

Module 2. Periodization and Training Methods

2.1 The Training Process

2.1.1 Basic Concepts of Periodization

Historical Overview - Rome and Greece

Ever since the beginning of muscle strength training, the same question has persisted: What can be done to improve strength? We can find this question in ancient literature. In the second century B.C., the famous Roman physician and philosopher Galen had proposed in his treatise, "Preservation of Health," an interesting method of exercise categorization that began with a series of "strength exercises, but without speed", to then develop "speed separate from strength", and finally "performing intense exercises that combine strength and speed" (as cited in Issurin, V.B. 2010, p.191).

Another great example comes from ancient Greece: the famous Philostratus, "the Athenian", also in the second century B.C., in his essay titled *Gymnasticus*, he described the preparation of an Olympic cycle made up of ten months of general training followed by a one-month period of specific training in the city of Elis prior to the games. In this case, its similarity with current practices is startling. Its sequence of short, medium and long loads within four-day training cycles are a brilliant illustration of the approach to periodization in the Ancient Age (as cited in Issurin, V.B., 2010).

In the Last Century

The fundamentals of modern periodization were established in the former USSR. Russian scientists and trainers took it upon themselves to publish literature about the separation of the training process into two periods: a general one, focused on cardio-respiratory aptitude, general coordination and athletic capability, and a more specific one focused on the techniques and tactics of the sport. This division predominated in team sports (Issurin, V.B., 2010), and even today we can see the tendency to divide training up in accordance with this method. In the 1950s, there were numerous publications in Russia that provided scientific support to this practice. However, the first summary of this research was published by **Matveyev** in 1966, making him the founder of the **theory of sports training**.

Nowadays, training periodization such as "the subdivision of a training season into shorter periods and training cycles" (Issurin, V.B., 2010, p.192) is an indispensable part of the theory of training.



What is Periodization?

Periodization in strength training refers to the planned changes in the variables of the training program: the order of the exercises, the choice of exercises, the number of reps, the amount of reps per set, the intensity of the training, the volume and number of training sessions per day, so that these modifications aid in increasing the athlete's performance (Fleck, S.J., 2011). The main objectives of periodization are: optimize the athlete's adaptation to brief periods of time (such as a week or a month), as well as long periods (a year, a four-year Olympic cycle or the length of an athletic career). In every case, the aim is to achieve peak performance at a specific moment of the season and avoid plateaus of low athletic performance (Fleck, S.J., 2011).

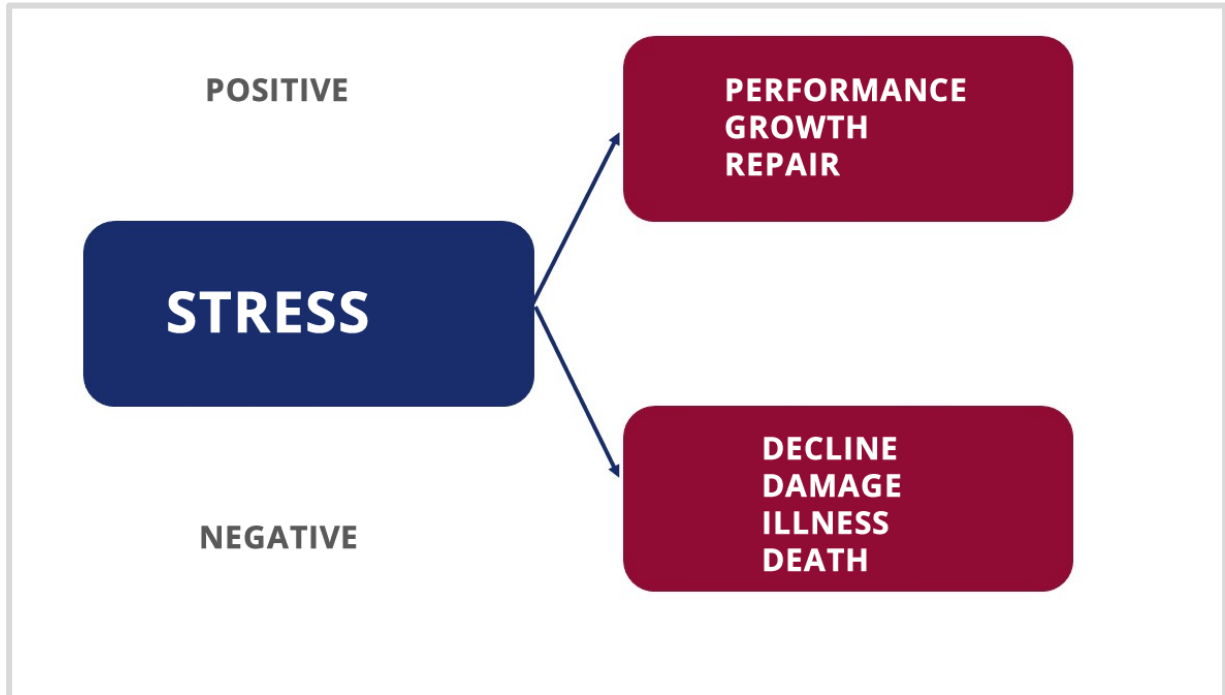
The Physiological Basis: General Adaptation Syndrome.

In 1936, **Hans Selye** outlined an astonishing new paradigm for his time, publishing an article in which he postulated that, regardless of the nature of the harmful stimulus, the organism responds in a stereotyped manner. This reaction represents an attempt by the organism to adapt to the new condition it is subjected to, and he named it **General Adaptation Syndrome (GAS)** (Bértola, D., 2010). GAS, according to Selye, consists of three universal stages. The first stage is called the **alarm reaction**, the second is that of **resistance**, and the third is the **exhaustion** stage. If the organism is subjected to a load or a "stressor", it produces a partial decrease in the organism's ability to overcome this element, and it enters the state of alarm. If this first stage is survived and the harmful stimulus persists, the organism enters a second stage where it stabilizes its functions to virtually normal levels, building a resistance. But if this situation continues as such, the organism will enter a third stage of exhaustion. Selye used the term stress (meaning tension, pressure, duress) to define the condition in which the organism responds to the harmful agents ("stressors"). GAS suggests that living organisms have the ability to adapt on their own to the environments which surround them (Selye, 1950).

It is important to understand GAS, since it explains the adaptations that occur in the process of strength training. Selye identified two forms of stress: a **beneficial stress** which produces growth, and a **detrimental stress** which results in decay, damage, disease or death (Figure 1.) (As cited in Siff, M.C. & Verkhoshansky, Y. 2004)



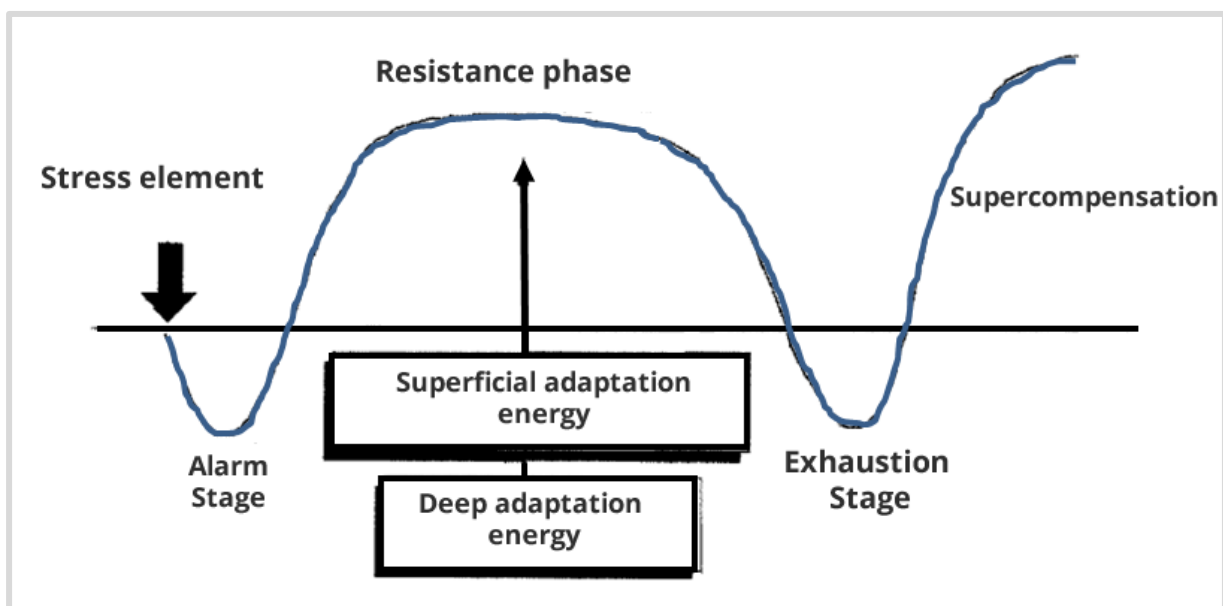
Figure 1: Different Types of Tension and their Possible Consequences According to Selye



Source: Adapted from Siff & Verkhoshansky, (2004). Superentrenamiento, p.105.

A proper periodization of strength training will allow the individual a harmonious interaction among performance, growth and repair; at the same time, we should be on the lookout for discomfort, aches, and minor injuries in our athletes, since the presence of these is a viable indicator of the beginning stages of detrimental stress (Siff, M. C. and Verkhoshansky, Y., 2004).

Figure 2: Selye's General Adaptation Syndrome Model



Source: Adapted from Siff, M. C., & Verkhoshansky, Y., (2004) Superentrenamiento, p.107.



Principles of Training Periodization

Progressive Overload Principle

According to Greek mythology, Milo of Croton was the first person to apply the progressive overload principle. To become the strongest man in the world, Milo started picking up and carrying a calf for one full kilometer every day. As the calf grew, Milo became stronger. After some time, the calf had grown into a large bull and Milo was the strongest man in the world at that time, thanks to a long-term progression (Bompa, T. & Buzzichelli, C., 2015). The improvement in performance is a direct result of the quality of the training. From the start up to the elite, the load must be increased gradually according to the athlete's physiological and psychological ability. Every drastic change in athletic performance requires a long period of training and adaptation. Just as an athlete's organism reacts physiologically, the nervous system, coordination functions and psychological adaptation to deal with new stressors all progress gradually (Bompa, T. & Buzzichelli, C., 2015).

Variety Principle

Contemporary training requires many hours of work from the athlete. The volume and intensity of training are in constant variation, and the exercises are repeated numerous times. To achieve a heightened performance, the player must overcome a threshold of 1,000 hours of training a year (Bompa, T. & Buzzichelli, C., 2015). The monotony and boredom that can be caused by all of this training work become motivational obstacles. On top of this, one must consider the fact that performing the same exercises at the same intensity and volume over a long period of time may cause injuries due to overuse (Kraemer, W. J. y Fleck, S., 2007).

To counteract this, it is generally suggested for one to alternate variables in order to enrich the training process; some methods of doing this are: alternating exercises, varying the sets, repetitions, the type of gear being used, the type of muscle action and speed, always taking into the account the present time of year and the main objective behind the training.

Individuality Principle

Each athlete is unique and unrepeatable, and, as such, should be treated according to his or her abilities, potential and environment. Often, trainers attempt to apply the training programs of other star athletes on their players, and neglect to consider the needs, experience and characteristics of their own athletes; or worse yet, they subject young athletes to the training plans of much more seasoned players. However, even players with similar performance potential may have different tolerance levels towards training. The ability to recover is also a differentiating factor among athletes that must be taken into consideration. When a work program is introduced, the athlete's lifestyle must be considered, as well as socio-emotional issues that surround him, as these will influence him ability to adapt to the training.



Specificity Principle

In order to be effective, training must include specific adaptations towards the sport being practiced, whilst considering the fact that the more specific the stimulus, the larger the burden on the musculoskeletal system; thus, more attention must be placed on volume, intensity and recovery from said stimuli.

The Five Laws of Strength Training

According to Bompa and Buzzichelli (2015), there are five laws that cannot be overlooked in strength training to ensure the athlete's adaptation as well as avoid injury. These are:

1) Develop breadth of joint movement:

- Most of the exercises must be performed in an optimal range of movement in joints such as the hip, knees and ankles. Above all, flexing and plantar dorsiflexion must be emphasized during the first phases of the athletic development.

2) Develop Tendon Strength:

- Misunderstanding the specificity principle or lack of a long-term vision causes trainers to neglect the proper strengthening of tendons and ligaments. Without their anatomical adaptation, intense training may lead to injuries. Training them appropriately may cause them to increase their diameter and thus improve their ability to withstand tension and torsions.

3) Develop Core Strength:

- The arms and legs are only as strong as the core (we will elaborate on this in module three). A proper training program must first focus in trunk strengthening before going into other movements. These muscles act by absorbing the impact of jumps, bounces or plyometric exercises once the body is stabilized and represent the union or transmission of strength between various parts during complex movements.

4) Develop the Stabilizers:

- The muscles that perform a primary action are more efficient if they have strong stabilizers. These contract isometrically to stabilize the joint and allow another body part to perform. Poorly stimulated stabilizers inhibit the capacity of work of bigger muscles.

5) Train Movements, Not Muscles:

- Team sports have different goals than bodybuilding. Strength training in team sports seeks to improve the athlete's performance in the game and optimize their skills; this is achieved if these tasks can be simulated during training. We know the in-game techniques are complex polyarticular movements that occur, most of the time, in an unexpected fashion.

Solé Fortó (2008) says:

Periodization divides the season in cycles (one or two), which are then structured into periods. Each period seeks to acquire an athletic form. Specifically, the **preparatory period** seeks to acquire an athletic form, while



the **competitive** period seeks to maintain optimal form; the **transitory** seeks to prevent the relative loss of said form. Each period consists of various stages of training, where the burden is regularly applied on time.

The season is made up of the following stages:

- a) Preseason:** Preparation phase which seeks to acquire the athletic form so the competitive calendar may be guaranteed to start. Generally, in team sports, it is six to eight weeks long.
- b) Competition or League Stage:** It takes place during the competitive calendar. It consists of one or two matches per week. It seeks to achieve a high stability state that, as the match progresses, may evolve into a state of maximum performance. It lasts around 6 to 9 months.
- c) Regenerative Stage:** It happens once the league is finalized, and it seeks to help the player recover physically and psychologically. It also has an objective of preventive hygiene, where maintenance and compensation loads are applied. (P. 177).

2.1.2 Linear vs. Undulating Periodization

Training periodization has proven its effectiveness in athletic performance, in recreational training and in the field of recovery. In a meta-analysis of over 100 studies performed between 1962 and the year 2000, Rhea and Alderman (2004) found that periodized training programs achieve greater strength gains and power than non-periodized programs. Even with similar volume and intensity, the authors discovered that periodized training accomplished greater increases in strength and power than non-periodized training.

Periodized training programs are usually designed in accordance with two very different models: **linear** and **undulating models**.

The **linear model** consists of starting with a high volume and low intensity; as the training progresses, the volume decreases and intensity increases in order to maximize the gains in strength and power (Fleck, S., 2011). These training plans require several months to complete. In a linear program, the periods last four to six weeks in a determined area; for example, 1 to 6 or 8 to 12 reps per set. Within this type of periodization there are several different stages, each with a specific name and objective: hypertrophy, maximum strength, maximum strength/power and power. Most programs of this kind attempt to achieve a peak in strength gains before entering the power stage (Fleck, S., 2011).

Undulating periodization (also called non-linear) requires constant variations of intensity and volume within cycles of six to ten days of work, in which training protocols of the neuromuscular system are alternated (Kraemer, W. J. and Fleck, S. J., 2007). In this way, the areas of training vary as the training itself progresses, meaning the amount of reps and sets will vary from one session to the next. The simplest pattern to follow in this type of programming utilizes three areas: from 4 to 6, from 8 to 10, and from 12 to 15 rep



maximums in a total of three weekly trainings, training each area once a week (Fleck, S. J., 2011).

Seeking to compare strength gains in university students after performing undulating periodizations (UP) or linear periodizations (LP), Rhea, Ball, Phillips and Burkett (2002) divided 20 males aged 21 into two groups, and evaluated them on bench and leg presses. The training consisted in performing three sets of both tested exercises, three times a week, for 12 weeks. The LP group performed 8 reps per set between weeks one and four, 6 repetitions on weeks five to eight, and 4 repetitions on weeks 9 to 12. While the UP group alternated its trainings during the twelve weeks in the following manner: 8 repetitions on Mondays, 6 repetitions on Wednesdays, and 4 repetitions on Fridays. After twelve weeks of training, both groups showed significant improvement in strength, through the UP group was clearly the strongest of the two. We plot the results in the following table:

Table 1 Experiment by Rhea et al. (2002)

	Week 1 kg [2.2 lbs] total bench-press	Week 12 kg [26.4 lb] total bench-press	% of change of bench press week 1-12	Week 1 kg [2.2 lbs] total leg press	Week 12 kg [26.4 lb] total leg press	% of change of leg press week 1-12
LINEAR	83.41 (± 12,86)	94.55 (± 10.72)	14.4 (± 10.4).	266.82 (± 55.38).	331.36 (± 68.18).	25.7 (± 19.0).
UNDULATING	66.59 (± 19.23).	83.41 (± 20.27).	28.8 (± 19.9).	230.23 (± 65.05).	350.23 (± 80.82).	55.8 (± 22.8).

Source: adapted from Rhea et al., 2002. S.p

The researches comparing both of these models generally last between nine and fifteen weeks. Some comparisons show greater strength gains with UP, in university students, such as Rhea et al., (2002) and Monteiro et al. (2009), while other comparisons do not show significant differences between both periodizations. In most of the comparisons, the subjects are young men with little or no experience in weight training, such as in Kok, Hamer and Bishop (2009), and Prestes, De Lima, Frollini, Donatto, and Conte (2009), which is why more data is expected with more experienced athletes to obtain more conclusive information. Only one study performed with experienced athletes (American football players from US universities) (Hoffman et al., 2009) indicated that UP is equal or possibly more effective than LP when it comes to maximizing strength gains.

Muscle power, weight and body composition also do not seem to show any significant differences after performing both periodizations (Rhea et al., 2002; Hoffman et al., 2009; Kok et al., 2009; Monteiro et al., 2009; Prestes et al., 2009)

Flexible Undulating Periodization

It is a relatively new method of periodization that uses the non-linear model, but allows for changes in the training based on the athlete's predisposition to train in a specific area. The decision to change the training from one specific area to another is based in various types of data. For example, performing a test prior to training, such as a vertical jump, a



long jump and/or throwing a medicine ball a few minutes before starting work can help determine how prepared a player is to train on a specific area. The first sets of the first exercises can also be monitored to determine the area that will be worked on during the session (Fleck, S. J., 2011).

For example, if during a vertical jump prior to the start of training the player is unable to reach at least 90% of his previous record, it may be that he is in a state of fatigue. The same can be said if - at the start of the session - the athlete performs 7 reps of an exercise with the same weight with which he usually performs 10 reps. Fatigue and other physiological factors such as DOMS (delayed onset muscle soreness) or psychological stress can be determining factors in the inability of the athlete to perform in a state of peak disposition.

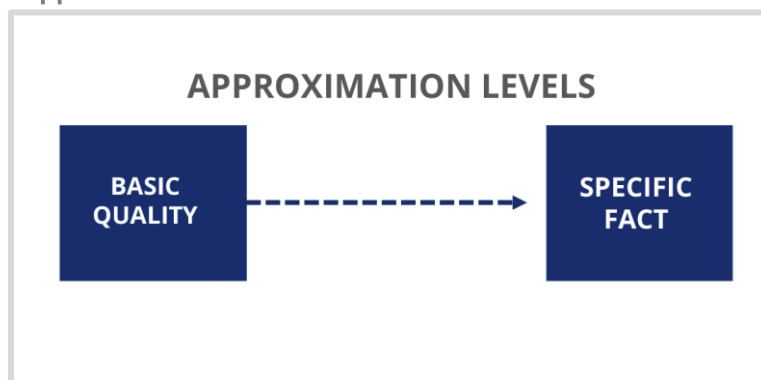
Whatever the cause, if a moderate-intensity training and moderate-volume training are scheduled (for instance, four sets of 10 to 12 reps) and the athlete is not favorably disposed, the training area should be replaced by a different area (for example, three sets of 12 to 15 reps). It is also possible to change in the opposite way; for instance, if a low-intensity and high-volume training is scheduled and during the prior tests the athlete reaches a 100% in their vertical jump, this indicates that it can be changed to a high-intensity area of 4 to 6 reps, since there are no signs of fatigue and the athlete is able to perform a high-intensity training (Kraemer, W.J. & Fleck, S.J., 2007).

Shimano et al. (2006) performed research with a group of university soccer players using flexible UP during a 16-week season. The strength sessions were modified based on the subjective evaluation of the coaches and the cardiac frequency during technical and tactical trainings and matches. Not only did the players maintain their values in vertical jumping, short springs and oxygen consumption during the entire season, but they also had significant increases in lean body mass and muscle power (17% in upper body and 11% in jumps with load).

2.1.3 Levels of Approximation (adapted from Seirulo, 1994)

If we require the player to apply a specific amount of strength on a particular motor act (for example, a handball throw), he must have gone through several stages prior to training, which we will refer to as "**levels of approximation**".

Figure 3: Levels of Approximation

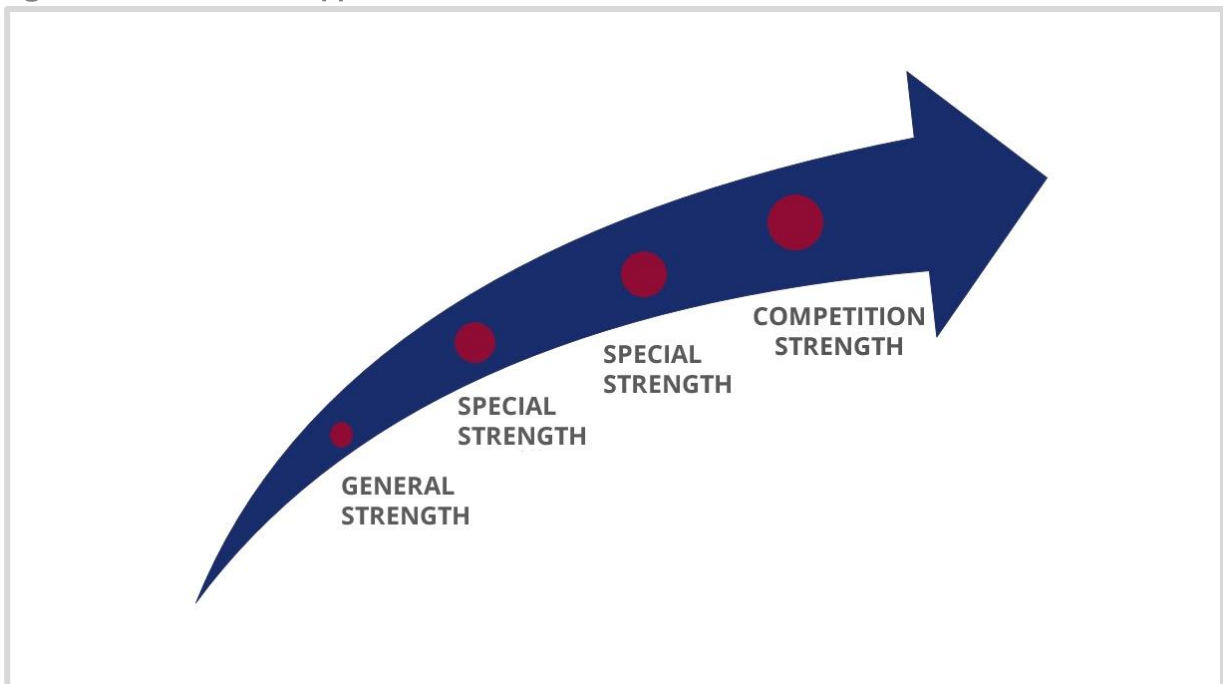


Source: adapted from Seirulo, 1994. p. 14



According to Seirulo (1994), there are four levels of approximation that determine the specificity of a task in relation to the particular game action; these will allow us to program and organize contents during planning. These are: **general strength, directed strength, special strength, and competition strength.**

Figure 4: Four Levels of Approximation



Source: adapted from Seirulo, 1994. p. 14

In each level, we can establish three strength categories corresponding to the specific sport; in the case of handball or basketball:

- Vying or racing strength: fighting for a position, a change of direction, or a one-on-one.
- Jumping strength: Rebounds, throws, layups or blocking an opponent's shot.
- Throwing and passing strength: With one hand, two hands, different techniques.

On the other hand, it is very important to distinguish three types of exercises when designing a task.

- Basic or Fundamental: It is of great importance since it is the jumping-off point for all subsequent work.
- Application or assimilation: attempts to transfer the fundamental exercise to the technical action to be optimized.
- Complementary or Compensational: It attempts to alleviate or assuage the aggressiveness of the previous exercises, which are frequently damaging to the athlete's osteoarticular system.

The proper programming of the levels of approximation allows the coach to:

- Develop coordination aspects in players' actions more effectively.
- Reach the best possible shape and maintain it for longer.
- Localize the areas of inspection and evaluation of the player's performance.

1st level: General strength.

The athletes work on all kinds of strength exercises that are not necessarily specific to the sport in question.

This stage is configured thusly:

Table 2: Characteristics of the 1st Level, General Strength

• It is developed analytically based on the muscle groups that perform a specific motor action and collaborate at the nearest joints.
• The conditions of muscle resistance are varied.
• Body postures are not similar to the game actions.
• Speed conditions are varied, but structurally similar to the motor pattern it attempts to approximate.
• The overloads must be different, but always greater than the motor pattern in a way that allows for strength increases in that muscle group.
• The instruments used shall be varied and different according to the specific game.
• The tasks must involve a high value of self-control and little to no tacit component.
• There is a coordination component that is unspecific to its basic aspects.

Source: Adapted from Seirulo (1994) p. 16

2nd level: Directed strength

It allows the improvement of the technical-tactical action through the increase of strength. The strength work continues, but more closely resembles the game with a relative transfer.



Table 3: 2nd Level, Directed Strength

<ul style="list-style-type: none">• Global development of kinetic chains that constitute each group of motions, throws, jumps, etc.
<ul style="list-style-type: none">• The resistance conditions are more in line with, or more complimentary of, the game specifics.
<ul style="list-style-type: none">• The athlete's body positions look more like the game's.
<ul style="list-style-type: none">• Speed conditions are very close to the specific ones.
<ul style="list-style-type: none">• The overload must be greater but a lot closer to the game action to allow further increase of speed.
<ul style="list-style-type: none">• The instruments may be varied but more similar to the specific ones, to stimulate points of contact.
<ul style="list-style-type: none">• Self-control is decreased, while control via exteroception increases and tactical contact elements are introduced.
<ul style="list-style-type: none">• Self-control is decreased, while control via exteroception increases and basic tactical elements are introduced.
<ul style="list-style-type: none">• Coordination components align with the specific motor function.

Source: Adapted from Seirulo, 1994. p. 17

3rd level: Special strength

The work becomes more attuned to the characteristics of the sport in question. In basketball, for example, explosive strength when grabbing a rebound or making a lay-up. The work must simulate the game action in a coordinated fashion.

Table 4: 3rd Level, Special Strength

<ul style="list-style-type: none">• Global quality development, placing emphasis on the specific kinetic chain of each motor pattern.
<ul style="list-style-type: none">• Resistance conditions are identical, or as close as possible.
<ul style="list-style-type: none">• Body positions are equal and difficult in comparison to the global and segmented positions, as a result of the previous tasks.
<ul style="list-style-type: none">• Speed conditions identical or, if possible, greater.
<ul style="list-style-type: none">• Equal or lesser overload in relation to speed.
<ul style="list-style-type: none">• Instruments identical in design and size that favor the points of contact.
<ul style="list-style-type: none">• High self-control and extremely high exteroceptive requirements with complex tactical elements.
<ul style="list-style-type: none">• The coordination component must be greater than the needs of the specific task.

Source: Adapted from Seirulo, 1994. P. 18.

4th level: Competition strength

This level must be developed simultaneously by the physical trainer and the coach, since it involves tactical components. They are real-life or simulated exercises meant to repeat



game motions where strength plays a principal role. The load to be mobilized (for instance, a ball, a partner or rival) must be the same as in competition.

In situations of real "simulated" play, some parameter of the same may go through hypertrophy by putting emphasis on a specific sequence in which strength is needed to resolve it under the established conditions. Throwing only from "X distance" puts emphasis on the strength manifestation for the throw, and if it is done in a real game situation it is a competitive exercise to improve this quality. We must keep in mind that these exercises can improve strength substantially on their own, but result in stagnation in quality improvement when they are the only ones being practiced. Furthermore, the maintenance and level control reached through not just an entire season, but through the years of the athlete's career, is of great difficulty. Therefore, the competitive exercises that are often performed "inconsistently" by some trainers, must be taken into consideration in the assessment of strength training, and must be proportionally included with exercises from level 3, which are the closest transporters to strength capacity from their origin as general exercises. (Seirulo, 1994, p. 19).

Currently, Schelling (2009) proposes that the levels of approximation adapt to this new structure:



Figure 5: Schelling's (2009) Levels of Approximation

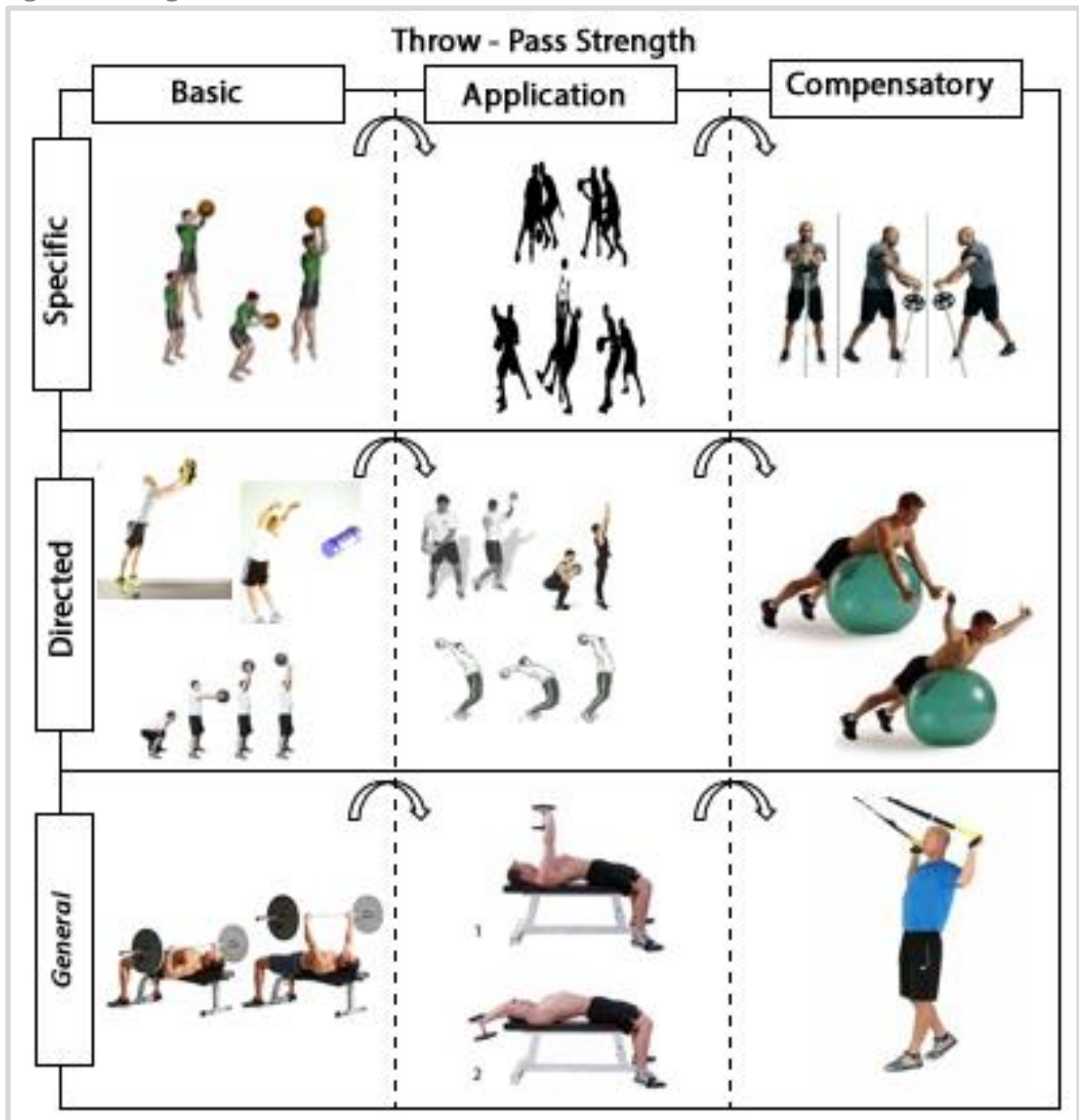
	Guidance	Approximation Level	Methodology		
Cognitive Functional	Competitive	Level V (Actual Game)	Actual Game With or without rewarding content or concept	Group track	Track sessionsk
	Special	Level IV (small groups)	Technical element + Decision-making Define possible decisions beforehand.		
	Directed	Level III (technical)	Training session (with/without ball) Without decision-making (or simple)	Individual track	
		Level II (physical - technical)	Same as technical motion Small overloads (weights-elastics)	Sesiones Físicas (Pista o no)	Progress to developing a game element from the physical condition to the in-game situation
General	Level II (physical - technical)	Similar to technical motion High load			
	Level 0 + (Guided)	Working the muscles implied in the motion Without similarities in the movement			
Conditional Structural		Level 0- (Not guided)	Working the muscles not implied in the motion complementary / compensatory		

Source: adapted from Schelling, 2009. p. 20.



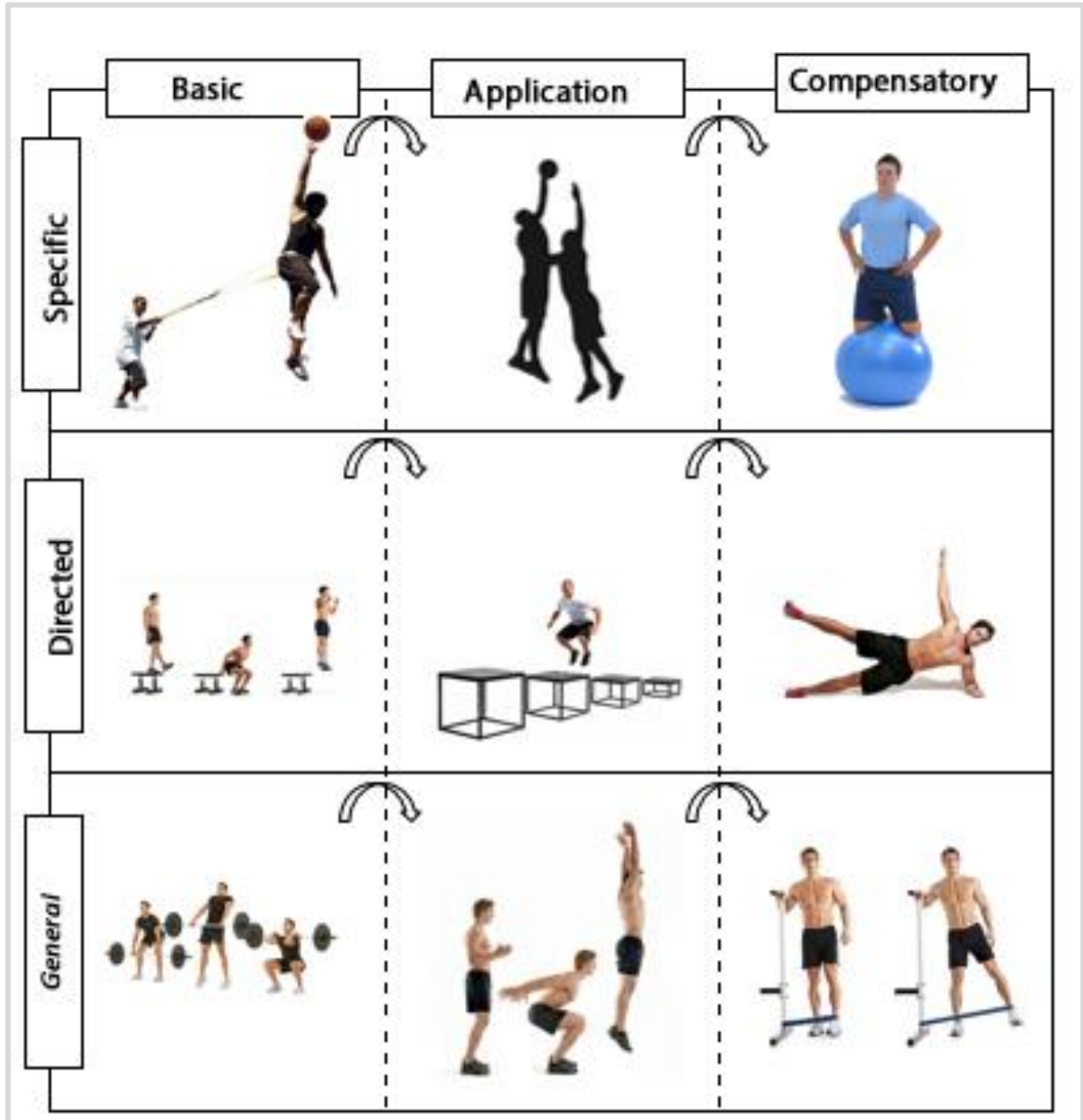
2.1.4 Applied Example of Levels of Approximation (Basketball)

Figure 6: Strength of Throw-Pass



Source: Prepared by the author based on Seirulo, 1990, p. 31-35

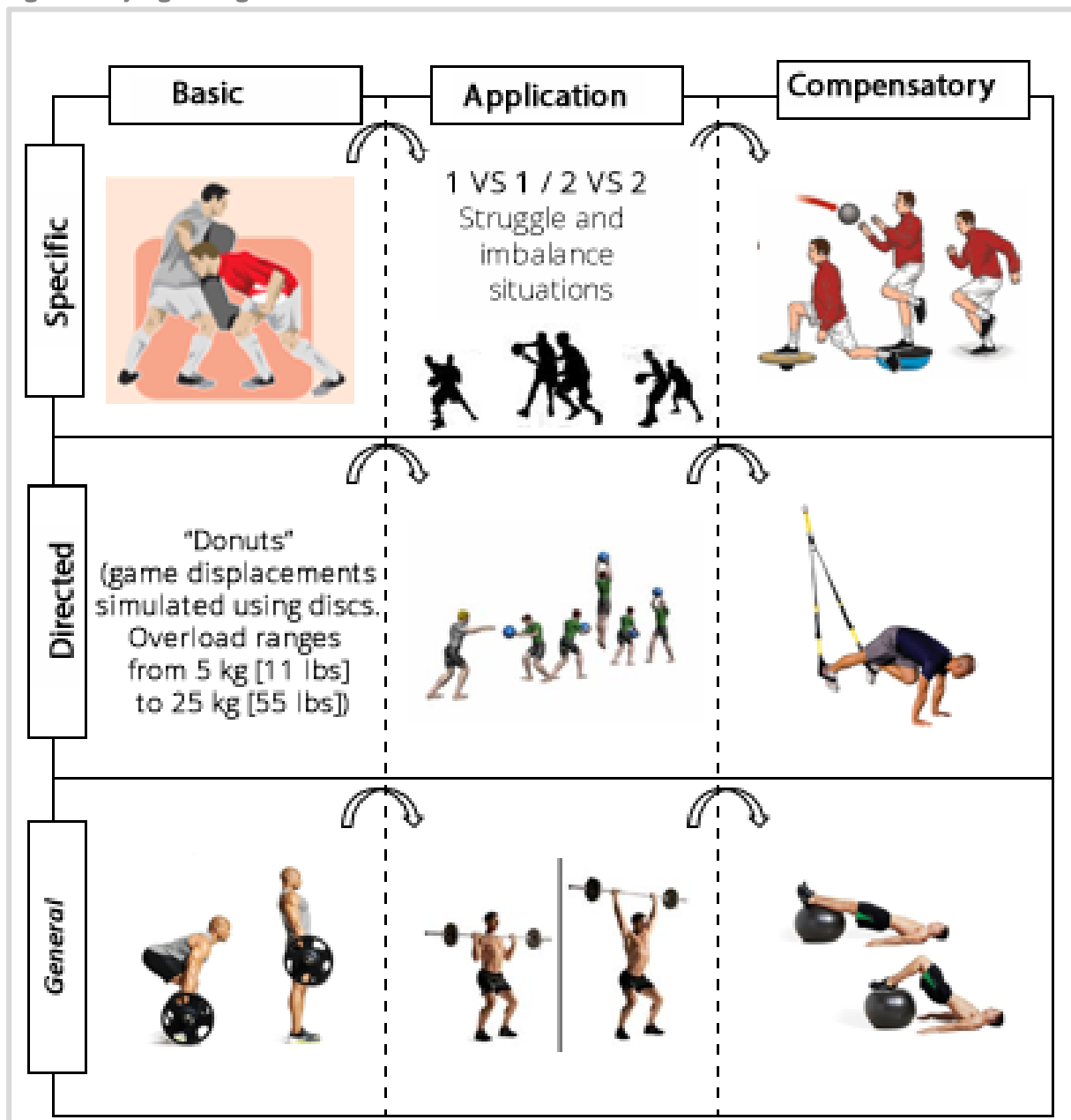
Figure 7: Strength of Jump



Source: Prepared by the author based on Seirulo, 1990, p. 31-35



Figure 8: Vying strength



Source: Prepared by the author based on Seirulo, 1990, p. 31-35

To understand this proposition a little better, you will find this video applied to handball useful: <https://goo.gl/8zwdudq> (Jordi Cañadas, 2014).

2.2 Training Methods

2.2.1 Machines vs. Free Weights

In training for fitness and quality of life, we can say that using machines or other free weights (such as bars, discs, kettlebells or unstable methods such as the physioball or suspension straps) are not inherently superior to each other. Both methods have their pros and cons. For example, free weights are affordable, portable and easy to obtain in any commercial area; they can be carried in a simple bag and transported anywhere to be used prior to training. Meanwhile, a gym machine offers a specific resistance that allows the user to focus on technical execution and perform simple movements; while on the other hand, they take up a lot of space and cannot be transported.

The main difference between the two training methods is in the fact that, when using free weights, the individual is able to move in a three-dimensional plane: forwards, backwards, horizontally and vertically. This is very important since it allows the athlete to mimic the movements of the game. Also, not only do they involve more muscle mass, but the athlete must also work to stabilize his own body while fighting resistance. However, the risk of injury increases if the right technique is not applied.

Machines, meanwhile, are fixed in place; this allows the individual to move in one or two planes at most. That is why using them exclusively may lead to a lack of functional adaptation. This leads to a high risk of injury as a result of the lack of use of stabilizing muscles, which are ignored when using these tools in favor of stimulating the bigger muscle groups and increase mobilized weight.

Though the market for machines has evolved notably in the last 20 years, most gyms still feature those variable overload machines, where the load is increased by adding or removing weight plates, that generally weight between 5 and 10 kg [11 to 22 lb] each. These machines are built in a standardized way, where the makers attempt to satisfy the demands of a public that is more geared towards physical fitness training than sports training (Dappa, D. 2000).

We can find the following advantages and disadvantages of using this kind of equipment.



Advantages of Using Variable Resistance Machines

- 1) They are a great way to train specific muscle groups in an isolated manner.
- 2) They are safer to the health of the athlete than the usage of free weights.
- 3) They simplify organization and distribution of space in group training.
- 4) It is very easy to increase or decrease the load, which decreases training times.

Disadvantages of Using Variable Resistance Machines

- 1) Displacement of the load occurs in a pre-determined and stable range. In team sports, motor actions are variable and unstable.
- 2) It works on simple motor actions that have little to do with the complex technical movements in team sports.
- 3) The speeds of execution are relatively slow, which hampers a high power production.
- 4) Its production is geared towards satisfying the market established by average people, which means that taller athletes such as volleyball or basketball players, as well as shorter athletes (such as those that partake in judo, wrestling, boxing) are often not able to use it.
- 5) Often, a load increase is too high a percentage for the athlete; since it has fixed increases (plates of 5 to 10 kg [11 to 22 lbs]), in some cases athletes are unable to lift the increased load, which generally happens to beginner athletes who cannot lift a lot of weight.
- 6) Many times, the total amount of weight that the machine is able to carry is not a sufficient stimulus for very strong athletes.
- 7) Often, its market price is too high and they do not represent an increase in the quality of training, making its purchase unproductive.

It is important to keep in mind that this analysis is in the context of team sports; if the main reason for training was health and quality of life, these assessments would be significantly different.

It is worth pointing out that in order to decide which methods to use, one must analyze the cost and benefit of each one and keep a balanced point of view, focused on the ends one chooses to pursue with training. While the free weights should be the cornerstone for any strength training program, the machines may be a great help that can aid in the development of certain muscle groups in need of an extra stimulus.

2.2.2 Weight Lifting-Derived Methods

Weightlifting is one of the classic sports of the Olympic Games. It is competed in two different modes: **snatch** and **clean and jerk**. In the snatch, the athlete raises the bar high above his head in a single movement at a very quick speed (1.6 - 1.7 m/s) (Cappa, 2000). In this exercise, weight lifters are able to move very heavy loads that represent around 2.4 times their own body weight in the lightweight category (54 kg [119 lb] or less) and 2.17 times in the heavyweight categories (100 kg [222 lb] or more). The heavy loads plus the



incredibly high speeds of execution make this an ideal movement to develop great muscle power.

The second exercise is the clean and jerk. In this exercise, the bar is also lifted above the head; not in one, but in two movements. In the first movement, the bar is taken from the ground up to the shoulders and is then considered *clean*, while in the second movement the bar is moved from the shoulders to above the head. In this exercise, a weightlifter can lift up to 2.9 times his now body weight in the lightweight categories (54 kg [119 lb] or less) and 2.17 times in the heavyweight categories (100 kg [222 lb] or more) (Cappa, D., 2000).

These kinds of movements are known for being the activities with the highest levels of power achieved by a human being in any strength exercises. For example, a 100 kg [222 lb] lifter can produce 3,000 watts of pure power, compared to the 1,100 that is generated in a squat (Garhammer, J., 1993). Due to these exercises' capacity to generate enormous levels of power, as well as their movement patterns and velocity which are relatively similar to sporting activities, these exercises are considered to be one of the best ways to increase athletic performance (Stone, 1993).

Table 5: Maximum Power Generated by Various Exercises

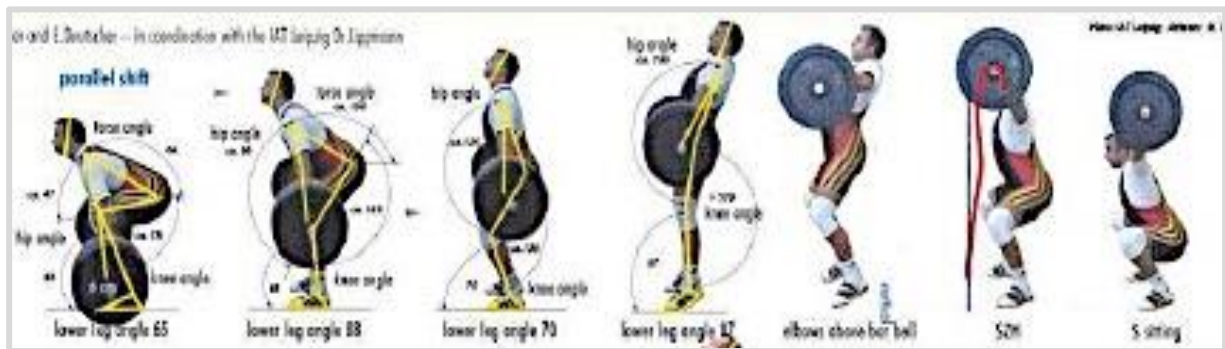
Maximum Power Generated by Various Exercises		
Exercise	Absolute power in watts	
	Male - 100 kg [222 lb]	Female - 75 kg [165.3 lb]
2nd time	5,400	2,600
Clean	3,000	1,750
Snatch	2,950	1,750
Squat	1,100	
Dead lift	1,100	
Bench press	300	

Source: adapted from Haff, Whitley, & Potteiger, 2001.

The ideal loads to maximize power production in this type of exercises appear to be above 80% of a rep maximum (RM) (Garhammer, J., 1993); this heightened percentage is inherent to the nature of the exercise (high speed and great strength produced).



Figure 9: Snatch



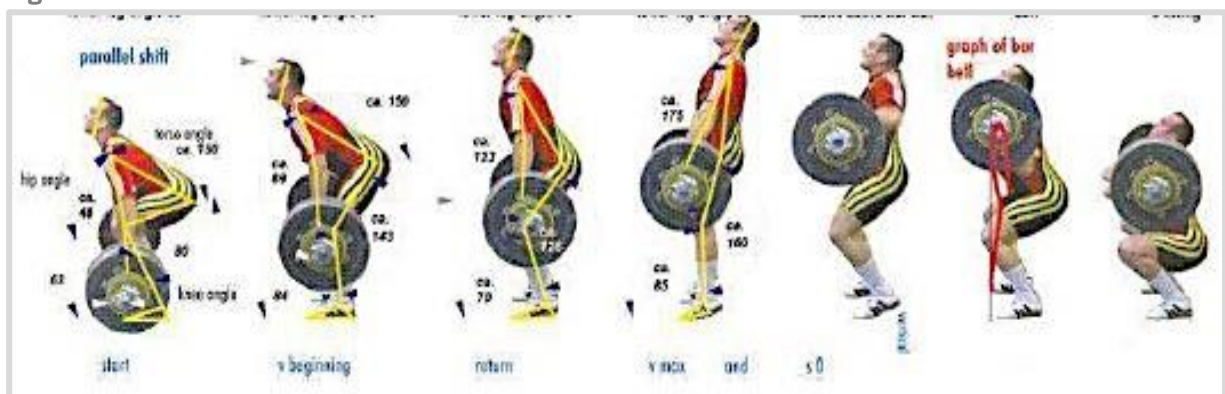
Source: adapted from Böttcher, & Deutscher, 2004, as cited in Zawieja-Koch, 2005, p. 9.

According to the rules and regulations of the International Federation, when performing a snatch, the athlete stands facing the bar, grabbing it with palms down and flexing both knees. From this position, the bar is pulled in a single movement from the floor until the maximum extension of both arms over the head. During the entire process, the bar is kept very close to the body and can be slid over the thighs. Only the athlete's feet may touch the platform through the entire movement. The weight, once it is lifted, must remain static; that is to say, held up with both arms and legs stretched out and feet lined up in parallel. Once the referee gives the signal, the athlete may drop the bar onto the competition platform.

In the following video, you can observe what we have described here:
<https://goo.gl/0bNLEp> (Frank Rothwell, 2015)

Meanwhile, the clean and jerk is split up into two parts: the clean and the jerk. In the first part (the clean), the athlete stands facing the bar, grabbing it with palms down (in a closer angle than in the snatch) and knees well bent. The weight is lifted in one single movement from the platform up to the shoulders, and may be accompanied by a jump. During this continuous movement, the bar must not touch the chest before it gets to its final position, generally on the clavicle or chest, with arms fully bent. Then, the athlete's feet must return to the initial position before beginning the second part. The athlete must complete the first part with his feet in the same line and legs completely extended, parallel to the trunk and the bar.

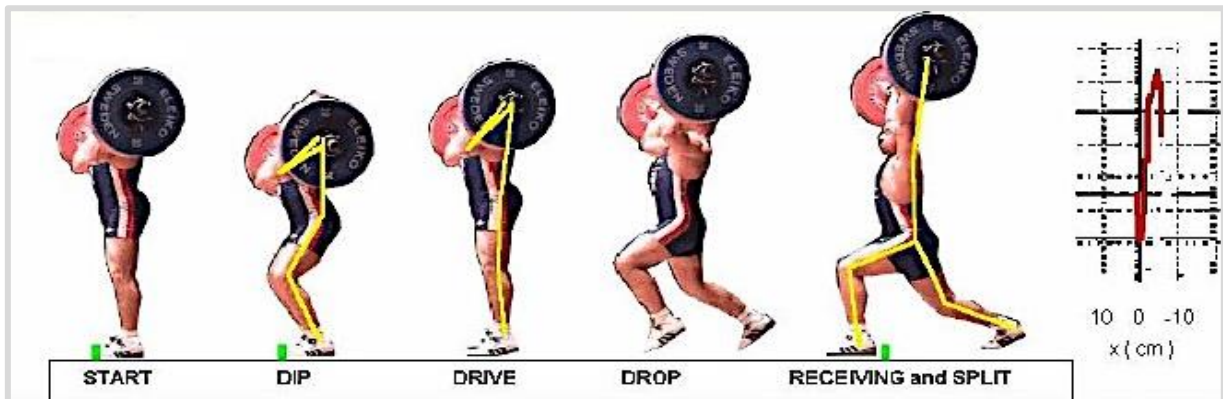
Figure 10: Clean



Source: adapted from Böttcher, & Deutscher, 2004, as cited in Zawieja-Koch, 2005, p. 9.

In the second part of this movement, the athlete flexes and extends his legs energetically while the arms raise the bar; all of this occurs in a single movement until reaching maximum arm extension. After this, the athlete must return to the same parallel line to the plane with the trunk and bar with his legs completely extended, awaiting for the referee to allow them to lay down the bar.

Figure 11: Clean and Jerk



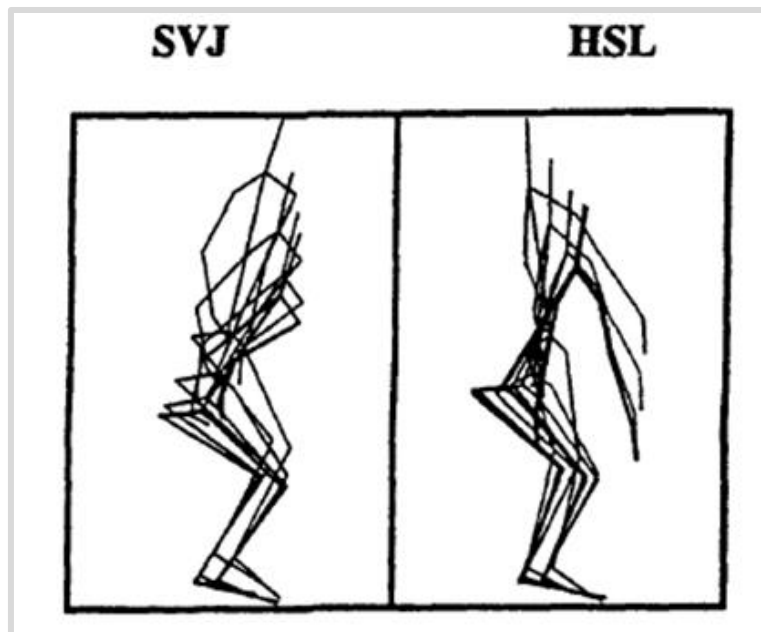
Source: adapted from Böttcher and Deutscher, 2004, p. 9.

In the following video, you can observe what we have described here: <https://goo.gl/iOTF2G> (kettlebellsport, 2013).

From a practical standpoint, using the complete lifts (from the ground) in the context of sports training does have some complications, which is why variations or derivatives are used to maximize the power building. In these kinds of exercises, you begin with a hanging bar, that is to say, on the thighs, above or below the knee (depending on the technical school), which requires less amplitude of movement. It has been proven that the use of this kind of exercises improves performance significantly in jumps as well as short distance springs (20 yards or 18.2 meters), but not as much in changes of direction.

The training programs that incorporate variations of the snatch and the clean and jerk improve their capacity for vertical jump between 2.8% and 9%. (MacKenzie, S.J., Lavers, R.J., & Wallace, B., 2014). The reason for this improvement is based on the kinematic similarity between performing a vertical jump and this kind of exercises, as demonstrated by Canavan (1996). In the following figure you can observe what we have just described:

Figure 12: Similarity in Movement of Body Segments during a Squat Jump Compared to a Power Snatch



Source: Canavan, Garrett, & Armstrong, 1996 p. 130.

On the left side of the picture we see the movement of the body segments in a squat jump, and on the right a power snatch.

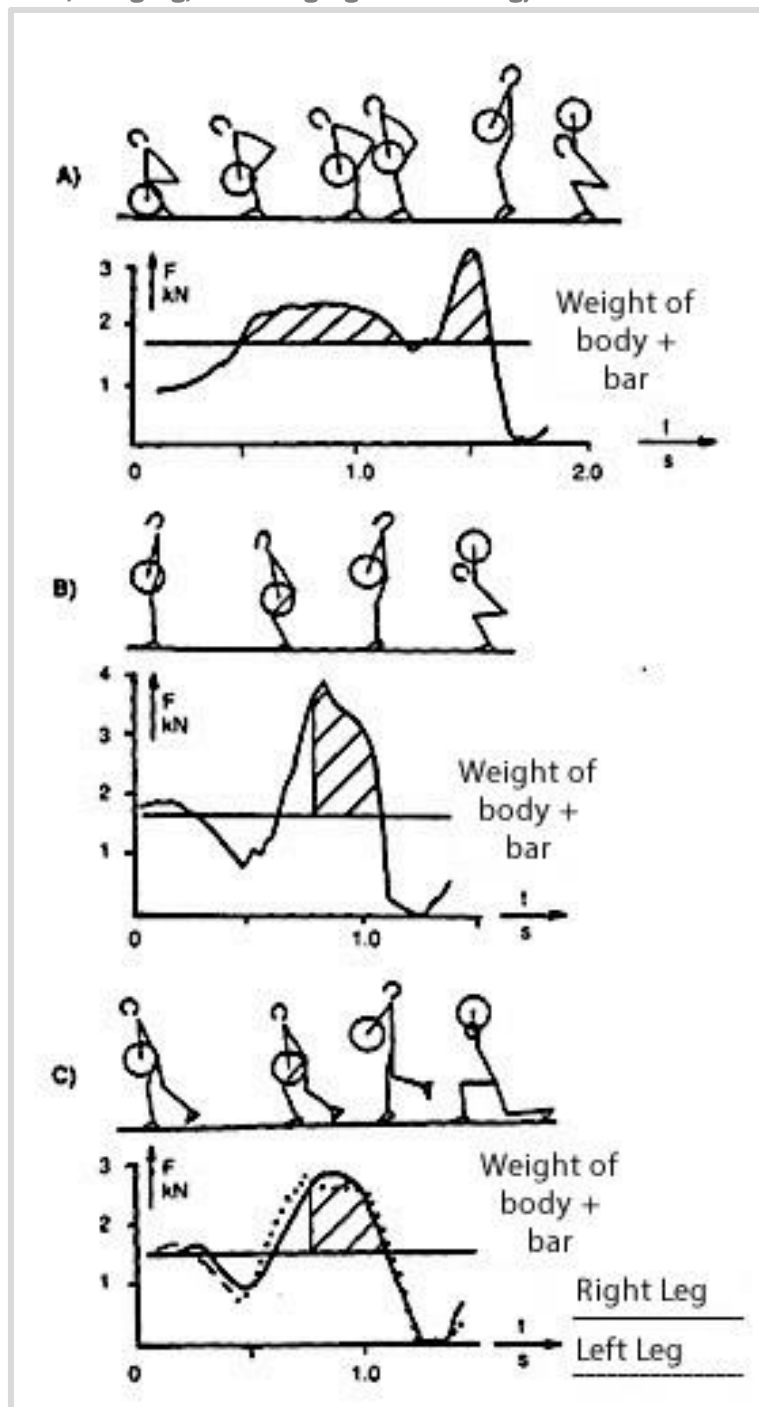
It is recommended to use weightlifting derivatives in training programs due to the following reasons:

- They are exercises that generate a tremendous amount of muscle power.
- The technique is simpler than the full motor pattern, which is why athletes who are relatively inexperienced in overload training can learn it more easily.
- By not raising the bar from the ground, we can avoid the slower phase of the exercise and perform the phase that generates more power.
- They resemble powerful athletic motor patterns such as a counter movement jump (CMJ).
- For tall athletes with wide wingspan such as volleyball or basketball players, these exercises allow for an easy adaptation and protection of their joints.

In the following figure, we see the ground reaction force and a snatch's development time. On image A) we see a traditional snatch with two legs from the ground with 80 kg [176 lb], on image B) a hang snatch with two legs and 85 kg [187.3 lb], and in C) a hang snatch with one leg and 65 kg [143.3 lbs].

It is interesting to note the possibility of realizing unilateral variances as a method to improve the power production in this type of motions that characterize team sports, such as, for example, layups in basketball. As seen in variant C), the athlete may develop with one leg over 50% of what he can perform on both.

Figure 13: Comparison of Ground Reaction Force and Development Time in 3 Different Types of Snatch (from the floor, hanging, and hanging with one leg)



Source: (Bartonietz 1996, p. 30).

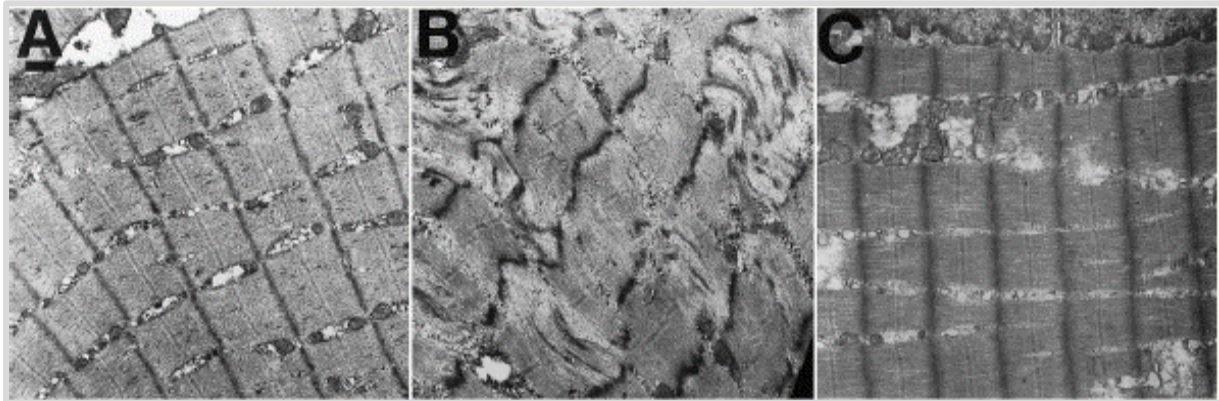
2.2.3 Eccentric Work

Eccentric work, more accurately called eccentric overload work, is one of the great innovations of sports entertainment of the last 20 years. Its efficiency has been proven not only in the field of sports performance, but also in injury prevention and rehabilitation of

various pathologies such as Achilles or patellar tendinitis (Tous Fajardo, J. 2010). Eccentric actions are capable of producing more strength than concentric actions since the crossed bridges generated by the actin filaments and myosin use the elastic energy stored due to stretching (Norstrand, 2008) and in this way, its mechanical efficiency is higher and its metabolic cost is lower (Enoka, R.M., 1996)

This mechanism of tension over crossed bridges, when the fibers are elongated, causes disruptions in the myotendinous junctions, contributing to damaging muscle tissue and generating pain and inflammation (Hortobagyi, et al., 1998) In the next figure, we see longitudinal cuts on the vastus lateralis muscle before (A), two days after (B), and seven days after (C) performing ten sets of 10 repetitions of an eccentric exercise for quadriceps. Image B shows the disarray of the filaments and extensive damage, and in C the full recovery the following week.

Figure 14: Longitudinal Cuts on the Vastus Lateral Muscle



Source: Hortobagyi et al., 1998, p. 496.

The utilization of predominantly eccentric exercises in the field of sports is of great importance. In muscle tears, it is accepted that the tearing mechanism is produced when the contracted muscle stretches over its limits, meaning it cannot sustain a specific tension in elongation (Noonan, T. & Garrett, W.E., 1999) to which eccentric exercises provide a protective effect known as the repeated bout effect. This phenomenon occurs after a session of eccentric work and after its full recovery takes place, the repetition of the same stimulus only causes a minimal muscle damage, meaning that it increases the tolerance threshold for muscles to process that load and produces a protective effect that makes the muscle less vulnerable to tears (Tous Fajardo, J., 2010), an effect that could last several months.

Although the exact mechanisms of this preventive phenomenon generated through eccentric work training are not fully known, there are three theories that attempt to explain it:

- **Neural Theory:** according to this theory, the initial damage is the result of a great intensity of stimulus on a relatively small number of quick muscle fibers. After this period, an increase in the activation of motor units towards the same stimulus can be observed.



- **Connective Tissue Theory:** This hypothesis states that the damage is produced after an eccentric work session at the level of non-contractile connective tissue, thus, it becomes injured and the myofibril integrity is lost. It is suggested that the later remodeling of the connective tissue filaments has a preventive effect.
- **Cellular Theory:** This theory proposes that the muscle damage is caused by micro-ruptures in the sarcomere, caused by a repetition of eccentric actions and that after a period of adaptation, there is an increase in the number of connected sarcomeres, which would impede further damage (McHigh, M. P. Connolly, D.A., Eston, R. G. & Gleim, G. W., 1999).

To program these eccentric exercises in the training process we must know not just the benefits, but the setbacks they can cause. We can synthesize the negative aspects of the acute response after this type of stimulus in the following way:

- Immediately after performing it, muscle rigidity increases and, consequently, flexibility is decreased (Cleak, M. J., 1992).
- They generate delayed onset muscle soreness (DOMS) (Nosaka, K. & Newton, M., 2002).
- Muscle micro-ruptures of Z discs, sarcomeres, titin and nebulin. This causes the release of muscle enzymes into the bloodstream, stimulating an inflammatory response that can last up to a week (Marqueste, T. et al., 2004).
- Alteration of the sensory organ response with its corresponding decrease in motor control (neuromuscular spindles and sinewy organs of Golgi) (Marqueste et al., 2004).

To synthesize the positive effect of applying eccentric stimuli, apart from the protective muscle effect we can also consider that:

- They increase strength significantly, generating less fatigue than concentric actions (Hortobagyi et al., 1998).
- There is more crossed adaptation (this is because, on a neural level, the application of stimulus produces an adaptation in the contralateral limb) than concentric actions (Hortobagyi et al, 1998).
- They increase synthesis and remodeling of type I collagen in tendons, which is what makes it into an effective rehabilitation agent for tendinopathy (Langberg et al., 2007).

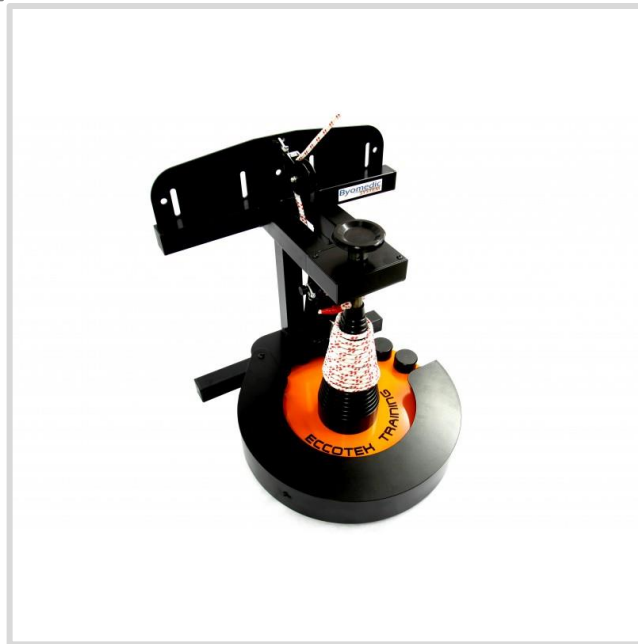
Eccentric Overload Training Methods:

- 1) Isoinertial Machines (Conic Pulleys and Yo-Yo Machines)** This type of technology was created to alleviate, in astronauts, the effects of physical inactivity caused by the micro gravity environment (Norrbrand, L., 2008). The conic pulley, also known as the Versa Pulley, is a cone attached to a fixed inertia wheel that can have weights added to it to alter the moment of inertia. The cone is tied to a rope that, once you pull on it, creates a variable inertia during the breadth of movement and with it a greater resistance in the narrower part of the cone. The direction of the traction of the rope can be applied in any one of the three dimensions, which allows for the



possibility of developing complex, specific and nearly limitless movements (Tous Fajardo, J., 2010)

Figure 15: Conic Pulley



Source: [Untitled image about conic pulley] (Undated). Taken from: <https://goo.gl/LKsc2k>

When the Yo-Yo machine is used, the disc and the inertia cone go together towards a structure. Unlike the pulley, a cord is not used, but a transmission strap that is tied to the structure's axis that goes along with the disc, while the other end of the strap is attached to a piece that the individual wears (belt, jacket, etc.), through which it exerts traction. When the athlete performs a concentric action by pulling the strap, the wheel turns, and it does not stop once it completes its trajectory. This is due to its inertial, which causes the strap to recede and creates a strong pull over the person in the opposite direction to where they pulled; in this way, the individual creates a resistance that is able to slow the wheel, until it depletes its previously pent-up kinetic energy and stops completely. Being that this eccentric action is of lesser angular displacement than the concentric action and having equal energy in both directions, an overload is generated due to the superior eccentric torque (Tous Fajardo, 2010).

Figure 16: Yo-Yo Machine



Source: [Untitled image on the Yo-Yo machine] (s. f.) Taken from: <http://goo.gl/GLXIbV>

The difference between both isoinertial mechanisms is in the fact that the conic pulley can develop very high eccentric speeds with moderate levels of strength, while the Yo-Yo machine is capable of producing higher levels of strength but lower speeds (Tous Fajardo, J., 2006).

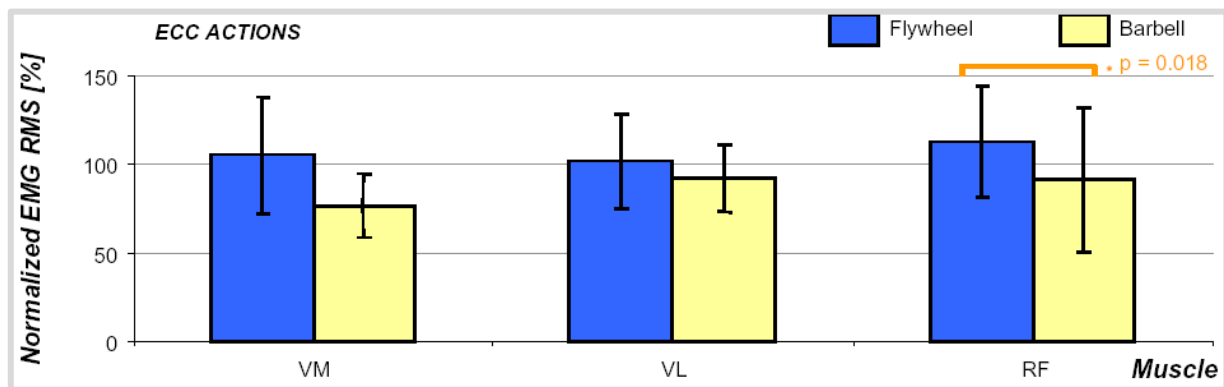
Tous Fajardo, Norrbrand, Pozzoy Tesch (2006) compared the electric activation of quadriceps in subjects performing squats with a bar and squats using an isoinertial device. The authors found a higher activation of the rectus femoris in both the concentric and the eccentric phases while using the Yo-Yo (see following figures) than performing traditional squats. This can be a great resource, especially in subjects with a weak trunk that are unable to tolerate heavy loads in their upper body. Identical results were found in studies about the activation of the hamstring (Tous Fajardo et al., 2006), which makes the isoinertial machines effective methods to prevent injury in this muscle group.

Figure 17: Squat with an Isoinertial Device vs. Squat with an Olympic Bar



Source: Tous Fajardo et al., 2006, p. 8

Figure 18: Electromyography (EMG) isoinertial squat (in blue) vs. bar squat (in yellow)



Source: Tous Fajardo et al., 2006, p. 9

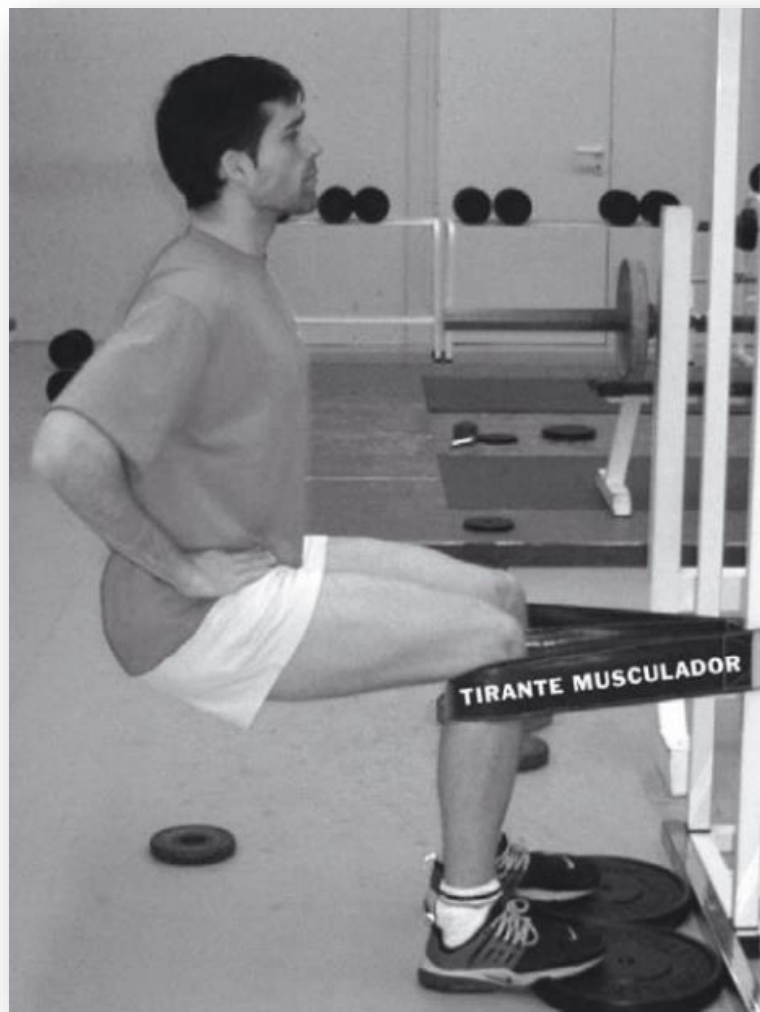
We can see in this figure the comparison between the values of electromyographic activation in the eccentric phase (ECC) of a squat using a Yo-Yo machine (blue-colored bars) or performing a traditional squat with a bar (yellow-colored bars) for three different muscle groups (VM: vastus medialis, VL: vastus lateralis, RF: rectus femoris). Significant differences can be observed in all of the muscles, in favor of the Yo-Yo machine.

Watch the following instructional video: <https://goo.gl/kxuz2J> (Inerxial, 2013).

- 2) The **muscle belt or Russian belt** is a strap made up of flexible material with ends which unfold in coils to place on legs or other body parts.



Figure 19: Muscle belt or Russian Belt



Source: Da Silva et al., 2005, p. 46.

Figure 20: Muscle Flexor or Russian Belt



Source: [Untitled image about muscle flexor or Russian belt] (Undated). Taken from: <http://goo.gl/oDvP8c>

With relative safety and without any major risks to the athlete, the use of the strap allows two types of muscle stimuli: on one hand, the execution of isometric or static actions in stretching, and in the other, dynamic actions in stretching (as eccentric overload).

Table 21 analyzes the results obtained from the myoelectric activity for four different exercises involving the muscles that make up the quadriceps. the percentage of activation comparing it to the performance of one squat with belt using 20 kg [44 lb] is shown in parenthesis. It is very important to point out that performing squats with 150 kg [330.6 lb] on the rectus femoris is only equivalent to activating 84% and 64% in concentric and eccentric phases respectively.



Figure 21: Comparison of Electric Activity of the Quadriceps for Exercises with Muscle belt, Leg Extension and a Classic Squat

Exercise	Muscle (uV signal) Difference in parenthesis BELT-20 kg)			Phase of muscular action
	Vastus medialis	Vastus lateralis	Rectus Femoris	
Muscle belt squat	252 (92)	153 (77)	202 (81)	Eccentric
Quadriceps (0 kg [0 lbs])	379 (107)	243 (84)	236 (83)	Concentric
Muscle belt squat	275	198	248	Eccentric
Quadriceps (20kg [44 lbs])	354	288	284	Concentric
Leg extensions 75 kg [165 lbs] (CKC machine)	188 (68)	164(83)	177(71)	Eccentric
	249 (70)	217 (75)	179 (63)	Concentric
Classic squat with 150 kg [330 lbs])	308 (112)	202 (102)	209 (84)	Eccentric
	369 (104)	228(79)	182 (64)	Concentric

Among the most important benefits of the use of this device we have the following:

- I. It allows for eccentric muscle action without any major risks, in a gradual, progressive and controlled way.
- II. By creating less shearing force than other exercises, it becomes a safer alternative for articulations.
- III. It is an affordable option for training with large groups of players, since its manufacturing is simple and if you have more than one, it will allow for better time management in large teams.
- IV. It is an effective element in the prevention of biarticular breakage and tendinopathy.
- V. It can be used in almost any place, as long as the floor is not very slippery and it can be anchored to a post.

3) Utilization of one's own body weight and/or with the help of a partner: It is an effective method when working with large groups, or when we lack economic means to acquire machines, or moving them is required.

Within this group, we can name exercises such as the Nordic curl, which has been successfully introduced into some training programs geared towards strength improvement and decreasing injuries, although it has been criticized for its aggressiveness.

Squats on inclined planes have also proven to be effective in the rehabilitation of tendinopathy and knee strength extension programs.

Finally, although there are no studies about this topic yet, we can use a partner's resistance in playful ways and exercises that attempt to produce an eccentric overload.

2.2.4 Unstable Methods

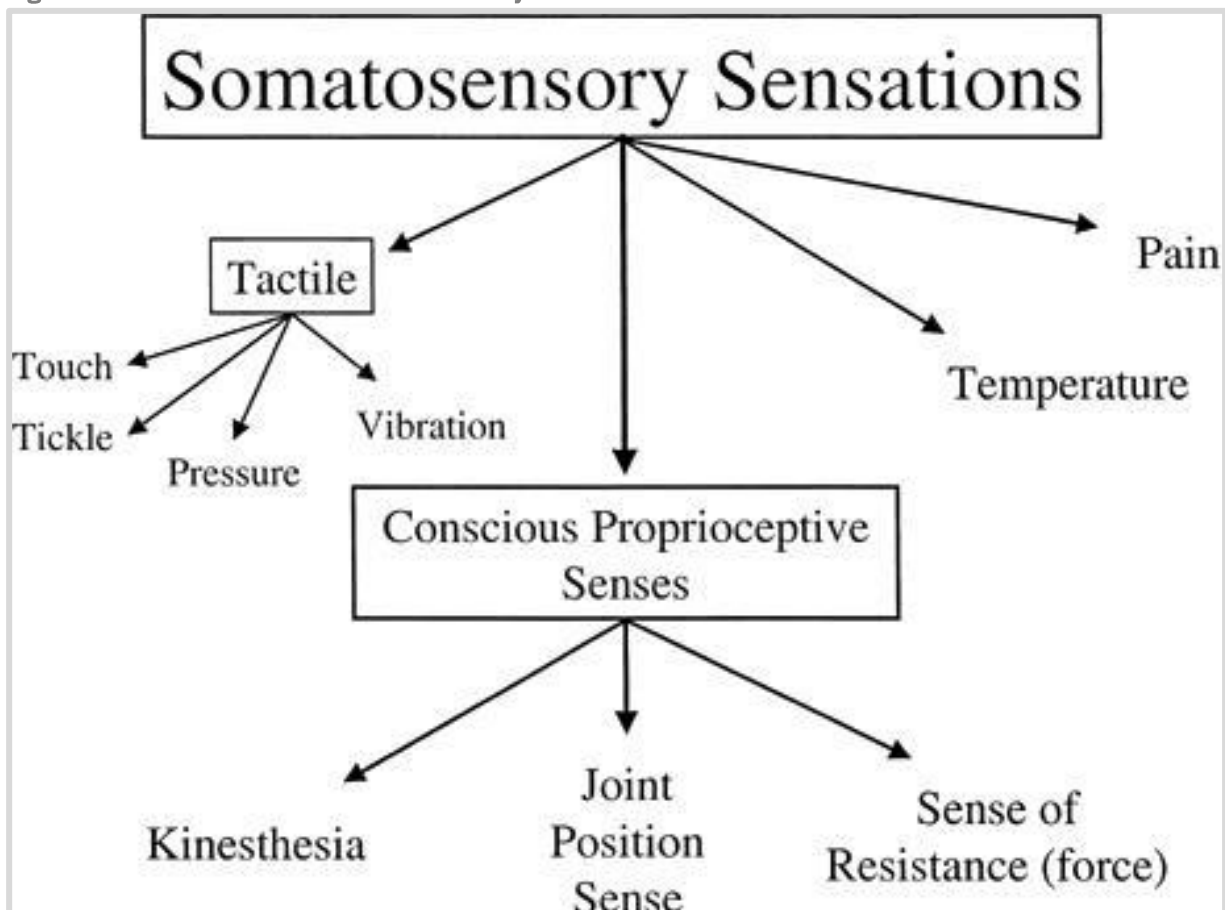
Equilibrium and stability training currently occupy an essential role in athletic performance management and injury prevention (Behm, D.G. & Anderson, K. G., 2006). There are various methodologies and exercises that implement various proprioceptive work devices. In 1906, Sherrington defined **proprioception** as "the culmination of all the neuronal inputs originating in joint, sinewy, muscle and deep tissue proprioceptors" (as



cited in Romero, 2010, p. 169). Scientific evidence indicates that thanks to this type of training, muscle strength, coordination and equilibrium are improved (Behm, D., Drinkwater, E. Willardson, J., & Crowley, P., 2010).

The athlete's central nervous system (CNS) gets the necessary information from the **somatosensory system** (also known as the proprioceptive system -SP-), from the **vestibular system** and the **visual system** to control movements. The feelings of proprioception are those that have to do with the body's physical state, the sensations of movement, of pressure at the bottom of your feet and even of equilibrium. These sensations are felt through specific **mechanoreceptors** in the skin, muscles, ligaments and tendons. They can perceive pressure, vibrations, sense of position of an articulation and kinesthesia. The importance of proprioception is unquestionable, since it helps avoid abnormal articulation movements both in positions of extreme tension as well as when flexing. Its prophylactic effect in injury prevention is beyond any discussion, although its contribution to complex movement coordination is also very valuable (Jerosch, J. & Prymka, M., 1996)

Figure 22: The Sources of Somatosensory Sensations



Source: Adapted from Riemann & Lephart, 2002, p. 73.

We must keep in mind that proprioceptive work should focus on generating disturbances that stimulate the *proprioceptors*; this can be achieved in situations that are especially favorable to optimize the ability of reaction and equilibrium before that sudden stimuli,



which can be done in static and dynamic ways. In the selection of tasks to complete, it is extremely important to stimulate the proprioceptors in the areas we are interested in, through the appropriate tasks (Romero, 2010).

Those who defend this mode of training argue that the unbalance generated by unstable platforms cause a larger stress to the neuro-muscular system in comparison to the floor and fixed chairs. According to this theory, strength gains would be due to mechanisms of muscle hypertrophy, and the optimization of neuromuscular coordination as a consequence of a better complementarity of the work among synergistic, stabilizing and antagonistic muscle groups.

When we talk about work on unstable methods, we refer to sitting, falling, kneeling, lying down or standing on objects such as PhysioBalls (Swissball), dynamic discs (Dyna Discs), equilibrium boards (WobbleBoard), high density foam rollers (FoamRoller), Bosu (stands for both sides to use), mattresses, mini trampolines, and other similar objects (Behm, D. G. & Anderson, K., 2006), although we could also cause instability with objects that are half filled with liquid or sand.

While we could infer that this type of training is only beneficial for athletic performance, they could be advantageous if we just focused on them. Therefore, it is the objective of this analysis that you incorporate the elements that allow you to introduce those sorts of tasks into an appropriate environment and within a varied and specific program.

Historically, rehabilitation and prevention of injuries (such as a sprained ankle or knee) have focused their work in muscle building and have ignored the proprioceptive deficiencies. Proprioception is a matter of posture, of movement, of changes in equilibrium, as well as in knowledge of position, weight, and resistance to objects in relation to one's own body weight. Unstable bases are the answer to the problem of reeducation of the proprioceptive system to minimize the inconveniences caused by the lack of coordination (Hoffman, M. & Payne, V. G., 1995).

According to the specificity principle, the loads should replicate game situations, or, at least, be as close an approximation as possible. Since not all forces are generated under conditions of stability in matches (for example, a jump shot, or a rival's change of direction, a dribble to elude a defense, a pivot, etc.), training should attempt to replicate a game's demands.

While in team sports nearly all situations are developed in a dynamic equilibrium, traditional training is done in situations of stationary equilibrium. With regards to this, Shimada et al. (2003) found no correlation between dynamic balance (a walk) and static balance, and other authors report secondary effects of balance and adjustment to disturbances; the problem is that in those studies one can only simulate relatively similar conditions; meaning, work on unstable platforms cannot replicate game situations exactly. Therefore, its effectiveness to manage performance is still up for debate (Wahl, M.J. & Behm, D.G., 2010). According to Willardson (2009):

The optimal method to increase proprioception and stability in any sport consists in practicing the sport's own abilities on the same surface on which



the competition takes place. Unfortunately, this is not always possible, which is why alternative challenges may be necessary. (p. 108).

The utilization of unstable methods in training may cause the individual to be incapable of generating maximum levels of strength and muscle power, and it is worth mentioning that as instability increases, there is a greater activation of the antagonist muscles to provide greater equilibrium, which may generate even bigger decreases in strength. With the purpose to analyze the influence of training on unstable bases and different conditional variables, such as jumps, agility tests and 10 and 40 yard sprints, Cressey, West, Tiberio, Kraemery Maresh (2007) compared two groups of training for ten weeks: one of them was performing exercises on inflatable bases, and the others would perform the same exercises on the ground. The team that trained on a stable base had a superior performance in every aspect that was evaluated. The authors concluded that, while the utilization of these elements has shown effectiveness in the rehabilitation of injuries, their utilization to increase athletic performance should be carefully analyzed.

Let's summarize, then, the benefits of training on unstable surfaces:

- They reduce the risk of ankle and knee injury, which makes it important for prevention; here, Caraffa (1996) and Verhagen and Van Mechelen (2009) agree.
- They play an important part in the rehabilitation of ankle and knee ligament injuries (Lephart, S., Pincivero, D., & Giraido, J., 1997).
- It increases the activation of core musculature more than the same exercises on stable surfaces (Fowles, J., 2010)
- It improves muscle coordination and strategies of muscle activation in the muscles of the ankle (McKeon, P. & Hertel, J., 2008).
- It improves static equilibrium (Anderson, K. & Behm, D. G., 2005).

Finally, some things to take into consideration when training on unstable surfaces:

- Their effects on improvements to maximum strength and power are null or insignificant, at best, and should not be used as the main method for the development of these aspects (Cressey, E. et al. 2007).
- They have lower electric activation of leg and upper body musculature compared to the same exercises performed on stable surfaces (Behm, D. G. & Anderson, K. 2006).
- To avoid contradictions in the specificity of movement, it is important to control the execution of movements on unstable surfaces since, generally, they are performed at very low speeds, while the action is generally very fast in sports (Willardson, J. Fontana, F. & Bressel, E. 2009).



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