reflex (coordination factor).

It is indicated that the flexion of the knees in the counter-movement must be 90°, although reality indicates that the individual must perform the counter-movement at the angle which one finds most comfortable, and in which one's counter-movement jump technique indicates.

During flexion, the trunk must remain as straight as possible to avoid any influence from it on the result of the involvement of the lower limbs.

Figure 16: Counter movement jump (CMJ)

Source: goo.gl/bhZE6m

During a CMJ, the storage and recovery of elastic energy in the muscle and tendon contribute 25-50% to the performance improvement after a counter-movement gesture (Shorten, 1987). The average gains between a CMJ and a SJ are between 15-20%.

If the differences between a CMJ and a SJ are less than 10%, this means that the effectiveness of using the SSC is insufficient, but if the differences are greater than 20%, then they indicate that there is a deficit in the muscle's contractile capacity.

Characteristics of the CMJ

- Characteristic investigated: explosive strength, nervous recruitment capability, expression of the FT percentage, reuse of elastic energy, and intermuscular and intramuscular coordination.
- Type of activity: concentric work preceded by an eccentric activity (counter-movement).
  During the eccentric phase, the nervous system is involved and both the active (cross-bridges) and passive (tendons) elastic elements are stretched with the subsequent storage of elastic energy that is reused during the thrust phase (Baldino, 2014).
  The pre-activation of the nervous system that is revealed during the eccentric work allows the subjects with a high percentage of slow fibers to have time to recruit tonic motor units (ST) that require an activation time longer than the phasic ones (FT). Therefore, at the beginning of the thrust, the nerve activity expresses its highest level (Viitasalo and Bosco et al, 1982) both in fast and slow subjects, making a noticeable difference with respect to SJ, in which there is a progressive increase of the development of force and myoelectric activity (Bosco et al, 1987).
- Relationship to other parameters and functions: Correlation with the results from sprint (r=-0.75) (Bosco, 1981; Padullés, in Bosco 1994), Abalakov Test (Padullés in Bosco 1994), Seargent

Test, with long jump from standstill, peak torque in the Cybex isokinetic dynamometer, maximum isometric force, area of the FT muscle fibers of the vastus lateralis (Mero et al., 1991) and percentage of FT of the leg extensor muscles (Bosco and Komi, 1979).

Table 11 shows counter movement jump (CMJ) reference data from international level athletes.

Table 11: Counter Movement Jump (CMJ) Reference. Male Athletes (Bosco, 1995)

Sport	CMJ (cm)
Rugby (Italy)	38.5
Hockey (Norway)	40
Soccer	37.2
Handball (Italy)	41
Soccer (Italy)	43.5
Baseball (Finland)	42
Volleyball (Finland)	46
Volleyball (Italy)	45.5
Volleyball (USSR)	49
Volleyball (Norway)	53
Marathon	27
800-1500 m	39
400 m	44
100-200 m	49.5
Long jump	51.7
High jump	51.5
Shot put	63

Source: Bosco, 1995.

Counter movement jump variant: 1-leg counter movement jump

This variant of the counter movement jump consists of performing the CMJ with only one leg. To do so, the CMJ is performed in the traditional manner, but it is done first with one leg (two to three attempts), and then with the other (two to three attempts).

This way of performing the CMJ is used frequently to analyze whether a healthy athlete has a balanced level of explosive strength (with reactive or eccentric mode followed by concentric, with a long SSC) in both legs, as well as subjects who are going through an injury recovery program; the progress of the injured leg's reactive explosive strength progress needs to be analyzed with respect to the healthy leg.

3. Rocket jump (RJ)

It is a jump without any counter-movement or swinging of the arms, from a squat or a deep relaxed flexion. It is characterized by having a double peak of force in the thrust phase, and a high correlation with the maximum values obtained in deep squat.
Used to quantify the movement of the lower limb extensor muscles, in their deepest angles, by subtracting the SJ value.

The method for performing the RJ is as follows:

- **a)** Subject is standing on the contact platform in the squat or deep squat position and stays in this position for 3 to 4 seconds, relaxed.
- **b)** Hands are placed on the waist, making it impossible for the subject to break contact with the waist. Thus, at the point of takeoff, it will not be possible for the subject to use the arms to help with propulsion.
- **c)** On the assessor's command, the subject performs a maximal vertical jump.

Figure 17: Rocket jump (RJ)

Source: http://goo.gl/b3iV7n

4. Drop jump (DJ) or vertical jump with a landing from a variable height (20 - 100 cm)

The execution method of the DJ is as follows:

- **a-** Subject is standing on a step, box, etc., at a certain height, with hands either on the waist, or free hanging, according to what the assessor determines, with legs extended and trunk upright.
- **b-** The subject lands by taking a step forward.
- **c-** Upon making contact with the platform, perform a violent exertion by attempting to perform a vertical jump to maximal height.
- **d-** Angle of the knee on takeoff = 180°.
- **e-** Landing with the feet hyperextended.

The drop height varies depending on the subject's capability (20-100 cm).

Figure 18: ***Drop jump*** **(DJ)**

Source: http://goo.gl/4T9zLR

Progress must be made on the drop height, taking two aspects into consideration. On the one hand, the contact time is less than 250 ms or 300 ms (Schmidtbleicher and Gollhofer, 1982) and, on the other, the height of the jump after the landing is greater than or equal to the CMJ height.

At the point of contact, the subject must stop the downward movement as quickly as possible, trying to block the knees, so as to move upwards as fast as possible.

- Characteristic investigated: muscular stiffness or hardness, that represents neuromuscular capacity to develop extremely high force values during the stretch-shortening cycle, viscoelastic behavior of the extensor muscles, myotatic or stretching reflex, and proprioceptive inhibitor behavior (Golgi tendinous corpuscles).
- Type of muscular activation: activation of extensor muscles of the legs following the SSC.

When landing from heights of about 30-40 cm (11.8-15.7 in), the main muscles used are the triceps surae. With higher heights, greater use is made of the thigh muscles (Schmidtbleicher and Gollhofer, 1982).

5. Reactive jump test for 5 to 60 seconds. Evaluation of the mechanical power of the alactic and lactic anaerobic metabolism

The method of performing the jumps is identical to that of the CMJ, with the only difference being that they are performed one after another during a predefined period.

Bosco and Komi (1982) indicate that the flexion of the knees must be 90°, and that as a result of fatigue, in tests of more than 30 seconds, the flexion does not reach that angulation.

If there is a variation in the jump angle (e.g. 50°), the power log should not be regarded as valid, since this angle variation causes a 30 % improvement in energy performance with regard to wide angular variations (close to 90°).

The reality shows that it is very difficult to obtain 90° angulations in all the jumps of individual athletes that perform this type of test. Thus, we would take logs of the flight times, contact times and centimeters jumped, but not the power logs, because they would have a wide margin of error.

On average, one jump per second should be achieved, as long as the 90° angle is respected. If this is not the case, the number of jumps will be greater. During the performance of these types of jumps, we have two major variants: the performance of reactive jumps over a short duration (5"-15"), or over medium or long duration (15" to 60"). In our specific case we are interested in the performance of reactive jumps over a short duration.

Continuous or reactive jumps test over a short duration (5 - 15 seconds)

Bosco (1982) proposes that the reactive jumps test over a short duration should be applied on athletes where explosive strength is an important function in the results of the competition.
Calculation of the resistance capacity to fast force
Two values are provided by the continuous jump test: the mechanical power and the mean height (H10) achieved during the jumps.
Capacity of resistance to fast force: H10/HCMJ, where:

- H10: mean height of the jumps in 10 seconds.
- HCMJ: height of the CMJ.

Another formula would be:
Capacity of resistance to fast force: Hf/Hi, where:

- Hf: mean of the last three jumps.
- Hf: mean of the first three jumps.

The relationship between these values must always be close to 1.

Table 12 displays reference values for resistance to fast force (Bosco, 1994).

Table 12: Resistance to Fast Force Values (Bosco, 1994)

H15/HCMJ x 100 Individual sport	Level	H15/HCMJ x 100 Team Sport
80	Low	70
90	Medium	80
100	High	90

Source: Bosco, 1994.

Other results that we obtain and can use in a longitudinal analysis of data is the average height or average flight time, and the average contact time in the 10-second reactive jump test, which is the most frequently used in our environment for working with times where anaerobic alactic system prevails in the energy intake.

Variant of the continuous or reactive jumps over a short duration test (5 - 15 seconds)

This variant of reactive jumps consists of the performance of brief reactive jumps with only one leg. For that, the reactive jumps are performed in the traditional manner, but they are done first with one leg (one or two attempts), and then with the other (one or two attempts).

This way of performing reactive jumps is used frequently to analyze whether a healthy athlete has a balanced level of resistance to explosive strength (with reactive or eccentric mode followed by concentric) in both legs, as well as subjects who are undergoing an injury recovery program; the progress of the injured leg's resistance to reactive explosive strength needs to be analyzed with respect to the healthy leg.

6. Squat jump with increasing loads on the shoulders of up to the body weight (SJbw) and others

The steps for carrying out the test are as follows:

- **a)** Soles of the feet are planted on the contact platform.
- **b)** Knees bent to 90°.
- **c)** Straight trunk.
- **d)** Angle of the knee at 180° in maximal extension.
- **e)** Feet hyperextended at the point of contact with the mat.

Characteristic investigated: maximal dynamic force with light loads and heavy loads (SJ_{bw}). Nervous recruitment capability (Bosco and Komi, 1982). Expression of the morphological structure of the extensor muscle of the legs (transverse section of the muscles and the dimension of the fibers, both FT as well as ST) (Bosco, 1985). Activation method: (positive) concentric work.

Relationship to other parameters and functions: SJ with low loads (10-40 kg [22-88 lbs]) is correlated to SJ and CMJ. The SJ_{BW} is related to maximal isometric force, which is very important for the force transformation from basic to fast force.

This test should only be performed if the athlete is fully aware of weightlifting techniques and has a very high level of strength in the musculature of the lower body and postural muscles of the trunk.

If the athlete does not have a high level of strength in the muscles involved in the exercise, the risk of injury is higher, which is why it will be necessary to apply it in situations where the subject being evaluated really requires it and is fully prepared for the demands of the test.

7. Reactive Jump Test with Bent Knees for 5 to 7 Seconds With and Without Obstacles

According to what was suggested by Vittori (Bosco, 1994), this test can be performed with or without obstacles. It represents a variant of the DJ test, in which the intramuscular and intermuscular coordination play an important role, as well as the ability to use the arms, elastic energy and stretching reflexes.

The test consists of performing a number of vertical jumps during a relatively short period of time (5 to 7 seconds), in which the greatest height is sought in each jump, being in contact with the ground for the shortest possible time. The elevation of the center of gravity and the contact time are measured.

During the test execution, the knees must be bent to the maximum and the arms can be used. The use of the arms contributes 15% to 25% of the achieved result.

Figure 19: Reactive Jump Test

Source: http://goo.gl/hEgs4X

8. Abalakov (ABK) Test, Seargent Test and CMJ with Swinging of the Arms

These tests allow us to learn about the benefits that the swinging of the arms has on the vertical jump capacity: its execution is the same as that of the CMJ, but in this case, the performer does not keep the arms on the waist, instead the athlete will have to increase the thrust capacity by means of coordinated swinging of the arms (Harman, 1990).

The differences between the Abalakov and Seargent tests have to do with the way they measure. In the former, a tape is placed between the legs, attached to a belt and a piece of metal upon which it slides. The latter measures the difference in height between an extended arm and the highest point of reach after a jump.

With the contact platform we perform the Abalakov test, measuring the flight time and the height of the jump, where we have very active participation of the arms and the trunk in the thrust.

Figure 20: Abalakov (ABK) Test

Source: http://goo.gl/Qx4Bcz

Table 13 displays data for jump and reach (vertical jump) with momentum of arms (Cappa, 2000).

Table 13: Vertical Jump Values with the Help of the Arms (Cappa, 2000)

Age (years)	Females (cm)	Males (cm)
5	17	17.8
6	18	19
7	21	22
8	22	23.5
9	24	26
10	28	29
11	29.5	31
12	33	33.9
13	32.5	37.5
14	33	38
15	32.5	41
16	33	44.5
17	33.1	48
18	33.2	50

Source: Cappa, 2000.

9. Maximum Jump (max., MJ or maximal jump)

It is a free vertical jump with the only restriction that the takeoff and landing must be performed on the evaluation surfaces. Strictly speaking, this jump is not technically a vertical jump. Therefore, and for safety reasons, the contact mat must be placed on a non-slip surface so that the athlete does not slip during takeoff or landing. This jump is used to quantify the quantitative component by simple difference with the ABK, in addition to indicating the ceiling in terms of the athlete's jumping ability.

A convenient way of evaluating this jump is with the use of two mats: one for the takeoff and another for the landing.

For this jump, one or two steps can be taken that serve as prior thrust. The number of steps will depend on the characteristics of the technical gesture to be measured, as well as the specific technique of the subject to be assessed and their efficiency in order to achieve the best performance.

Figure 21: ***Maximum Jump*** **(max. or MJ)**

Source http://goo.gl/jcbDo9

10. Long Jump or Horizontal Jump Tests

They consist of predominantly horizontal jump tests, so as to obtain the longest distance from a jump or succession of jumps.

In the same way as the tests that were analyzed earlier, the long jump can be performed in the following ways:

- **a)** Long jump or horizontal jump without counter-movement and without swinging of the arms. In this case, the subject is situated in the jump position with knees bent at 90º, maintaining that angulation for about 3 to 4 seconds, and then jumps.
- **b)** Long jump or horizontal jump with counter-movement and without swinging of the arms. The subject - standing upright at the jump takeoff point with hands on the waist - performs a counter-movement and jumps forward.
- **c)** Long jump or horizontal jump with counter-movement and swinging of the arms. The person can perform a counter-movement before the jump in this case, and may also use his arms to generate balance that assists him to thrust.

Long jump or horizontal jump variant: long jump or horizontal jump on 1 leg

This variant of the long jump or horizontal jump consists of performing the long jump or horizontal jump with only one leg. The long jump or horizontal jump is performed in the traditional manner (i.e. in variants where there is no use of arm movements for its execution), but it is done first with one leg (two to three attempts), and then with the other (two to three attempts).

This way of performing the long jump or horizontal jump is used frequently to analyze whether a healthy athlete has a balanced level of explosive strength (with pure concentric or reactive mode, i.e. eccentric followed by concentric), in both legs, as well as subjects who are undergoing an injury recovery program; the progress of the injured leg's (active and reactive) explosive strength needs to be analyzed with respect to the healthy leg.

In the FCB Basketball Training department, monaxial force platforms are used for monitoring players' jumps. The following variables are those which are primarily monitored and controlled:

- Peak concentric force (N).
- Concentric contraction time (s).
- Eccentric phase time (s).
- Time from the start of the movement until the peak of maximum force (s).
- Mean force applied in concentric phase (N).
- Mean force applied in eccentric phase (N).
- Ratio of the mean force applied in concentric-eccentric phase (%).
- Flight time (s).
- Flight height (cm).
- Peak relative maximal force in concentric phase (N/kg).
- Maximal velocity in concentric phase (m/s).
- Peak relative power (W/kg).
- Peak landing force (N).
- Peak relative force on landing (N/kg).
- RFD on landing (N/s).
- Asymmetry of force applied in concentric phase (% L,R).
- Asymmetry of the peak maximum force (% L,R).

Pre-programmed jumps are to be performed on a periodic basis in order to monitor these variables.

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