

# Module 2. Coadjuvant Training in the Structured Microcycle.

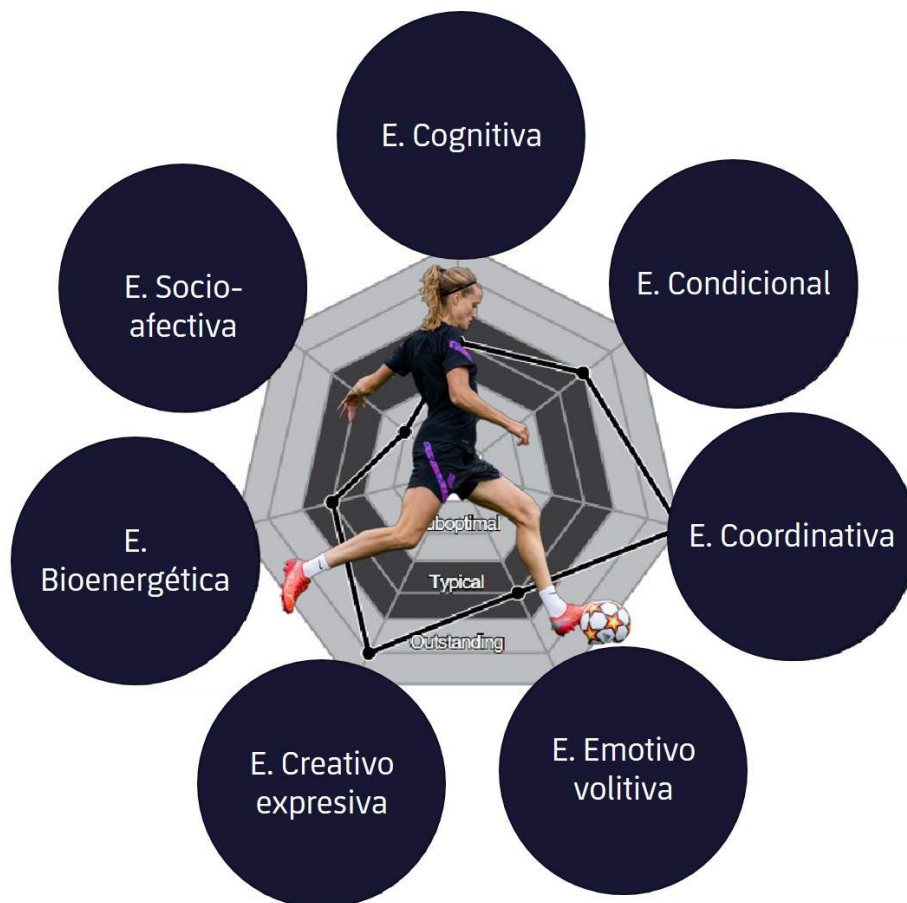
The trend in the last decade has been to consider female athletes as complex and unstable dynamic systems that change state based on accumulated situations of imbalance during their experience. A change in any of the parts that make up the athlete will influence the rest. Therefore, when proposing training tasks, we must assess how our proposal will affect the overall behaviour of the player and not just the part of the system in which we intervene. As explained in Module 1, we cannot think of the football player as something independent, but rather the interaction of the player with the environment will bring out different possibilities of action. These possibilities of action are specific to the environment and the player. That is why, it is important to understand how the individual characteristics of the player interact with the competitive environment. In 1977, Prigione identified humans as dissipative structures, providing the keys to understanding this possibility that makes each individual unique and unrepeatable as a result of the processes that shaped them in their specific environment. To apply systemic theory to practice, Paco Seirul-lo Vargas proposed an explanatory model where the athlete is at the centre as the central object of training. Seirul-lo Vargas (2017) understands the player as the dissipative organisation resulting from the ability to interconnect all these dimensions, which he calls structures (Image 1).

The structures are the following ones:

- Socio-affective structure: linked to the relationship and identification with teammates and the role that each one plays. Its functionality is manifested in the quality and stability of socio-affective interpersonal relationships based on the feelings and emotions that occur during specific football practices.
- Coordinative structure: related to mobility, laterality, and dissociations. Its functionality is manifested in the ability to execute the desired and efficient movement, regardless of the environment in which it has to be performed. This structure aims at effectiveness and efficiency.
- Cognitive structure: responsible for the perception-action process. Its functionality is manifested in the efficiency to gather, identify and process relevant information from the game environment.

- Emotional-volitional structure: related to one's own feelings and mood (level of anxiety, fatigue, stress, leadership, etc.). It identifies, regulates, and manages all emotions and desires that drive or hinder movement. This structure is determined by the effort required to achieve desired objectives.
- Expressive-creative structure: related to the expressive ability and interpersonal relationships that arise in competition and training. This structure builds communication forms that are useful, necessary, and identifying for the game and the way of experiencing and interpreting it (the self with our team).
- Bioenergetic structure: related to energy pathways. It contributes and renews bioenergy, making the development of all structures possible.
- Conditional structure: related to motor abilities. Its functionality is manifested through the ability to generate intramuscular tension (strength) and the different manifestations related to space/time (speed/resistance).

**Image 1. Structures that make up a female player**



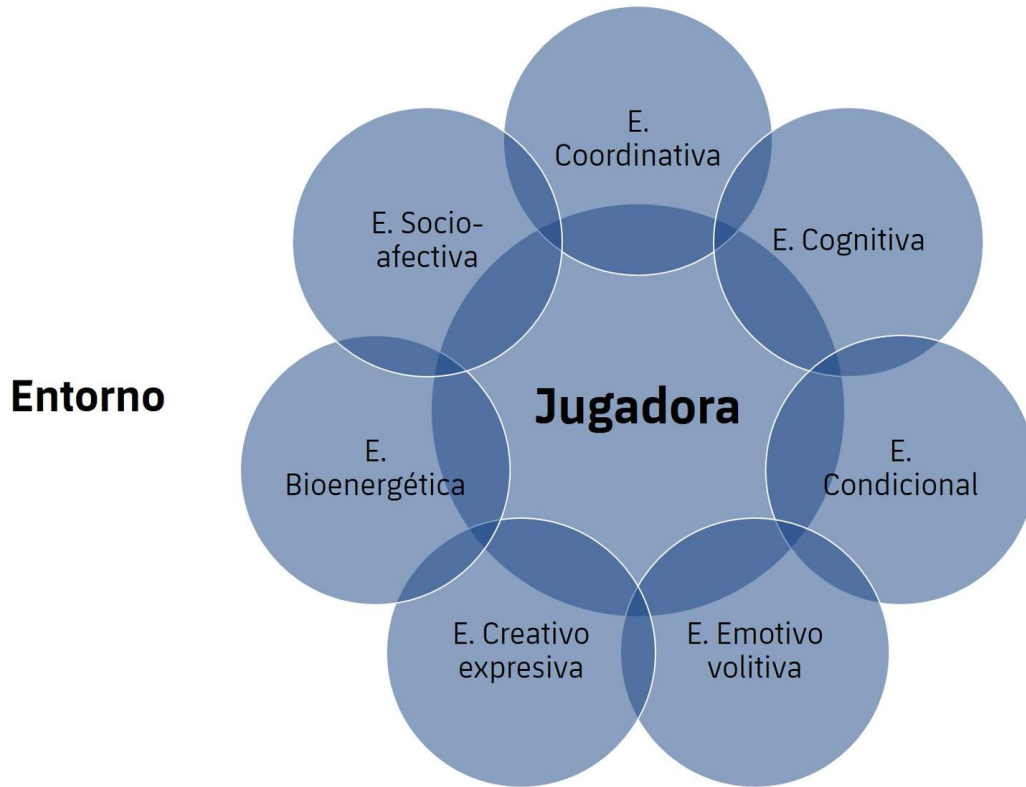
Source: prepared by the authors based on Seirul-lo Vargas (2017).

E. Cognitiva	Cognitive Structure
E. Socioafectiva	Socio-affective Structure
E. bioenergética	Bioenergetic Structure
E. Creativo expresiva	Expressive-creative Structure
E. Emotivo volitiva	Emotional-volitional Structure
E. Coordinativa	Coordinative Structure
E. condicional	Conditional Structure

In this way, a systemic version of the player can be obtained from her multifunctionality, which allows her to interact through tasks that will be called preferential simulating situations (PSS). PSSs intervene in the configuration of all these dimensions, and in each one with a certain priority according to the conditions of the environment (Image 2).

**Image 2. PSS, environment and structures**

# SSP



Source: prepared by the authors based on Seirul-lo Vargas (2017).

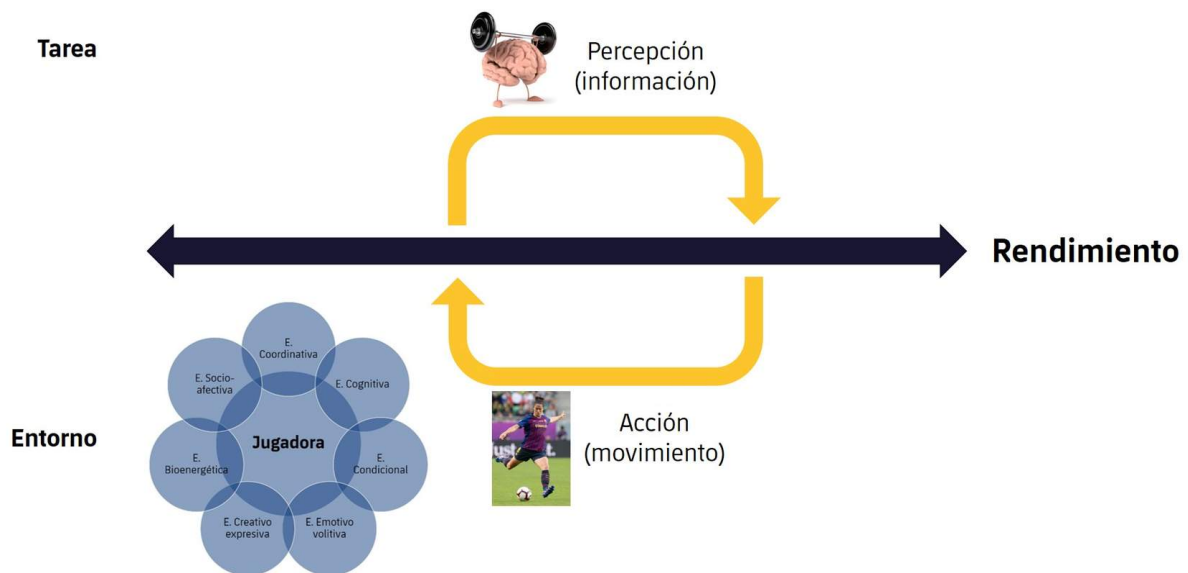
Entorno	Environment
SSP	PSS
Jugadora	Female player

The aim is to reach a dynamic interaction between the different open systems that make up the player and the environment and the task to plan appropriate training situations. From a holistic point of view, the training process is understood as a development of synergies between different departments, specialists, and individuals who join their forces and motivations to improve the player in a global way. The

objective of all the multidisciplinary areas that have an influence on the players is to guide them in their development and detect the constraints that prevent that development. Through training (we'll analyse this in this module), we can improve the constraints that prevent the athlete from performing better.

Image 3 represents the complex process players go through to reach performance which is understood as a self-organisation phenomenon resulting from the continuously dynamic interaction between the characteristics of the female player, and the possibilities of action offered by a specific competitive environment (Button, Seifert, Chow, Davids and Araujo, 2010; Renshaw, Davids, Shuttleworth and Chow, 2009). As mentioned in Module 1, Gibson (1979) proposed that information detection (perception) regulated the action and vice-versa, and how task performance reinforces the functional behaviours in dynamic performance environments.

**Image 3. Performance**



Source: prepared by the authors.

Tarea	Task
Rendimiento	Performance
Percepción (información)	Perception (information)
Acción (movimiento)	Action (movement)

In this way, each player responds individually to the same task based on their characteristics and adapting to the game context. Since it is very difficult to find the

ideal model for each player, Schöllhorn, Hegen and Davids (2012) propose to offer each athlete a great variety of exercises to induce a response resulting from self-organisation with the task. The same simulating situation for a fast or slow player will make each of them use their strengths, seeking those scenarios in which their possibilities of action in the game contribute to get a positive outcome for their interests. This self-organisation sought in training situations consists in the spontaneous creation of behaviour patterns and their respective changes when they occur in situations far from equilibrium (unstable). Therefore, the mistake must be considered a necessary fluctuation for learning to take place (Balagué Serre, N., Torrents Martín, C., Pol Cabanellas, R. and Seirul-lo Vargas, 2014). Furthermore, motor practice scenarios must be created where the system is perturbed to provoke these learning experiences. This can be achieved through variability, which will be studied in Module 3.

Variability not only helps improve a player's specific 'technique', but also modifies the overall structure of movement towards a more efficient behaviour. Strength training should be oriented towards improving these couplings, including the perception-action process. Learning a movement not only leads to the efficiency of that *attractor*, but also modifies the *attractors* of the system globally (Balagué Serre et al., 2014). Therefore, any transfer of a skill that one possesses to a new one will occur as long as there is dynamic correspondence between them (specificity); this topic will be discussed further in Module 3. As a summary, transfer between two movements will occur if the movement characteristics are respected between both.

Unlike other training models, Seirul-lo (2017) proposes some initial practice conditions respecting dynamic correspondence with the environment, to prioritise the task situations that stimulate the athlete towards the selected training objective and, therefore, achieve adaptations in the player.

## Unit 2.1. Coadjuvant Training

Structured training is composed, as its name suggests, of the structures of the athlete that result from the form of expression in motor action during team practice. The relationships that exist between the different structures and their organisation facilitate relationships with the specific competitive environment of football (Tarragó, Cos, Gordillo, Lizarraga, and Martín, 2005). It is proposed to evolve towards a new paradigm where we move from rational, analytical, reductionist, linear, and quantitative to a new one that is intuitive, synthetic, holistic, non-linear, and qualitative (Seirul-lo, 2017).

When it comes to understanding structured training, two supplementary forms of training which make it up must be considered:

- *Optimiser training* (OT): it is in charge of the planning, design, execution and control of the training tasks, and its objective is to optimise the athlete's performance in all the competitions they take part throughout their sporting life (Seirul-lo, 2017; Tous-Fajardo, 1999). So, basically, this training is designed to prepare for competition and requires that the training tasks are carried out in an environment and with elements that are specific to the game.
- *Coadjuvant Training* (CT): it is composed of all the practices that allow the athlete not only to enjoy a state of achievement and protection of their health, which enables them to carry out the tasks proposed by the OT every day (Tous-Fajardo, 1999), but also allows optimising those components, structures, and systems that each specialty demands, facilitating and bringing the athlete closer to the desired level of performance.

The coadjuvant training directly impacts the performance of athletes by preparing them to train at a higher level. Moreover, it influences the demands of the competition in order to carry out the necessary optimising loads and also maximise individual potentialities from a systemic perspective.

During the coadjuvant training, although all structures will be taken into account, the following structures will be prioritised:

- *Conditional and bioenergetic structures*: this provides the physical contribution to the development of the player's activity. Its most representative values are related to the classic concepts of strength, speed, and resistance. The bioenergetic structure will provide the energetic support for the action (Colosio, Pedrinolla, da Lozzo, and Pogliaghi, 2018), and the conditional one corresponds to the muscular actions that generate movement (Cronin, McNair, and Marshall, 2001).
- *Coordinative structure*: it is responsible for the execution of the movement in the desired form, with a close relationship to technique. Its objective is the motor control of the action, with spatial creation and temporal control of the same action. It falls within the context of the perception-action cycle (Newell, Broderick, Deutsch, & Slifkin, 2003).
- *Expressive-creative structure*: it is trained to a lesser extent, since in some tasks the aim is to leave them open so that athletes can find a motor solution and be prepared for any situation and in any condition (Bernstein, Latash, & Turvey, 1996).

### **2.1.1. Groups of Movements**

The optimisation of the player through coadjuvant training does not aim to maximise only one of their qualities. It involves exposing the football player to certain training situations that cause certain stress in one of the structures that configure them, so that they are forced to adapt in a continuous process of self-organisation (Serrano, 2012). The game situations will be solved through movement and interaction with teammates and opponents. For this reason, the specific movements in the sport will be the ones that lead the football player to evolve and specialise (Seirul-lo, 2017).

It is necessary to observe which are the motor actions and basic motor skills of football (Jukic et al., 2019; Kokstejn et al., 2019) that players will need for the competition. Seirul-lo (2017) classifies strength manifestations into four large groups based on their connection to basic motor skills (e.g., throwing, jumping, movement) and skills (e.g., fighting).

#### **Image 4. Groups of Movements in Football**



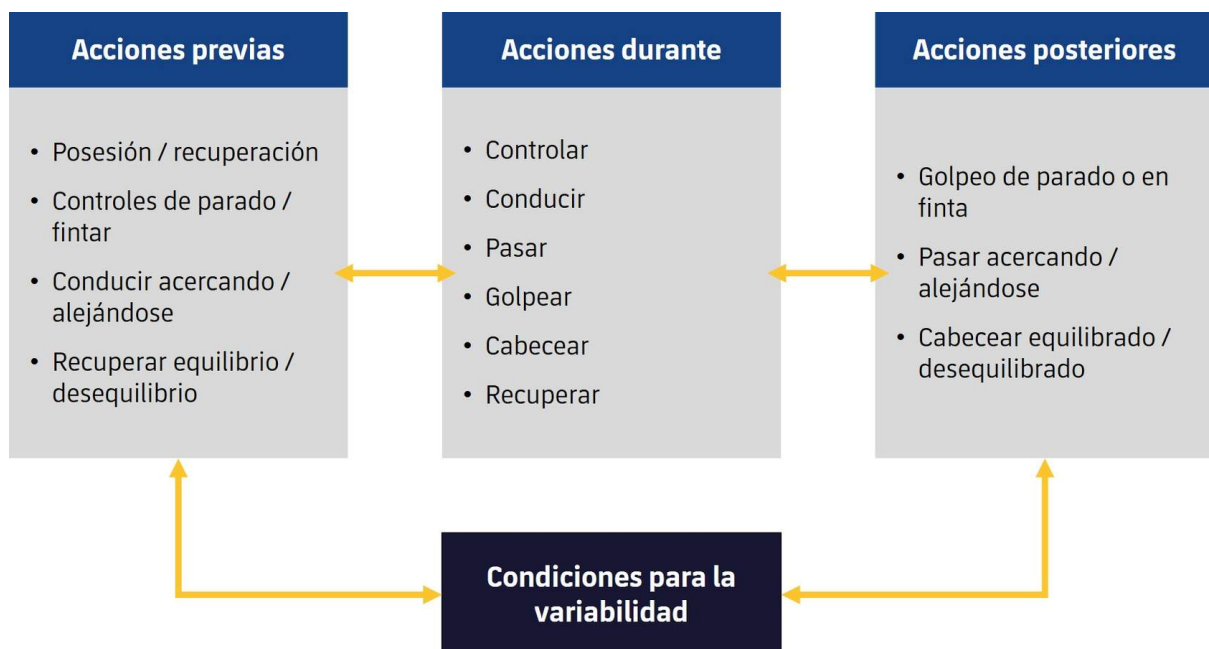
Source: prepared by the authors.

Lucha	Fight
Salto	Jump
Lanzamiento	Throw
Desplazamiento	Movement
Fuerza	Strength

**Throwing strength or ball interaction:** In football, we can consider ball interaction as a key element of the game. Therefore, all sports movements that are linked to the way of interacting with the ball will be of vital importance. Thus, ball interaction strength will seek to ensure that motor actions such as passing, and throwing can be performed with the appropriate levels of muscle tension to maximise their technical

execution. A higher kicking speed is related to a higher speed of the foot when kicking the ball, and a higher angular speed of the knee joint, along with a faster approach of the player to the ball. Therefore, to improve these aspects of kicking, appropriate training exercises should be designed (Cronin et al., 2001). Muscle strength contributes greatly to the speed the ball gets when being kicked. Significant relationships have been shown between the muscle strength of the knee extensors (Manolopoulos et al., 2013), hip flexors (Dutta and Subramaniam, 2001), and kicking performance. The different manifestations of kicking in football can be worked on in the following way:

**Image 5. Throwing Actions**



Source: Prepared by the authors based on Gómez, Roqueta, Tarragó, Seirul-lo, Cos, 2019, p. 24.

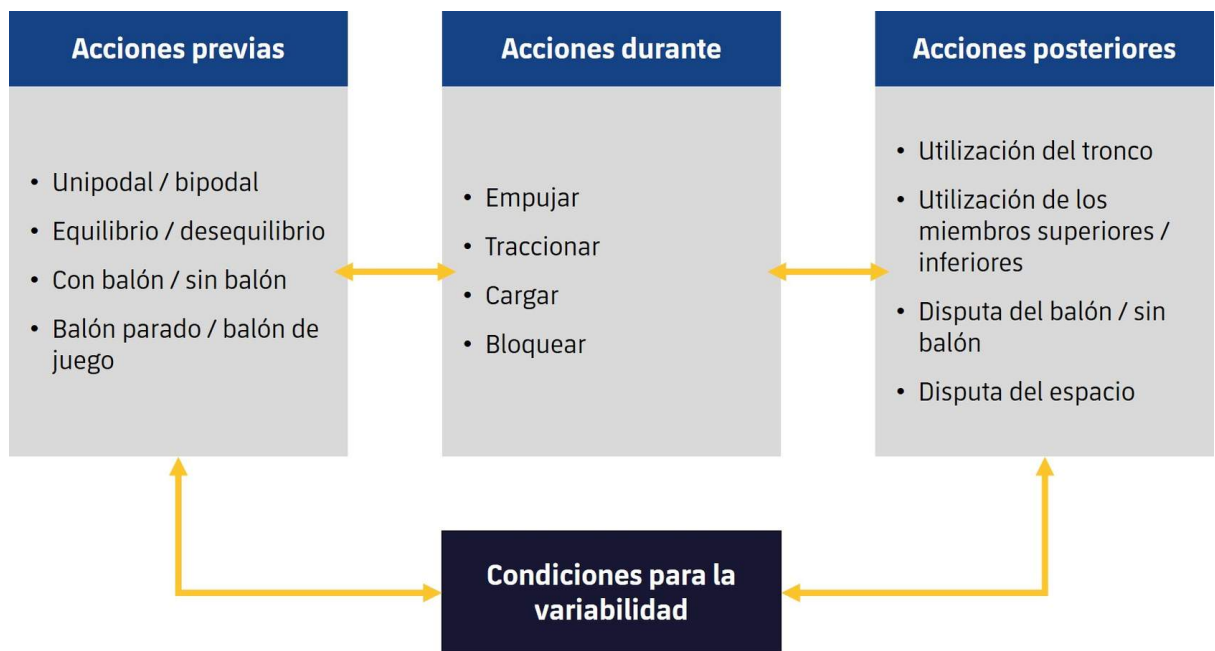
Acciones previas	Previous actions
Posesión/recuperación	Possession/ Recovery
Controles de parado/fintar	Control to stop/feint
Conducir acercando/alejándose	Dribbling towards/ away

Recuperar equilibrio/desequilibrio	Balance recovery/ Imbalance
Acciones durante	Actions while playing
Controlas	Controlling
Conducir	Dribbling
Pasar	Passing
Golpear	Kicking
Cabecear	Heading
Recuperar	Recovering
Acciones posteriores	Subsequent actions
Golpeo de parado o en tinta	Stationary or feint kick
Pasar acercando/alejándose	Passing towards/ away
Cabecear equilibrado/desequilibrado	Balanced/imbanced heading
Condiciones para la variabilidad	Conditions for variability

**Fighting Strength:** the need to win space and ball possession is another characteristic of football, creating situations of direct opposition with the opponent for the dispute of space or the ball. Many times, it requires complex motor skills with the addition of an external destabilising factor such as the opponent. Therefore, different solutions with high levels of force application must be sought. For fighting strength, the feedforward control mechanism (ability to anticipate) is very important. This mechanism is based on the identification of a situation that the subject relates to previous experiences. In this way, a pre-activation of muscles is carried out during the fighting process that has the ability to protect the locomotor system structures from a harmful load. This preparation of the musculoskeletal system occurs thanks to previous experience in sports situations and facilitates continuous learning. This

anticipation mechanism used when minimising disturbances and maintaining correct posture is relevant in all training situations, but in the case of fighting strength, it is of vital importance. For example, valgus/varus moments and internal/external rotation applied to the knee during unexpected changes of direction double compared to pre-planned situations. The different manifestations of fighting in football can be worked on in the following way:

**Image 6. Fighting Actions**



Source: Source: Prepared by the authors based on Gómez, Roqueta, Tarragó, Seirul-lo, Cos, 2019, p. 23.

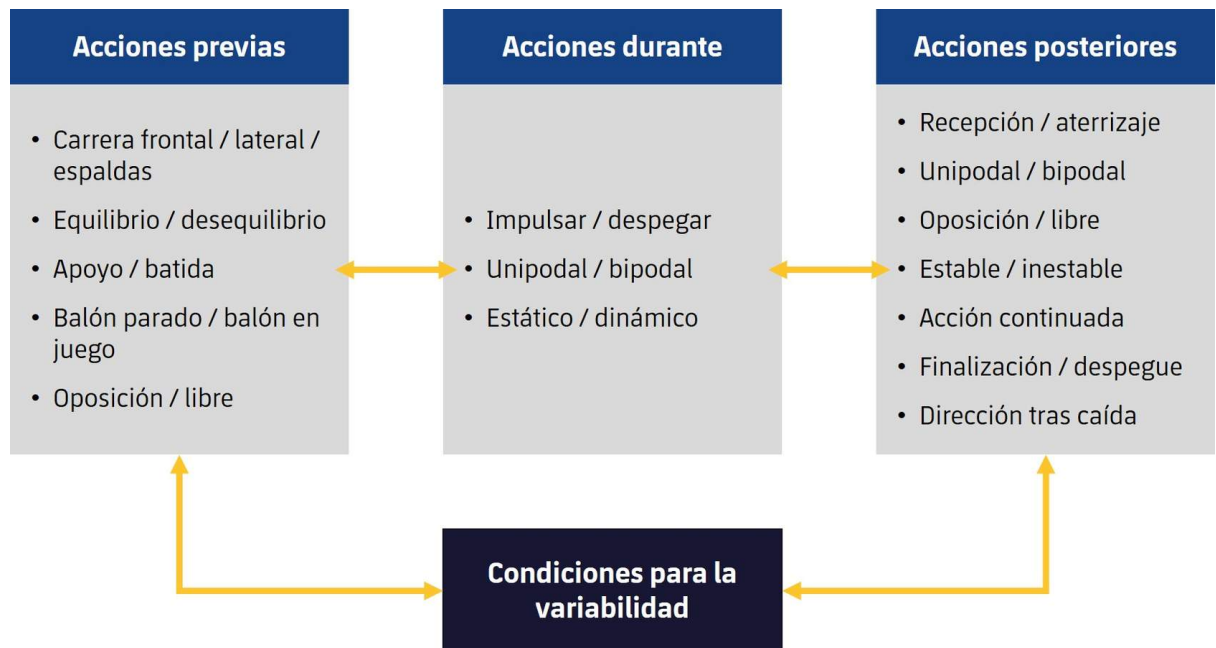
Acciones previas	Previous actions
Unipodal/bipodal	One-footed/two-footed

Equilibrio/desequilibrio	Balance/ Imbalance
Con balón/sin balón	With a ball/ without a ball
Balón parado/balón de juego	Set piece/ Ball in movement
Acciones durante	Actions while playing
Empujar	Pushing
Traccionar	Pulling
Cargar	Loading
Bloquear	Blocking
Acciones posteriores	Subsequent actions
Utilización del tronco	Using the trunk
Utilización de los miembros superiores/inferiores	Using upper/ lower limbs
Disputa del balón/sin balón	Ball dispute/ Off the ball dispute
Disputa del espacio	Struggle for space
Condiciones para la variabilidad	Conditions for variability

**Jumping strength:** Many technical and tactical actions require a jumping action to be successfully performed. For example: a header. Therefore, we must add to a motor skill (e.g., Jumping) some changing and dynamic spatio-temporal adjustments based on the technical action and tactical decision. In this way, the greater the motor repertoire of the execution of the jump, the more possibilities of success and less risk of injury the football player will have. The jumping performance is affected by both neural and muscle aspects. Jumping higher requires greater vertical acceleration, achieved before take-off from the ground and obtaining the highest

possible initial speed. To achieve this, the player needs to generate the greatest possible force in a short period of time, increase muscle mass, and improve neural mechanisms through training (Ziv and Lidor, 2010). The different manifestations of jumping in football can be worked on in the following way:

### Image 7. Jumping Actions



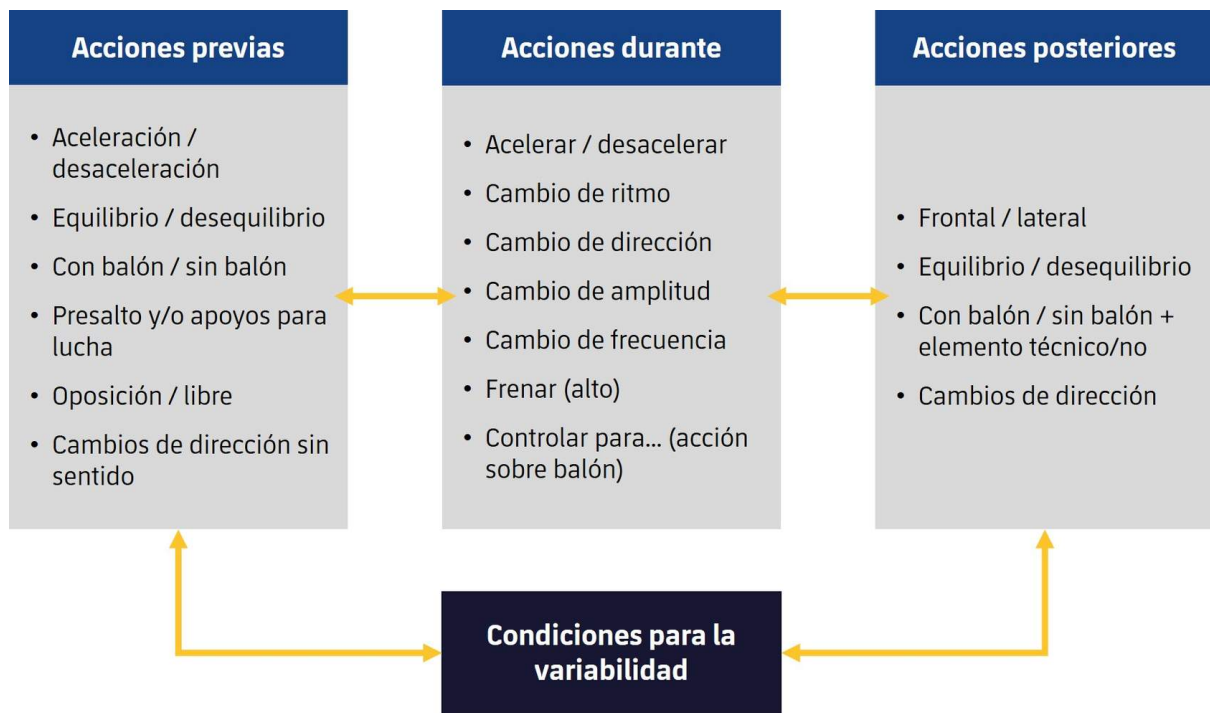
Source: Source: Prepared by the authors based on Gómez, Roqueta, Tarragó, Seirul·lo, Cos, 2019, p. 23.

Acciones previas	Previous actions
Carrera frontal/lateral/espaldas	Forward/lateral/backward Sprint
Equilibrio/desequilibrio	Balance/ Imbalance
Apoyo/batida	Support/ Take-off
Balón parado/balón en juego	Set piece/ Ball in movement
Oposición/libre	Opposition/ Free
Acciones durante	Actions while playing

Impulsar/despegar	Propel/ Take off
Unipodal/bipodal	One-footed/two-footed
Estático/dinámico	Static/Dynamic
Acciones posteriores	Subsequent actions
Recepción/aterrizaje	Reception/ Landing
Unipodal/bipodal	One-footed/two-footed
Oposición/libre	Opposition/ Free
Estable/inestable	Stable/ Unstable
Acción continuada	Continuous action
Finalización/despegue	Completion/ Take-off
Dirección tras caída	Direction after fall
Condiciones para la variabilidad	Conditions for variability

**Movement strength:** Marching and running are basic motor skills that are constantly manifested in football throughout the playing space. These occur in different directions and at various speeds, with frequent changes of direction and stops. Improving acceleration is more influenced by the improvement of concentric strength, impulse, and activity of the knee extensors, while maximum speed is more related to the stretch-shortening cycle, lower limb stiffness, and hip flexors (Sleivert and Taingahue, 2004) due to the decrease in ground contact time, which is considered important kinematically to improve maximum sprint speed (Weyand et al., 2010). The different manifestations of movement in football can be worked on in the following way:

**Image 8. Movement Actions**



Source: Source: Prepared by the authors based on Gómez, Roqueta, Tarragó, Seirul·lo, Cos, 2019, p. 22.

Acciones previas	Previous actions
Aceleración/desaceleración	Acceleration/ Deceleration
Equilibrio/desequilibrio	Balance/ Imbalance
Con balón/sin balón	With a ball/ without a ball
Presalto y/o apoyos para lucha	Pre-jump and/or support for fighting
Oposición/libre	Opposition/ Free
Cambios de dirección sin sentido	Useless changes of direction
Acciones durante	Actions while playing

Acelerar/desacelerar	Accelerate/ Decelerate
Cambio de ritmo	Change of pace
Cambio de dirección	Change of direction
Cambio de amplitud	Change of amplitude
Cambio de frecuencia	Change of frequency
Frenar (alto)	Stopping (stop)
Controlar para... (acción sobre balón)	Controlling for... (action with the ball)
Acciones posteriores	Subsequent actions
Frontal/lateral	Forward/ Lateral
Equilibrio/desequilibrio	Balance/ Imbalance
Con balón/sin balón + elemento técnico/no	With a ball/ without a ball + technical element/ no technical element
Cambios de dirección	Changes of direction
Condiciones para la variabilidad	Conditions for variability

These strength manifestations make up the groups of movements which are linked to the sports movements characteristic of each sport. Thus, for instance, we can consider that a pass or a kick are actions which belong to the throwing strength group of movements. In the same way as when the athlete's structures were defined, while increasing the specificity of exercises, these groups of movements will start connecting with each other. Besides, exercises are made up of combinations of many and even all of the groups of movements as it happens in real games.

The perception of the game is greatly influenced; that is why coaches encourage players to perceive game situations more clearly in the matches we create for them

in training sessions. This can transform players into organisms without the ability to adapt to stimuli different from those present in training. The same happens with the movements proposed in strength sessions: if they stimulate a little or are nonspecific, the player will interpret that the perceived information is unnecessary when it is actually necessary. In this way, "deafferentation" will occur (stop sending information to the tissues). It will be important for the player to learn to perceive relevant information given in their interaction with the game in the form of movements.

Throughout Module 3, in the task design section, we will delve deeper into tasks for different motor skills proposed for football. Additionally, based on the different athlete's structures and groups of movements, a planning is developed in which training is approached as a progression of movement proposals with different levels of sports specificity. There, the importance of different athlete's structures will be progressively emphasised until tasks are created where all of them converge similarly to sports competition. As already mentioned in this module, it is proposed that there always be a foundational structure for the design. Generally, this structure will be of a conditional or bioenergetic, coordinative or cognitive nature.

### **2.1.2. Types of Sessions**

The types of sessions have distinct objectives and characteristics, but, at the same time, they are supplementary forming an ecological support of highly optimising multifactorial processes for female football players. The advantage of integrated training in relation to complex systems is extremely important to increase player's effectiveness (Balagué Serre et al., 2014).

As mentioned many times in this module, every stimulus to which we expose our players aims to help them perform better and, therefore, reduce their risk of injury. Training is inherently preventive: it protects against internal and external constraints that have been previously exposed. As a result, each and every type of session listed below serves the preventive and performance improvement goal.

The types of sessions developed in the first team of women football are: restoration coadjuvant, structural coadjuvant, and specific qualities coadjuvant sessions.

#### **Restoration Coadjuvant Training**

This type of training is focused on optimising recovery means after sessions that may have caused damage to athletes due to the intensity with which they were developed (either in training or competition). This recovery must be carried out comprehensively in all their structures, although preferably in the conditional, cognitive, coordinative, emotional-volitional, and bioenergetic ones (Calleja-González et al., 2018). This is a multidisciplinary work that we will carry out

in cooperation with other teams and specialists (doctors, physiotherapists, nutritionists, psychologists, etc.).

### **Structural Coadjuvant Training**

It is a general type of training focused on the correction, adjustment, anticipation, control, and protection of the athlete. It is often related only to the morphological modification of the body of the football player through decontextualised training. However, this type of session is focused on conditioning the different tissues in order to prepare them to support the high specific load of the competition actions. Additionally, the goal is to achieve the necessary balance and predisposition of the muscle chains that participate in the various executions of each specific action. In structural sessions, it is necessary to:

- Work on stabilising muscles as an essential and facilitating element of efficient sensorimotor action (Arboix-Alió et al., 2021).
- Prepare tissues for eccentric and unexpected actions.
- Increase the efficiency of coordinative abilities.
- If identified as necessary through applied hypertrophy as discussed in Module 1, changes in composition (lean mass, especially lean muscle mass and body fat mass) could be achieved.

Structural training seeks to optimise conditional and bioenergetic structures, preferably to improve the coordinative structure in relation to the environment. There are structural sessions with a metabolic goal (HIIT): these consist of alternating circuits of very high intensity with exercises that involve a high percentage of body mass with other periods of variable recovery depending on the goal. Among the different options of metabolic training, there are some where the goal is fat loss; that is, those training strategies where the goal is to temporarily speed-up the metabolic rate and, consequently, increase calorie consumption, favouring the residual thermal effect also called EPOC (excess post-exercise oxygen consumption).

### **Specific Qualities Coadjuvant Training**

According to Seirul-lo Vargas (2017), it is based on an adapted methodological proposal where a breakdown of the game into areas of work and contents is proposed. Additionally, an alternative training of these contents is suggested based on their orientation and the levels of approximation (seen in Module 3) that can be obtained without hindering the technical execution levels of each player. "Areas of work" refer to the four specific strength manifestations required in football:

movements, jumps, fights, and throws. "Content" refers to the specific technical ability, with all its variations; for example, go step, crossover step, acceleration, deceleration, etc. Each of them will be related to one or more practice areas. The organisation of specific qualities training is developed based on the degree of similarity that the exercises have to competitive practice (Seirul-lo Vargas, 1998). This is, the proposal of these exercises will be made based on the orientation and different levels of approximation. "General orientation" refers to those actions where all types of strength manifestations, variable speeds, and trajectories are practiced which are not necessarily visually specific, but which are specific in intention. "Directed orientation" refers to those actions that have a relationship with the movements that occur in the gesture. It should be highlighted that exercises with special orientation and competitive orientation are not considered in coadjutant training, as they are part of the optimising training. Once the contents are defined, the orientation and levels of approximation of the different areas of strength manifestations in football are studied. In Module 3, the different practice systems in training sessions of specific qualities coadjutant strength are discussed.

## **Unit 2.2. Strength Training Adaptations: Do the Actions Performed Have the Desired Effect?**

Humans have a tendency towards suboptimal behaviour: they strive to be slightly better than their competitors, evolve for survival, and develop those skills that are most necessary to remain competitive in their environment. In development, it is necessary to expose the player to situations that force the system to reorganise itself to improve their adaptability. If the player always solves the same situation in the same way, they create an attractor that prevents them from solving the task in different ways. Instead of creating "automatisms," the focus should be on training adaptability. Physical trainers should create tasks that facilitate the emergence of divergent responses, promoting the generation of more flexible players capable of generating new adaptations. The ability to respond in different and efficient ways will increase performance as a result of expanding the possibilities of adaptation to the environment. Therefore, the player will have a greater repertoire of situations in which the system is close to balance, and competitive stimuli will be less stressful. As a result, their performance will increase, and they will likely reduce the number of factors that can lead to injury.

In summary, it is necessary to have knowledge of the interactions that occur during competition and that can help establish the strength needs of female football players from a holistic perspective. From this point, a proposal should be developed through

coadjuvant and optimising training included in the structured training, giving preference to the structures developed by Seirul-lo through strength training based on sports movement.

## **Unit 2.3. Strength Training Goals: Demands of the Conditional Structure in the Competitive Environment**

So far, we have discussed the importance of strength training based on improving specific football skills (jumping, moving, changing direction, kicking, etc.). All of these skills are related to the application of force, as described in Module 1. Traditionally, strength has been trained in team sports in a gym setting, without contextualisation to the demands of the sport. The expectation was to transfer gains in muscle strength to competitive performance through subsequent technical and tactical work on the field. However, this approach seems to be quite distant from the specific demands of football, where explosive actions are repeated in the game in a constant and complex situation of cooperation-opposition. It is also true that a misunderstood perception of this reality has led some physical trainers to design strength training programs using only specific loads, without considering that players are already exposed to a high degree of specificity in field training. For this reason, we must not only analyse the determined strength requirements of football but also how much and in what quality coaches cover the specific strength needs in their field tasks. It should not be forgotten that the more specific a training load is, the more aggressive it will be for the musculoskeletal system, and therefore, this will increase the injury risk in players. On the other hand, the incidence of injury due to non-specific loads (such as weightlifting) is very low compared to many other sports activities (Hamill et al., 1994). However, sports medicine professionals try to find a cause-effect relationship between weight training and injuries.

In this module, we will introduce our perspective on strength training based on scientific or empirical evidence obtained by different professionals based on their valuable experience.

Tous-Fajardo (1999) proposes that the ultimate goal of strength training is injury prevention and performance improvement. The mechanisms by which strength training improves performance and reduces the occurrence of injuries are basically the same. Taking into account only the conditional, coordinative, and bioenergetic structures, when a player is strong and highly coordinated, she will be more able to handle the forces that occur on the field. A more efficient movement results in better performance and less fatigue, which is one of the known factors that cause injuries.

### **2.3.1. Improvement of force application ability (conditional/coordination/bioenergetic structure)**

In football, there is a strong association between the ability to run at maximum speed and levels of strength and power in female football players (López-Segovia et al., 2011). This is because strength is the primary physical ability, and the others derive from it, as it was described in Module 1. There is a stronger correlation between strength and the ability to accelerate than between strength and maximum speed in the sprint (Wisløff et al., 2004). Ground contact times during sprint acceleration, change of direction, and jump are higher than in the sprint. This means that force can be applied for a longer range of time. The longer the contact time, the more important the capacity to apply force in time, and the greater the impact that strength and power training can have on performance. Although several authors certify that strength training plays a key role in improving sprint performance, not all training programs are capable of increasing the player's maximum sprint speed (Shalfawi et al., 2013). This may reveal the inadequacy of some of the stimuli used in traditional training programs to improve sports skills. When the training level of the athletes is high, specific explosive strength training is required (Bishop et al., 2011). Stronger football players are prepared to run faster and run more times without a decrease in speed (López-Segovia et al., 2011). The ability to activate more motor units after strength training can decrease fatigue and reduce the loss of power when repeating high-intensity actions (Silva et al., 2013). Stronger players also have a greater capacity to maintain a high level of force and power production at the end of the game due to the positive correlation between strength and resistance (Silva et al., 2013). This has also been related to muscle-tendon stiffness (Bishop et al., 2011). Plyometric training significantly increases muscle-tendon unit stiffness, allowing muscles and tendons to store and release more elastic energy and reduce the amount of wasted energy (Saunders et al., 2004). Reducing energy demand results in less oxygen consumption. This explains the strong association between running economy and resistance linked to plyometric training (Saunders et al., 2004).

Improvements in motor unit activation and synchronisation, muscle-tendon stiffness, and the efficiency of the stretch-shortening cycle can have a beneficial impact on sprints performance and the ability to repeat them (Buchheit et al., 2010).

This brief summary shows that strength training allows to optimise performance, but understood from a reductionist perspective. However, the interpretation from our complexity-based approach does not allow us to affirm that increasing the capacity in an isolated and decontextualised manner, without relating the conditional structure to the coordinative or cognitive ones, improves performance in competition.

### 2.3.2. Injury Prevention

Neuromuscular/proprioceptive training has shown evidence of its effectiveness in reducing injury incidence in sports that involve changes of direction (Hübscher et al., 2010). Several factors can help understand the effectiveness of strength training in reducing the risk factors of injury (Image 9). Some of the most important factors are:

- The ability to react quickly and produce force rapidly favours stability and balance during this initial ground-contact phase. This is crucial because most acute sports injuries occur in the early phase of foot-ground contact (Krosshaug et al. 2007).
- Increasing muscle-tendon stiffness and neuromuscular impulse (through plyometric training) that shortens the time between muscle activation and contraction (mechanical delay) and increases the speed at which force is produced after the onset of contraction (rate of strength development) (Waugh et al., 2014).
- Higher potential for coactivation during the initial ground-contact phase by improving the ability to produce force rapidly (Waugh et al., 2014).
- Increasing the size and strength of the ligaments and tendons as strength is gained with training. Ligaments and tendons must also adapt to efficiently support and transmit these greater forces to the bones (Waugh et al., 2014).
- Improving neuromuscular control of the lower limbs. Modifications in the attractors of muscle activation after plyometric training involve greater preactivation and more symmetrical coactivation between the quadriceps and hamstrings and also between the hip abductor and adductor (Chimera et al., 2004; Hewett et al., 1996). These motor control patterns improve lower limb alignment and provide a more stable knee position when landing (Chimera et al., 2004; Cuoco and Tyler, 2012). Enhanced preactivation and the stiffness of the muscle-tendon complex increase the load absorbed by muscles and tendons and decrease the load transmitted through joints and ligaments (Chimera et al., 2004; Fouré et al., 2011).
- A stronger musculoskeletal system and an improved preactivation (feedforward) will also optimise reactive stability and the state of alert against sudden movement perturbations, such as being pushed, contact with an opponent, or unexpected game situations (Blazevich et al., 2007; Blickhan et al., 2007; Bosch, 2012).

- Improving neural impulse that will be transferred to similar movements in football. (Zatsiorsky, 1995). Since more motor units can be activated simultaneously, the contractile stress during high-intensity actions is distributed over a greater number of muscle fibres that get contracted. This will limit the amount of muscle damage (McHugh et al., 1999). High-intensity actions in football involve repeated episodes of stretch-shortening cycles in which a rapid lengthening of a muscle is followed by an immediate shortening.
- Changes in connective tissue and the elastic properties of the muscle that increase the ability of the muscle-tendon complex to store and release more elastic energy (Markovic and Mikulic, 2010). A more efficient movement mechanics and a greater reliance on passive production of elastic force can decrease the stress imposed on contractile elements and reduce neuromuscular fatigue and muscle damage (Byrne et al., 2004; Johnston et al., 2014). The strongest players have greater eccentric strength and ability to use the stretch-shortening cycle (Miyaguchi and Demura, 2008).
- Increase in the number of sarcomeres connected in series (Alegre Durán, 2004). This will decrease the possibility of sarcomeres being stretched to the limit. Therefore, a greater number of sarcomeres in series will reduce sarcomere tension during constant episodes of muscle stretching, and it will limit subsequent muscle damage (McHugh et al., 1999). This is achieved through ballistic, full range of motion, and eccentric strength training.

### **Image 9. Neuromuscular Risk Factors**



Source: prepared by the authors based on Romero, 2019, p. 16.

Alteración feedforward	Feedforward alteration
Fatiga neuromuscular	Neuromuscular fatigue
Desequilibrio extremidad no dominante – Dominante	Imbalance non-dominant limb - dominant limb
Pobre Stiffness muscular	Poor muscle stiffness
Déficit en el control de la estabilidad postural	Deficit in postural stability control
Déficit muscular en la estabilidad del tronco	Muscle deficit in trunk stability
Alteración de la activación muscular	Alteration in muscle activation
Alteración de la sensibilidad propioceptiva	Alteration in proprioceptive sensitivity

Factors such as peripheral and central fatigue negatively affect neuromuscular control and alter landing mechanics (Cortes et al., 2013). As fatigue levels increase, hip extension, knee valgus, and ankle supination angles progressively increase during deceleration, landing, and change of direction actions (Borotikar et al., 2008). These altered movements as a result of fatigue decrease movement efficiency and increase the risk of injury (Koga et al., 2010; Krosshaug et al., 2007).

Muscle imbalances (expressed as the agonist/antagonist relationship) and central weakness increase the risk of injury (Herman et al., 2012). An effective strength routine will correct these agonist/antagonist muscle imbalances and postural control imbalances. Ultimately, neuromuscular control of the player will be improved.

Performing high-intensity actions repeatedly throughout a training or a match causes neuromuscular fatigue and damage (Silva et al., 2013). The post-match decrease in fatigue in players with higher strength values can be attributed to neural, connective tissue, and cellular adaptations (Johnston et al., 2014). These players better tolerate forces associated with high-intensity actions, and this influences a decrease in post-match recovery time (Nédélec et al., 2012).

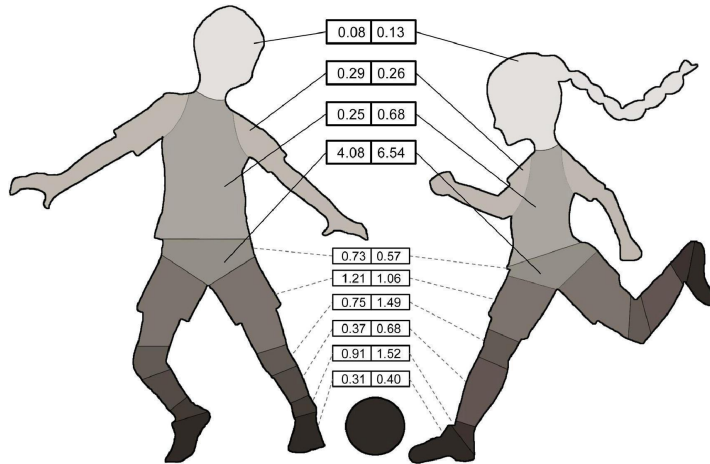
In Image 9, conditioning factors related to the player at the tissue level and their response to stimuli are described. However, these models based on isolated performance or injury parameters do not provide enough information about the coordinative patterns that generate performance or injury. Therefore, to better understand this, the reality of coordinative patterns must be understood. As discussed in Module 1, motor actions are the result of the interrelationships of the player with the task and the environment. Consequently, these identifiable limitations do not always occur in all movements but sometimes only occur in some movements where the information perceived by the player determines that this restriction is generated. Thus, the analysis of injury risk factors must contain the context where that movement limitation occurs.

When thinking about women's sports and football, knee injuries always come to mind. Women who participate in team sports currently have a risk between 2.3 and 9.7 times higher than men of suffering an anterior cruciate ligament (ACL) tear. In the case of Spanish women's football, it is 6.3 per 1000 hours of exposure (23 per 1000 hours in games and 5 per 1000 hours in training) (Robles-Palazón et al., 2021). This situation is described in Image10.

Although these data are merely descriptive, they are often used to unintentionally convey fear. The media, for example, constantly reports on injuries suffered by women and blame these injuries on team sports as if they are dangerous for women

and girls simply because they are women. In other words, according to this view, women, due to their biology, are determined to suffer more injuries than men.

**Image 10. Risk of Injuries in Men and Women**



Source: Robles-Palazón et al., 2021, <https://n9.cl/6jrok>

But is it a biological problem or something else? It is known that there are differences in activation between male and female football players during change of direction and stopping:

- Female football players have less activation in hip abductors and hamstring muscles. In other words, posterior muscles in some of these movements do not perform their function (Collins et al., 2021; Landry et al., 2007; Woodhouse et al., 2021).
- Additionally, women have more electromyographic activity in the rectus femoris muscle. Normally, there are more quadriceps injuries in women's football, as this excess activation during changes of direction (a very recurrent action in football) generates overloads in the quadriceps due to excessive use.

Also, when analysing change of direction and decelerations, men and women have different movement strategies. The most frequent ones are:

- Greater knee adduction and valgus, linked to less activation of peritrochanteric muscles.
- Less hip, knee, and ankle flexion during the execution of movements. This generates less cushioning of actions and more joint impact against the ground.

However, it is time to go beyond purely descriptive gender comparison studies that still dominate the literature. Instead, it is time to critically examine the underlying causes of these differences and whether they really reflect a higher risk of injury for physically "active" women (Benjaminse et al., 2011). Although descriptive studies provide valuable information, the cause-effect relationships made in a complex context such as the human body are very questionable. The risk of injury should be examined taking into account biomechanical and neuromuscular contributions jointly and not in isolation, as well as knowing the perceptual information that makes the task unable to be solved. Therefore, it must go beyond an isolated gender approach.

In other sports, such as ballet, gymnastics, or dance, athletes accumulate a lot of training during their youth where they constantly have to land. Despite incorporating similar high-risk movements and high training loads, the disparity in ACL injury rates is not present between women and men. These athletes, who are exposed to risk landing movements as in football, are a sample that is worth analysing. A group of authors made the same comparison between men and women by observing their activation and biomechanics during landing as was previously done in football. The results revealed that landing strategies are similar between men and women. In addition, they found a relationship between the age at which athletes (men and women) started training and hip angle in the frontal plane during landing (Orishimo et al., 2009). This group of authors, by validating their previous hypotheses, decided to analyse and group these landing strategies according to the sport that men and women practised. They analysed football, basketball, handball, and gymnastics players and wanted to see their behaviour during landing. Thus, they found that male team sport players, male gymnasts, and female gymnasts had similar landing strategies. However, women who practise team sports have a greater valgus in the knee during landing compared to others (Liederbach et al., 2014). Therefore, these findings suggest that the potential dangerous landing pattern "specific to women" may not be due to gender, but rather to the age of starting training, its quality, and the hours of exposure to the sport.

Everything is more complex than the cause-effect relationships that often arise in science due to how inclusion criteria are established in many scientific journals. Although information is limited and very biased, it can be used as a starting point, always understanding that the current reality of women's sports, as it is in a process of evolution with a very marked slope, makes it difficult to use the available information from a few years ago.

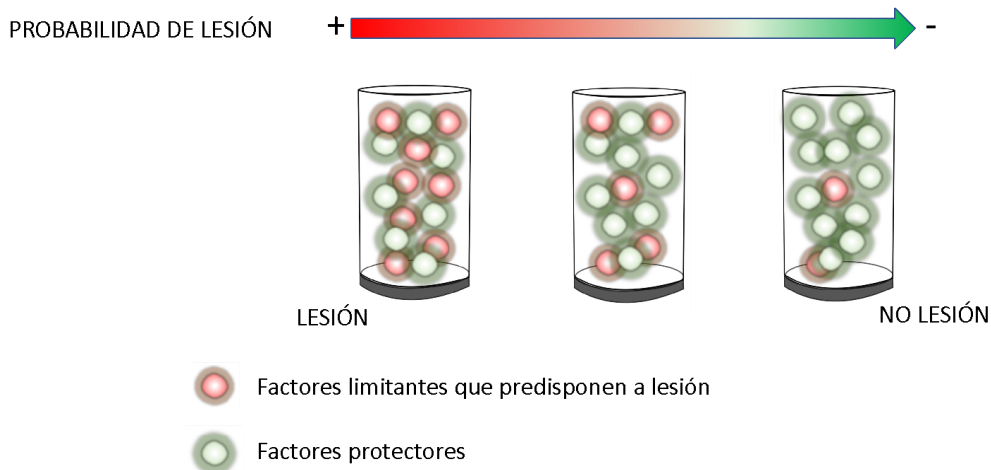
### **2.3.3 Prediction of Injuries**

The process by which an athlete becomes injured is influenced by their individual characteristics and how they relate to their environment, and vice versa. This

complicates the task of knowing when to expose football players to a stimulus and in what quantity/quality, as going too far or falling short can result in her not being able to play a game in the short or long term.

We would like to be able to predict when a football player will get injured. Traditionally, through hierarchical models, biomechanical characteristics that predispose to injury have been analysed, seeking correlation between the model parameters and predisposition to injury. However, the predictive capacity of a statistical model established by continuous variables (such as strength levels or joint mobility) is very low. That is, any football player within the study group (strong or weak) is exposed to injury. What we do know is that weaker athletes are more likely to get injured; however, we do not know when. In addition, continuous variables tend to vary over time, which means that the predictive value of the measurement will possibly change, and constant assessment would be needed to update such "model." The occurrence of injuries is determined by countless factors: the individual constraints of the athlete (internal limitations or constraints), task-related factors (task constraints), and factors of the environment (constraints of the environment) that shape our movement strategies. These strategies can be considered as emerging physical behaviours that are shaped by the constantly changing interaction between the complex athlete-environment. Therefore, to better understand these processes, we must focus on the study of coordinative patterns, taking into account the relationship/coupling between different segments and joints with the environment instead of analysing kinematic measures. Being such a complex and changing process, we cannot currently predict injuries. However, this should not lead us to do nothing; the only thing we can do is trying to identify the player's strengths and weaknesses in relation to the demands of the game and prescribe training based on that constant analysis of the continuous variables. For example, if there is a probability of rain, what can we do today to deal with that future event (if it finally occurs)? Taking an umbrella and wearing rain gear. What for? To prepare for the worst-case scenario, but without trying to predict when it will happen. We should not try to predict what will happen, but prepare the players for the worst-case scenario in the future and reduce the probability of multifactorial emergent responses that lead to injury.

### **Image 11. Probability of Injury**



Source: prepared by the authors.

Probabilidad de lesión	Probability of Injury
Lesión	Injury
Factores limitantes que predisponen a lesión	Constraining factors that predispose to injuries
Factores protectores	Protective Factors
No lesión	No Injury

## Unit 2.4. Neuromuscular Response

In football, performance is determined by the need that the player controls movement (coordinative structure). As movement becomes more complex, the central nervous system (CNS) will be less and less able to control it, and the movement pattern may become unstable. The CNS obtains the necessary information to control the movements of our body from three subsystems: the somatosensory system, the vestibular system, and the visual system (Hewett et al., 2002; Lephart and Jari, 2002).

Although the visual and vestibular systems contribute, peripheral mechanoreceptors are the most important from a training perspective.

Mechanoreceptors are found in different parts of the body, including the skin, joints, ligaments, tendons, and muscles. Afferent pathways transmit inputs to three levels of motor control and are associated with areas such as the cerebellum. Motor neuron activation can occur in direct response to peripheral sensory input (reflexes) or descending from higher centers (automatic or voluntary movement) (Fort and Rodríguez, 2013).

We understand neuromuscular control as precise muscle activation that enables coordinated and effective action development (Williams et al., 2001). The different strategies of neuromuscular control to carry out a coordinated and effective action are intramuscular coordination and intermuscular coordination

### **2.4.1. Intramuscular Coordination**

One of the main neural factors affecting strength refers to the intramuscular coordination of one same muscle. Several control mechanisms are involved: spatial recruitment (increasing the number of recruited motor units), temporal recruitment (increasing the frequency of motor unit impulses), and the synchronisation of different motor units to produce a maximum voluntary contraction (Cometti, 1998; Fort and Rodríguez, 2013; Tous-Fajardo, 1999).

### **2.4.2. Intermuscular Coordination**

The central nervous system avoids unstable high-intensity movements because they are dangerous to tissues and reduce performance before muscles and tendons reach their load capacity limit, avoiding possible injury. For example, in a sprint, the hamstrings are exposed to a high load because they are functioning at high speed. Sometimes they go beyond their tolerable limit and tear. However, most athletes rarely get injured because, in a healthy body, muscles never reach the limit of their capacity, as long as the movement is coordinated. Therefore, it is important that the movement is stable and controllable. A movement is controllable if it can withstand external (uneven surfaces when running, an underinflated ball, or even when opponents fight for the ball, etc.) and internal perturbations (mainly fatigue). These processes of inhibition of information may be behind the phenomenon of instability, understood as the perception of not being able to control the movement during the task. Instability causes our body to behave protecting itself in the short term by decreasing the activity of the affected joint in the set of tasks that the athlete performs. The major drawback is in the long term; if that instability manifests itself with constant joint inhibition, this behaviour is perpetuated in actions that the player needs to carry out in their daily life and, therefore, they will become deconditioned and harm the execution of sports actions.

Movement control includes built-in mechanisms to ensure that perturbations have a reduced impact on movement efficiency. As a result, there are characteristics in the movement control system that ensure they are carried out safely. One of the most important mechanisms for regulating movements and making them stronger is "compensation". When movements are performed at such a high speed that they are not controlled, there will be more errors ("noise") in the signals transmitted to the muscles by the CNS. An increase in noise will cause mistakes in the movement during the process. To achieve usable and precise motor action, the "noise" must be attenuated in some way. This is done by activating not only the agonists (the muscles that ensure the planned joint movement), but also the antagonists (co-contractions) (Kelso, 1991). When agonists and antagonists contract (co-activate) at the same time, they are more or less balanced. This dampens any errors in the signals from the CNS. Therefore, the correct balance is affected by a series of muscle properties that are not subject to neuronal control, such as the strength/length and strength/speed characteristics of muscles and the elastic properties of tendons (Fort and Rodriguez, 2013). These properties affect how muscles respond to signals from the central nervous system. The elastic components of the muscle-tendon unit affect the change in muscle length, and muscle length affects the strength of the muscle action.

Co-contractions are the basis of the muscles' self-organisation capacity and correct mistakes in movement. At the same time, antagonists inhibit the action speed of agonists, and the movement will be slower. In other words, the more speed, the more noise, the more co-contractions, and therefore, the more movement speed will be inhibited. Co-activation is used (especially when new or ballistic actions are performed) when the execution speed increases and it is necessary to provide stability to maintain a constant joint position (Lloyd, 2001).

Co-contractions not only inhibit the intensity (speed and strength) with which a movement can be executed but also reduce muscle slack. This is a positive aspect because slack reduces the intensity at which the movement can be performed. Creating pre-tension with the help of co-contractions reduces the constraining effect on the potential intensity of the movement caused by muscle slack, and, therefore, it allows the player to move faster and with more force. In that sense, there is a conflicting position between maximising the intensity (speed and strength) of the movement, controlling the movement, and reducing muscle slack through co-contractions.

### **Image 12. Co-contractions at the Start of a Sprint**



Source: prepared by the authors.

The image above shows the hamstrings, which are active trying to flex the knee, while the quadriceps are trying to extend it. There is pre-tension that enables the player to move faster.

In summary, performance in explosive actions is conditioned by a limit that occurs before the limits of the locomotor system are reached. This is a natural response that has two objectives:

- Performing the controlled movement in an environment where unpredictable disturbing forces exist.
- And protecting the athlete from injury by reducing the load on the locomotor system.

Currently, we know that the strategies employed by the neuromuscular system are modifiable through training (Hewett et al., 2013; Hübscher et al., 2010). Thus, when new movements are experienced, the task is initially performed with high levels of co-activation and, as it is learned, progresses to reciprocal activation (Lloyd, 2001). That is, in actions produced in football, we need to reach a balance between co-activation (which provides stability and protection) and reciprocal activation (which can increase the muscle efficiency of the sports action). In addition to the mentioned strategies, we must highlight feedback and feedforward mechanisms to optimise neuromuscular control during the game.

**Image 13. Types of Actions where Co-contractions and Inhibition Occur.**



Source: Fort and Rodríguez, 2013, <https://n9.cl/jbolw>

Principios Neuromusculares	Neuromuscular Principles
Activación agonista – antagonista	Agonist - Antagonist Activation
En	In
Nuevas acciones	New Actions
Acciones balísticas	Ballistic Actions
Aumento de la velocidad de ejecución	Increase in Execution Speed
Necesidad de estabilidad articular	Need for Joint Stability
Inhibición recíproca	Reciprocal Inhibition
Agonista – antagonista	Agonist - Antagonist
Movimientos poliarticulares automatizados	Automated multi-joint movements
Consolidación de aprendizajes (de coactivación a inhibición)	Consolidation of Learning (Co-activation and Inhibition)

Understanding how the neuromuscular system works is essential to design more appropriate strength trainings and thus, ensure the functional stability of tissues during sports actions (such as changes of direction or landings from a jump). It is not only important to work on this system in the context of injury prevention and treatment but also for improving sports performance (Fort and Rodríguez, 2013).

### **2.4.3. Strength Training Based on Coordination**

Training based on coordination is nothing but the preferential selection of the coordinative structure in strength tasks. We should observe how movement control limits performance. If it is only limited by the load capacity of the musculoskeletal system, it is better to train the conditional structure since it does not make much sense to base strength training on coordination. However, performance is not limited by this ability but rather by the way the movement is designed; thus, we should focus on the player's coordinative structure. As mentioned before, control based on co-contractions reduces performance at high intensity. Therefore, it is useful to consider the consequences of motor control within strength training and to make movement patterns solid through strength exercises. In turn, challenging strength exercises are the most useful strategy for elite football players to develop their skills. However, the development of this strategy depends on a good understanding of how sports movement is structured.

Sports actions involve a series of kinetic chains to mobilise the body. The coordination of these chains leads to the transfer of energy from one body segment to another, resulting in the sum of forces.

Closed and open kinetic chains are commonly used to classify different movements. Closed kinetic chains refer to when the distal segment is fixed and force is produced against the fixed object to move the proximal segments and therefore the body. Open kinetic chains refer to when the distal part is free to move. However, these terminologies become confusing, especially when complex movements involve a combination of closed and open kinetic chains. Using this classification, human movement is the product of open, closed, or combined kinetic chains that function independently or simultaneously. For example, running involves both closed and open kinetic chains. The stance leg is a closed kinetic chain that results in propulsion, while the swing leg is an open kinetic chain movement.

The ability to produce repetitive, powerful, and energetically efficient movements is almost a prerequisite for success at the highest level in sports. Efficiency is the relationship between the output and input of energy, and therefore, it improves when the energy production increases in relation to the input. Energy losses in the kinetic chain can lead to premature fatigue. It's been proved that fatigue reduces the proprioceptive sense (Lee et al., 2003), alters scapulothoracic and glenohumeral

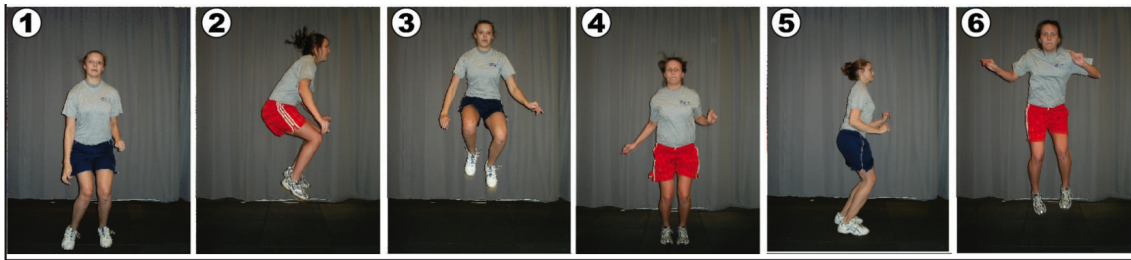
movement (Ebaugh et al., 2006), increases tibial translation in healthy knees (Wojtys et al., 1996), reduces postural control, and increases joint impact while running (Christina et al., 2001). Therefore, fatigue is a significant risk factor for injuries in football. Consequently, it is essential to optimise the kinetic chain to be effective in the way it transfers muscle energy to a powerful movement. To do this, intermuscular coordination must be improved and the storage and release of elastic energy through the kinetic chain must be optimised. It is also important to have a good strength base and the abilities derived from it, such as balance, stability, and strength. For example, a stable trunk is required for sprinting. Strong periarticular hip muscles are fundamental in generating a base for energy to be effectively transferred during a shot on goal. When there are energy losses, movement speed decreases. As mentioned in the Intermuscular coordination section, for the player to improve their power and speed, other muscles must be recruited to a greater extent to compensate the energy loss in the system.

Without taking into account any other structure a part from the coordinative one, when performing a movement, players who are able to transfer energy effectively through the kinetic chain with minimal losses have an advantage in performing better. Conversely, poor movement mechanics can increase stress on the joints and soft tissues of the kinetic chain. An unfavourable usage of proximal segments to transfer energy can exert greater pressure on distal segments. For example, excessive rearfoot eversion and hip adduction are thought to be risk factors in people with patellofemoral joint pain (Barton et al., 2012).

While the kinetic chain is often discussed in relation to movement production, the concept can also be expanded to explain how the body can absorb forces during movement deceleration, such as landing from a jump. Body deceleration and eccentric muscular action can impose excessive forces on tendons, making the athlete susceptible to developing tendinopathies. Optimising the use of the kinetic chain to absorb forces will reduce overload. It has been shown that rigid landing strategies and dysfunctional hip sequencing at landing are more present in athletes with patellar tendinopathy (Bisseling et al., 2007; Edwards et al., 2010). In this situation, the kinetic chain is not used effectively to decelerate the body, so that forces are distributed through the anatomical structures.

The following image shows some examples of different dysfunctional landing and take-off strategies during the jump.

#### **Image 14. Dysfunctional Movement Strategies in Landing**



Source: prepared by the authors.

### Image Description

1. Valgus in a limb during landing
2. Hips do not reach parallel (peak of jump)
3. Hips are not parallel during take-off.

Feet during landing:

1. Shoulders are not in line with the feet.
2. Feet are not parallel (front - back).
3. Foot contact time is not at the same time.

The different strategies can be categorised as:

- Ligament dominance. The muscles do not sufficiently absorb ground reaction forces, so the joint and ligaments must absorb large amounts of force over a brief period of time.
- Leg dominance. Tendency to support all the weight on one leg.
- Quadriceps dominance. Tendency to stabilise using quadriceps.
- Trunk dominance. Inability to properly perceive the position of their trunk in three-dimensional space and they do not allow further movement after a perturbation.

The intervention that could be done considering only the coordinative structure is shown in the following image.

### Image 15. Intervention

MECANISMO LESIVO	DESEQUILIBRIO NEUROMUSCULAR	INTERVENCIÓN
Aducción de rodilla en la caída	LIGAMENT DOMINANCE	Entrenar la técnica adecuada
Pequeño ángulo de Flexión de rodilla en la caída (desplazamiento adelante)	QUADRICEPS DOMINANCE	Fuerza de la cadena posterior
Caída asimétrica	LEG DOMINANCE	Entrenar simetrías (SIDE/SIDE)
Incapacidad para controlar el centro de masas	TRUNK DOMINANCE	Core Stability y entrenamiento de perturbaciones

Source: prepared by the authors.

Mecanismo Lesivo	Injurious Mechanism
Desequilibrio Neuromuscular	Neuromuscular Imbalance
Intervención	Intervention
Aducción de rodilla en la caída	Knee adduction in landing
Ligament Dominance	Ligament Dominance
Entrenar la técnica adecuada	Training proper technique
Pequeño ángulo de Flexión de rodilla en la caída (desplazamiento adelante)	Small angle of knee flexion in landing (forward movement)
Quadriceps dominance	Quadriceps Dominance
Fuerza de la cadena posterior	Posterior chain strength
Caída asimétrica	Asymmetric landing
Leg dominance	Leg dominance

Entrenar simetrías (SIDE/SIDE)	Training symmetries (SIDE/SIDE)
Incapacidad para controlar el centro de masas	Inability to control the centre of mass
Trunk dominance	Trunk dominance
Core Stability y entrenamiento de perturbaciones	Core Stability and perturbation training

Probably, all these neuromuscular imbalances should be trained in relation to the specific task and see how movements are modified when having specific stimuli.

Strength training should be aimed at improving performance. Reducing injuries will be a consequence of the above. This training should maintain some dynamic correspondence with competitive movements and respect, whenever possible, the ecology of the environment in which the movement occurs in the game. In this way, not only strength levels or tissue quality improve, as described in the prevention section, but the necessary coordination for efficient movement is also optimised. Efficiency is understood as improvement in energy flows; that is, the specific distribution of energy based on the information that comes from the environment and the specific interactions that occur between players and their actions in relation to everything else.

Strength training should contain variability in movement: functional variability and not random. This variability will provide the player with greater adaptability and flexibility in the sensorimotor system to capably manoeuvre in a multitude of contexts. Functional variability is an indicator of healthy motor action (Glazier et al., 2006). Performing tasks in which the athlete needs to adapt their behaviour to the task constraints will contribute to increasing the player's interaction possibilities with the complex environment (Button et al., 2020). As Bernstein pointed out several decades ago (1996), repeating the same movement never leads to the same movement trajectory, regardless of the amount of practice, experience, or skill level.

### **Image 16. Training**

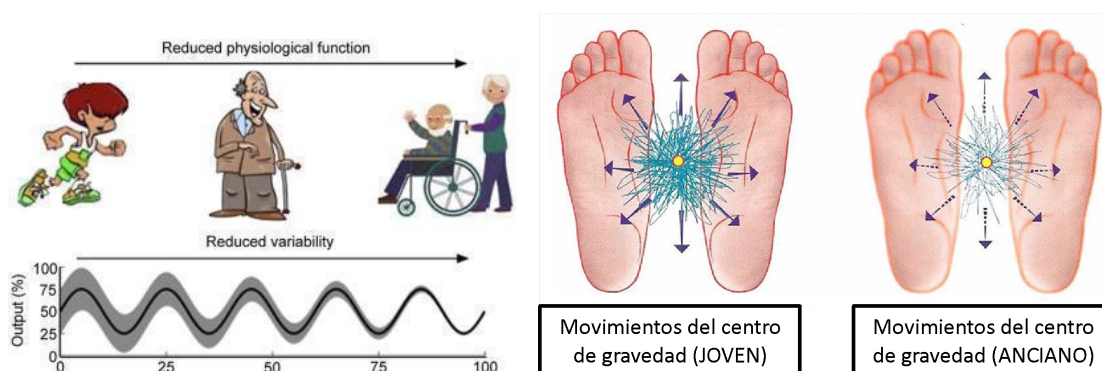


Source: prepared by the authors.

In training, variability can occur during the process or in the result. The variability can be linked to having a variety of available strategies to solve the same task, increasing, in this way, performance flexibility. It can also be found when different components contributing to performance counteract each other's variations to ensure the result (as in Image16).

Therefore, imposing a coordinative overload is, in theory, a way to create increasingly new or more flexible sensorimotor patterns so that the player can continue to learn and diversify their movement solutions in a given task. This complexity is necessary for systems to adapt to changing conditions, as loss of complexity results in decreased adaptive capacity. Throughout life, movements become more predictable, and the body is unable to adapt to changes in the environment. This explains why elder people fall down more often (Image 17).

**Image 17. Movement Variability in young and elderly people**



Source: Bosch and Cook, 2015, <https://n9.cl/b562x>

Movimientos del centro de gravedad (JOVEN)	Movements of the Centre of Gravity (YOUNG)
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(Anciano)	(ELDERLY)
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The combination of stability and flexibility concepts in human behaviour is an inherently complex phenomenon. Stability is necessary in movement, but since instability is the origin of stable motor behaviour (Davids et al., 2008), the combination of stability and flexibility is a major challenge for the neuromuscular system. The human body, through interactive processes between different structures, has multiple ways to reorganise its own instabilities (Spencer and Schöner, 2003). Therefore, the system does not need the brain in a decisional process, but rather, new information that is perceived demands reorganisation of the system towards a new state. Thus, flexibility arises from the same properties of the system that generate stability (Spencer and Schöner, 2003). In this sense, training should not only seek more stability in behaviours (repetition), but also promote evolution towards the ability to generate new states of stability.

Specific training loads on the field and in competition can create imbalances in football players that increase the probability of injury. Therefore, we must seek balance and progression in strength training proposals from the nano-level (e.g., developing *tensegrity* at the level of muscle cells and the musculoskeletal system) to the *micro*-level (intramuscular and intermuscular coordination in movement) and the *meso*-level (sports movements in competition). At the same time, this proposal is related to the orientation of tasks, and therefore, also to their level of specificity, representativeness, and complexity in relation to competition.

## Unit 2.5. Periodisation

We have a problem when programming training stimuli in football, since although much of our knowledge is based on athletics programs and the knowledge generated by this discipline, the complexity of interactions between athletes and the environment in football complicates the task of knowing the necessary intensity and volume to perform a "good" program. It is clear that we should seek a synergy between different training stimuli, taking into account its complex nature since load is not only base on conditional and bioenergetic parametres, it is much more complex. We should not only train to be able to jump or run. Instead, the athlete must be prepared to improve their interaction in the game context, including the player and their behavioural relationships with the team. However, it is clear that we must make decisions despite the complexity of the training process.

Starting with the pre-season, the player must be progressively prepared for the demanding training and competition loads they will have to endure. It is a period

where adaptations are many. The player must adapt in all their structures: conditional (muscle tissues, connective, bone, etc.), bioenergetic, and coordinative, and return to playing football after a period without activity. If the coach's game model is modified, it will generate the need for the athlete to adapt to the behaviours required and also to know how their teammates behave. Therefore, we must start with low complexity tasks to facilitate these co-adaptation processes between players. In addition, explosive actions such as kicks or sprints should wait a while to be included in pre-season sessions, progressively moving towards more aggressive tasks for the structures. Therefore, strength training will have a more protective than performance objective, starting with general sessions without taking into account the coupling processes between perception-action cycles. It is difficult to estimate the duration of this type of work during the pre-season, as it must adapt to the characteristics of the players in the team. For example, in a year of Euro Cup, where the players will have just competed and only have between seven and ten days of rest, a long adaptation phase is not necessary; however, players who do not compete in the Euro Cup will have a month of holiday and will need a longer adaptation.

During the season, within the micro cycle, training will be determined primarily by the previous game and the time needed by the players to recover their previous performance levels. There is evidence that indicates that 48/72 hours is the time needed to recover from neuromuscular fatigue, physical and oxidative stress, and inflammatory markers. Therefore, the first few days of the week will be of low volume and intensity. In addition, recovery sessions and the compensatory session should be taken into account for players who did not participate in the game. For those who played, efforts will be low in impact and low in complexity. Training on the day after the game or two days after it? This will depend on certain variables such as the time of the season (more load can be applied in session +2 than in session +1; doing a session on +1 will favour recovery and doing it on +2 will increase the load for the week) or the players' state of mind.

The -4 session of the week will aim at training the conditional structure. The actions will not be very complex, and it is the best day for structural work in case any player needs it since there will be no interference effect between field training and coadjuvant training. Moreover, several days will be needed to recover from this type of effort.

-3 session will be a session in which specific qualities will be carried out. This will be the highest-load session of the week in which all the player's structures will be worked on. However, peripheral fatigue will not be the highest of the week because polyarticular exercises will be performed, which will not generate as much waste.

In -2 session, compensatory and structural exercises will be carried out with a protective role. The training load is reduced to recover from the stimuli of the previous days.

The -1 session will be dedicated to explosive actions that do not generate harmful waste for the game the next day.

The following image summarises what has been discussed so far.

**Image 18. Summary of the Microcycle**



Source: prepared by the authors.

Fuerza	Strength
Estado condicional	Conditional Status
Inicio de sesión	Beginning of Session
Coordinativo	Coordinative
Liberación	Release
Potencia	Power
Competición	Competition
Recuperación	Recovery

Recuperación Compesación	Recovery Compensation
Mañana	Morning
Regimen de fuerza	Strength Routine
Regimen de resistencia	Resistance Routine
Estructural	Structural
Coordinativo	Coordinative
Estructural	Structural
Liberación	Release
Velocidad	Speed
Régimen de velocidad	Speed Routine
Competición	Competition
Recuperación	Recovery
Estructural	Structural
Recuperación compensación	Recovery Compensation

## References

**Alegre Durán, L. M.** (2004). *Cambios en la arquitectura y biomecánica del músculo esquelético tras un entrenamiento de fuerza explosiva* [Tesis doctoral]. Retrieved from: <https://dialnet.unirioja.es/servlet/tesis?codigo=105009>

**Arboix-Alió, J., Buscà, B., Aguilera-Castells, J., Fort-Vanmeerhaeghe, A., Trabal, G., and Peña, J. (2021).** *Competitive balance in male European rink hockey leagues. Apunt. Educ. Física i Esports*, 3, pp. 75-80.

**Balagué Serre, N., Torrents Martín, C., Pol Cabanellas, R. and Seirul-lo Vargas, F. (2014).** Entrenamiento integrado. Principios dinámicos y aplicaciones. *Apunts: Educación Física y Deportes*, 116, pp. 60-68. Retrieved from: <https://revista-apunts.com/entrenamiento-integrado-principios-dinamicos-y-aplicaciones/>

**Barton, C. J., Levinger, P., Crossley, K. M., Webster, K. E. and Menz, H. B. (2012).** *The relationship between rearfoot, tibial and hip kinematics in individuals with patellofemoral pain syndrome. Clinical Biomechanics*, 27(7), pp. 702-705.

**Benjaminse, A., Gokeler, A., Fleisig, G. S., Sell, T. C. y Otten, B. (2011).** *What is the true evidence for gender-related differences during plant and cut maneuvers? A systematic review. Knee Surgery, Sports Traumatology, Arthroscopy*, 19(1), pp. 42-54.

**Bernstein, N. A., Latash, M. L. y Turvey, M. T. (1996).** *Dexterity and its development.* Psychology Press.

**Bishop, D., Girard, O. and Mendez-Villanueva, A. (2011).** *Repeated-sprint ability. Part II. Sports Medicine*, 41(9), pp. 741-756.

**Bisseling, R. W., Hof, A. L., Bredeweg, S. W., Zwerver, J. and Mulder, T. (2007).** *Relationship between landing strategy and patellar tendinopathy in volleyball. British Journal of Sports Medicine*, 41(7). DOI: 10.1136/bjism.2006.032565

**Bosch, F. and Cook, K. (2015).** *Strength training and coordination: an integrative approach.* Rotterdam: 2010 Publishers.

**Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M. and Ahmaidi, S. (2010).** *Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. The Journal of Strength & Conditioning Research*, 24(10), pp. 2715-2722.

**Button, C., Seifert, L., Chow, J. Y., Davids, K., and Araujo, D. (2020).** *Dynamics of skill acquisition: An ecological dynamics approach.* The United States: Human Kinetics Publishers.

**Calleja-González, J., Mielgo-Ayuso, J., Sampaio, J., Delextrat, A., Ostojic, S. M., Marques-Jiménez, D., Arratibel, I., Sánchez-Ureña, B., Dupont, G. and Schelling, X. (2018).** *Brief ideas about evidence-based recovery in team sports.*

*Journal of Exercise Rehabilitation*, 14(4), pp. 545-550. DOI: <http://dx.doi.org/10.12965/jer.1836244.122>

**Christina, K. A., White, S. C. and Gilchrist, L. A.** (2001). *Effect of localized muscle fatigue on vertical ground reaction forces and ankle joint motion during running.* *Human Movement Science*, 20(3), pp. 257-276.

**Collins, K. S., Klawitter, L. A., Waldera, R. W., Mahoney, S. J. and Christensen, B. K.** (2021). *Differences in Muscle Activity and Kinetics Between the Goblet Squat and Landmine Squat in Men and Women.* *Journal of Strength and Conditioning Research*, 35(10), pp. 2661-2668.

**Colosio, A. L., Pedrinolla, A., da Lozzo, G. and Pogliaghi, S.** (2018). Heart rate-index estimates oxygen uptake, energy expenditure and aerobic fitness in rugby players. *Journal of Sports Science & Medicine*, 17(4). Retrieved from: <https://pubmed.ncbi.nlm.nih.gov/30479532/>

**Cometti, G.** (1998). *La pliometría*. Barcelona: Inde.

**Cronin, J., McNair, P. J. and Marshall, R. N.** (2001). *Velocity specificity, combination training and sport specific tasks.* *Journal of Science and Medicine in Sport*, 4(2), pp. 168-178.

**Dauids, K. W., Button, C. and Bennett, S. J.** (2008). *Dynamics of skill acquisition: A constraints-led approach.* The United States: Human Kinetics.

**Dutta, P. and Subramaniam, S.** (2001). *56 effect of six weeks of isokinetic strength training combined with skill training on football kicking performance.* *Science and Football IV*, 3(3). DOI: <https://doi.org/10.2466/pms.99.2.701-710>

**Ebaugh, D. D., McClure, P. W. and Karduna, A. R.** (2006). *Effects of shoulder muscle fatigue caused by repetitive overhead activities on scapulothoracic and glenohumeral kinematics.* *Journal of Electromyography and Kinesiology*, 16(3), pp. 224-235.

**Edwards, S., Steele, J. R., McGhee, D. E., Beattie, S., Purdam, C. and Cook, J. L.** (2010). *Landing strategies of athletes with an asymptomatic patellar tendon abnormality.* *Medicine and Science in Sports and Exercise*, 42(11), pp. 2072-2080.

**Fort, A. y Rodriguez, R.** (2013). Análisis de los factores de riesgo neuromusculares de las lesiones deportivas. *Apunts Medicina de l'Esport*. DOI: <https://doi.org/10.1016/j.apunts.2013.05.003>

**Gibson, J. J.** (1979). *The ecological approach to visual perception.* Boston: Houghton Miffling.

**Hewett, T. E., Paterno, M. V. and Myer, G. D.** (2002). *Strategies for enhancing proprioception and neuromuscular control of the knee. Clinical Orthopaedics and Related Research®*, 402, pp. 76-94.

**Hewett, T. E., Stasi, S. L. di y Myer, G. D.** (2013). *The American Journal of Sports Medicine Current Concepts for Injury Prevention in Athletes After Anterior Cruciate*. DOI: <https://doi.org/10.1177/0363546512459638>

**Hübscher, M., Zech, A., Pfeifer, K., Hänsel, F., Vogt, L. and Banzer, W.** (2010). *Neuromuscular training for sports injury prevention: a systematic review. Medicine & Science in Sports & Exercise*, 42(3), pp. 413-421.

**Tarragó, J. R., Cos, F., Gordillo, A., Lizarraga, M. A. and Martín, J. A.** (2005). *Training in team sports: coadjuvant training in the FCB. Apunts Educación Física y Deportes*, 35(138), pp. 13-25.

**Jukic, I., Prnjak, K., Zoellner, A., Tufano, J. J., Sekulic, D. and Salaj, S.** (2019). *The importance of fundamental motor skills in identifying differences in performance levels of U10 soccer players. Sports*, 7(7). DOI: [10.3390/sports7070178](https://doi.org/10.3390/sports7070178)

**Kelso, J. A. S.** (1991). *Behavioral and neural pattern generation: The concept of neurobehavioral dynamical systems. In Cardiorespiratory and motor coordination.* The United States: Springer.

**Kokstejn, J., Musalek, M., Wolanski, P., Murawska-Cialowicz, E. and Stastny, P.** (2019). *Fundamental motor skills mediate the relationship between physical fitness and soccer-specific motor skills in young soccer players. Frontiers in Physiology*, 10. DOI: <https://doi.org/10.3389/fphys.2019.00596>

**Landry, S. C., McKean, K. A., Hubley-Kozey, C. L., Stanish, W. D. and Deluzio, K. J.** (2007). *Neuromuscular and lower limb biomechanical differences exist between male and female elite adolescent soccer players during an unanticipated side-cut maneuver. The American Journal of Sports Medicine*, 35(11), pp. 1888-1900.

**Lee, H. M., Liau, J. J., Cheng, C. K., Tan, C. M. and Shih, J. T.** (2003). *Evaluation of shoulder proprioception following muscle fatigue. Clinical Biomechanics*, 18(9), pp. 843-847.

**Lephart, S. M. and Jari, R.** (2002). *The role of proprioception in shoulder instability. Operative Techniques in Sports Medicine*, 10(1), pp. 2-4.

**Liederbach, M., Kremenic, I. J., Orishimo, K. F., Pappas, E. and Hagins, M.** (2014). *Comparison of landing biomechanics between male and female dancers and*

athletes. Part 2: influence of fatigue and implications for anterior cruciate ligament injury. *The American Journal of Sports Medicine*, 42(5), pp. 1089-1095.

**Lloyd, D. G.** (2001). *Rationale for training programs to reduce anterior cruciate ligament injuries in Australian football. Journal of Orthopaedic & Sports Physical Therapy*, 31(11), pp. 645-654.

**López-Segovia, M., Marques, M. C., van den Tillaar, R. and González-Badillo, J. J.** (2011). *Relationships between vertical jump and full squat power outputs with sprint times in u21 soccer players. Journal of Human Kinetics*, 30. DOI: 10.2478/v10078-011-0081-2

**Manolopoulos, E., Katis, A., Manolopoulos, K., Kalapotharakos, V. and Kellis, E.** (2013). *Effects of a 10-week resistance exercise program on soccer kick biomechanics and muscle strength. The Journal of Strength & Conditioning Research*, 27(12), pp. 3391-3401.

**Newell, K. M., Broderick, M. P., Deutsch, K. M. and Slifkin, A. B.** (2003). *Task goals and change in dynamical degrees of freedom with motor learning. Journal of Experimental Psychology: Human Perception and Performance*, 29(2), pp. 379-387. DOI: <https://doi.org/10.1037/0096-1523.29.2.379>

**Orishimo, K. F., Kremenec, I. J., Pappas, E., Hagins, M. and Liederbach, M.** (2009). *Comparison of landing biomechanics between male and female professional dancers. The American Journal of Sports Medicine*, 37(11), pp. 2187-2193.

**Renshaw, I., Davids, K., Shuttleworth, R. and Chow, J.** (2009). *Insights from ecological psychology and dynamical systems theory can underpin a philosophy of coaching. International Journal of Sport Psychology*, 40(4), pp. 580-602.

**Robles-Palazón, F. J., López-Valenciano, A., Croix, M. D. S., Oliver, J. L., García-Gómez, A., de Baranda, P. S. and Ayala, F.** (2021). *Epidemiology of injuries in male and female youth football players: a systematic review and meta-analysis. Journal of Sport and Health Science*. DOI: 10.1016/j.jshs.2021.10.002

**Romero Rodríguez, D (2019).** *La fuerza y la potencia como cualidad clave en la readaptación de lesiones deportivas*. Module 1. Certificado en Entrenamiento de la Fuerza: de la Rehabilitación al Rendimiento. Barca Innovation Hub.

**Saunders, P. U., Pyne, D. B., Telford, R. D. and Hawley, J. A.** (2004). *Factors affecting running economy in trained distance runners. Sports Medicine*, 34(7), pp. 465-485.

**Seirul-lo Vargas, F.** (2017). *El entrenamiento en los deportes de equipo*. Spain: Mastercede.

**Serrano, J. L. A.** (2012). La planificación actual del entrenamiento en fútbol. Análisis comparado del enfoque estructurado y la periodización táctica. *Acciónmotriz*, 8, pp. 27-37.

**Schollhorn, W., Hegen, P. and Davids, K.** (2012). *The nonlinear nature of learning-A differential learning approach. The Open Sports Sciences Journal*, 5(1). DOI: 10.2174/1875399X01205010100

**Shalfawi, S. A. I., Haugen, T., Jakobsen, T. A., Enoksen, E. and Tønnessen, E.** (2013). *The effect of combined resisted agility and repeated sprint training vs. strength training on female elite soccer players. The Journal of Strength & Conditioning Research*, 27(11), pp. 2966-2972.

**Silva, J. R., Magalhães, J., Ascensão, A., Seabra, A. F. and Rebelo, A. N.** (2013). *Training status and match activity of professional soccer players throughout a season. The Journal of Strength & Conditioning Research*, 27(1), pp. 20-30.

**Sleivert, G. and Taingahue, M.** (2004). *The relationship between maximal jump-squat power and sprint acceleration in athletes. European Journal of Applied Physiology*, 91(1), pp. 46-52.

**Spencer, J. P. and Schöner, G.** (2003). *Bridging the representational gap in the dynamic systems approach to development. Developmental Science*, 6(4), pp. 392-412.

**Tous-Fajardo, J.** (1999). *Nuevas tendencias en fuerza y musculación*. Barcelona: Editorial Hispano Europea.

**Weyand, P. G., Sandell, R. F., Prime, D. N. L. and Bundle, M. W.** (2010). *The biological limits to running speed are imposed from the ground up. Journal of Applied Physiology*, 108(4), pp. 950-961.

**Williams, G. N., Chmielewski, T., Rudolph, K. S., Buchanan, T. S. and Snyder-Mackler, L.** (2001). *Dynamic knee stability: current theory and implications for clinicians and scientists. Journal of Orthopaedic & Sports Physical Therapy*, 31(10), pp. 546-566.

**Wisløff, U., Castagna, C., Helgerud, J., Jones, R. and Hoff, J.** (2004). *Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. British Journal of Sports Medicine*, 38(3), pp. 285-288.

**Wojtys, E. M., Wylie, B. B. and Huston, L. J.** (1996). *The effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. The American Journal of Sports Medicine*, 24(5), pp. 615-621.

**Woodhouse, L. N., Tallent, J., Patterson, S. D. and Waldron, M.** (2021). *Elite international female rugby union physical match demands: A five-year longitudinal analysis by position and opposition quality*. *Journal of Science and Medicine in Sport*, 24(11), pp. 1173-1179.

**Ziv, G. and Lidor, R.** (2010). *Vertical jump in female and male basketball players—A review of observational and experimental studies*. *Journal of Science and Medicine in Sport*, 13(3), pp. 332-339. DOI: 10.1016/j.jsams.2009.02.009