Module 4. Integrative Reading

The objective of this integrative reading is to present a summary of the concepts covered during this course.

Team sport athletes (basketball players, soccer players, volleyball players, etc.) require specific training programs to optimize performance because the requirements of each individual vary according to one's own biological and psychological characteristics, the sport in question, one's position on the field, team tactic and strategy, the competition calendar, etc.

Strength or Force can be defined as each muscle group's capacity to generate tension at a specific execution speed (Knutgen, H.G., & Kraemer, W.J., 1987) according to Newton's second law: $F = m \times a$ (F: force, m: mass, a: acceleration). Thus: the capacity to accelerate the mass of a subject or an instrument depends on the muscles' capacity to generate tension. Using this same logic, power is the result of the force by the velocity at which the movement is carried out.

In many sports, from the physiological perspective, production of **muscle power** is one of the most important factors of athletic success (Stone, M. H., Moir, G., Glaister, M. & Sanders, R., 2002). From this perspective, there are two fundamental variables to understand:

1) The rate of force development.
2) Maximum power.

The first variable is associated with the concept of *explosive strength,* which is directly related to the capacity to accelerate objects, including one's own body mass (Schmidtbleitcher, D., 1992). Muscle movements that maximize the production of power are jumps, shots, throws, and kicks (which include both kicking and hand impact) These actions are characteristic of team sports, are characterized by exerting maximum speeds, and are highly dependent on muscle strength and power (Young, W. B., & Bilby, G. E., 1993). Likewise, changes of direction, feints and accelerations also depend on strength and power.

According to Zatsiorsky (2006), it takes an individual 400 m (437.45 yd) to achieve maximum production of isometric strength. However, with in-game actions, time is limited and players must apply as much strength as possible during very short time periods (earlier we learned that soccer ball impact spans 15 m (16.4 yd) at the most and during a sprint a sprinter makes contact with the ground for approximately 70 m (76.55 yd)). That is why it is important to understand that strength gains do not also translate to improving in-game movement performance.

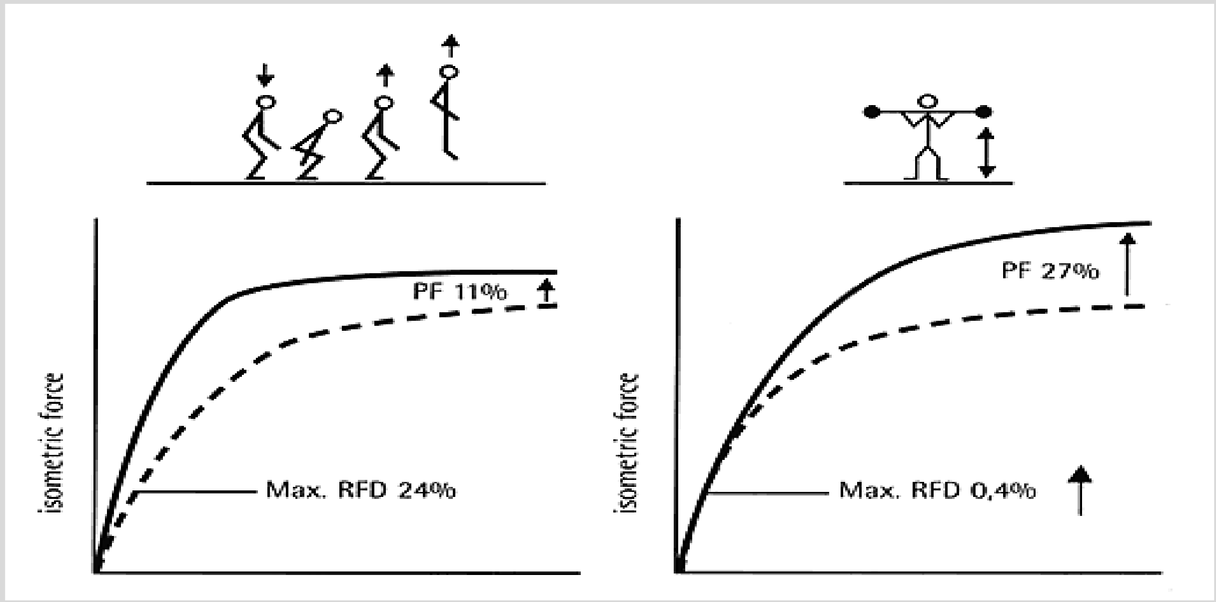
Training with *low speed-high strength production* type exercises, such as weighted squats, will only raise one of the ends of the force-velocity curve and will not be enough to increase movement speed or explosiveness, since generating large amounts of strength and the ability to apply that strength at the highest possible speed, are two different things. That is why training with specific loads and speeds will increase muscle activation. Adaptations of the nervous system in response to muscle power training differs from adaptations in response to traditional overload training, which stimulates muscle hypertrophy. Power training increases activation of motor units (MUs) and promotes selective recruitment and synchronization of these MUs with a much higher threshold. This increased muscle activation, improved interaction between synergists and decreased co-activation of antagonists all contribute to improved production of power.

The use of very heavy loads in strength training is based on the **size principle** (Henneman, E., 1957); according to this principle, the MUs recruited range from those with much lower thresholds (smaller) to those with higher thresholds (larger). The former are predominantly composed of type I fibers, typically well "equipped" for resistance activities; meaning, long duration and relatively low intensity. High-threshold MUs have type II muscle fibers, which are more easily fatigued but produce a greater power rate than type I fibers. More of these MUs will be recruited as the strength requirement increases.

There is also a positive correlation between power and maximum strength, in both upper and lower body activities. We have seen that maximum strength exercises (high force-slow execution) such as squats help improve explosive activities because all movements of this type start from zero or from slow speeds and help generate large amounts of power in their acceleration phase. Using high speed during these movements or training with very heavy loads and slow execution can also negatively affect the production of high levels of strength. That is why we have looked at how the strength used in squats, cleans or snatches correlates very strongly with the vertical jump but considerably poorly with sprints.

If the time that an athlete is in contact with the ground increases, that means that there is more time to exert force and thus capacity for the movement could increase. However, during most sports movements, force is applied for about 0.1 or 0.2 seconds, which is why the rate of force development (RFD), understood as the neuromuscular system's capacity to produce the greatest amount of force in the least amount of time possible, has a determining role in improving sports performance. Movements inherent to sports are so quick that there is not enough time to produce maximum manifestations. That is why, in team sports, it is not the strongest athletes but rather those that can produce the most force in the least amount of time possible that have the advantage; and in order to achieve greater force and velocity in these movements, training must focus on improving RFD. While using maximum loads increases the height of the force-velocity curve, RFD anticipates the curve, which means a higher level of muscle strength is achieved in the early phases of muscle contraction (see Figure 1).

Figure 1: Effects of training with jumps and heavy loads on maximum isometric strength and the speed of strength development



Source: Baker, Wilson, & Carlyon, 1994.

There are many studies that demonstrate that in order to increase power manifestations, athletes must train at high speeds and resistances. In monoarticular movements, maximum power registers at around 30% of 1 RM; however, Newton and Kraemer (1994) demonstrated that training with low loads between 30% and 45% of 1 RM at maximum speeds significantly diminishes the production of power during the second half of the range of movement. This occurs as a consequence of the activation of antagonist muscles and absence of agonist muscle activity in order to be able to decelerate the bar and reach zero speed toward the end of the movement. Total deceleration is 24% of the entire circuit of a heavy load and 52% with a light load (Elliott, B. C., Wilson, G. J., & Kerr, G. K., 1989).
Using ballistic movements, where the load can be kicked, launched or released, allows acceleration and power to increase during the full angle of the movement. Olympic weight lifting, as well as ballistic and plyometric exercises are, thus, very superior to traditional exercises in terms of producing power given that when we use them we train the system to decelerate the movement in its final phase. These exercises don't adhere to the size principle; when we do them at a high speed with significant production of power, high-threshold motor units are activated first.

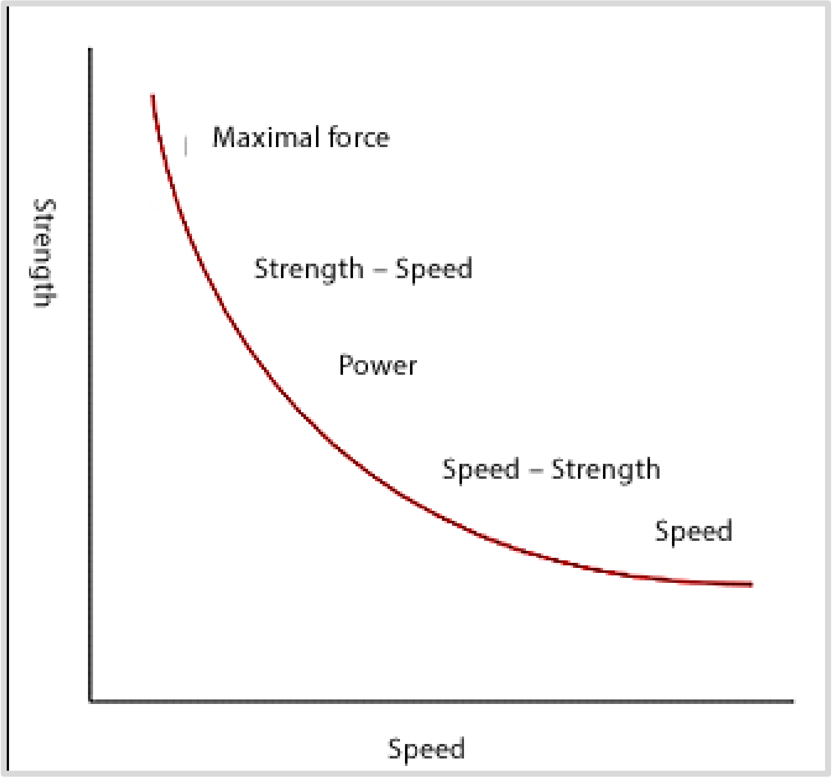
Weight lifting

These types of movements are the activities that generate the most power in human beings (Haff, G. G., Whitley, A., & Potteiger, J. A., 2001). Snatches and jerks exhibit greater values than those demonstrated by squats and dead weight (Garhammer, J., 1993). Variants of these exercises called ***weight lifting derivatives (WLD)*** are used to prepare team sport athletes; these are versions of competition exercises that respect the different biomechanics exhibited by, for example, basketball players, handball players or other very tall players such as volleyball players. According to Hoffmann, Cooper, Wendell and Kang (2004), WLD exercises allow players to:

1) Activate a large number of motor units quickly and simultaneously.
2) Learn to apply force in a sequential and coordinated way.
3) Greatly accelerate the bar.
4) Utilize the stretch-shortening cycle with large loads.
5) Train the same muscle groups that are used in sports motor patterns.
6) Improve explosive strength.
7) In turn, these exercises are challenging for the athlete.

In North America, these exercises are widely used by sports coaches of leagues such as the NBA (National Basketball Association) (95% of trainers acknowledge implementing them in their strength programs), the NFL (National Football League) (88%) and the NHL (National Hockey League) (100%) (Simenz, C. J, in: Dugan, & Ebben, 2005; Ebben, & Blackard, 2001; Ebben, Carroll, & Simenz, 2004).

Figure 2: The force-velocity curve



Source: Prepared by the author

In order to improve RFD, exercises in which you keep your hands on the bar during the entire range of movement are preferable to those in which you let go of the bar at some point. We just need to determine the load of ballistic exercises in order to optimize the production of power. Peak power in traditional exercises (squats and bench presses) is around 30% of 1 RM, but this can vary according to the exercise, as in whether it is upper or lower body, as well as the athlete's experience (Baker, D., Nance, S., & Moore, M., 2001). Training adaptation is specific to the execution speed of the exercises carried out (Behm, D. G., & Sale, D. G., 1993). Training with heavy loads and slow speed results in massive

increases of power for low speed and high force movements, while ballistic training with low loads lead to the greatest increase in the speed of the movements. Exercises that span the entire length of the force-velocity curve should be incorporated into training to optimize athlete performance (McBride, J. M., Triplett-McBride, T., Davie, A., & Newton, R. U., 2002). Verkhoshansky, Y., and Siff, M. C. (2004) proposed a distinction between velocity-force and force-velocity. They propose that these two manifestations belong to different areas of the curve and require different training modalities.
If plyometric exercises and sprints are done at maximum movement speeds and low values of maximum strength (due to not using any external load), these exercises are located at the extreme right of the curve. Jumps with loads between 10% and 45% of 1 RM promote the greatest velocity-force increases. The optimal load to maximize the production of power in weight lifting-derived exercises is in the range of 60% to 80% of 1 RM, and is, therefore, ideal for improving the force-velocity part of the curve (see Figure 2).

The foregoing refers to general aspects of strength work. Now, in reference to team sports such as handball, Seirulo (1990) makes the following distinction between strength manifestations:

- Strength to throw or pass.
- Strength to jump.
- Strength for different types of displacement that occur during an event:
  - Displacements using opposition or struggle.
  - Running displacements in their various forms.

Displacements are a fundamental aspect of the game. They are the basis upon which other motor abilities are developed. Due to displacements, the player can move and create/occupy spaces that help him obtain advantages over his rival, whether through defensive or offensive movements. For this, athletes must be capable of accelerating, stopping, and changing direction at maximum speeds, which requires very high levels of strength, not just in the legs but also in the lumbopelvic musculature, so that these movements are effective.
Jumps, for their part, are some of the most important game movements, not only during offense (jump shots, hitting the ball, a lay-up, or faking out the opponent) but during defense as well, when the athlete must try to block his opponent. Therefore, optimizing this capacity is a priority as it can offer advantages during execution of the motions described above; increasing this capacity also greatly influences displacements and situations involving struggle and physical contact.
Throws constitute the most attractive and important actions during an event given that the purpose of any tactical situation is to achieve a good shot or throw. These motor patterns require very high levels of explosive strength.
Lastly, in agonostic situations involving struggle, two or more players face off to gain possession of a space or object, which results in physical contact between them. These actions occur during offense and defense and affect all players. In order to obtain the advantage in these situations, high levels of overall strength must be achieved in order to maintain a position or drive an opponent out in order to occupy a disputed space.
Seirulo (1990), in pursuit of developing strength capacity in team sports, proposed an innovative method for his time to facilitate the transfer of this capacity to in-game actions,

a proposal that consists of four **levels of approximation** in which the exercises correspond to a determined level, depending on the relationship or specificity of the execution conditions in the competition.

Once the physiological requirements inherent to a sports discipline are known, it is essential to identify which motor behaviors are manifested

The levels are organized in such a way that the tasks to execute are more or less similar to the motor pattern inherent to the game. For this, it is important to distinguish the factors to keep in mind: those that correspond to the task (the resources of the environment, various types of muscle activations, the type of overload and quantity of movements) and those that correspond the motor pattern (variance in the type of execution, combining movements and modifying the space).

In this way, according to Seirulo (1990), 4 levels of approximation are defined:

- General.
- Directed.
- Special.
- Competitive.

According to this methodology, the intention is not to increase strength values in isolated conditions, in general and aimlessly, but rather to try to give the movements a clear direction in order to optimize specific motor patterns with the characteristics inherent to the game. In this sense, both the strength developed and the task engaged in have to be specifically oriented to actions that allow the player to optimize his technical performance and, by doing so, his sports performance.

The physiological adaptations that this type of training seeks are: to increase neuromuscular coordination (intra and intermuscular) by recruiting more motor units and increasing the frequency of triggering nervous stimuli, which allows for greater synchronization and reflex activity of the muscle, and also to decrease mechanisms that inhibit the capacity to generate maximum muscle tension (Rosal Asensio, T., 2002).

Warm-up - Strength - PAP - Preventing injuries

The first part of training is fundamental for the athlete because it prepares him for the central part of the session, not only from a physiological perspective, but from a socio-affective and neuromuscular perspective as well. This is the time when we can incorporate strengthening exercises that allow the player to cope with the demands of training and competition with a lower risk of injury.
While we rest, our organisms ensure that everything is working properly. During physical activity, all systems operate at a more intense level in order to tolerate exercise:

respiratory volume is increased in order to provide more oxygen to the lungs, the heart distributes more oxygenated blood to the muscles so that they can function and remove waste generated during the transfer of energy, the blood vessels expand in order to receive oxygen, hormones, and nutrients in areas that need them, while the areas least used narrow to reduce blood flow, etc. This all occurs in a very efficient way and at a higher temperature than resting temperature, and the best way to increase temperature is precisely through a progressive warm-up that starts off slow and postpones the more intense work for the minutes prior to the session or competition (Kirkendall, D., 2014).

This warm-up can be done by simply running and doing exercises that increase speed gradually. But in team sports there are other needs and requirements, which is why any warm-up routine should incorporate, in addition to this aerobic activation, dynamic stretching, some type of agility and motor control task, compensatory and/or preventive strength exercises, static and/or dynamic stability and SSC activities.

Strength and stability tasks during this part of the session have proven to be effective not only in soccer, thanks to the FIFA (Fédération Internationale de Football Association) 11+ program, but also in many other disciplines such as basketball, hockey, rugby, and volleyball, among others.

Another aspect to bear in mind when doing a warm-up activity is **post-activation potentiation (PAP),** defined as the acute and temporary increase of muscle performance as a consequence of a previous muscle contraction, generally stemming from a very high-intensity overload exercise (Turner, & Fletcher, 2014). Authors such as Sale (2002) and Hogdson, Docherty and Robbins (2005) have studied the PAP phenomenon extensively and, based on their analysis, have proposed two potential mechanisms: one at the neural level and another at the cellular level. According to the first one, doing maximum contractions or contractions close to the maximum prior to doing explosive exercises with no load, stimulate the central nervous system (CNS) in a way that increases high-threshold MU recruitment. The quantity of rapid fibers activated increases after lifting heaving loads, which improves subsequent ballistic exercise. At the cellular level, PAP augments the phosphorylation of light chains of myosin, which increases the sensitivity of actin and myosin binding to calcium ion (Ca+), thus increasing contraction speed.

Traditional exercises such as bench presses and squats, WLD exercises such as power cleans or snatches and explosive exercises are all effective at inducing the PAP effect. Most protocols use very intensive loads that range from 87% to 93% of 1 RM. The rest period between potentiating exercise and the task varies; it depends greatly on the subject's training level, the potentiating exercise in question, and the task to execute after that. Seitz (2015) found that when squats are used, the wait time can vary between 4 and 12 minutes; for their part, cleans requires a pause of around 7 minutes, bench presses from 3 to 16 minutes, and when we use plyometric exercises, shorter periods of 0 to 4 minutes are necessary. In any case, stronger athletes respond differently from weaker athletes, and the effect appears sooner and to a lesser degree.

The core

One of the topics that has received the most attention in sports training and the scientific literature in the past few years is that of the lumbopelvic region in regard to its stability and strength generation in competitive motor patterns. The core's stability has been defined as the ability to control the trunk's position and movement over the pelvis in order

to allow for production, transfer, and optimal control of strength and movements toward the end segments in integrated activities (Kibler, W. B., Press, J., & Sciascia, A., 2006).
The role of lumbopelvic musculature in athletic performance varies according to the specificity of the movement. It can work as a stabilizer of movements that require torque production for the muscles of the limbs, such as kicking, hitting, batting and/or tennis swings. It can also generate rotational force (or assist it) in shots, headers, volleyball hits, tennis serves, handball throws, etc. In any case, some research studies report that there is no significant improvement in isolated movements like the vertical jump, sprints or agility exercises after core training. That is why it is believed that the lumbopelvic region behaves in a highly specific way (Schilling, J., 2012).

The information on lumbopelvic stability training effectiveness in regard to improving athletic motor patterns is far from being conclusive, but there are some approximations: Wagner (2010) analyzed the influence of the core's dynamic or isometric strength on how fast college soccer players shoot the ball in order to determine whether lumbopelvic musculature plays an important role in stability or whether it generates and transfers strength to the limbs during athletic motor patterns. The greatest correlations found between taking a shot and isometric strength were attributed to the core's stabilizing action over the trunk by resisting any counter movement (that would result in a loss of strength during the kicking action). Sæterbakken, Van den Tillaar and Seiler (2011) analyzed the influence of a core training program on unstable surfaces and closed chain exercises on handball throwing speed in youth players. After seven weeks of work, they found significant increases in the throws, from 2% to 7%. The changes were attributed to improved stability while throwing.
Although some studies show positive results in specific actions such as throws and shots after core training programs, athletes need to execute movements that are similar to athletic motor patterns, that is, more specific movements rather than isolated repetitive tasks that are unrelated to them. This means that this musculature must be stimulated during repetitive motor patterns similar to movements inherent to the sport and not in an isolated manner (Willardson, J. M., 2007).
Good options to strengthen this body region are jump training, unstable bases, Bosu, physio balls, etc. The proprioceptive system (which provides the sense of position relative to the location of the body and force exerted during a movement and that is composed of neuromuscular zones and Golgi tendon organs in the joints) is effectively trained using these devices and constitutes a highly valuable tool in stimulating the core (Behm, D. G., & Anderson, K. G., 2006). Its effectiveness at preventing injuries has been scientifically proven (Hüscher et al., 2009) and, therefore, it should be incorporated into the training programs of all sports teams.

Eccentric muscle work - isoinertial devices

In the past 20 years, science has been demonstrating the benefits of including **eccentric muscle work (EMW)** in team sports. This has allowed researchers, coaches and kinesiologists to create exercise protocols related to this type of muscle activation and develop specific machines for training that stimulate this type of overload at the muscular level. In this way, EMW has been gaining more space in strength training due to its proven benefits both in performance and injury prevention (Mateo Cortés, J., 2013).

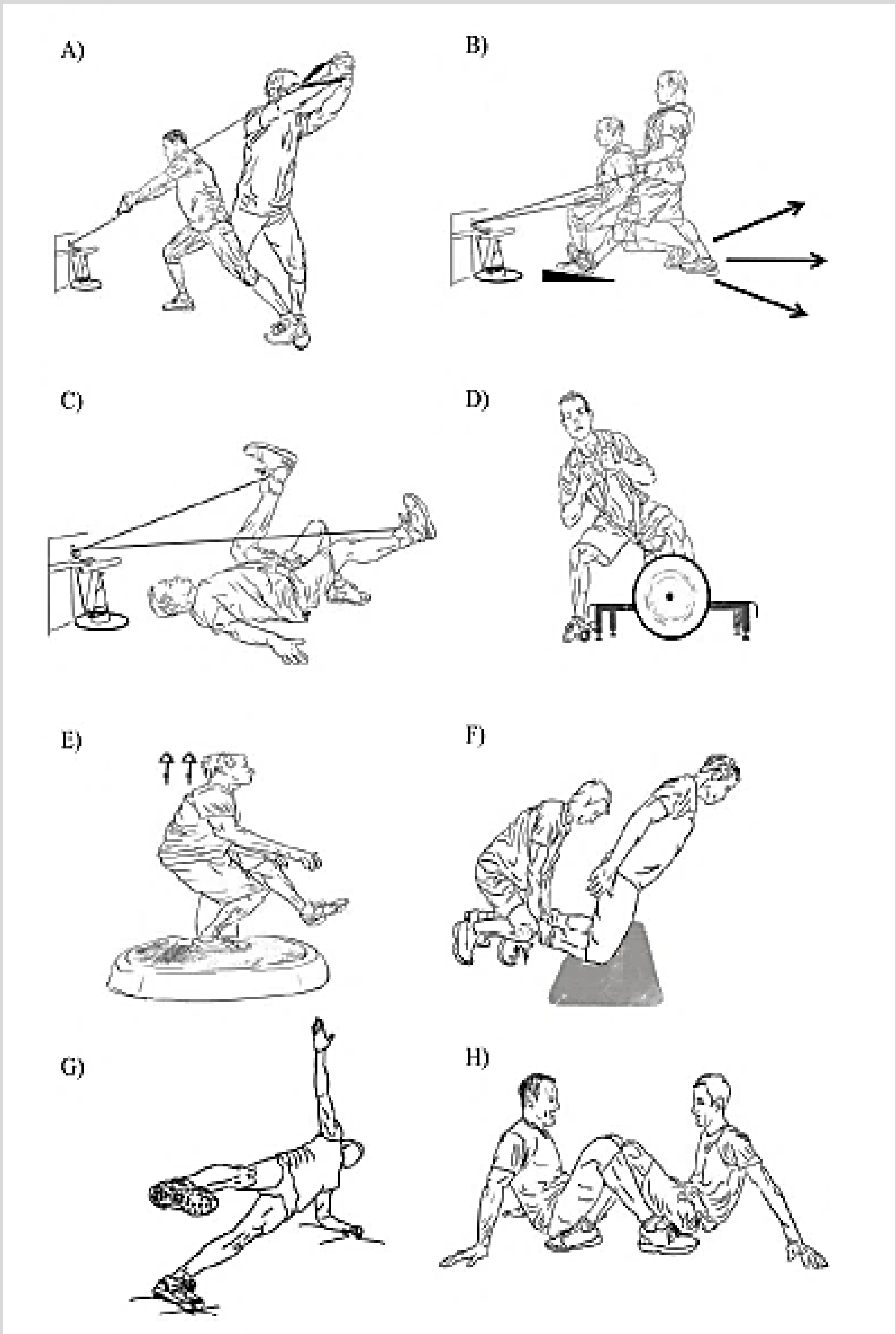
Muscle injuries (especially hamstring injuries) are the most recurring in sports like soccer, American football and rugby, as well as in sprinters. In many cases, these woes lead to a considerable loss of training and competition time, which leads to significant monetary losses and decreased performance (Opar, M. D. A., Williams, M. D., & Shield, A. J., 2012). Mair, Seaber, Glisson & Garrett (1996) have indicated that most muscle injuries that result from sports are the consequence of excessive activation of the muscle when it is extended; this mainly occurs during running maneuvers and changes of direction. The eccentric phase produces greater muscle activation peaks compared to the concentric phase for the same movement, which lowers the muscular energy absorption capacity and subsequently, may lead to a torn muscle. In sports like soccer or rugby, to protect the musculature of the anterior rectus muscle, special attention must be paid while shooting the ball and running long sprints, which produce high-intensity accelerations and decelerations that can cause injury. In contrast, abductors and hamstring muscles are more vulnerable during running movements with short sprints that include changes of direction, quick decelerations, sudden stops and starts, and also in rotation movements (Romero, D., & Tous, J., 2010).

In high performance soccer, the time allocated to strength training during the season is limited. Hence the quest to find efficient and performance-enhancing strategies during specific movements and prevent injuries is crucial. The random nature of soccer movements implies a need to introduce more challenging training methods that allow the athlete to see various possibilities in action; this could involve new emerging behaviors and generate optimum movement synergies (Tous-Fajardo, Gonzalo-Skok, Arjol-Serrano, & Tesch, 2015). It is thus essential to incorporate variability and different contexts to training in order to increase the efficiency of practices and optimize player performance.

In this context, we now see the use of Yo-Yo machines, isoinertial belt tensioners and muscle straps. As we learned in the previous readings, eccentric muscle training reduces the number of injuries in the long-term, and improves performance.

Tous-Fajaro (2016) discovered that a two-series program of 6 to 10 reps of eight eccentric overload exercises that involve one's own body weight and isoinertial machines (see Figure 5), once a week for 11 weeks, improves not only the ability to change direction but also linear velocity and jumps with counter movements, which would suggest that this paradigm is an effective way to promote effective adaptations in athlete performance.

Figure 3: Eccentric overload exercises with body weight and isoinertial machines



Source: Tous-Fajardo, 2016, p. 68.

The player is *tired*

We have seen that one of the most important aspects of athlete performance is the capacity to recover after a game or training session and that great teams and players are capable of staying in great shape not only after an event, but during successive games and tournaments as well.
Fatigue began to be studied in 1915 when Mosso proposed that:

> When lifting weight, we must take two factors into account, which are both susceptible to fatigue: the first is of a central and purely nervous origin- call it will; the second is peripheral, and is the potential energy of the biological aspects transformed into mechanical work (as cited in Noakes, T. D., 2012, p. 2).
>
> It took more than a century to discover what Mosso thought was obvious: during exercise, the brain and muscles alter how they work, muscle changes are characterized by a decrease in contraction strength and speed, and fatigue is primarily an emotion that is part of the body's complex way of protecting itself from potential injuries. "The fatigue mechanism is one of the wonders of the human body" (Noakes, T. D., 2012, p. 3).

When teaching an athlete about recovery strategies, it is fundamental to acknowledge the **etiology of fatigue.** Being aware of the fatigue mechanisms related to a certain discipline and its practitioners can greatly help adapt training planning, recovery strategies, and maintain performance. We must also bear in mind that in team sports there are variables that lead to decreased performance related more to mental than physiological aspects, some of which are: the scoreboard status, the level of the opponent, if the game is at home or away, among others, as well as the influence of events that may arise that could trigger significant modifications in player behavior, such as an adverse referee ruling, coping with audience disapproval, or an argument between teammates, to mention a few examples. All of these variables should be incorporated into the athlete's performance analysis since they would help explain, at least partly, the causes of fatigue, and allow adequate recovery strategies to be proposed (Lago Peñas, C. Martín Acero, R., Seirul-lo Vargas, F., Alcalde, J., and Hernández Moreno, J., 2011).

The coach's role

The coach is a cornerstone of athlete optimization; the task of providing adequate feedback at the right time and the right word at the precise moment can make all the difference to a player's performance. In strength training, for its part, the presence of a responsible professional is abundantly justified.
Mazzetti et al. (2000) researched the power and strength gains under the supervision of a coach. To do this, they divided the individuals in their study into two groups and assigned them the same training for 12 weeks. One group had the assistance of a coach and the other group did not. The subjects were tested on maximum strength during squats, bench presses, power during jumps with load and on body composition. The authors found

significant improvements in all the analyzed variables in the group under direct supervision.

The same results were found by Coutts, Murphy and Dascombe (2004), who demonstrated that the presence of a coach also improves athlete adherence to the training program and increases intensity and load. The presence of a coach allows athletes to obtain instantaneous feedback regarding technique, as coaches ensure safety while performing the exercises and also increase motivation and competitiveness during the sessions.

We chose to end this reading with this topic because we believe the presence of a coach is fundamental since attitude and motivation are key to optimizing the player, and truly make all the difference.

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