

Module 1. Introduction to Strength in Team Sports. Our Paradigm

1.1 Basic Notions of Strength in Team Sports

Our hope for this course is to be able to act as a jump-start for your improvement process as an athlete, coach or kinesiologist. We will attempt, over the course of this experience, to not only provide you with conceptual support bases, but also the scientific and empirical support that back up specific behaviors in the field of strength training as applied to team sports.

We will divide the presentation into three broad sections: the first will address itself to conceptualizing and defining topics related to strength; the second part will be oriented towards how to periodize and analyze the most effective training methods; and the third part will dedicate itself to developing an effective training program according to the needs of your team, your athlete or you, yourself.

We want to wish you success on this voyage we are beginning together; we hope that you will enjoy the reading and that this certificate will help you in your professional development and that it will awaken your curiosity to continue contributing to the growth of our discipline.

Dominant paradigm and analysis of the athlete as a hypercomplex structure: More is better?

Traditionally strength training for team sports has been associated with isolated work in the weight room or the gym, without any relation to the motor actions that a player should put into practice on the field. According to behaviorist and mechanistic theories, this kind of work has tried, by means of quantitative practices and through linear sequences of exercises, to "construct" a player who can meet the needs of a dominant model.

This behaviorist and mechanistic paradigm understands the universe as a mechanical system composed of parts, the human body as a machine and life in society as a competitive struggle for existence where the predominant belief is one of unlimited material progress by means of the growth of economic and technological power (Capra, F. 1998). Based on this paradigm, it can be inferred that the development of the athlete depends, in large part, on:



- The evolution of the rules.
- The evolution of the demands of competition.
- The conceptual evolution of the coach.
- The evolution of the social and economic value of the sport.
- The evolution of the research and technology applied to the sport.

But this model has begun to decline, and has given way to a new way of understanding the world, according to which the axis that shapes the process of improvement is that of the person-athlete whose lived experiences provide them with a mixture of energy flows that is unique and unrepeatable. This mixture generates a specific make-up for each individual and produces a personal self-modeling path that cannot be reproduced in another subject nor repeated in the same person-athlete at a different moment (Seirul-lo Vargas, F., 2003).

According to the complexity paradigm, the central axis of the training process is the human-athlete; it is not a body that moves, but rather a person who moves. This conception of movement involves all of the structures that make up this individual in a holistic manner.

In this way, it is necessary to understand what we call **capacities**, like strength, endurance, movement range, etc., are nothing more than sectorial forms of evaluating one part of the processes that occur in a system belong to a hyper-complex system (a human being) at a certain moment of its existence.

With this in mind, we will try to reinterpret the process of strength training within a systemic and holistic framework, giving priority to highly variable situations and contents, as each individual interacts with their environment in a unique experience.

But we do not fall into this trap: many trainers, in the zeal to provide only specific loads, do not consider the necessary requirements for athletic practice, and forget that the more specific the training with respect to the competition, the more stress it creates for the athlete and the more it increases the risk of injury.

As we will see further on, strength training has, from our perspective, two fundamental objectives: on one hand, to optimize the athletes' performance, and on the other hand to prevent injuries or at least to limit them. Using scientific research and experiences we will attempt to explain some practical and theoretical aspects so that you will be capable of shaping your practice and achieving these two fundamental premises with your team, your club or your athlete.

The difficulty of training strength in team sports

The main characteristic of team sports is the **environmental variability**: the situations that arise may never be repeated. For this reason, it is difficult to measure them, above all if we consider that traditionally the training models come from individual sports. Today, with advances in scientific research, we can sharpen the training models and



approximate the reality of our sport, leaving behind perspectives biased towards track and field and swimming, as was the case years ago when only physiological and/or biochemical parameters mattered for analyzing our athletes' performance.

Thanks to the evolution of technology and science, today there are scientifically valid tools that can be carried in a pocket, like cellphone applications. With questionnaires like the RPE (*rating of perceived exertion*) we can get closer to the measurement of what our athletes are really feeling, which could be very different from what trainers think that our athletes feel. Software like Data Volley, Amisco Pro or Sagit (for handball) allow us to get closer not just what happens in the sport in general, but also what is happening to our team in real time.

1.1.1 Practical Definitions of Concepts

Strength - basic physical quality

"Remember, movement is life" said the ancient samurai Miyamoto Musashi and, for there to be movement, there has to be a muscle action. We should understand the broad possibilities of muscle action that the human being is capable of would not be possible without **muscle strength**, whether it is expressed through movements like walking, running, throwing, sitting down or even moving your eyes to read this text (see Figure 1).



Figure 1: Basic concepts and equations

From a physics point of view, force is the influence that acts on an object causing it to change its state of motion as defined by Newton:

$$F = M \times A \quad (\text{force is equal to mass times acceleration})$$

$$A = \frac{V_f - V_i}{T} \quad (\text{acceleration is equal to Final Velocity minus original velocity divided by time taken})$$

$$F = \frac{M \times (V_f - V_i)}{T} \quad (\text{Fuerza es igual a la masa multiplicada por la resultante de Velocidad Final Menos Velocidad Inicial sobre el tiempo empleado})$$

Thus: Power is the capacity to perform a task in as little time as possible:

$$P = \frac{\text{Work}}{\text{Time}}$$

But since work is equal to:

$$Tr = \text{Strength} \times \text{Distance}$$

We can therefore say that:

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

Y como velocidad es distancia sobre tiempo entonces simplificado esto decimos que: And since velocity is distance over time, this can be simplified by saying that:

$$\text{Power} = \text{Force} \times \text{Speed}$$

The units of measure for these manifestations are as follows:

FORCE = Newtons (N)

WORK = Joules (J)

POWER = Watts (W)

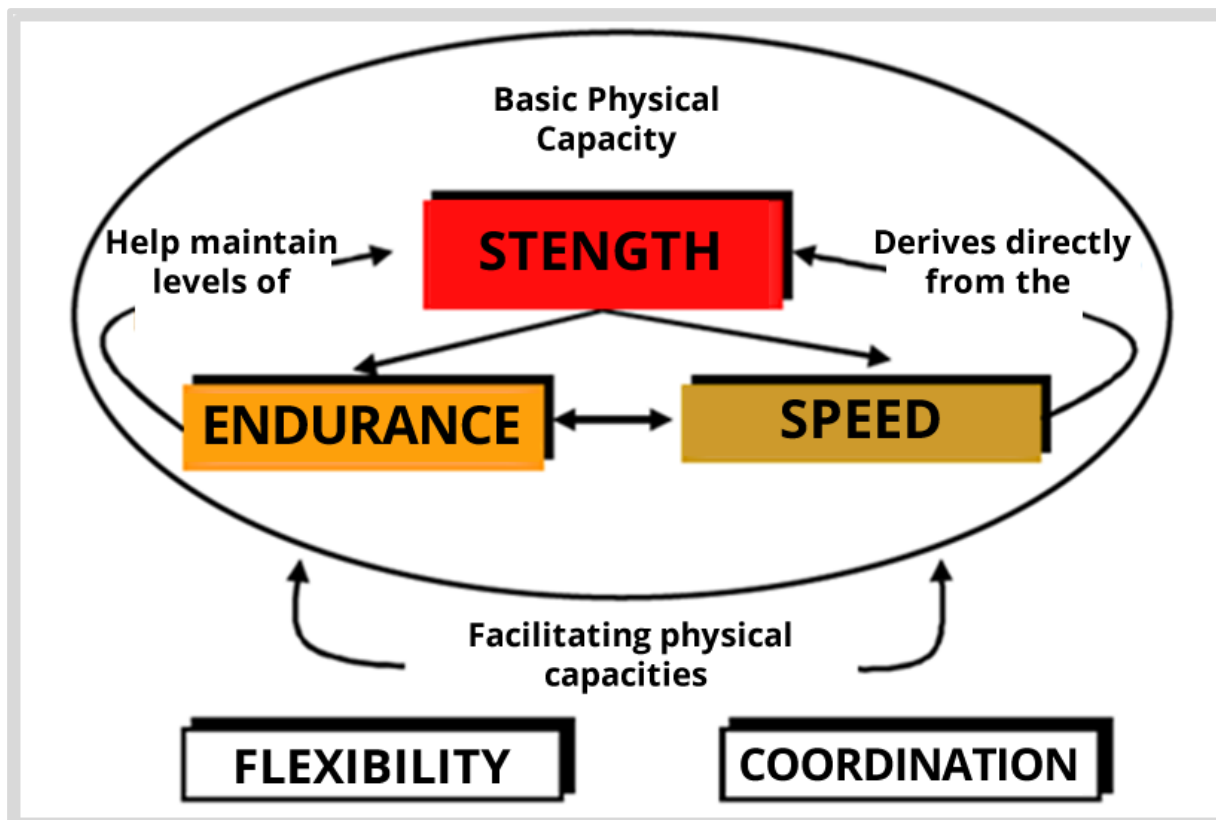
Source: adapted from Knuttgen, and Kraemer, 1987.

There are three basic parameters for understanding strength. These are:

- 1) The level of force:** the amount of force applied in a certain action.
- 2) The time that given force is applied:** the amount of force applied per second (related to the idea of explosive strength). When this power is understood as the capacity to carry out motor actions in a minimum time frame, its importance becomes clear.

- 3) **The amount of time that a given amount of force can be maintained:** when we refer to maintaining sub-maximal muscle actions for a given amount of time we are referring to the concept of *endurance*.

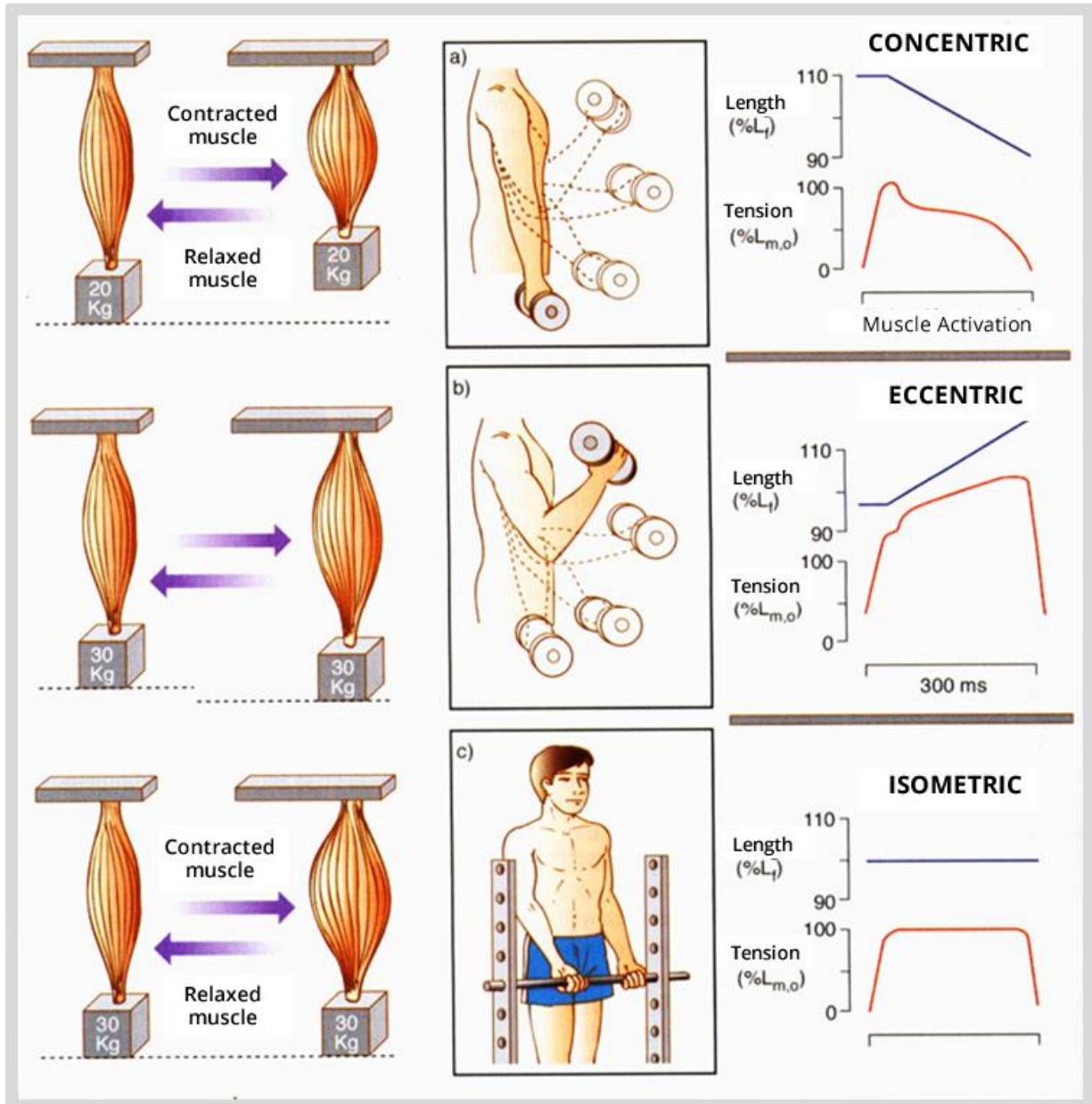
Figure 2: Manifestations of muscular strength



Source: Adapted from Tous Fajardo, 1999.

According to Zatsiorsky (2006), **strength** is the ability to overcome or counteract an external resistance through muscular effort (tension). If the muscle action is in the opposite direction as the resistance and overcomes it, this is called a **concentric action**; if it is in the same direction as the resistance, but does not overcome it, but rather produces active stretching of the musculature due to gravity, it is called **eccentric action**; while when the length of the muscle action does not change it is called an **isometric action** (see figure 3).

Figure 3: Concentric, eccentric and isometric action



Source: Recovered from López Chicharro, 2006. Adapted from Knuttgen, & Kraemer, 1987.

Strength is the capacity for generating tension that each muscle group can produce at a specific execution velocity.

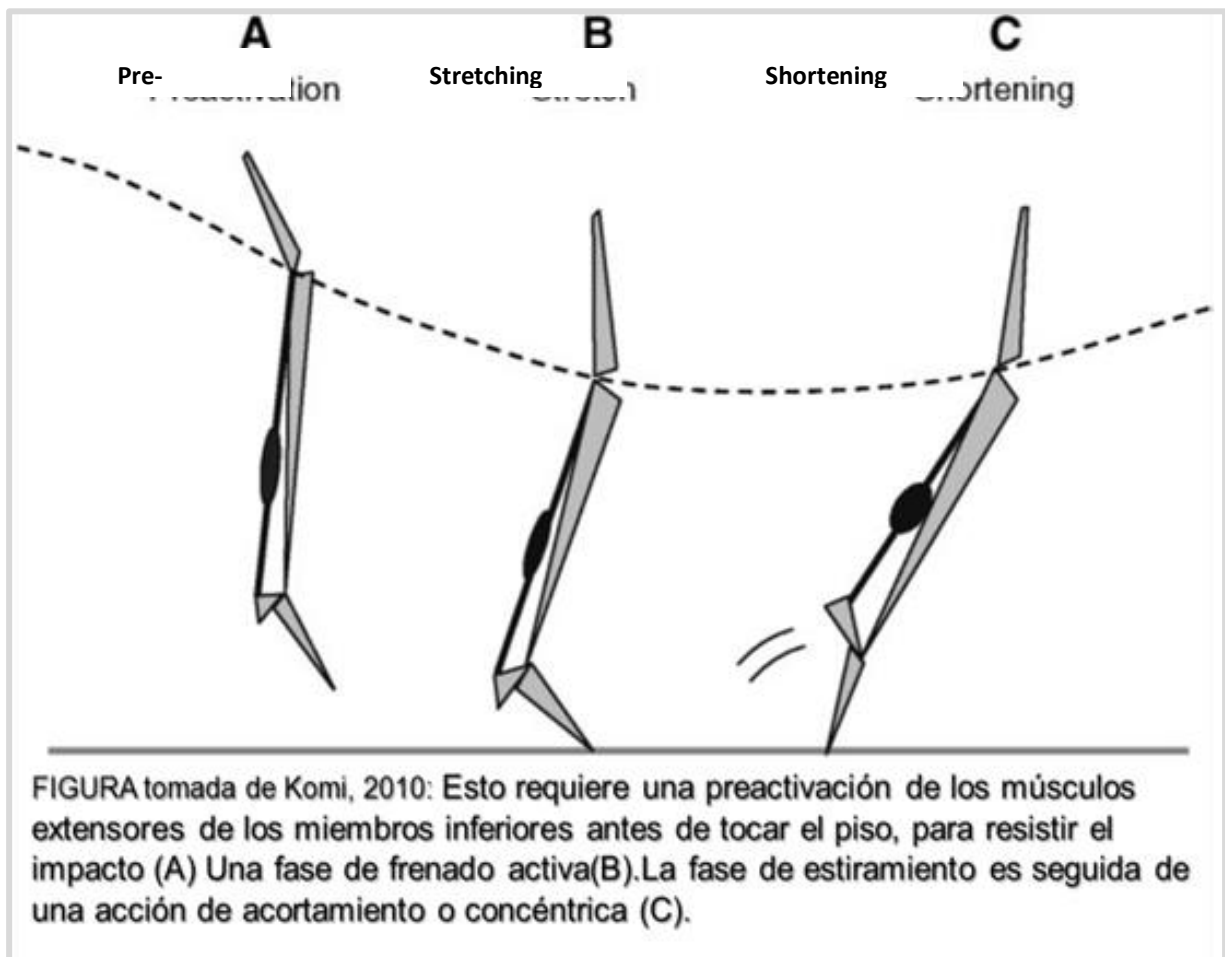
Knuttgen, & Kraemer, (1987). Vol. 1 Num.1 pg. 6

1.1.2 Stretch-Shortening Cycle and the Speed of Strength Development

Stretch-shortening cycle (SSC)

When actions are taken continuously with the goal of creating an eccentric-concentric pre-activation, and the transition time between the eccentric and concentric phases is very short, what is called the **stretch-shortening cycle (SSC)** occurs (Komi, P. V., 1992). According to Verkhoshansky (2006), this has to do with the specific muscular capacity to exert a very strong motor effort and then an intense mechanical stretch, that is, during the rapid transition from eccentric work to concentric work.

Figure 4: Pre-activation and SSC



Source: Komi, P. V., and Nicol, C., 2010.

SSC comes from the observation that all of the body segments are subject to impact or to stretching forces. Running, walking and jumping are typical examples where external forces, gravity, for example, lengthen the muscle. In this lengthening phase, the muscle is acting eccentrically, and this phase is followed by a concentric action.

Explosive Strength and Rate of Force Development or RFD

Maffiuletti et al. (2016) define **explosive strength** as the ability to increase force or torque as rapidly as possible by means of a rapid muscle action from rest or from a low level of muscle activation. Schmitz Bleichter (1992), in turn, divides these explosive actions into two types: these with a **short SSC** (less than 250 milliseconds) and those with a **long SSC** (greater than 250 ms).

Why are these concepts so interesting for team sports? Because according to studies carried out by McInnes, Carlson, Jones and McKenna (1995) in basketball, while these actions represent only 15% of the total actions carried out in a game, they are the actions responsible for success or failure during competition.

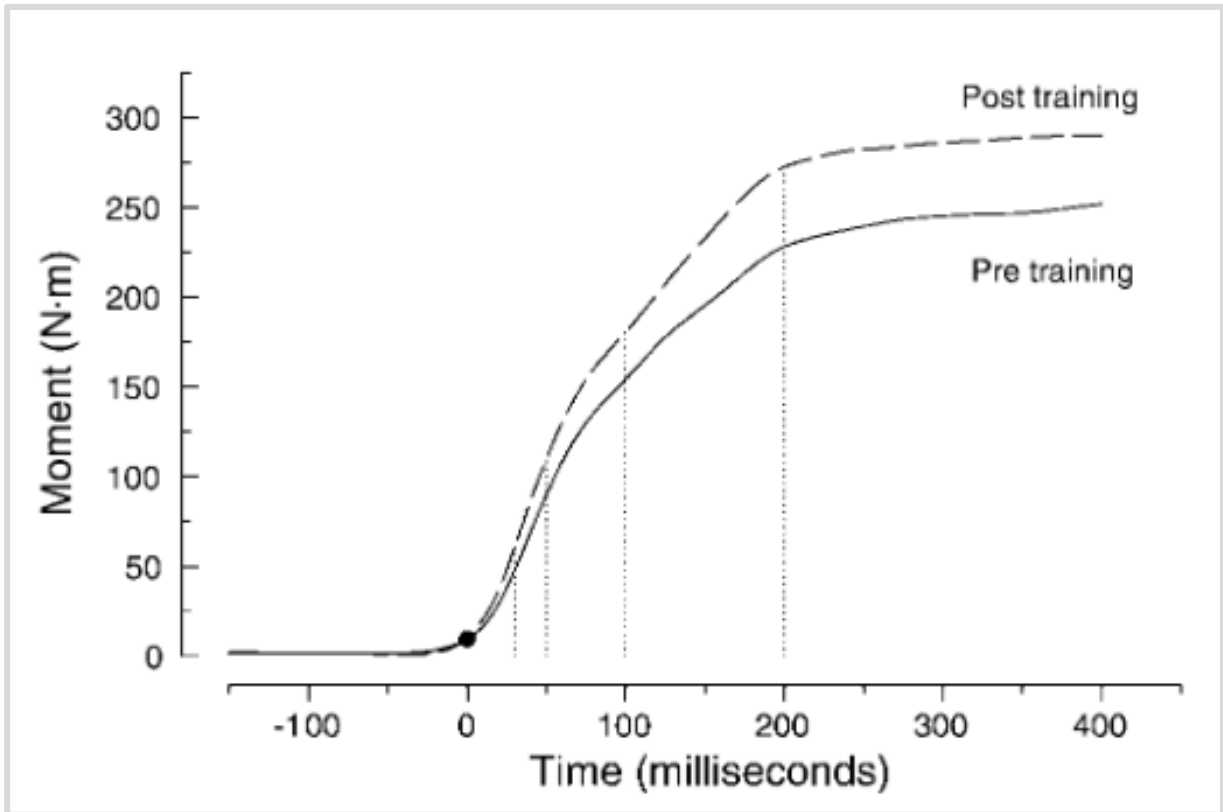
In team sports, actions like a jump to head the ball, a spike in volleyball, a jump shot in basketball or a shot in soccer, to cite only a few examples, are short duration high power actions, as we will analyze further on.

The **rate of force development (RFD)**, therefore, is derived from the force-time curve recorded during a voluntary explosive muscle activation. Evaluation of this curve, if we compare it with a maximum muscle contraction, has, in principle, the following advantages: 1) it appears to be more related to athletic tasks, 2) it is more sensitive for detecting acute and chronic changes in neuromuscular functions and 3) it is potentially governed by different physiological processes (Maffiuletti, 2016).

In turn, this capacity for expressing strength in a short period of time is influenced by numerous factors of the neuromuscular system, among which we find those that contribute to the increase of maximum strength (transverse muscle surface area and firing frequency of motor units) as well as those that affect the time required to achieve a given level of strength (the type of fiber and the muscle-tendon stiffness) (Maffiuletti, N., 2016).

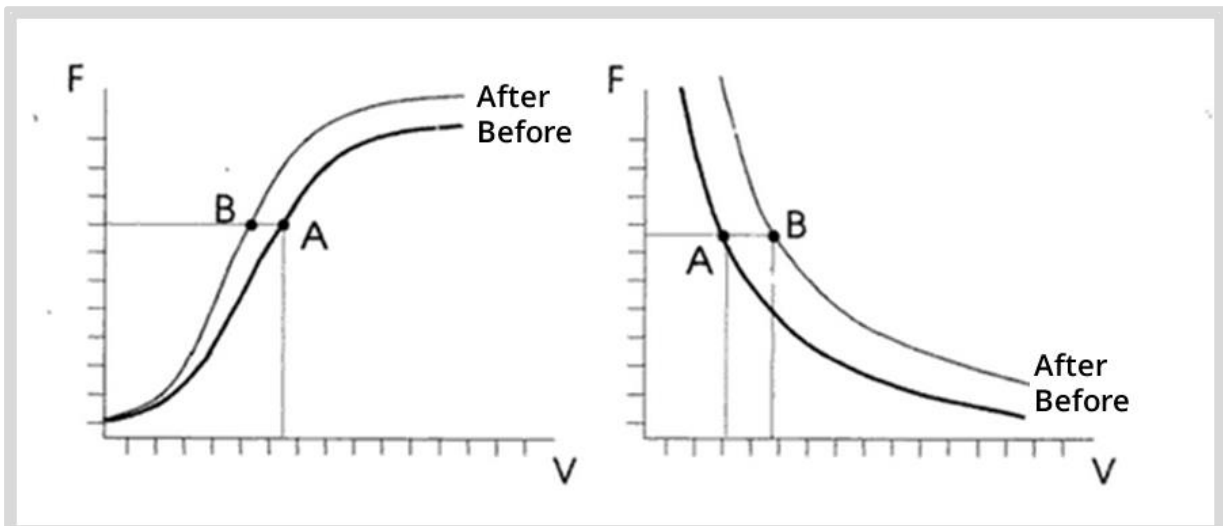


Figure 5: Rate of force development before and after training



Source: Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002, p. 1319. Fig. 5. Average momentum-time curve for 15 subjects before and after a 14 week strength training. The beginning of the contraction is marked by the black circle at time zero. The dotted vertical lines indicate intervals of 30, 50, 100 and 200 ms relative to the start of the action. More pronounced inclines can be seen after training in the first 200 ms of the curve.

Figure 6: Comparison of force-time and force-velocity curves



Source: adapted from Gonzales Badillo & Ayestarán (2002) p. 49. To the left we see the Force-Time (f-t) curve, and to the right the Force-Velocity (f-v) curve. Both are analyzed before and after a training session with heavy loads. The changes produced in the F-T curve are similar to the ones observed in the F-V curve. The more force we can generate at the same previously applied velocity, or the faster we are able to achieve the same resistance, the better our force-velocity curve will be.



As we see in Figure 6, a correct training program will have as its result **shifting the force-time curve upwards and to the left**, meaning that the athlete is capable of exerting more force over the same amount of time. To achieve this, the selection of the exercises to be carried out is fundamental. We will talk about this further on.

1.1.3. Physiological Aspects of Muscle Actions

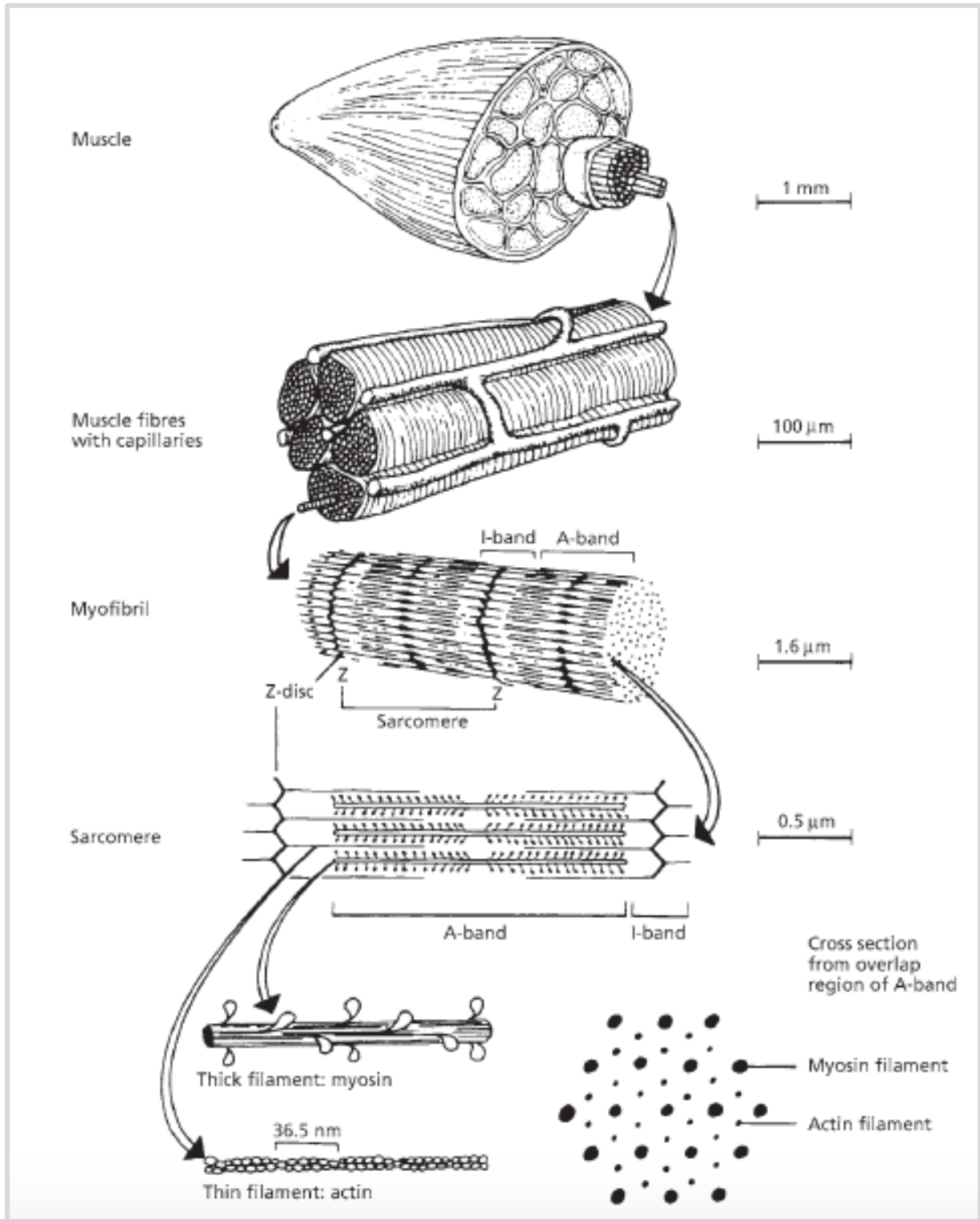
Muscles are made up of two components: one **active, or contractile**, and the second **passive, or non-contractile**. The first part consists of thousands of interlaced fibers, and its primary objective is to slide them along each other to produce movement. The other part, the passive component, refers to the sheaths, fascia and tendons, whose purpose is to provide a structural framework, not movement itself.

Each muscle is made up of thousands of tiny fibers, all of them coated in a sheath of connective tissue called **endomysium**. When a collection of fibers is grouped together in bundles, these groupings are called **fascicles**; these in turn are coated in their own sheath called **perimysium**. Finally, the muscle, composed of a grouping of fascicles, is sheathed in the fascia or **epimysium** (Verkohshansky, Y., 2004).

At the microscopic level, a muscle fiber is made up of thousands of myofibrils arranged in parallel, which are in turn made up of groups of sarcomeres. The **sarcomere** is the part of a myofibril bounded by two successive **Z disks** and is the building block of skeletal muscle. Its length when relaxed is approximately 2.2 microns, and it is made up of thick filaments of a protein called **myosin** and thin filaments of a protein called **actin**. In order to generate a muscle contraction, it is necessary that there be a temporary connection between the myosin heads and the actin filaments, or what is known as "**cross-bridge**" (Verkohshansky, Y., 2004).



Figure 7: Representation of the structural composition of muscle tissue



Source: Edman, K. (1992). Contractile performance of skeletal muscle fibres. Strength and power in sport, p 114.

The myofibrils are **striated**, and the ability of muscle proteins to alter the map of polarized light allows us to differentiate distinct zones or bands, like the **I-bands** and the **A-bands**. In the middle section of each of these bands there is a brighter band called a **H-**



band, which can be seen with a microscope only when the muscle is relaxed. In each H-band there is a **M-band**, within which the adjacent myosin filaments are interconnected. Additionally, the **Z disks** intersect the I-bands transversally and unite the ends of the actin filaments. Along with the transversal connections made by the M-bands between myosin filaments, a protein called **desmin** interconnects sarcomeres between adjacent myofibrils. Furthermore, the elastic filaments of **titin** interconnect the M bands with the Z disks.

Sliding theory

During muscle shortening, the I and H bands stretch, while there are no changes in the lengths of the A-bands. Therefore, when a muscle shortens, there is an increase in the superimposition of the thin filaments over the thick filaments in the sarcomeres.

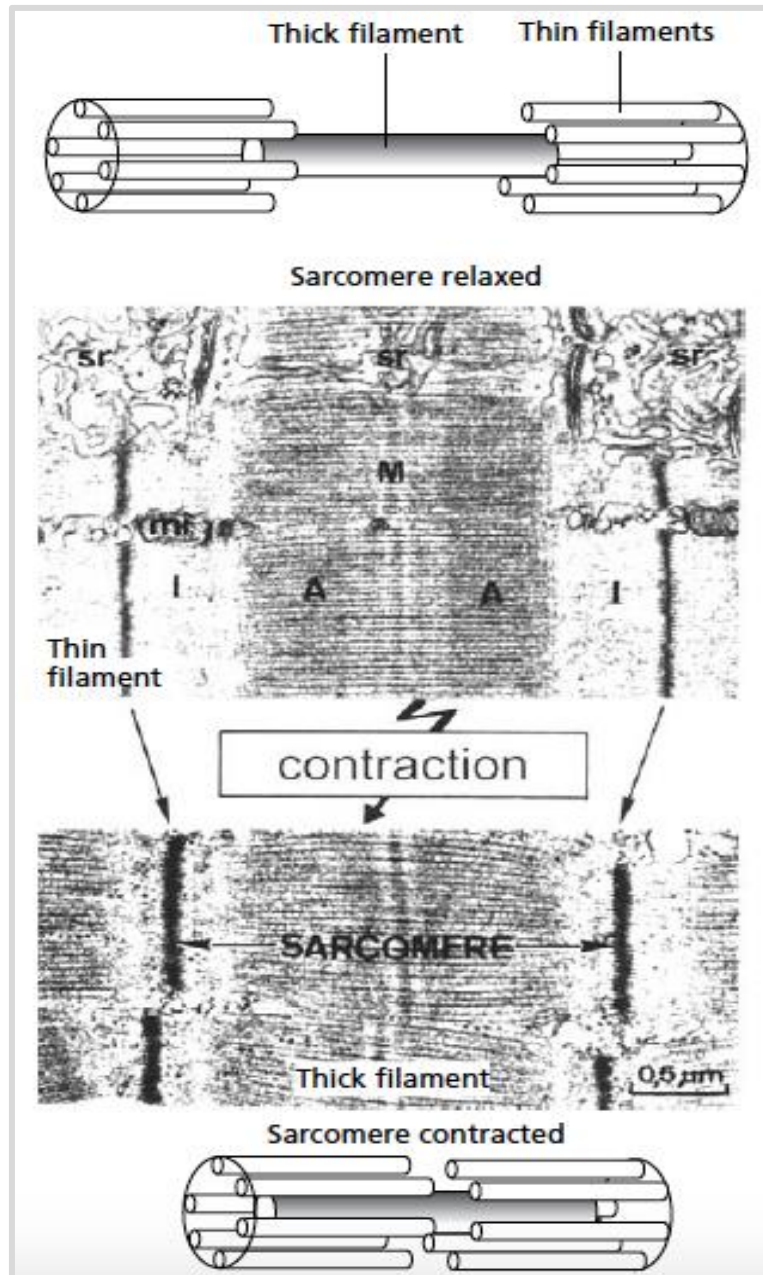
According to Verkhoshansky (2004):

The sliding theory postulates that in a resting state the active zones of the actin filaments are inhibited by the **troponin-tropomyosin complex** and this keeps the myosin cross-bridges from interacting with these zones. When the concentration of calcium ions (Ca^{2+}) is sufficiently high, this inhibition is overcome. This occurs when an electrical impulse is transmitted by nerve fibers to the muscle fiber, and the sarcoplasmic reticulum that surrounds each myofibril suddenly frees calcium ions into the sarcoplasm (the "plasma" inside of muscle cells). The nerves that provide the stimulation are called **motor neurons**. Their cell bodies are located in the brain or in the spinal column and send long cables (axons) to certain muscle cells. The ends of these axons are divided into various terminals upon entering the muscle and each terminal forms a **neuromuscular union** with a single muscle fiber. This union or synapse covers a very narrow space between the membranes of the axon terminal and the muscle fiber, called the **synaptic cleft**. The electrical impulse provokes the synaptic vesicles inside the axon terminal to release a special transmitting substance (a neurotransmitter) called **acetylcholine** that travels across the cleft and gives the signal to the sarcoplasmic reticulum to release the calcium ions. When the concentration of calcium ions released reaches a certain level, the heads of the cross-bridges appear to bind to the active receptors of the actin filaments, they incline at a sharper angle and pull the actin filament among the thick myosin filaments. This process of energy production that involves the highly energetic phosphate molecule **ATP (adenosine triphosphate)** and its derived byproduct **ADP (adenosine diphosphate)** is apparently produced to establish a cycle of successive pulls by the cross-bridges which in successive steps provoke a



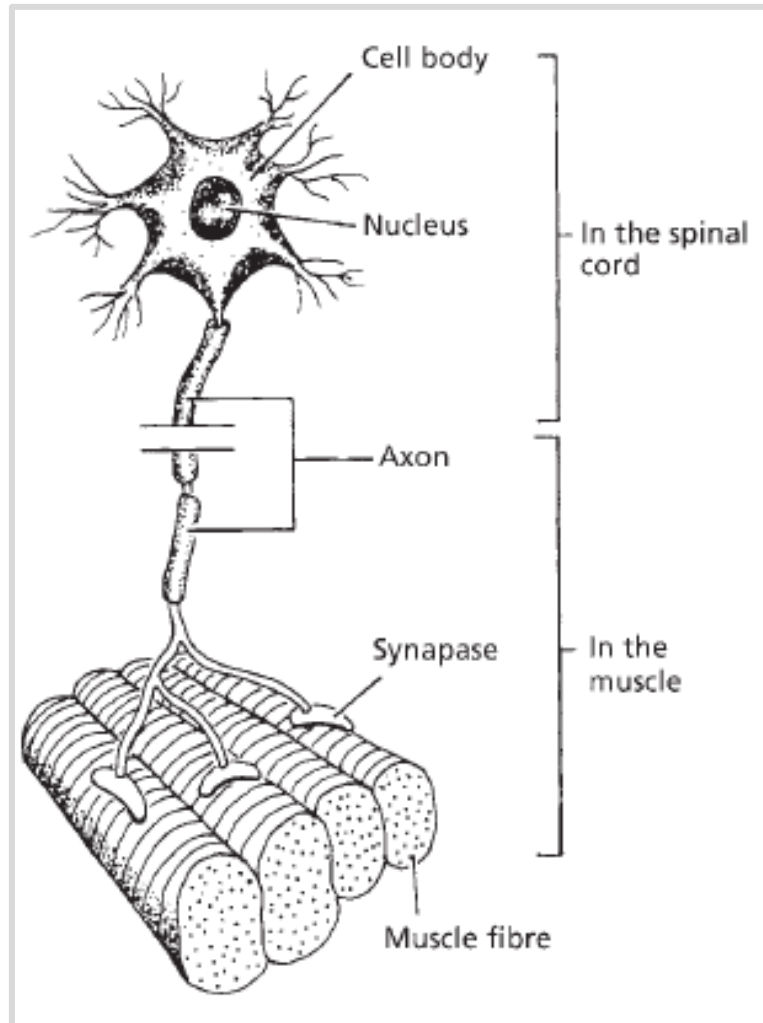
shortening of the muscle. The contribution of numerous and tiny pulls carried out by thousands of myofibrils combines together to produce the activation of the entire muscle group.

Figure 8: Illustration of the sliding muscle theory



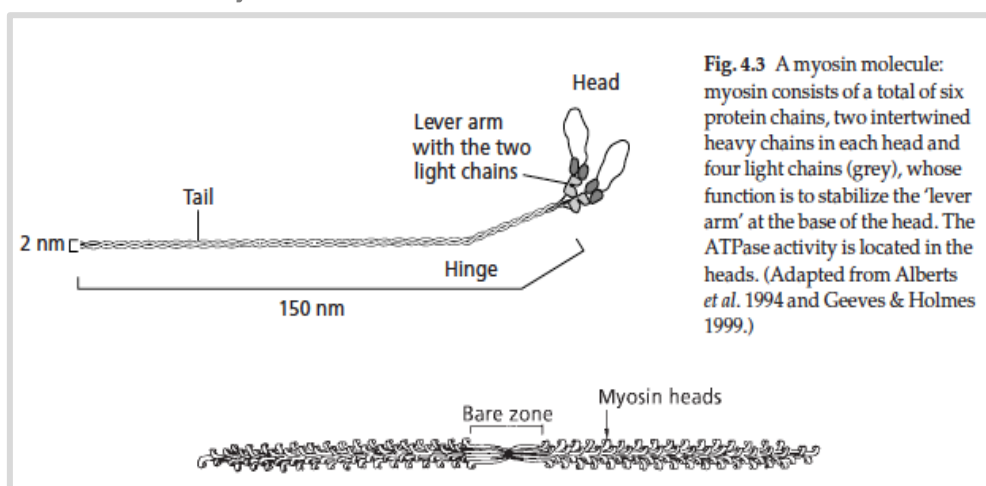
Source: Billeter, R., & Hoppeler, H. (2003). Muscular basis of strength. Strength and power in sport, 50. In a relaxed state, the Z lines are separated by approximately 2.5 μm . The thin filaments and the thick filaments overlap only partially. In a shortened state, the Z lines are closer together, and the actin and myosin filaments overlap over almost their entire lengths. A= A Band, M=M Line, Z Line

Figure 9: The motor unit



Source: Billeter, R., & Hoppeler, H. (2003). Muscular basis of strength. *Strength and power in sport*, 50.

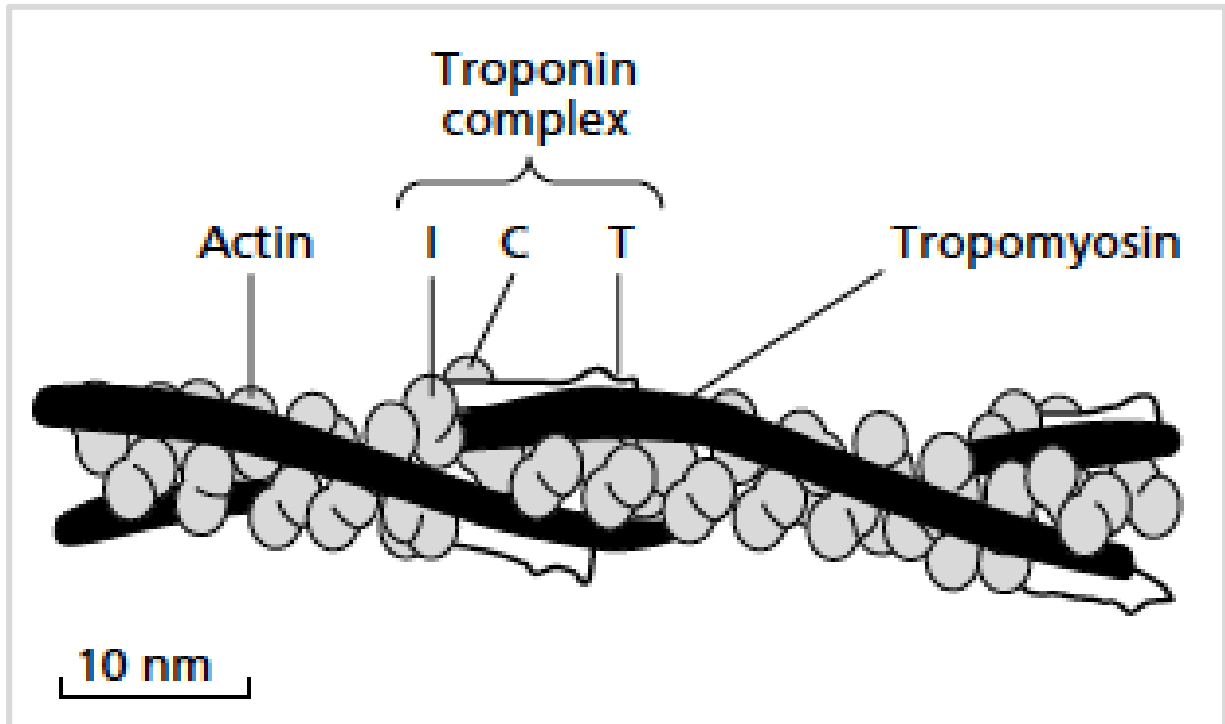
Figure 10: Illustration of myosin



Source: Adapted from Billeter, R., & Hoppeler, H. (2003). *Muscular basis of strength. Strength and power in sport*, 50. Each molecule of thick filament (myosin) consists of a rod-shaped tail (composed of double-threads of meromyosin) and a head (made of two masses of globular protein). Approximately 200 of these molecules combine to form a myosin filament, with the protrusions of the head/neck located on the sides of the filament. These protrusions constitute the cross-bridges.



Figure 11: Illustration of a thin filament of actin



Source: Adapted from Billeter, R., & Hoppeler, H. (2003). Muscular basis of strength. Strength and power in sport, p 50.

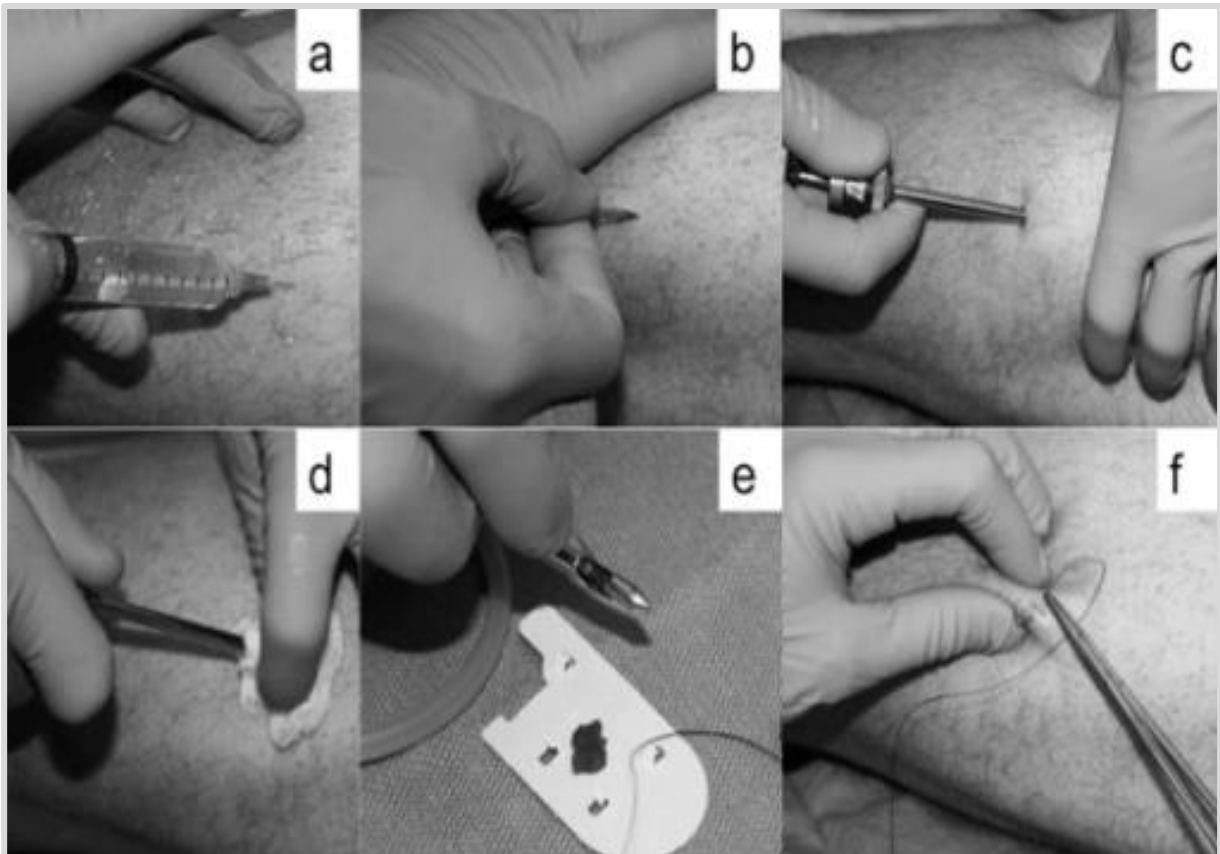
In the image the thin filament is composed of three materials: actin, tropomyosin and troponin. The column of the filament has the form of a helix of interwoven wool, determined by the lengths of a same basic thread of actin molecules weakly connected to an adjacent strip of tropomyosin. The two lengths are coiled, and along the length of the tropomyosin strip triple groups of troponins are attached at regular intervals. This group has three parts, and each one has a different purpose: one globule has a marked affinity for actin, another for tropomyosin and the third for Calcium. It is believed that the first two keep the actin and the threads of tropomyosin together, while the globule that is attracted to Calcium plays a crucial role in the interaction with the calcium ions that initiates the muscle activation, generating a process in which the active zones of the actin filament are exposed so that the myosin cross-bridges can fasten to them.

Types of muscle fiber

Human muscle is made up of different types of fibers that can be classified in different ways, and whose analysis requires a very invasive technique like a **muscle biopsy**. The percentages of these fibers differ between individuals, and also between different muscles. Some muscle groups contract more slowly (those that contain a higher proportion of **type I or slow-twitch (ST)** fibers) and other muscle groups have faster contraction speeds (they have a high proportion of **type II or fast-twitch (FT)** muscle fibers). In any case, the majority of muscle groups have a fairly homogeneous mixture of the two types of fibers. Training with high loads at high speeds can benefit the rapid

contraction muscle groups, while training with low loads, low speeds and many repetitions can benefit the slow contraction muscle groups. Understanding this aspect is key for correctly selecting the exercises to employ based on the type of fiber that predominates in a given muscle.

Figure 12: Muscle biopsy



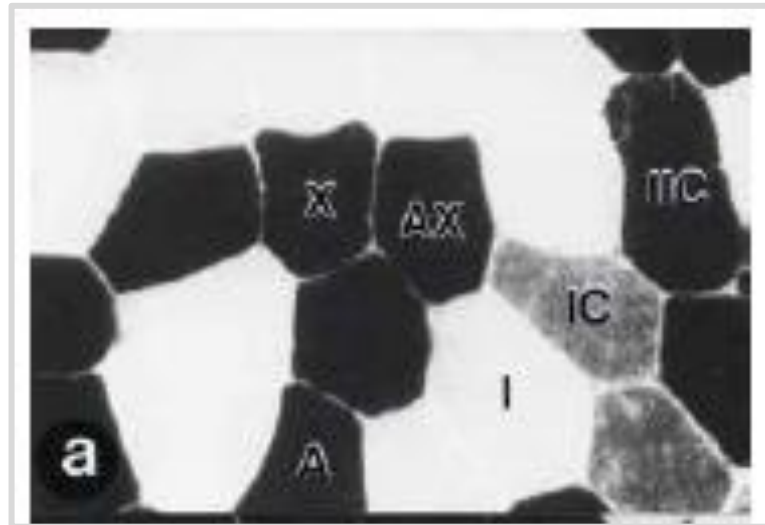
Source: [Untitled image of Muscle biopsy] n.d. Recovered from goo.gl/SSBcV6. Obtaining a sample of muscle tissue by means of a biopsy is a complex procedure that requires administering a local anesthetic, making a small incision and inserting a needle to remove a small piece of muscle.

Today, one of the most commonly used methods for differentiating different types of fibers is the enzyme ATPase's sensitivity at a given pH. **Myosin-ATPase** is an enzyme located in the head of the cross-bridges and is closely linked to the breakdown of ATP into ADP, inorganic phosphate (Pi), H⁺ and energy; thus, it is vital for the generation of cross-bridge cycles. This classification system is possible because different types of myosin-ATPase are found in the muscle fibers. When the selected fibers are dyed and at different pH conditions, the color of the fibers varies based on their composition.

Once the fibers have been distinguished, their contraction speed, capillary and mitochondrial density, etc. are analyzed. This method correlates very well with the contents of the **myosin heavy chains (MHC)** and with biochemical analysis of the metabolic enzymes in each fiber (Scott, Stevens & Binder- Macleod, S. A., 2001).



Figure 13: Example of muscle biopsy



Source: Fleck, S. J., & Kraemer, W. (2014). *Designing Resistance Training Programs*, 4E. Human Kinetics. Muscle tissue stained at a pH of 4.6. We can see the type I, IIa, IIax, IIx and IIx fibers.

While depending on the method we can find various types of fibers, to summarize we can say that there are two large groups of muscle fibers (each with subtypes) with individual characteristics, which we will analyze below:

Table 1: Main differences between type I and type II fibers

Characteristics	Type I	Type II
Force per transverse area	Low	High
Myofiber activity of ATPase (pH 9.4)	Low	High
Intramuscular ATP storage	Low	High
Intramuscular PC storage	Low	High
Contraction speed	Slow	Fast
Time to relax	Slow	Fast
Activity of glycolytic enzymes	Low	High
Resistance	High	Low
Intramuscular glycogen depots	No differences	
Intramuscular triglycerides depots	High	Low
Myoglobin content	High	Low
Activity of aerobic enzymes	High	Low
Capillary density	High	Low
Mitochondrial density	High	Low

Source: adapted from Fleck, & Kraemer, 2014

So, we can see that **type I** muscle fibers have appropriate characteristics for carrying out activities that are predominantly aerobic with low intensity and long duration, as they have an elevated mitochondrial capacity, greater capillary density and high enzymatic activity. On the other hand, **type II** fibers show a higher speed for phosphorylation of ATPase, so their contraction times are fast and they relax more quickly; their energy substrates are predominantly anaerobic, which makes them more susceptible to fatiguing more quickly, and are therefore ideal for short duration and high potency activities.

The existence of various subtypes of type I and type II fibers has been demonstrated. In particular, type II fibers can be **type II a**, with aerobic and anaerobic characteristics, or **type II x** (previously called II b), which have essentially anaerobic characteristics. In relation to the transformation of fibers from one group to the other, it has been proven that this occurs within a muscle group itself, and can occur in various direction, except for the transformation of a type I fiber to a type II (Pette, D.& Staron, R. S., 1997).



The following videos are fairly detailed explanations about how muscle contractions operate at the neuro-physiological level:

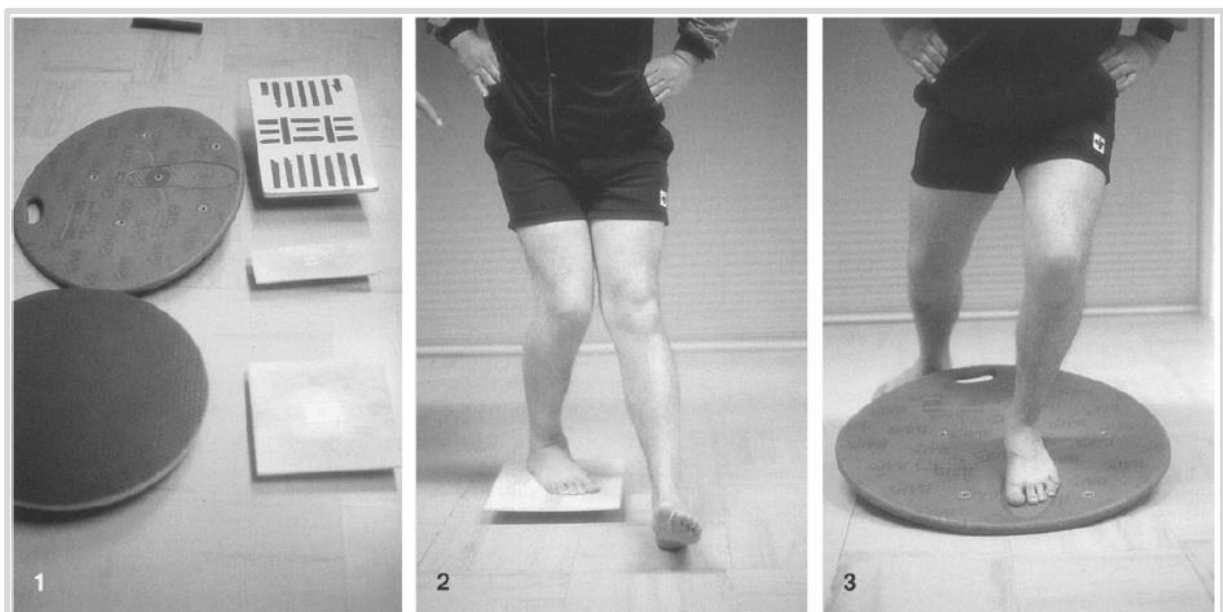
- <https://www.youtube.com/watch?v=C4fmTt01bbo> (Summary of the mechanism of muscle contraction, 2015)
- <https://www.youtube.com/watch?v=jqy0i1KXU04> (Crash Course, 2012)

1.1.4 Objectives of a Correct Training Program

Correct strength training can mark the difference between two teams with similar performance not only during a game but also throughout a season. The two fundamental premises of a correct strength training program are: **to improve performance in competition** and **to diminish the risk of injury**.

With respect to affecting the prevention of injuries, Caraffa, Cerulli, Projetti, Aisa and Rizzo (1996) found significant decreases in anterior cruciate ligament injuries in soccer players in the Italian league after proprioceptive training with balance boards. The authors followed nearly 600 players from 40 teams in Italy over three seasons. They were divided into control and experimental groups. The experimental group carried out exercises with balance boards 20 minutes before training five days a week. The control group simply carried out the training sessions. After the monitoring, they found an incidence of 1.15 anterior cruciate ligament injuries per season per team among those who did not carry out any prior exercise, and only 0.15 per season among the teams that used proprioceptive training.

Figure 14: Balance boards that formed part of the study

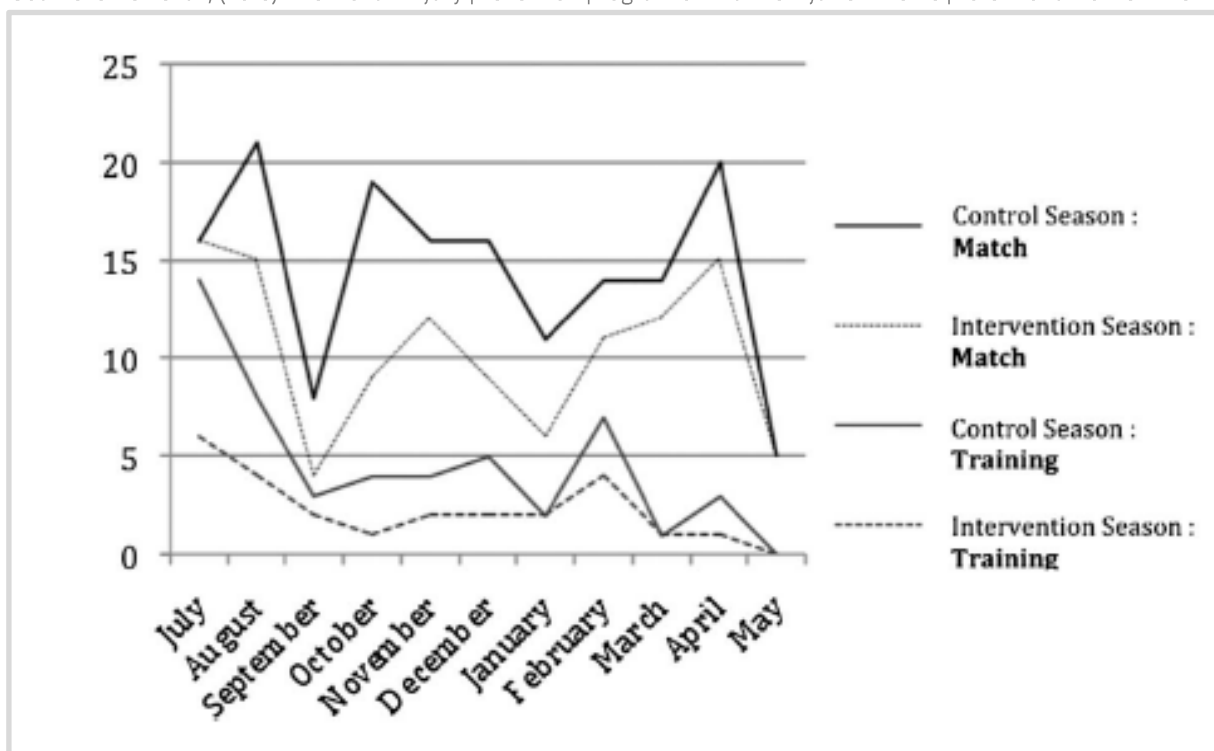


Source: Caraffa et al., Prevention of anterior cruciate ligament injuries in soccer (1996), p4:19-21.

Owen et al (2013) found similar results with 49 soccer players, analyzing the incidence of a twice weekly training program during one season. Each session included stability, strength, core and joint mobility exercises. Then, the results of this season were compared with those obtained in the following season where there was no intervention.

Figure 15: Comparison of injuries during the control season versus the preventative season.

Source: Owen et al., (2013) Effect of an injury prevention program on muscle injuries in elite professional soccer. The



Journal of Strength & Conditioning Research, 27(12), 3275-3285.

This study concluded that a program that involved strength exercises can help effectively diminish the risk of injury among soccer players, above all of muscular injuries.

Laursen, Bertelsen and Andersen (2014) carried out a meta-analysis that involved 25 studies, 26610 subjects and 3464 injuries. The objective of this analysis was to determine the effect of strength, proprioception and stretching interventions. The authors concluded that strength training and proprioceptive work had a significant influence on injury reduction, while stretching did not have a result. Additionally, the strength exercises had more positive effects than proprioceptive training.

While historically there has existed the myth that weight training is unsafe or dangerous for athletes, Hamill (1994) underscored the relative safety of overload training for young athletes when the number of injuries in this discipline were compared with other kinds of sports like soccer, basketball or rugby. To do so he conducted statistical monitoring of different kinds of sports and reviewed the number of injuries produced in competition



and training. While soccer presented 6.2 injuries for each 100 hours of practice and basketball 1.92, weight training presented a notably lower number of 0.0035 injuries.

Figure 16: Summary of comparative injuries and averages by athletic discipline

Table 1 Summary of Injury Statistics Derived From Survey							Table 2 Multi-Sport Comparative Injury Rates	
Sport	Serious injury	Other injury	Partic- Total	Particip- ipants	Particip. hrs (PH)	Injuries per 100 PH	Sport	Injuries per 100 participation hours
Rugby	10	40	50	520	6,250	0.8000	Schoolchild soccer	6.20
Soccer/Rugby	24	66	90	1,770	65,750	0.1400	UK Rugby	1.92
Cricket	0	3	3	950	18,525	0.0300	South African Rugby	0.70
Athletics	0	2	2				UK basketball	1.03
Winter sports [†]	17	58	75	3,230	125,700	0.0600	USA basketball	0.03
Summer sports [†]	1	13	14	2,840	142,355	0.0098	USA athletics	0.57
Soccer*	0	7	7	1,300	50,300	0.014	UK athletics	0.26
Basketball*	0	9	9	2 sch.	?		UK Cross-country	0.37
Gymnastics*	1	7	8	1 sch.	?		USA Cross-country	0.00
Badminton*	0	4	4	1 sch.	?		Fives	0.21
Cross-country*	0	3	3	1 sch.	?		P.E.	0.18
Tennis*	0	3	3	1 sch.	?		Squash	0.10
WT/WL ^a	1	0	1	4,698	80,725	0.0012	USA football	0.10
Weight training	1	2	3	520+	25,190	0.0120	Badminton	0.05
Weightlifting	1	1	2	560+	148,370	0.0013	USA gymnastics	0.044
Total 3-5	3	3	6	5,868+	254,285	0.0023	UK tennis	0.07
All WL (est) ^b	2	1	3	1,634+	168,551	0.0017	USA powerlifting	0.0027
All WT (est) ^c	1	2	3	4,040+	85,733	0.0035	USA tennis	0.001
							Rackets	0.03
							USA volleyball	0.0013
							Weight training	0.0035 (85,733 hrs)
							Weightlifting	0.0017 (168,551 hrs)

[†]Two schools provided a partial analysis by individual sport; these figures do not include that analysis (indicated by *).
^aRespondents did not differentiate. ^bAssumes 25% of undifferentiated WT/WL time was WL and includes all WL injuries. ^cAssumes 75% of same (see^b) and includes all WT injuries.

Note. From data in Refs. 3, 12, 14, 19, 21, and 23.

Source: Hamill, 1994, 8(1), p 53-57.

Federations like FIFA (International Federation of Association Football) have proposed warm-up programs aimed at improving strength and injury prevention, such as FIFA 11+. A session of the well-known program is composed of 15 exercises divided into three parts with an approximate duration of 20 minutes, and should be carried out at least two times per week. The main components are: 1) an initial part of aerobic activation and stretching, 2) core and leg strength exercises, and 3) exercises for agility and changes of direction. Al Attar (2015), with the goal of analyzing the effectiveness of these interventions, carried out a meta-analysis that involved nine studies, 5481 individuals, 428633 hours of exposure and 1753 injuries. His results found that over the long run, those players who practice the FIFA 11+ have between a 20% and 50% better chance of preventing injuries than those players who did not do any strength training.

You can download the FIFA 11+ program and watch explanatory videos at the following link: <http://f-marc.com>

In relation to improving the athletes' performance, there are many studies that show that systematic strength training brings about an increase in physical capacities, such as jumping to spike a ball in volleyball, throwing in baseball and handball, shooting in



soccer, the *scrum* in rugby, etc. Below we will analyze some of these studies on improvements in different motor skills as a result of overload training and its combination with specific technical gestures.

Newton and McEvoy (1994) analyzed the influence of two types of training on throwing speed in baseball among amateur players. One group of players made throws with a 3kg (6.6 lbs) medicine ball from the chest and over the head, and the other group did bench press and pullover exercises. The total duration of the training was eight weeks and the results demonstrated that, contrary to the authors' expectations, the traditional strength training produced better results for maximum distance reached and for the speed of the throws. From this we can deduce the importance of training not only with specific exercises but also with general strength exercises.

Table 2: Comparison of throwing speed and Strength in 6 RM in baseball players

Throwing speed						
Group	N	Before training (m . s ⁻¹)		After training (m . s ⁻¹)		% Change
		M	DS	M	DS	
Control	8	32.5	1.6	32.3	2.3	-0.7
MedBall	8	31.0	1.9	31.5	1.5	1.6
Tr. Weightlifting	8	31.7	2.5	33.0	2.2	4.1*

* Significant change pre - post training at $p < 0.05$.

6 RM Strength Pre and Post Training						
Group	N	Before training (Kg)		After training (Kg)		% Change
		M	DS	M	DS	
Control	8	59.6	12.3	61.6	12.9	3.4
MedBall	8	51.2	6.0	55.8	5.1	8.9*
Ent. Weightlifting	8	48.7	5.4	59.8	5.0	22.8**

* Significant change pre - post training at $p < 0.05$. + Significant difference in the percentage of change among the group Ent. Weights and the other two groups at $p < 0.05$.

Source: Newton and McEvoy, 1994, 198-20

In volleyball, Newton, Kraemer and Haekkinen (1999) analyzed the effect of ballistic type training in the jump attack among 16 university level players of the National Collegiate Athletic Association NCAA I and they found a significant improvement of 6.3% after eight



weeks of training the jump with three steps of approximation (from 78 to 83 cm [30.7 to 32.7 in]).

In soccer one can take some concepts from these studies and apply them to jumping to head the ball or training for specific motor patterns for the goalkeeper.

We will analyze in depth the effects of different interventions on different actions belonging to the sports in unit II.

1.2 The Role of Strength - from Theory to Practice

1.2.1 Strength Levels - Characteristics of Team Sports

In team sports, as the required level of play increases, the physiological requirements and the load that the players have to tolerate increase as well. There exists, therefore, the concept of **strength threshold**, that is, reaching given strength levels that permit the athlete to perform at an optimal level based on the requirements of the level of competition she participates in, although, once this threshold is reached, increasing strength levels does not necessarily imply unlimited improvements in performance. For example, Neymar is a player who needed to increase his strength levels when moving from the Brazilian league to the Spanish league, or in basketball, the famous case of Michael Jordan, who had to re-adapt his strength levels to overcome the tough defense of the Detroit Pistons, to name a few cases.

In some leagues like the NBA, strength evaluations are carried out for the players who are being chosen by the franchises, in order to know their current state. This facilitates obtaining data from the different tests that are carried out based on the position they occupy on the court, with the goal of understanding the differences and the steps to take to approach the elite level. In leagues like the North American basketball league the NBA, there is a database on their official website of different measurements made of the players who have been chosen to participate in that competition.

In volleyball, for example, the federations need to submit the height values reached in blocking and attacking actions for each player on the team. This means that we can have an approximate indicator of how much our athletes need to improve if we want them to compete at a given level. That said, the scientific literature talks about absolute values at the international level of 325 (295-349) cm [128 (116-137) in] for blocking and 343 (320-



362) cm [135 (126-142.5) in] for jumps to spike (Sheppard, J.M., Gabbett, T.J., & Stanganelli, L. C. R., 2009).

For sports like soccer there are no standardized protocols for evaluating strength. Therefore, it is extremely difficult to compare results between studies and/or determine a profile of the requirements to participate in a given level of competition. Additionally, we need to recognize the enormous diversity of factors that complicate the analysis of soccer. For example, Cometti, Maffiuletti, Pousson, Chatard and Maffulli (2001) compare the 10 m to 30 m (11 to 32 yd) sprint, the squat jump and the CMJ (countermovement jump) of players in the French league 1st division with players in the 2nd division and the amateur league. The others did not find significant differences for any of the evaluated jumps between amateur players and professionals, and the CMJ values were actually higher among the amateur athletes (43.93 cm \pm 5.65 vs. 41.56 cm \pm 4.18 [17.29 in \pm 2.22 vs. 16.36 in \pm 1.65]). Neither did they find variations in the 30 meter (32 yard) sprint. On the other hand, for the 10 meter (11 yard) distance, they found that the 1st division players were significantly faster. The scientific literature finds values for this distance between 1.79 and 1.90 seconds (Stølen, T., Chamari, K., Castagna, C., & Wisløff, U., 2005), this means that the 1st division soccer players are capable of besting the 2nd players by a meter at the 10 m (11 yd) distance. This kind of advantage takes on a decisive importance for the result of an encounter.

Additionally, in the specialized literature we can find vertical jump values somewhere between 47.8 and 60.1 cm (18.8 and 23.7 in) (Stølen et al., 2005). The goalkeepers have the highest values, and the midfielders jump significantly higher than the other players on the field.



Table 3: Results of different conditional tests based on the position occupied by each player from 2000 to 2008 in the NBA (North American Basketball League)

Conditional component	Test	Point Guard (N=123)	Shooting Guard (N=118)	Small Forward (N=101)	Power Forward (N=197)	Center (N=101)
Strength	Maximum reps with 84 kg (185 lb) Bench Press	8.0	10.5	11.2	12.8	11.5
Power	Standing Vertical Jump (cm)	74.7	75.2	75.7	72.3	67.7
	Running Vertical Jump (cm)	88.9	88.6	87.6	83.1	77.6
	Maximum Reach (cm)	333.7	345.9	351.8	353.4	355.9
Speed	23 m (25 yard) Sprint (s)	3.20	3.23	3.25	3.32	3.44
Agility	Lane Test (s)	11.16	11.34	11.37	11.73	12.17
Body size	Height (cm)	183.9	192.1	198.4	202.5	208.1
	Body mass (kg)	83.4	91.4	96.8	106.5	113.5
	Wingspan (cm)	194.5	203.7	209.4	215.1	220.2

Source: Adapted from Drinkwater, 2012, p. 1839.

1.2.2. Analysis of Typical Muscle Actions in Team Sports

For team sports, actions that have to do with dodging or feinting, with changes of direction to overcome a rival one-on-one, with a jump to obtain an advantage either with throws or with shots on goal represent situations related to success in competition. Here we will analyze agility and changes of direction.

Agility and changes of direction

Agility has been defined as a rapid movement of the entire body with changes of speed or direction in response to a stimulus (Sheppard, J. M. & Young, W. B., 2006). Implicit in this definition is that the term comprises both a decision-making mechanism as well as the result of that event: a change of direction or speed. **Changes of direction (COD)** can



be described as movements where no immediate reaction to a stimulus is required, that is it deals with a previously planned response (Brughelli, M., Cronin, J. Levin, G. and Chaouachi, A., 2008).

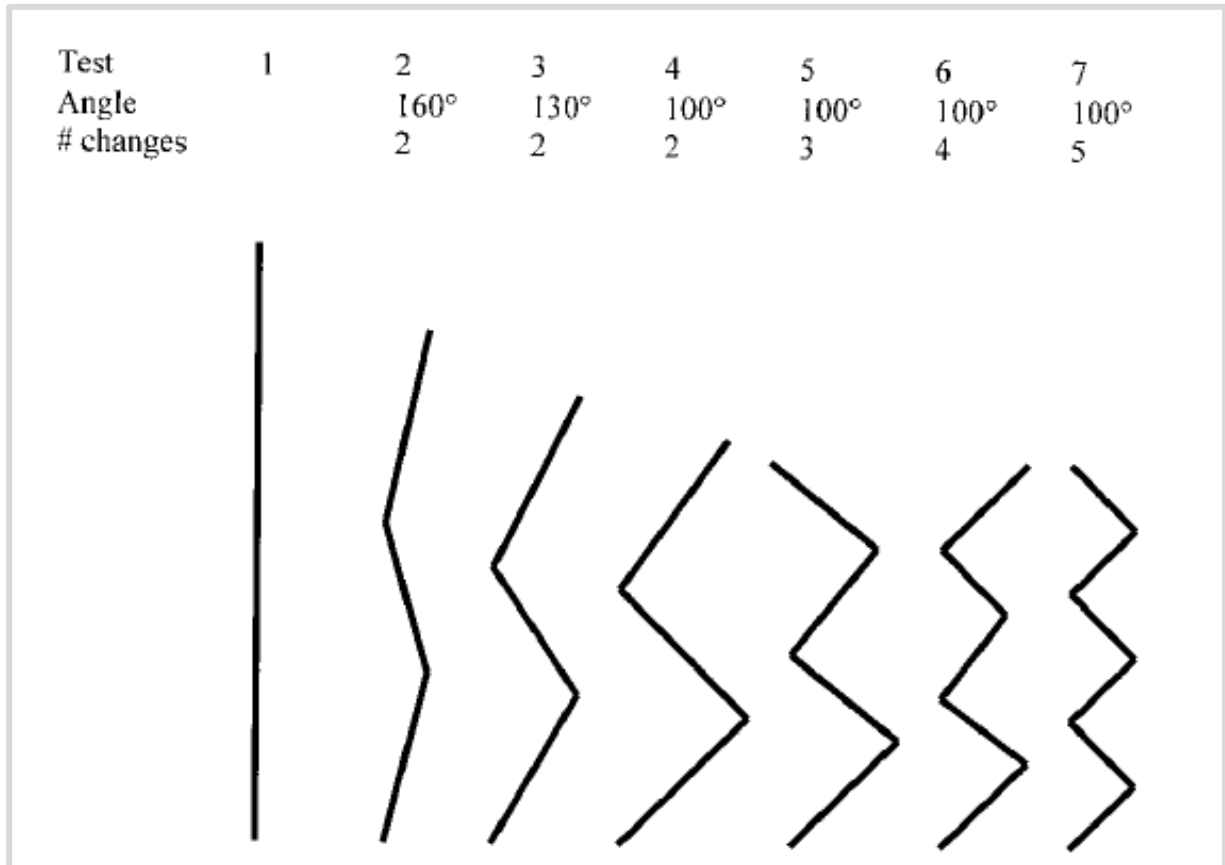
A soccer player carries out between 700 and 1400 COD during a game, that is one every 2 to 4 seconds (De Hoyo et al., 2016). This ability is primarily determined by sprinting speed, strength, technique and anthropometric characteristics (Brughelli, M., et al., 2008).

Historically trainers have imagined a strong relationship between linear sprints and changes of direction; the scientific evidence, however, does not support this theory. For example, Young, Hawken and McDonald (1996) investigated the relationship between linear velocity and velocity with COD among Australian rugby players. This study compared: linear sprints, sprints after a bounce of the rugby ball (unanticipated), sprints that included three planned 90° changes of direction, same as above but including bounces of the ball and, finally, sprints with three 120° changes of direction. The authors found that the correlation between linear velocity and the various agility tests was very low, which indicates that sprints, sprints with COD and sprints after a bounce of the ball are determined by very distinct and specific qualities.

Recently young et al. (2001) evaluated 36 athletes in a 30m (32 yd) linear velocity test and 6 agility tests that included 2 to 5 changes of direction at different angles. After being evaluated, the subjects trained twice a week during six weeks in two groups, one which performed 20 to 40 m linear sprints and the other which performed 20 to 40 m sprints with COD (3 to 5 100° changes). After training, the subjects were re-evaluated and the linear velocity group improved in the straight-line test, but had insignificant gains in the test with changes of direction. In fact, the more complex the task (more COD), the smaller the improvement. By contrast, the training that included COD obtained significant increases with the test with changes of direction, but did not improve at linear velocity.



Figure 17: Description of the 7 30 m (32 yd) tests used by Young (1996)

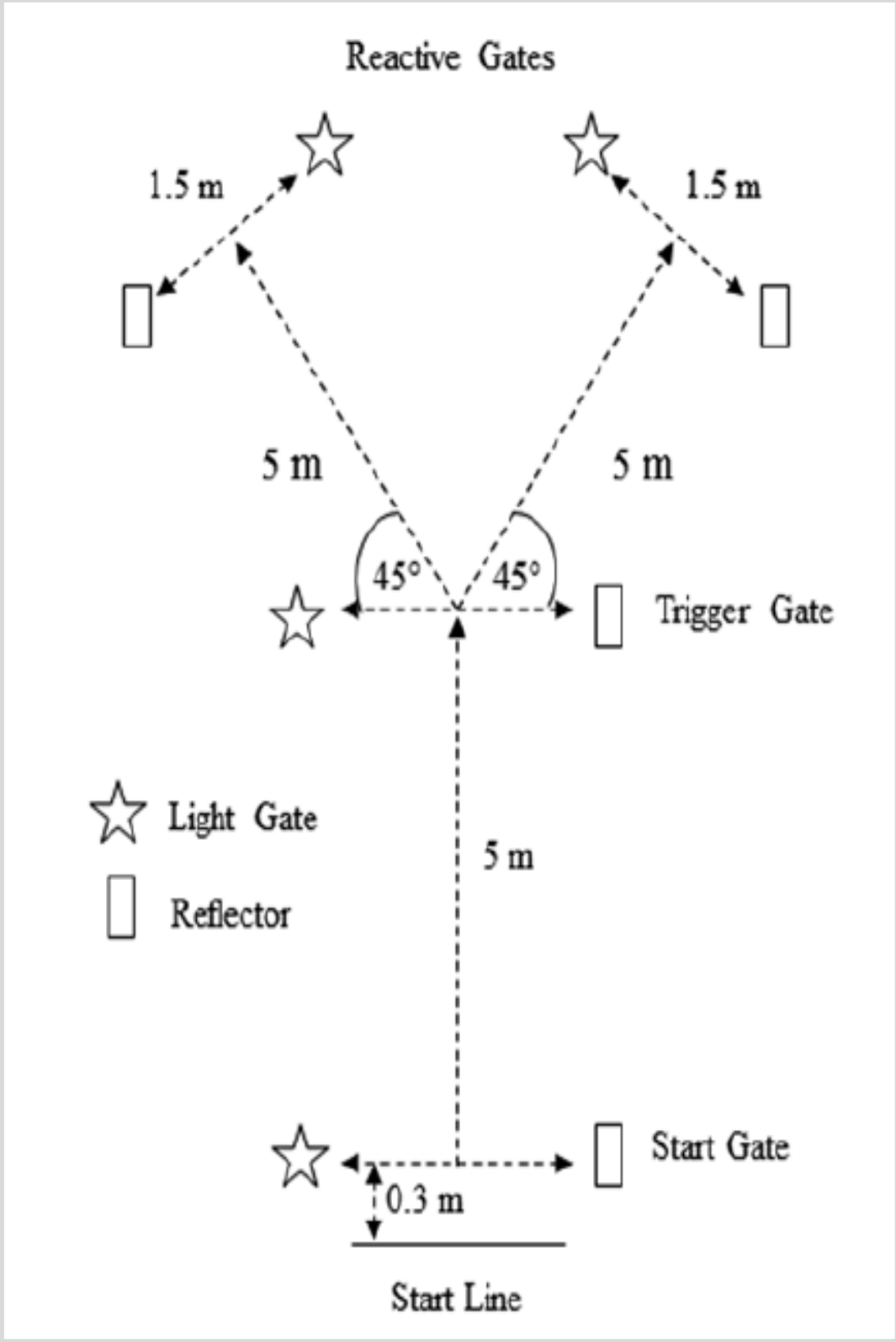


Source: Young, McDowell, & Scarlett, 2001, p. 316.

Training for linear velocity and for agility are specific to each, and produce limited transferability between each other.

Another important part of the COD is the execution of complex abilities like passing the ball in soccer or dribbling in basketball. These tasks imply a level of difficulty that can affect the athletes' performance. So the training for this ability should consider the influence of decision-making, as observed by Lockie, Jeffriess, McGann, Callaghan and Schultz (2014). These authors analyzed the correlation between a 10 m (11 yd) sprint, a 10 m total "Y" shaped sprint and a final sprint that was the same as the second one, but responding to a visual stimulus. The objective was to determine using two groups (the first made up of semi-professional basketball players and the second by amateur basketball players) if there were differences in accomplishing these tests. The researchers did not find significant differences between the groups for the 10 m (11 yd) distance, nor for the planned event. All the same, there were significant differences in the third test, from which they concluded that planned tasks and those which include reaction to stimuli have different physical qualities.

Figure 18: Planned and reactive agility test proposed by Lockie (2014)



Source: Adapted from Lockie, R. G., Jeffriess, M. D., McGann, T. S., Callaghan, S. J., & Schultz, A. B. (2014), p. 771.



Table 4: Changes of direction and decision-making

	Semi professional	Amateur	P Value
10 m (11 yd) sprint (s)	1.812 + 0.094	1.880 + 0.072	0.087
Planned to the left (s)	1.877 + 0.087	1.936 + 0.124	0.237
Planned to the right (s)	1.889 + 0.144	1.960 + 0.144	0.288
Reactive to the left (s)	2.519 + 0.167	2.672 + 0.132	0.036*
Reactive to the right (s)	2.528 + 0.191	2.696 + 0.118	0.029*

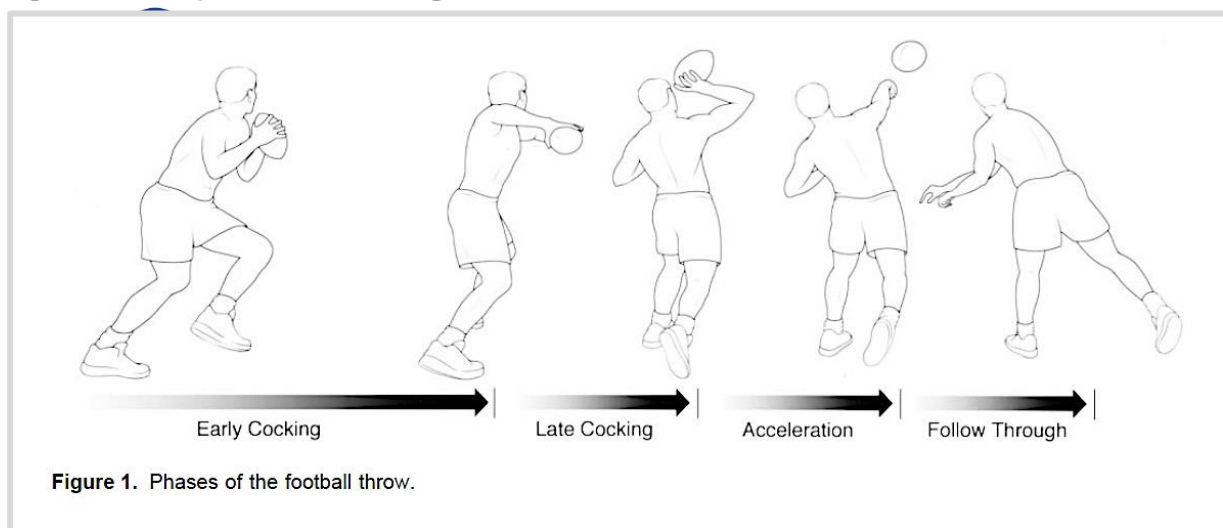
* Significant difference (P<0.05) between semi-professional and amateur group.

Source: Adapted from Lockie, R. G., Jeffriess, M. D., McGann, T. S., Callaghan, S. J., & Schultz, A. B. (2014), p. 771. Descriptive statistics about semi-professional basketball players (n=10) and amateurs (n=10) in 10 m (11 yd) sprints and a "Y" shaped sprint under planned and reactive conditions with cuts to the left and right. s = seconds; P= significance.

Throws

This kind of motor pattern has been studied extensively in North America for sports like American Football. Its improvement is an object of study for handball and water polo; hits in volleyball and tennis have also been studied, which are similar to throws from a biomechanical perspective. Kelly, Backus, Warren and Williams (2002) described four phases for a throw in American Football: early cocking, late cocking, acceleration and follow-through (see Figure 18).

Figure 19: Four phases of throwing in American Football.



Source: Kelle et al., 2002,p.838

In this study, the authors analyzed the behavior of the principle muscles linked to throwing using electromyography (EMG) and described a duration of 1.00 +/- 0.22 s for carrying out carrying out the motor pattern. Of all of the tested muscles, the rotator cuff muscles presented the highest levels of activation, not only during the follow through phase, but throughout the entire throw (see Table 6). Thanks to this study we can infer the importance of the correct functioning of this muscle group for preventing injuries and improving throwing.

Figure 20: Muscle activation in the four phases of throwing in American Football

Muscle	Early cocking		Late cocking		Acceleration		Follow-through		Total throw	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Supraspinatus	45	19	62	20	65	30	87	43	65	22
Infraspinatus	46	17	67	19	69	29	86	33	67	21
Subscapularis	24	15	41	21	81	34	95	65	60	28
Anterior deltoid	13	9	40	14	49	14	43	26	36	9
Middle deltoid	21	12	14	14	24	14	48	19	27	9
Posterior deltoid	11	6	11	15	32	22	53	25	27	11
Pectoralis major	12	14	51	38	86	33	79	54	57	27
Latissimus dorsi	7	3	18	9	65	30	72	42	40	12
Biceps brachii	12	7	12	10	11	9	20	18	14	9

^a Muscle activation given as percentage of maximal voluntary contraction (%MVC).

Source: Kelly et al., 2002, p. 840.

Another important analysis to carry out on this kind of motor pattern has do with how throwing speed and effectiveness are influenced by teaching the thrower to try to hit a target (see Figure 19). Van den Tillaar, R. and Ettema, G. (2003) set out to analyze this among handball players, for which purpose they proposed five throwing tasks:

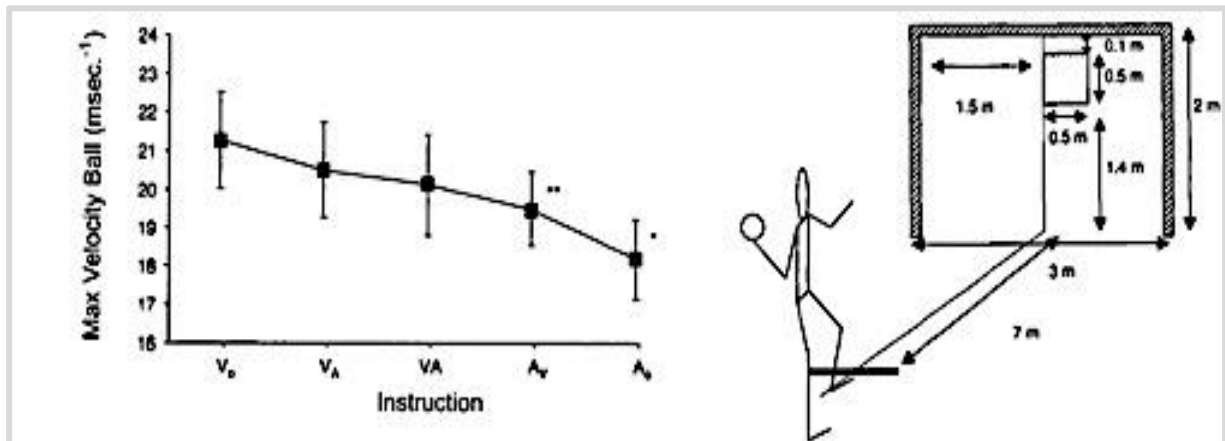
- 1) They asked the athletes to throw as fast as possible
- 2) To throw as fast as possible with the secondary intention of being precise.
- 3) They asked them to give equal importance to speed and precision.
- 4) To throw with precision as the primary objective and speed secondary.
- 5) The only objective was to hit the target.

The researchers found interesting conclusions from this experiment:

- 1) Asking for precision reduces speed.
- 2) The experienced throwers never threw at lower than 85% of the maximum speed.
- 3) The experienced throwers in the experiment were more consistent when the motor pattern was carried out at maximum speed than during slower executions.



Figure 21: Speed and effectiveness of throws



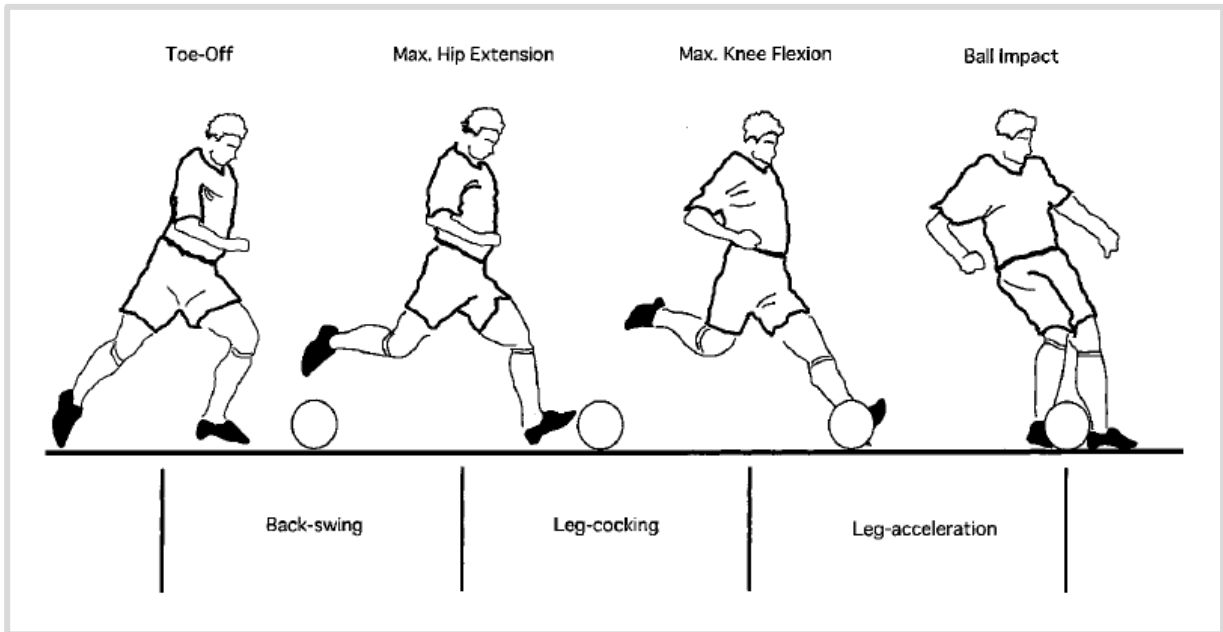
Source: Adapted from Van den Tillaar and Ettema (2003) p. 426. To the left we can see a graph with the average speed with the instruction given to each group, and to the right the experiment design indicating the objective and the distance proposed by Van den Tillaar and Ettema (2003).

Forthomme, Croisier, Ciccarone, Crielaard and Cloes (2005) compared the factors that affect the speed of a hit in volleyball among first and second division players in Belgium. In this interesting study, the authors found interesting differences between healthy athletes and those with a history of shoulder tendonitis; the second group presented a reduced angle of passive internal rotation in comparison to the players without a history of injury ($60^{\circ} \pm 13.5^{\circ}$ vs. $67.9^{\circ} \pm 8.9^{\circ}$) and lower ratios of external/internal rotation (ER/EI 0.57 ± 0.13 vs. 0.75 ± 0.12 at 60 degrees/second in concentric mode and 0.91 ± 0.14 vs. 1.13 ± 0.24 for the varied ratio). The hitting speed correlated significantly with the force of internal rotation of the shoulder and the dominant elbow. They also found significant differences in hitting speed based on the level of the athlete: the 1st division players hit at 100km/h 100.9 ± 6 vs. 90.4 ± 8.3 for 2nd division players. The impact height was 321.8 ± 10.8 cm vs. 305 ± 7.6 (with this being a factor that influenced the speed with which the ball flies).

Shots

Shots in soccer:

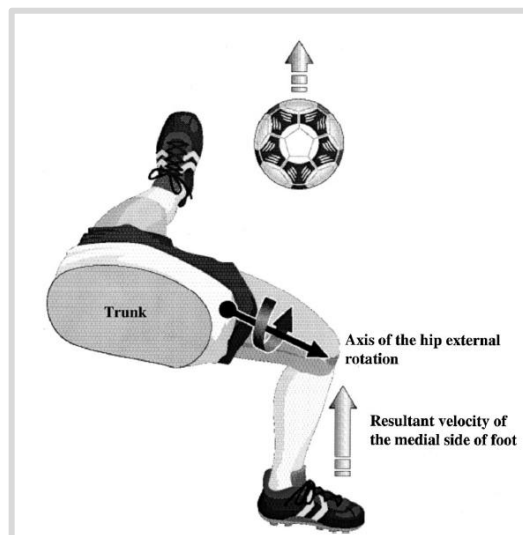
Figure 22: The phases of a shot in soccer



Source: adapted from Nunome, Asai, Ikegami, & Sakurai, 2002, p. 2030.

The trainers suggested that the increase in the **speed of the foot at the moment of impact**, the **coefficient of restitution** and the **mass of the foot and/or the leg** are the most important factors for increasing the starting velocity of the ball during a shot.

Figure 23: Mechanical model of a shot in soccer



Source: adapted from Nunome, Asai, Ikegami, & Sakurai, 2002, p. 2035. Aerial view of a hypothetical mechanism of a shot with the inside part of the foot. At the moment of the acceleration, the plane of the thigh rotates clockwise, orienting itself towards the outside. This allows the hip to rotate externally and thus directly increasing the forward velocity of the inner face of the foot.



The coefficient of restitution is the measure of the elasticity of the impact and the transfer of momentum from the foot to the ball. This is influenced by factors like the part of the foot that makes contact with the moving piece and the stiffness of the foot at the moment of impact. Asami and Nolte (1983) observed that the stiffness of the foot is crucial for obtaining a successful impact and that, when contact with the ball is made very close to the toes, the speed is compromised. Furthermore, the tibialis anterior activates strongly at the moment of contact with the ball, for this reason it is very important to maintain adequate levels of strength in the ankle dorsiflexors at the moment of force impacting the ball. The duration of the contact phase with the ball can last approximately 16 milliseconds. In this period, the knee extends between 8° and 20°, which indicates that the quadriceps have the potential to increase the shot.

The acceleration of the foot at the moment of impact does not just correlate significantly with the initial velocity of the ball after a shot in soccer, but also with the flight distance of the ball in Australian rugby (Ball, K. 2008).

Analyzing the biomechanical aspects and the muscle activations linked to shooting turns out to be fairly complicated due to the immense variety in technique. All the same, in broad strokes, among the muscle groups that participate actively in the shot are the hip flexor muscles and the knee extensor muscles like the psoas and rectus femoris respectively, followed by the vastus lateralis muscles. The rectus femoris is particularly important in this action as it is the most likely to be injured (Woods, C., Hawkins R., Hulse, M., & Hodson, A., 2002). The hamstrings and the glutes are also very active when making a shot. All the same, although they participate more during the follow-through phase as antagonists to decelerate the balance of the foot, the hamstrings are not significantly active at the moment of kicking, which would explain why this muscle does not get injured during this action, while it does during others like sprints and decelerations. When the thigh begins its forward movement, during hip flexing, the flexing angle of the knee decreases, causing an eccentric contraction of the quadriceps. While the leg continues to move forwards, the knee extends provoking a SSC (stretch-shortening cycle) in the quadriceps, which can generate around 20% more force than an isolated concentric action (Bober, T., Putnam, C. A., & Woodworth, G. G., 1987).

Shan and Westerhoff (2005) analyzed, from the biomechanical perspective, the shot in soccer using 3D cameras, and described the movements of the trunk and the arms associated with this event. They found two important conclusions from this analysis:

- 1)** A good shot is not only due to the action of the lower body, but rather to the complex interaction of all of the segments of the body.
- 2)** The trunk muscles or core should be trained in such a way as to facilitate the correct transmission of the forces within the movement. The role of the supporting leg in generation force, for its part, is not clear; we can speculate that the supporting force is important to provide a stable surface from which to quickly balance the kicking leg.



Relationship between strength training and performance of the shot

When relating strength training and shooting ability we should place an emphasis on the subjects that are being studied. Anthrakidis, Skoufas, Lazaridis and Zaggelidis (2008) compared the correlation between quadriceps strength and ball velocity in shots in two groups: the first was composed of beginning players, and the second of experienced players. Among the inexperienced players they found that the stronger the quadriceps, the stronger the shots. But with trained players, there was no significant correlation. This suggests that for experienced players, there are more influential factors than simply the strength of a muscle group for the performance of a shot, such as coordination.

Manolopoulos (2006) designed a ten week training program for maximum strength with an increase of loads from 50% to 95%, with general exercises, increasing the specificity as the weeks went on. This author found significant improvements in maximum strength, as well as in the speed of the foot and the ball.

The study by Jelusic, Jaric and Kukolj (1992) investigated the effect of a specific strength exercise applied to shooting. It divided the soccer players into a control group who carried out 5 training sessions and a game each week, and an experimental group that added two weekly sessions consisting of three series of six repetitions of a shooting exercise with a load: a cable was attached to the ankle kicking foot and they simulated a shot on goal. After 15 weeks, the experimental group increased the speed of the ball by 25%, while the control group only increased by 4%. The study concluded that a modest volume (36 repetitions weekly) of specific exercises as a supplement can have a significant effect on shooting performance.

In spite of this, Aagaard, Simonsen, Trolle, Bangsbo and Klausen (1996) did not obtain the same results. These authors observed that working in an isolated fashion on knee extensions and bends translated into strength gains of 11% and 30% respectively. All the same, these gains did not turn into significant increases in the shooting of elite Danish soccer players after 12 weeks of training. From this we can deduce two things:

- 3) The importance of training with specific exercises.
- 4) That working on isolated actions does not translate into performance gains for shooting.

Analysis of jumps

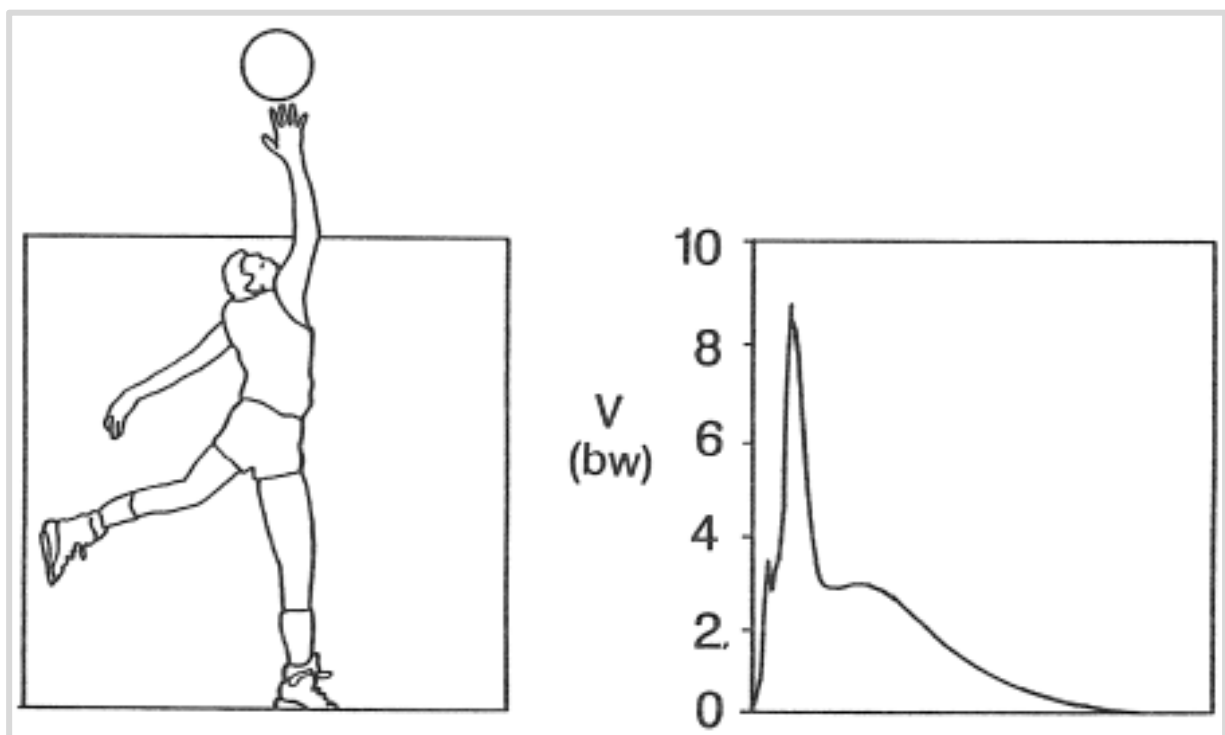
Jumps are fundamental motor patterns in team sports, being not only the most determinant actions, but also the most spectacular, like spikes and blocks in volleyball, shots in basketball and handball, jumps to head the ball and clearances by the goalkeeper in soccer, to cite only a few examples. The problem with this ability is the important impact that landing has on the joints.



In this section, we will focus on the training programs that optimize this contribution and on the importance of the landing from a jump as an action that generates high muscle activation and that can offer high injury risks to the athletes.

McClay et al. (1994) analyzed the duration and the intensity of the actions the joints are submitted to among professional basketball players of the NBA when they make contact with the ground. In contrast to other athletes (like long distance runners who tolerate about 2,6 times their own body weight in each stride), basketball players can tolerate as much as 8.9 times their own body weight when landing from maximal actions like layups or jumping to block, and up to 6 times during a jump shot (Cavanagh, P. R. and Lafortune, M. A., 1980).

Figure 24: Values of vertical force recorded for landings from layups in basketball



Source: Adapted from McClay, I. Robinson & Andriacchi et al. P. 230.

This is how intense these in-game actions are for the joints in only about 200 milliseconds, something very different from training in the gym where it is very difficult to apply forces higher than two or three times the body weight.

In volleyball, around 50% of the attack jumps are received with both feet, while in 38% the left foot lands first and then the right and in the remaining 12% the order of the feet is inverted (Tillman, M. D., Hass, C. J., Brunt, D. & Bennett, G. R., 2004).

From this we deduce the importance of educating our athletes on this type of motor pattern, as with the correct feedback we can reduce the intensity of the impact. Onate et al. (2001) discovered, in a study carried out with 63 subjects, that the group who was given feedback reduced their peaks of vertical force significantly. Prapavessis and

McNair (1999), in a study carried out with 91 adolescents (between 13 and 19 years old) who fell from a height of 0.3 m (1 foot), divided the sample into two groups, one of which was provided feedback about focusing on a given movement of hips and knees, as well as correctly supporting the bottom of the foot. The authors found reductions in the vertical force peak from $4.52 + 1.51$ to $3.57 + 1.10$ of the body weight in the group that received instructions, while the control group did not show significant changes.

While the impacts generated in landings can contribute to the bone health of our athletes, we should keep in mind that the constant repetition of these traumas can generate overuse injuries. For example, in a season of volleyball we can expect around 40,000 attacking hits (Reeser, J., Verhagen, E., Briner, W., Askeland, T. & Bahr, R., 2006), while in a single basketball game about 70 jumps are carried out (McClay et al., 1994). In relation to improving the jump, Baker (1996) classified two types of training for optimizing this capacity based on the biomechanics of the exercises and the impact in the neuromuscular system. To do so he identified **general strength exercises**, **special exercises** and **specific** ones based on the order of approximation of the athletic motor pattern. Next, we will define each of these in more detail.

- Among the general exercises, we find those movements that are intended to improve the maximum strength of the subject, like squats, lunges, deadlifts, etc.
- Among the special exercises, we find those exercises aimed at generating power once the values for maximum strength have increased. These exercises are characterized by generating higher power, faster execution and minimal lifting of the feet from the floor; examples are the power snatch, cleans or the power clean and jerk.
- The specific exercises refer to those stimuli that are similar to motor pattern used in competition. These can be exercises like jumps with load (weighted belts or resistance bands), repetitive multi-jumps (where the volume and the variation are the factor that alter the intensity) and jumps with depths or plyometric jumps (where the height of the jump is what generates the stress on the individual).

The capacity for jumping is influenced by two factors: the contractile capacity of the muscles and the ability to use the elastic energy of an SSC. If we make a vertical jump (without impulse from the arms) preceded by a rapid SSC, we say that this is a **CMJ (countermovement jump)**. If, in contrast, we do not pre-stretch, that is, if our starting position for the jump is with a 90° knee bend, we say that we have done a **squat jump (SJ)**. Traditionally these two jumps have been objects of study and analysis for the approximation of athletic motor patterns; the scientific literature indicates to us that there is a difference between these two tests of around 20% if we use the SSC. And if we add an arm impulse to the CMJ, this action can increase the height reached by 15% (Baker, D. 1996).



The time to carry out a CMJ varies between 530 and 550 ms. Within this time, the concentric phase can reach between 330 and 370 ms. The fact of having to apply a lot of force in a short period of time makes it so that the correct integration of general, special and specific exercises guarantees an improvement in this performance.

Starting from works published in the scientific literature, we can find eight recommendations for improving jumping capacity:

- 1) For beginners, general strength exercises are recommended, such as squats and their derivatives as these can significantly improve the vertical jump. But for trained athletes this is not sufficient; to increase the jump in a significant manner it is necessary to incorporate special and specific exercises.
- 2) Combining training methods seems to be the most effective manner for independently stimulating the contractile and elastic (neural) muscle components and thus improve the jumping indices.
- 3) In the case that combined training is not implemented, the most efficient way to increase jump height seems to be jumps with load from a squat, with a weight that stimulates maximum power production.
- 4) With respect to jumping, the role of periodization is not completely clear, perhaps due to the difficulty of developing training periodizations that can be kept up over the long term.
- 5) In exercises like jumps with load it is proper to begin with light loads to adapt the body progressively and reduce the injury risk.
- 6) For specific exercises, if loads are used it is recommended that they be very light (<10% of body weight). Higher loads could alter the biomechanics of the exercise causing a reduction of its specificity and/or the specific force applied. In the case of jumps with a fall, it is very important that the athlete have high strength levels (they should be able to lift 1.5 to 2 times their body weight at a maximum squat rep) as well as beginning with low heights.
- 7) The training programs can be designed and modified using the values obtained from the SJ and CMJ.
- 8) It is important to check that the athletes are in shape, free from injuries and free from orthopedic limitations when beginning with this type of training.



1.2.3 Starters vs. Substitutes. Changes Throughout the Season

In team sports, the players that enter relatively frequently in the formation that the coach makes to participate in games are called *starters*. These players have more minutes in the rotation than those who participate less (the *substitutes*). In the following paragraphs, we will examine the differences that exist between these two groups when beginning the season and we will see if there are changes during the season in either group.

Hoffman, Tenenbaum, Maresh and Kraemer (1996) analyzed the relation between different components of the physical condition of basketball players and the time that they spent on the court. The authors found that those players who spent more time on the court had higher strength indices in their legs, they jumped more and were faster. All the same, it is very interesting to recognize that those who played less time had better results in the endurance test.

Figure 25: Aaron Gordon of the Orlando Magic



Source: <http://www.trbimg.com/img-56fb3814/turbine/os-orlando-magic-score-139-to-beat-brooklyn-nets-20160329>



González et al. (2013) studied, in an excellent piece of research, the changes that were produced in different variable of the players' physical conditions over the course of a season with an NBA team (Orlando Magic), as well as analyzing the difference between starters and substitutes. After finishing a season where they played 82 games in 5 and a half months (two to five games per week), the results indicated that the players who played more time were not only capable of maintaining their levels of strength and velocity over the course of a season but also, apparently, the competition provided them with a stimulus that allowed them to increase their jump capacity significantly while that of the substitutes decreased. Furthermore, the substitutes maintained their muscle mass better than the substitutes; in spite of playing more they felt less fatigued and more alert. With respect to soccer, on the other hand, Kraemer et al. (2004) found that on a university level team both the players who started the match as well as their substitutes decreased in knee extensor strength significantly over the course of the season between 10% and 12%. At the end of the season, the starters reduced their jump capacity by 13% and were 4% slower in linear sprints. The substitutes, in turn, significantly increased their body fat in comparison with the starters. Both groups had low levels of testosterone in their blood and elevated cortisol levels (an indicator of overtraining). The authors concluded that the level of conditioning of the players at the beginning of the season is very important, as both starters and substitutes can see themselves affected by overtraining.

In sports where there are more collisions, the differences in physical condition between starters and substitutes are more evident. Young et al. (2005) found that, in Australian rugby, both in 10m (11yd) sprints, 30 m (32 yd) throwing speed and vertical jump, the starting players were more efficient (see graph).

Table 5: Differences in sprint, vertical jump, endurance and Yo-Yo test analyzing the differences between starters and substitutes in Australian Rugby.

	Starters	Substitutes
10 m (11yd) sprint (s)	1.86 + 0.06 (17)	1.94 + 0.09 (10)
Average speed = 30 m (32 yd) (s)	3.46 + 0.06 (17)	3.57 + 0.13 (10)
Vertical jump (cm)	62.8 + 3.7 (17)	59.4 + 5.2 (10)
V02 Prediction (ml.kg-1.min-1)	61 + 3.3 (16)	60 + 3.8 (6)
Yo-Yo (m)	747 + 128 (17)	547 + 61 (4)

Average and standard deviation ± (SD). The sample size is found in parenthesis.
 Source: Adapted from Young et al., 2005, p 26.

The factors related to athletic condition have greater or lesser importance depending on the sport we are dealing with. The multiplicity of conditional factors that affect the



performance of a soccer player is undeniable, for example, while in other sports this is not as crucial.

1.2.4 The Role of the Coach and Physical Trainer

These days, the legitimacy of the presence of an exercise and movement professional on coaching staffs and in athletic clubs has been widely validated. Their contribution is a fundamental part of the daily work, work that is not always seen but that the players feel, work that provides them with safety in each action they carry out in their position during the game and in the functions assigned to them by the coach (Seirulo, F. L. 1987). The work of these specialists is not just acting directly on the players; in fact, they have many more and far broader functions. We will try to analyze them below:

1) Planning and training programs and putting them into practice: The mission of the physical trainer (PT) is to achieve the finest athletic form possible for their athletes and maintain it for as long as possible, therefore avoiding injuries that limit the players' possibilities. On a team made up of between 12 and 30 players, achieving a high state of form and maintaining it is a very complex task. It requires carrying out daily monitoring and analysis of the training sessions, both of questions related to aspects of the conditioning loads as well as technical-tactical and socio-emotional aspects among other conditioning factors (Seirulo, F. L., 1987). In broad strokes, we could say that in this area the following functions are among the competencies of the PT:

- Pre-season planning: organization, location and content to be carried out.
- Throughout the course of the season
 - Programming training sessions.
 - Carry out special training sessions for substitute players who do not go on the field.
 - Special post-game recovery sessions for the players who did participate.
 - Special individual sessions to optimize a certain player's weak points.
 - Monitoring the actions and performance of the players during the game.
- In the post-season, recommending training programs for transition periods that help begin the new season in optimum conditions.

2) Individual sessions for developing specific capacities: athletes always have weak points to improve on, so the development of special tasks is an important part of the physical trainer's work; examples of this are the need to improve coordinated motor patterns, visual training, core strength, etc.



- 3) Prevention of and recovery from injuries:** This section deals with the application of so-called "Adjuvant Training" (Seiri-lo, F. L., 1987, p. 73). This involves carrying out sessions aimed at reducing the injury risk for the athlete, and in the case that an injury has already been produced, preparing activities that permit the player to rapidly reintegrate himself into the team's dynamic of training and competition. Here it is crucial to maintain good communication with the members of the medical staff in order to lay out objectives and methods of approach for the different injuries that the athletes present over the course of the season.
- 4) Carrying out tests for identification, recruitment and monitoring of players the institution is interested in:** The physical trainer can collaborate on the recruitment of talent by the club's talent scouts, providing a variety of tests aimed at conditioning that she considers relevant for the athletes of the institution, and the information so collected will allow decision-making both in the short term and the long term about the possibility of recruiting a certain player.
- 5) Assessing and programming conditioning programs for the lower division teams:** In general, all clubs that have teams both in higher leagues as well as medium and local level teams are obligated by the federation to present a certain number of teams in training leagues; it is also profitable and necessary from athletic and economic perspectives. Therefore, it is very important to present a series of guidelines and directions so that the youth players who are ready to move into the first team find themselves prepared from the conditioning perspective to integrate themselves into the rhythm of training at a higher level.
- 6) Therefore, the physical trainer should:**
- Be in continual contact with the coaching staff and physical trainers in lower categories.
 - Design training programs and organize content together with the aforementioned professionals.
 - Carry out monitoring and continual adjustments of these programs.
- 7) Analysis of the efficiency of athletes' in-game actions.** The physical trainer can provide the coach with useful information in real time, which allows him in tactical and strategic decision-making. The information gathered could be about our own team as well as about the opponents.
- 8) Training and education of the players in sports hygiene, nutrition and personal care:** the effects of excessive alcohol, the deterioration of health produced by smoking, and how sleep-deprivation affects performance are all well-documented in the scientific literature, to give a few examples for this point. In order to adopt or modify a personal behavior in light of these or other facts, it is fundamental to generate environments that provoke the athletes to convince themselves when presented with the evidence. It is important to carry out talks with the players to present them with reasons so that they can understand the



necessity of certain demands that the competition places upon them, reasons about how to eat properly before, during and after a game, about the importance of sleeping better, about what activities aid recovery after training sessions and competitions, how to avoid negative habits, etc. The physical trainer can hold these kinds of discussions during meetings, in the pre-season, or any time when interested players ask for them. This approach is crucial among younger players in order to improve their levels athletic culture and self-modeling with valid bases that are sustainable over time.

- 9) Create audiovisual material, research and publications:** it is fundamentally important to carry out the transmission of the information gathered over the course of the season, analyze individual cases and attempt to communicate them, in order to share them with other professional sand with the different levels of the institution with the goal of providing continuous training and to contribute to the evolution of the profession.

To conclude, it is important to emphasize that, during a strength session, the coach should watch over the safety of all of the athletes, analyze the technical execution of the tasks, provide effective and rapid feedback, make correct and not abusive use of technology, and, most importantly, stay motivated.

We will analyze, in order to understand this, the attitude of the coach. Rampinini, Impellizzeri and Castagna (2007) examined the effect of a situation that considered factors like the number of players, the dimensions of the field and the motivation provided by the coach on the intensity of a reduced field of exercises designed to improve aerobic capacity: twice per week over eight months, twenty amateur soccer players played a total of 67 mini-games with rests (3 vs. 3, 4 vs. 4, 5 vs. 5 or 6 vs. 6 games). The games were played on fields of play with three different dimensions:

- Small (12-24m wide X 20-32m long)
- Medium (15-30 m wide X 25-40 m long)
- Large (18-36 m wide X 30-48 m long)

Each mini-game consisted of three periods of four minutes with three minutes of active recovery between each period. These games were played both with and without the presence and motivational actions of the coach.

The authors found that the factor that had the largest impact on the physiological response was the stimulus provided by the coach, followed by the number of players and dimensions of the field. In all of the situations, the active presence of the coach increased the heart rate by 2.5% and the concentration of lactate in the blood by 30 %.

If we want to transmit intensity, we should remain active and intense during the training sessions.



References

- Aagaard, P., Simonsen, E. B., Trolle, M., Bangsbo, J., & Klausen, K.** (1996). Specificity of training velocity and training load on gains in isokinetic knee joint strength (Author's translation). *Acta Physiologica Scandinavica*, *156*(2), 123-129.
- Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P.** (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training (Author's translation). *Journal of applied physiology*, *93*(4), 1318-1326.
- Al Attar, W. S. A., Soomro, N., Pappas, E., Sinclair, P. J., & Sanders, R. H.** (2015). How effective are F-MARC injury prevention programs for soccer players? A systematic review and meta-analysis (Author's translation). *Sports medicine*, *46*(2), 205-217.
- Anthrakidis, N., Skoufas, D., Lazaridis, S., & Zaggelidis, G.** (2008). Relationship between muscular strength and kicking performance (Author's translation). *Physical training*, *10*(2), 2008.
- Asami, T., Nolte, V.** Analysis of powerful ball kicking. In: Biomechanics VIII-B, H. Matsui and K. Kobayashi (Eds.). (Author's translation). Champaign, IL: Human Kinetics, 1983, pp. 695-700
- Badillo, J. J. G., & Ayestarán, E. G.** (2002). *Fundamentos del entrenamiento de la fuerza [Fundamentals of strength training]. Aplicación al alto rendimiento deportivo* (Vol. 302). Inde.
- Baker, D.** (1996). Improving Vertical Jump Performance Through General, Special, and Specific Strength Training: A Brief Review (Author's translation). *The Journal of Strength & Conditioning Research*, *10*(2), 131-136.
- Ball, K.** (2008). Biomechanical considerations of distance kicking in Australian Rules football (Author's translation). *Sports Biomechanics*, *7* (1), 10-23.
- Bangsbo, J., Mohr, M., & Krstrup, P.** (2006). Physical and metabolic demands of training and match-play in the elite football player (Author's translation). *Journal of sports sciences*, *24*(07), 665-674.
- Barros, T., Valquer, Wellington., & Sant'Anna, M.** (1999). High intensity motion pattern analysis of Brazilian elite soccer players in different positional roles (Author's translation). *Medicine and Science in Sports and Exercise*, *31* (5 Supplement), S260.



Billeter, R., & Hoppeler, H. (2003). Muscular basis of strength. *Strength and power in sport*, 50.

Biospia Muscular. Recovered from http://userscontent2.emaze.com/images/1d92b1a4-edd6-4c33-a702-ce819640c68f/Slide32_Pic1_635994151594005891.png

Bober, T., Putnam, C. A., & Woodworth, G. G. (1987). Factors influencing the angular velocity of a human limb segment (Author's translation). *Journal of biomechanics*, 20(5), 511-521.

Brughelli, M., Cronin, J., Levin, G., & Chaouachi, A. (2008). Understanding change of direction ability in sport (Author's translation). *Sports Medicine*, 38(12), 1045-1063.

Capra, F. (1998). *La trama de la vida. Una nueva perspectiva de los sistemas vivos.* Barcelona, Anagrama.

Caraffa, A., Cerulli, G., Progetti, M., Aisa, G., & Rizzo, A. (1996). Prevention of anterior cruciate ligament injuries in soccer (Author's translation). *Knee surgery, sports traumatology, arthroscopy*, 4(1), 19-21.

Cavanagh, P. R., & LaFortune, M. A. (1980). Ground reaction forces in distance running (Author's translation). *Journal of biomechanics*, 13(5), 397-406.

Cometti, G., Maffiuletti, N. A., Pousson, M., Chatard, J. C., & Maffulli, N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players (Author's translation). *International journal of sports medicine*, 22(1), 45-51.

Crash Course (Uploader). (2012, Agosto, 27). *Big Guns: The Muscular System - CrashCourse Biology #31* [Archive of a YouTube video]. Recovered from : <https://www.youtube.com/watch?v=jqy0i1KXU04>

De Hoyo, M., Pozzo, M., Sañudo, B., Carrasco, L., Gonzalo-Skok, O., Domínguez-Cobo, S., & Morán-Camacho, E. (2015). Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players (Author's translation). *Int J Sports Physiol Perform*, 10(1), 46-52.

Drinkwater, E. J. (2012). Fitness and Anthropometric Testing in Basketball Players (Author's translation). In *Handbook of Anthropometry*, pp. 1837-1856. New York: Springer.

Edman, K. (1992). Contractile performance of skeletal muscle fibres. *Strength and power in sport* (pp. 114-133) Oxford: Blackwell scientific publications.



Fleck, S. J., & Kraemer, W. (2014). *Designing Resistance Training Programs, 4E* (Author's translation). USA: Human Kinetics.

Forthomme, B., Croisier, J. L., Ciccarone, G., Crielaard, J. M., & Cloes, M. (2005). Factors correlated with volleyball spike velocity (Author's translation). *The American journal of sports medicine*, 33(10), 1513-1519.

Gonzalez, A. M., Hoffman, J. R., Rogowski, J. P., Burgos, W., Manalo, E., Weise, K., & Stout, J. R. (2013). Performance changes in NBA basketball players vary in starters vs. nonstarters over a competitive season (Author's translation). *The Journal of Strength & Conditioning Research*, 27(3), 611-615.

Gonzales Badillo, J.J., y Ribas Serna, J. (2002). *Programación del entrenamiento de fuerza*. Barcelona: Inde Publicaciones.

Hamill, B. P. (1994). Relative Safety of Weightlifting and Weight Training (Author's translation). *The Journal of Strength & Conditioning Research*, 8(1), 53-57.

Hoff, J., & Helgerud, J. (2004). Endurance and strength training for soccer players (Author's translation). *Sports medicine*, 34(3), 165-180.

Hoffman, J. R., Tenenbaum, G., Maresh, C. M., & Kraemer, W. J. (1996). Relationship Between Athletic Performance Tests and Playing Time in Elite College Basketball Players (Author's translation). *The Journal of Strength & Conditioning Research*, 10(2), 67-71.

Izquierdo, M. (2008). *Biomecánica y bases neuromusculares de la actividad física y el deporte*. Bs.As., Madrid: Panamericana.

Jelusic, V., Jaric, S., & Kukolj, M. (1992). Effects of the stretch-shortening strength training on kicking performance in soccer players (Author's translation). *Journal of Human Movement Studies*, 22(6), 231-238.

Kelly, B. T., Backus, S. I., Warren, R. F., & Williams, R. J. (2002). Electromyographic analysis and phase definition of the overhead football throw (Author's translation). *The American journal of sports medicine*, 30(6), 837-844.

Knutgen, H.G., & Kraemer, W.J. (1987). Terminology and Measurement in Exercise Performance (Author's translation). *The Journal of Strength and Conditioning Research*, 1(1), 7831.



Komi, P. V. (Ed.). (1992). Stretch–Shortening Cycle. *Strength and power in sport* (pp. 169-179) Oxford: Blackwell scientific publications.

Komi, P. V., & Nicol, C. (2010). Stretch–shortening cycle of muscle function. *Neuromuscular aspects of sport performance, (Author's translation)1st edn.* Wiley-Blackwell, Chichester, 15-31.

Kraemer, W. J., French, D. N., Paxton, N. J., Häkkinen, K., Volek, J. S., Sebastianelli, W. J., ... & Vescovi, J. D. (2004). Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters (Author's translation). *The Journal of Strength & Conditioning Research*,18 (1), 121-128.

Lauersen, J. B., Bertelsen, D. M., & Andersen, L. B. (2014). The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials (Author's translation). *British journal of sports medicine*, 48(11), 871-877.

Lockie, R. G., Jeffriess, M. D., McGann, T. S., Callaghan, S. J., & Schultz, A. B. (2014). Planned and reactive agility performance in semiprofessional and amateur basketball players (Author's translation). *International Journal of Sports Physiology & Performance*, 9(5), p766-771.

Luca Merlini (uploader). (2015, Marzo, 3). Mecanismo de la contracción muscular [Archive of a YouTube video]. Recovered from: <https://www.youtube.com/watch?v=C4fmTtO1bbo>

Manolopoulos, E., Papadopoulos, C., & Kellis, E. (2006). Effects of combined strength and kick coordination training on soccer kick biomechanics in amateur players. (Author's translation). *Scandinavian journal of medicine & science in sports*, 16(2), 102-110.

Maffiuletti, N. A., Aagaard, P., Blazevich, A. J., Folland, J., Tillin, N., y Duchateau, J. (2016). Rate of force development: physiological and methodological considerations (Author's translation). *European journal of applied physiology*,116(6), 1-26.

McClay, I. S., Robinson, J. R., Andriacchi, T. P., Frederick, E. C., Gross, T., Martin, P., & Cavanagh, P. C. (1994). A Profile of Ground Reaction Forces in Professional Basketball (Author's translation). *Journal of Applied Biomechanics*, 10(3), 222-236.

McInnes, S. E., Carlson, J. S., Jones, C. J., & McKenna, M. J. (1995). The physiological load imposed on basketball players during competition (Author's translation). *Journal of sports sciences*, 13(5), 387-397.



McNair, P. J., Prapavessis, H., & Callender, K. (2000). Decreasing landing forces: effect of instruction (Author's translation). *British Journal of Sports Medicine*, 34(4), 293-296.

Newton, R. U., & McEvoy, K. I. (1994). Baseball Throwing Velocity: A Comparison of Medicine Ball Training and Weight Training (Author's translation). *The Journal of Strength & Conditioning Research*, 8(3), 198-203.

Newton, R. U., Kraemer, W. J., & Haekkinen, K. (1999). Effects of ballistic training on preseason preparation of elite volleyball players (Author's translation). *Medicine and science in sports and exercise*, 31(2), 323-330.

Newton, R. U., Rogers, R. A., Volek, J. S., Häkkinen, K., & Kraemer, W. J. (2006). Four weeks of optimal load ballistic resistance training at the end of season attenuates declining jump performance of women volleyball players (Author's translation). *The Journal of Strength & Conditioning Research*, 20(4), 955-961.

Nunome, H., Asai, T., Ikegami, Y., & Sakurai, S. (2002). Three-dimensional kinetic analysis of side-foot and instep soccer kicks (Author's translation). *Medicine and science in sports and exercise*, 34(12), 2028-2036.

Onate, J. A., Guskiewicz, K. M., & Sullivan, R. J. (2001). Augmented feedback reduces jump landing forces. *Journal of Orthopaedic & Sports Physical Therapy*, 31(9), 511-517.

Owen, A. L., Wong, D. P., Dellal, A., Paul, D. J., Orhant, E., & Collie, S. (2013). Effect of an injury prevention program on muscle injuries in elite professional soccer. *The Journal of Strength & Conditioning Research*, 27(12), 3275-3285.

Pette, D., & Staron, R. S. (1997). Mammalian skeletal muscle fiber type transitions (Author's translation). *International review of cytology*, 170(1997), 143-223.

Prapavessis, H., & McNair, P. J. (1999). Effects of instruction in jumping technique and experience jumping on ground reaction forces (Author's translation). *Journal of orthopaedic & sports physical therapy*, 29(6), 352-356.

Rampinini, E., Impellizzeri, F. M., Castagna, C., Abt, G., Chamari, K., Sassi, A., & Marcora, S. M. (2007). Factors influencing physiological responses to small-sided soccer games (Author's translation). *Journal of Sports Science and Medicine*, 25(6), 659-666.

Reeser, J. C., Verhagen, E. A. L. M., Briner, W. W., Askeland, T. I., & Bahr, R. (2006). Strategies for the prevention of volleyball related injuries (Author's translation). *British journal of sports medicine*, 40(7), 594-600.



Rønnestad, B. R., Kvamme, N. H., Sunde, A., & Raastad, T. (2008). Short-term effects of strength and plyometric training on *sprint* and jump performance in professional soccer players (Author's translation). *The Journal of Strength & Conditioning Research*, 22(3), 773-780.

Schmidtbleicher, D. (1992). Training for power events. *Strength and power in sport (Author's translation)*, 1, 381-395.

Scott, W., Stevens, J., & Binder-Macleod, S. A. (2001). Human skeletal muscle fiber type classifications (Author's translation). *Physical Therapy*, 61(11), 1810-1816.

Seirullo Vargas, F. (2003). *Sistemas Dinámicos y Rendimiento en Deportes de Equipo*. 1st Meeting of Complex Systems and Sport. INEFC, Barcelona.

Seirulo, F. L. (1987). Las funciones y competencias del preparador físico en un club deportivo. *Red: Revista de entrenamiento deportivo*, 1(1), 70-77.

Shan, G., & Westerhoff, P. (2005). Soccer: Full-body kinematic characteristics of the maximal instep Soccer kick by male soccer players and parameters related to kick quality (Author's translation). *Sports Biomechanics*, 4(1), 59-72.

Sheppard, J. M., Gabbett, T. J., & Stanganelli, L. C. R. (2009). An analysis of playing positions in elite men's volleyball: considerations for competition demands and physiologic characteristics (Author's translation). *The Journal of Strength & Conditioning Research*, 23(6), 1858-1866.

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: classifications, training and testing (Author's translation). *Journal of Sports Science and Medicine*, 24(9), 919-932.

Siff, M. C., y Verkhoshansky, Y. (2004). *Superentrenamiento (Vol. 24)*. Spain: Paidotribo.

Stephen M. Dowell (Orlando Sentinel) (uploader) (2016, Marzo, 29). Orlando forward Aaron Gordon slam dunks during the Brooklyn Nets at Orlando Magic NBA game at the Amway Center on Tuesday, [Homepage of a web page]. Recovered from: <http://www.orlandosentinel.com/sports/orlando-magic/os-orlando-magic-score-139-to-beat-brooklyn-nets-20160329-photogallery.html>

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer (Author's translation). *Sports medicine*, 35(6), 501-536.



Tillman, M. D., Hass, C. J., Brunt, D., & Bennett, G. R. (2004). Jumping and landing techniques in elite women's volleyball (Author's translation). *Journal of Sports Science and Medicine*, 3(1), 30-36.

Tous Fajardo, J. (1999). *Nuevas tendencias en Fuerza y Musculación. (New Trends in Strength and Bodybuilding.)* Barcelona: Autor.

Van den Tillaar, R., & Ettema, G. (2003). Instructions emphasizing velocity, accuracy, or both in performance and kinematics of overarm throwing by experienced team-handball players. (Author's translation). *Perceptual and motor skills*. 2003: 97: 423–434.

Verkhoshansky, Y. (2006). Todo sobre el método pliométrico (Vol. 24). Editorial Paidotribo.

Wisløff, U. L. R. I. K., Helgerud, J., & Hoff, J. (1998). Endurance and strength training for soccer players (Author's translation). *Medicine and science in sports and exercise*, 30(3), 462-467.

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with *sprint* performance and vertical jump height in elite soccer players (Author's translation). *British journal of sports medicine*, 38(3), 285-288.

Woods, C., Hawkins, R., Hulse, M., & Hodson, A. (2002). The Football Association Medical Research Programme: an Audit of Injuries in Professional Football—Analysis of Preseason Injuries. *British journal of sports medicine*, 36(6), 436-441.

Young, W. B., Hawken, M., & McDonald, L. (1996). Relationship between speed, agility, and strength qualities in Australian rules football (Author's translation). *Strength and Conditioning Coach*, 4(4), 36.

Young, W. B., McDowell, M. H., & Scarlett, B. J. (2001). Specificity of *sprint* and agility training methods (Author's translation). *The Journal of Strength & Conditioning Research*, 15(3), 315-319.

Young, W. B., Newton, R. U., Doyle, T. L. A., Chapman, D., Cormack, S., Stewart, C., & Dawson, B. (2005). Physiological and anthropometric characteristics of starters and non-starters and playing positions in elite Australian Rules football: a case study (Author's translation). *Journal of Science and Medicine in Sport*, 8(3), 333-345.



Young, W. B., & Rath, D. A. (2011). Enhancing foot velocity in football kicking: the role of strength training (Author's translation). *The Journal of Strength & Conditioning Research*, 25 (2), 561-566.

Zatsiorsky, V. (2006). *Science and practice of Strength training* (2nded) (Author's translation). USA: Human Kinetics.

