Module 4: Workload monitoring

Unit 4.1 Training theory. Adaptation mechanisms

A sound understanding of the scientific basis of training is necessary to improve our understanding of sports and the adaptation processes that occur across all facets of an athlete's body. Two of the theories that best explain these adaptation processes that result from performing physical activity are:

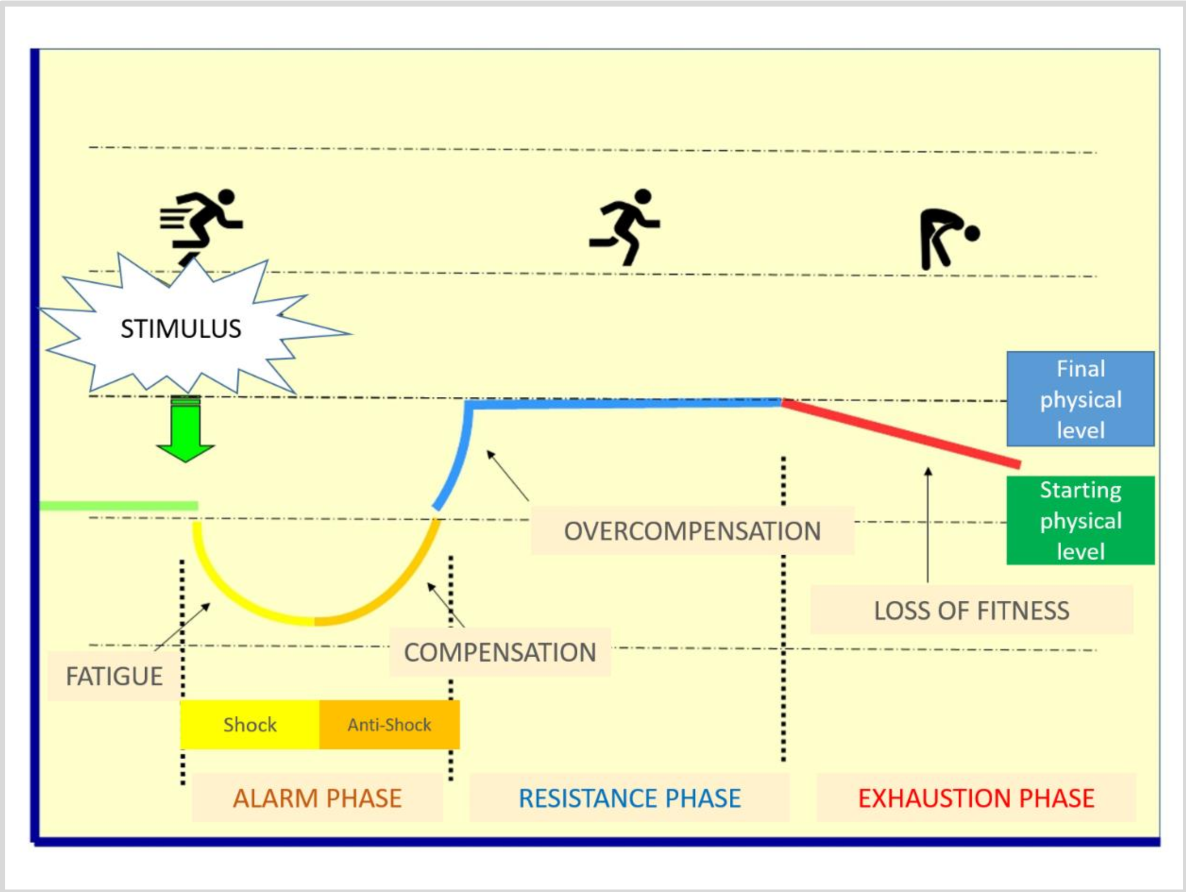
- General Adaptation Syndrome (GAS)
- Law of thresholds

General Adaptation Syndrome

This theory is based on the athlete's behavior in different situations that modify their state of equilibrium and generate different levels of stress. Described by Hans Selye in 1936, this theory states that the organism, when facing a stressful situation, reacts through a series of adjustments through which it attempts to restore balance (Wikideporte.com, 2014). Adaptation is divided into three main phases (see Figure 1):

- Alarm phase: the organism reacts to a stress situation with an imbalance (shock phase), followed by a rebalancing phase (anti-shock phase).
- Resistance phase: the body recovers and maintains a certain equilibrium, through which it gains a positive overcompensation and becomes more resistant to stimulation.
- Exhaustion phase: the organism does not attain equilibrium and ends up in a state of exhaustion. Excessive stress can lead to injury, or acute or chronic fatigue.

Figure 1: General Adaptation Syndrome applied to Fitness



Source: [Untitled image of the law of thresholds]. (u.d.). Retrieved from http://bit.ly/2HfaSUX

Law of thresholds

This law, also known as the Schultz-Arnold principle, is based on the threshold concept: a threshold is made up of the range of optimal stimuli in the intensity of a training session that will produce adaptations in the body. The range of optimal stimuli is normally between two intensities, called the adaptation threshold and the maximum tolerance threshold (see Figure 2).

Each athlete has a different threshold depending on variables such as age, sex, physical condition in addition to different thresholds for physical abilities: strength, endurance, velocity and flexibility. Based on each athlete's threshold, there are four types or classes of training stimuli–to make this explanation clear and relate it to team sports, let's establish that our team has four weekly training sessions that last between 75 and 90 minutes, plus a weekly competition in its microcycle:

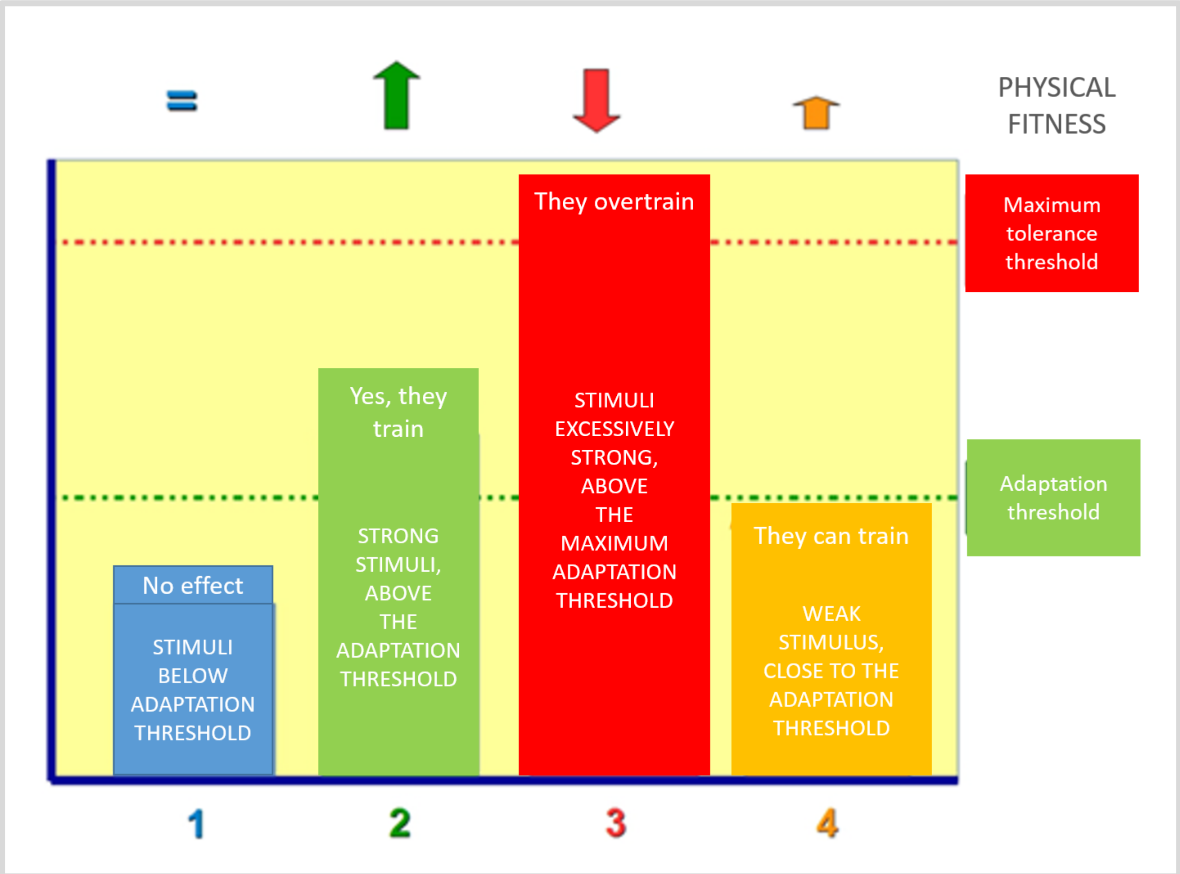
1. Stimuli below the adaption threshold (due to the minimal stimulus, does not result in adaptation in the body). In our example, isolated trainings of less than 30 min of group work will not produce enough stimulus to generate adaptations in the athlete.

2. Strong stimuli, above the adaptation threshold (due to its optimal stimulus, result in adaptation in the body and improve performance). In our team, the training sessions, which last between 60 and 100 minutes, will result in a positive adaptation and, typically, positive performance optimization for each of the players.

3. Excessively strong stimuli, above the maximum tolerance threshold (due to its high stimulus, results in overtraining which implies overexertion and causes a considerable state of fatigue). Used intermittently and sporadically, it can result in positive adaptations. To continue with the previous example, training sessions with the same average intensity, but of a much longer duration than usual (between 120 and 180 minutes), will cause a serious state of fatigue and, possibly, result in the athlete being overtrained.

4. Weak stimuli, close to the adaptation threshold (due to their proximity to the threshold, and the continuous and progressive repetition, they result in an adaptation in the body). From this example, this would be the case of more frequent training, but of a shorter than usual duration (between 50 and 60 minutes), whose stimuli are very close to the adaptation threshold, but which, due to their repetition and frequency, create positive adaptations in the player's body.

Figure 2: Law of thresholds



Source: [Untitled image of the law of thresholds]. (u.d.). Retrieved from https://goo.gl/8DzQRi

The principles of training can be defined as the set of rules and general guidelines used to plan, adjust and apply the training stimulus, in pursuit of the best possible adaptation of the athlete's body and the optimization of their performance. It is a concept more often associated with individual sports, but which also offers general training guidelines for team sports. The most relevant and necessary training principles in sports include:

Principle of generality or multilateralism: refers to the training session being global or generic, which means that it includes all of the sport's specific physical capabilities. This is closely related to how we understand team sports training. Variable, continuous and random practice from a multilateralism approach provide richer training stimuli for learning and performance optimization.

Principle of functional unit: refers to when the athlete works as a whole, and that this whole is much more than each of the parts. All structures (conditional, coordinative, cognitive,socio-affective, emotive-volitional, creative-expressive and mental) are totally related in any sports process, and we cannot train them in isolation as separate elements or compartments. Furthermore, if the training process is based on the principle of functional unit, in addition to optimizing the performance of athletes across many structures, we will simultaneously facilitate their motor and cognitive skills.

Principle of continuity: refers to training that maintains continuity and periodicity over time. The different stimuli need to be applied with an appropriate interval of time between each, taking into account that, according to the preferential physical capacity, they must be spaced out to a greater or lesser extent to produce optimal adaptations in the athlete's body. However, optimal stimuli with discontinuity can be useless and even result in a detraining process when there are periods of prolonged inactivity after periods of optimal training.

Principle of progression: also known as the principle of gradual increase of effort, this refers to training that is undertaken in a gradual and progressive way, respecting the athlete's current physical fitness. With small progressive stimuli and with the necessary continuity, greater improvements in performance can be obtained, but the most important outcome is that these improvements last longer over time.

Principle of individualization: refers to training that is individually tailored to the athlete. Even in individual sports, two athletes with the same specialty at the same moment of the season, will have different levels of physical fitness, personal and professional circumstances, weight, anthropometries and prior experiences, just to name a few of the main characteristics that must be taken into consideration when implementing an individualized training plan. In team sports, for a long time training consisted of providing the same content to all team members but, especially in present-day high performance sports, a lot of attention is being given to individualized stimuli based on the athlete's current condition, both during optimizing and adjuvant training sessions.

Principle of optimal load and recovery ratio: refers to the alternation of optimal training stimuli and recovery processes. Depending on the intensity and each stimuli and the preferential physical capacity, there are optimal recovery periods. These can range from 24 hours (in the case of aerobic endurance training) to 48-72 hours (in the case of anaerobic resistance or maximum strength training).

Principle of specificity: refers to training of a specific character for most of the application time. Said specificity can be based on, firstly, the muscle groups and the motor patterns most used in the sporting specialty and, secondly, the training content most similar to or that is reproducible or preferred from the competition. The principle of specificity may not be as relevant at early ages however in adults and high performance environments it is very important.

Conjectures about training

Within team sports, some principles of training are put into effect differently and can be substituted, implemented or modified as systemic conjectures. These conjectures, rather than being norms or rules, are derived from judgments or opinions based on the practical experience of well-known coaches in these sports. They contribute concepts to the practice that respond to the complexity of team sports and the competitive conditions of this environment:

Synchronous efficiency conjecture: refers to the commitment to identify the point up until which one (or several) training stimuli maintain the optimizing effect in their application on the same group of players. Based on variability and on this synchronic efficiency, for team sports, the norm is not to repeat an exercise more than three times with the same preference and the same assignments. The aim is to always look for new adaptations in the player.

Intrasystemic conjecture: when optimizing a system in a player's structure, a self-optimization (self-organization) of other systems in the same structure or in others can occur simultaneously. In our training tasks (preferential simulator situations [PSS]), one structure should be preferentially optimized, whilst others are favored at the same time. For example, we can use a circuit with preference for the conditional structure, where we incorporate technical (coordination) elements to achieve optimization in both structures.

Utility and temporary efficiency conjecture: it is important to know how much time in a session should be invested to optimize a certain system of a certain structure in order to be temporarily efficient. Following the idea that "a little bit of good is better", time should be used for optimization, without going over time or without providing sufficient time to achieve what we are really seeking to achieve in any training situation.

Hologrammatic conjecture: this refers to the requirement that each training unit should include the representation of all the elements of the game event that need to be optimized in a training session. Our biggest challenge is to get the most benefit out of each training situation, and to propose variables and structural superpositions in order to simulate all the game elements.

Synergistic conjecture: proposes practicing different combinations of content of training situations and their organizational strategies within the programming, until synergic effects between them are found. Synergies between the different episodes of the same training session should be generated, as well as different sessions within the microcycle, to promote connections and interrelations in the contents.

Competence conjecture: training situations must be compatible and almost identical to the game event situations that we want as a model for our team in the competition. All the organizational strategies that are programmed should be in line with one of the conjectures, or with several of them, and should never go against any of them.

Traditional planning vs team sports planning

Planning, periodization and programming

By planning, we mean the systematic and generalized development of a plan that contemplates, among other aspects, the training objectives, the main competitions, and all the training principles and conjectures, as previously discussed. Sports periodization, within planning, represents the partial intervals into which training is divided, in order to monitor the optimization of the athlete, and compile all the training and competition results. Programming is the operative form in which the periodization model is determined, the training work plans, contents, means and methods are organized and distributed, as well as the load distribution, expressed in volume and intensity values throughout the periodization.

The basic structures of training planning can be encompassed in different periods: multi-year, seasons, macrocycles, mesocycles, microcycles, training sessions, etc. Normally, these structures are designed with traditional planning in mind, typically for individual sports.

Microcycle: in most team sports, the basic structure is the microcycle (a period that normally takes place between 2 competitions), although it is traditionally understood as being one week. In high performance, the density and the number of weekly competitions can vary and, furthermore, the days of competition can vary, thus sometimes, within the microcycle, it is easier to see the structure of competition days (match day or MD) or the days before or after a match (MD + 1, MD - 4, MD - 3, MD - 2, MD - 1).

Mesocycle: in team sports, mesocycles usually cover the period of time between two important competitions (more important than a typical match). Traditionally, however, this period is understood as the time period of one month. In traditional planning, which has also been widely used in team sports and which is probably still used by elite coaching staff, the planning model known as the contemporary or ATR (Accumulation, Transmutation, Realization) model is followed. The content of these models is organized into three different blocks or mesocycles: 1) accumulation; 2) transmutation; and 3) realization, moving from more general to specific contents and with a load tendency that moves from volume to intensity.

Macrocycle: both in traditional and contemporary planning, these periods are better known as the pre-season (period prior to the official competition season), competitive period (most important part, where all official team or individual competitions take place), and transition period (which is usually a period of reduced activity, where the athlete recovers from all the effort in the competitive period and restores levels to start a new season again).

Season: the season is the entire period that includes macrocycles, mesocycles, microcycles and training sessions during a sports year. In team sports, when we train, we usually set a series of main objectives for the entire course of the season.

Multi-year plan: in traditional and large-scale planning, there are also multi-year plans, which usually extend from two to four years and typically include cycles across age categories; and at the elite level, they include world championships, European or Olympic cycles.

MULTI-YEAR PLAN

SEASON

MACROCYCLE

MESOCYCLE

MICROCYCLE

TRAINING SESSION

TRAINING EXERCISE

Functions of planning

The following functions of planning, specific to team sports, were outlined by Paco Seirul·lo (2017):

- Define the training objectives, drawn from each phase of the personalized plan and corresponding to the specific moment of the player's sporting life, to adapt them to the individual.
- Describe training elements that are specific to the specialty and are derived from the structural characteristics of the same, which are considered the most efficient for the achievement of those objectives.
- Logical organization of the training elements and contents that have been chosen, all in accordance with the principles and laws of the supporting theories of reference.
- Design the sequence and quantification of the training load according to the competition and the associated importance for the player, who must be taken by those elements at different moments of the training process.
- Select the individual's systems where loads will be directed to control the configuration of their performance.
- Establish the most suitable types of training for each and every one of the systems previously selected, as well as the application time and its consequence.

- Have the valid control mechanisms in place to monitor all these processes and their effects on the athlete's different systems.
- Have technology that supports the assessment of the athlete during the competition to analyze the impact generated.

All these functions maintain the training process in a continuous state of review to continually adapt it to the personal needs of each player. (Seirul-lo Vargas, 1998)

Tactical periodization (TP) versus structured training (ST)

In the realm of team sports, and more specifically in soccer, there are two up-to-date planning methodologies, based on the complexity of training and the competition in this sport. On the one hand, there is Vitor Frade's tactical periodization (TP). He is a professor at the Faculty of Sport of the University of Oporto, and his theories have been well represented in work by Tamarit (2013). On the other hand, there is Paco Seirul-lo's structured training (ST). He is a Barcelona INEFC professor and FC Barcelona (Soccer Club) physical trainer in handball and football for 20 years. The theoretical proposals have their differences but also some points in common, such as the following:

- They approach the athlete from a global point of view, based on the idea that the whole is more than the sum of its parts. The relationship and interaction between the different structures and elements that make up performance are considered especially relevant.
- They use specific training principles for team sports, where sometimes the usual laws, principles and planning concepts of individual sports cannot be applied:
  - Principle of complex progression: proposes a progression in the contents, which refers to the complexity within the principles of the model of the game.
  - Principle of specific horizontal alternation: proposes a series of contents that are given alternately during the session and the microcycle (morphocycle), based on three parameters related to muscle contraction (tension, duration and velocity regimes), in a way that guarantees the principle of an appropriate relationship between effort and recovery.
  - Principle of propensities: proposes the systematic repetition of game situations that can occur, or that we foresee could occur, for the players in the next match.
  - Principle of specificity or suitability conjecture: proposes undertaking different training situations (preferential simulator situations) that produce constant and

continuous optimization in the player for the next competition, as well as the necessary adaptations depending on their delimitation and on the roles to be performed.

Content structuring. Morphocycle pattern (TP) versus structured microcycle (ST)

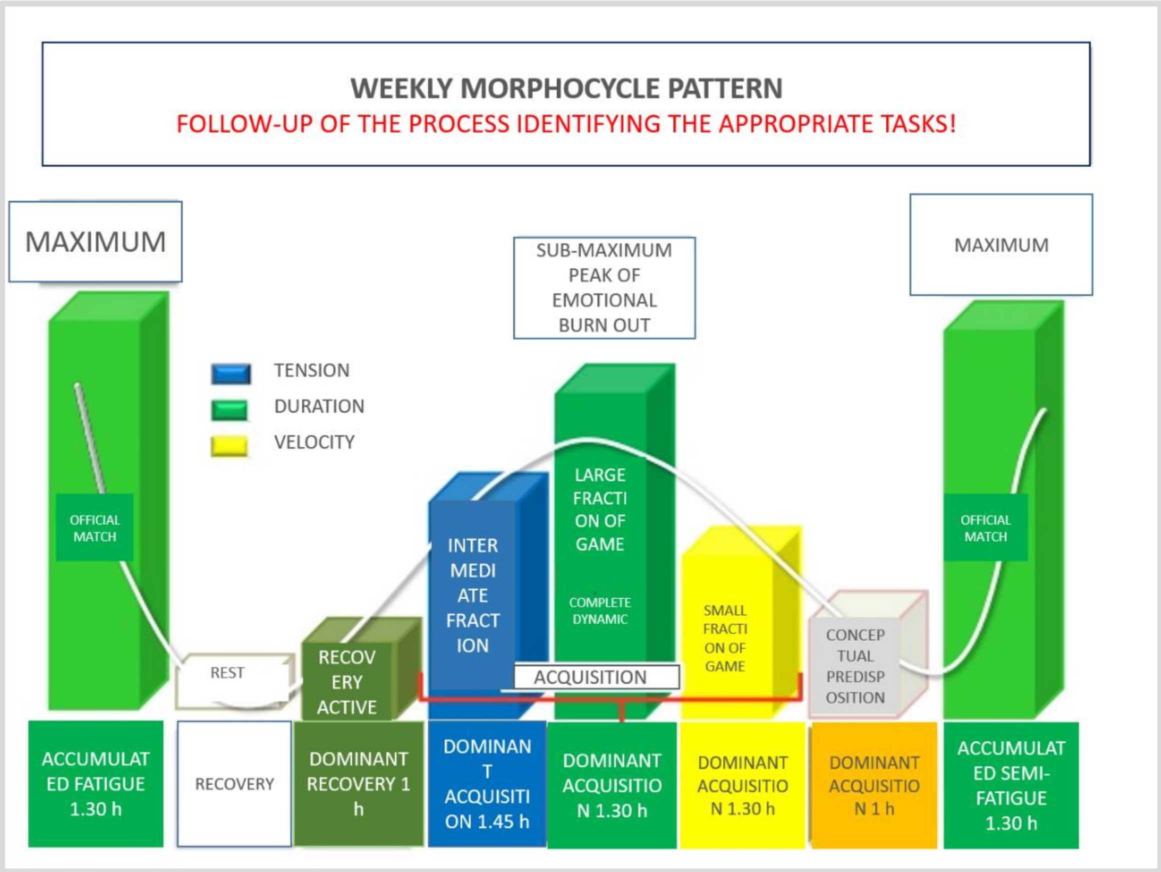
In tactical periodization, the standard morphocycle is the fundamental nucleus of the seasonal organization of training. Objectives revolve around preparation for the next game based on the analysis of the previous game (Arjol, 2012).

Within the weekly structure, two main phases are differentiated:

- Recovery phase: the two days following the previous game and the day before the next competition.
- Acquisition phase: the central days of the microcycle, in which the bulk of the training contents are worked on according to the principles and subprinciples of the game model.

The morphocycle format is identical or very similar over time and always uses the same training pattern, even with regard to the team's scheduled days off.

Figure 3: Weekly Morphocycle Pattern



Source: Espar, 2017, https://goo.gl/rJZGx1

Structured training (ST) is based on the fact that, in team sports, a team competes for 40 consecutive weeks, sometimes with one or two weekly competitions, and the athlete is subjected to maximum competition stress over an extended period of time. This load must be taken on as a specific and fundamental load within planning. Therefore, a training format is developed, the ST where the structured microcycle (SM) becomes the unit which allows for competition and is also how the different structures are modified during the week.

Within the weekly structure, four main phases are differentiated:

- **Restoration phase**: the objective is to restore the physical and mental effort used in the competition.
- **Implementation phase**: the objective is to facilitate preparation for the next game, so it focuses primarily on the introduction of new game concepts (defense or attack) depending on the opponent. To these new concepts, the specific needs of the team can be added based on the weak points from the previous match or the preparation for the next match.

- **Optimization phase**: the objective is to facilitate preparation for the next game, so it focuses primarily on the introduction of the game concepts already incorporated (defense or attack). These concepts are unique to our game model, our way of playing, those situations that make us recognizable as a team and that give us a feeling of belonging to a certain style.
- **Activation phase**: the objective is to facilitate the preparation for the next game by bringing together everything worked on during the microcycle. All the main situations during the week must be brought together and implement an adequate and effective activation so that the player efficiently recognizes the situations in competition.

Another distinguishing characteristic of this model is planning the SM sequences. Microcycles are normally planned three at a time and the load dynamic is integrated. We do not plan more than 3 microcycles, since all the dynamics must be implicit and related to each other. This is to ensure a horizontal and vertical relationship between the PSSs of the three planned microcycles, according to the calendar, the rival and the moment of the season. Once the three planning units are established, we can discuss SM using the conjectures (which are not traditional training principles) to identify the relationships that exist between the implementation and the optimization of the first and third week.

Unit 4.2 Training load: internal load-external load

The main objectives of high performance team sports are performance optimization and injury risk reduction. As seen in the previous unit, performance optimization is achieved through positive adaptations, once we follow the training principles and conjectures applicable to team sports. There is a lot of information available that can help us to establish optimal training monitoring through quantification of the loads.

In the world of training, the training load has traditionally been understood as the product of training volume because of its intensity:

$$(L = V * I)$$

More specifically, important authors in the field such as González Badillo and Ribas Serna (2002) define the training load as the combination of biological and psychological demands (**internal load**) caused by the training activities undertaken (**external load**).

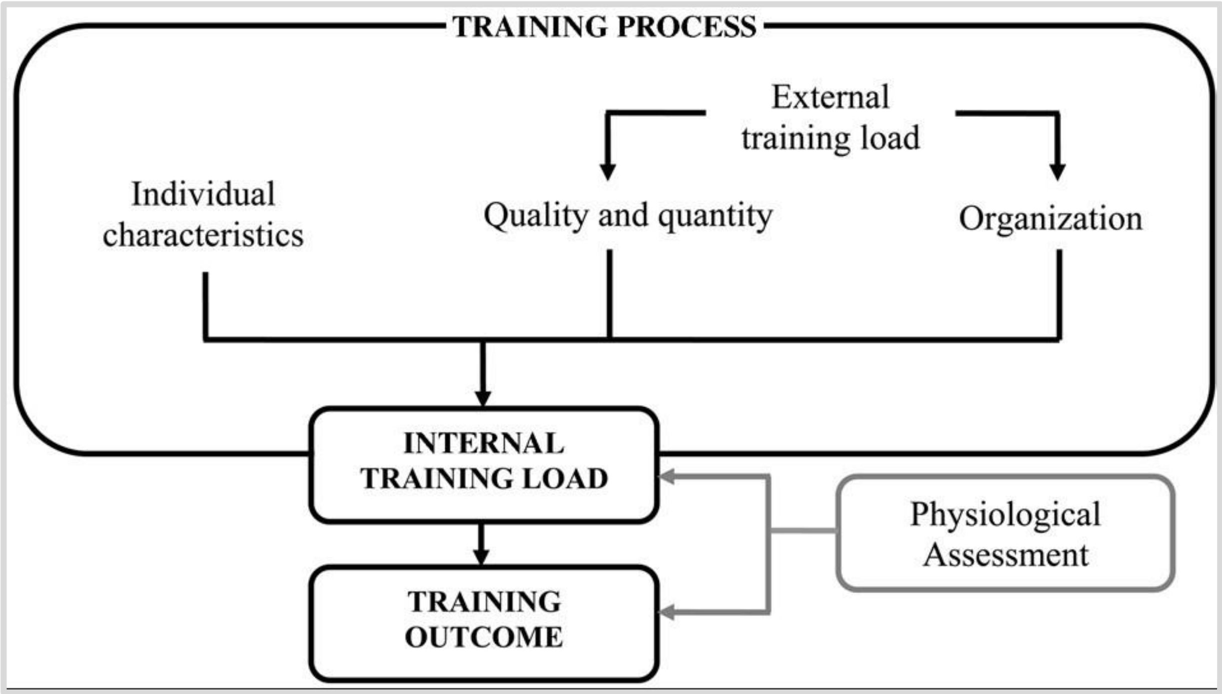
From both loads we can obtain enough information to monitor our athletes and from here we must be able to observe positive or negative adaptations in performance. Associations between internal and external load have been studied extensively in recent research, in order to better understand training process and, therefore, validate some of these internal measures (Mc Laren et al., 2017).

Internal load represents the biochemical (physical and psychological) and biomechanical responses that occur in the athlete. There are four main ways to quantify the internal training load in team sports:

- Heart rate (HR)
- Maximum oxygen consumption (VO2max)
- Rate of Perceived Exertion (RPE)
- Blood lactate concentration (BLC)

The external load represents the quantitative conditional workload performed during training or competition. It can be measured using tools such as GPS or multi-camera systems used to monitor training activity or competition, and from there, within team sports, an analysis of different performance variables tracked per day of the week, the microcycle and the season in question can be carried out. Maximum variables such as maximum speed reached, maximum acceleration and deceleration are analyzed in conjunction with other important variables such as total distance covered, high intensity running or high metabolic load distance, etc., which we will examine further later.

Figure 4: Physiological assessment of aerobic training in soccer



Source: Impellizzeri, Rampinini, & Marcora, 2005, https://goo.gl/q8wtZe

As an example of the relationship between internal and external loads, Impellizzeri et al. (2005), in their model of physiological assessment of aerobic training in soccer, provide a diagram that summarizes the relationship between the results of the training process, based on the athlete's individual characteristics, and the external load (quantity, quality and organization), with the physiological assessment based on the training results and the internal load.

Methods: Resources for monitoring internal load

Heart Rate (HR)

Heart rate has been one of the most used means to quantify load in team sports, due to it being a low cost, highly reliable and non-invasive method for measuring an athlete's physiological variables during most sport situations.

Heart rate monitoring has been studied and analyzed using two methods, which provide information about internal load control in team sports:

- First, the TRIMP method refers to the increase in heart rate, considering the duration of training multiplied by a factor of intensity, proposed by Bannister, Carter and Zarkadas (1999):

Men: duration (min) x (HRex - HRrest)/(HRmax - HRrest) x 0.64e ^ 1.92x

Women: duration (min) x (HRex - HRrest)/(HRmax - HRrest) x 0.86e ^ 1.67x

e = 2.712, x = (HRex - HRrest) / (HRmax - HRrest), HRrest = Average heart rate during recovery, and HRex = Average heart rate during exercise (Bannister, 1991)

- Another method used is the Edwards method (1993) with training zones. This is based on five zones, each of them with a pre-established value for the player, (50-60 % = 1, 60-70 % = 2, 70-80 % = 3, 80-90 % = 4 and 90-100 % = 5), taking into account HR reserve, that is, the HR maximum minus the HR at rest:

  Zone 1 = 50-60 % of the HR maximum; Zone 2 = 60-70 % of HR max.; Zone 3 = 70-80 % HR max.; Zone 4 = 80-90 % HR max.; Zone 5 = 90-100 % HR max (Edwards, 1993).

In our own research, the result of the doctoral thesis by Gómez, Pallarés, Díaz and Bradley (2013), we studied different internal load variables in elite soccer players, such as heart rate and rate of perceived exertion. Due to the scientific evidence that a soccer match is played at an average of 85 % of the maximum heart rate, we use this measure to create a variable of high intensity for the quantification of the training load (TTE> 85 % HR max. in minutes):

Figure 5: Average and quantification of the load of preparatory sessions and quantification of official matches (daily mean, weekly mean and weekly total) using heart rate.

	Daily Mean		Weekly Total	
	Elite (n = 21 weeks)	Sub-elite (w = 19 weeks)	Elite (n = 21 weeks)	Sub-elite (w = 19 weeks)
Quantification Preparatory Sessions				
TTT (min)	84.7 ± 13.5	81.4 ±13.9	244 ± 51	284 ± 49*
TTT > 85% HR_{max} (min)	18.2 ± 3.2	28.0 ± 8.2*	66.7 ± 11.9	90.4 ± 34.2*
% of TTT High Intensity (%)	21.8 ± 4.3	34.8 ± 8.8*		
RPE mean	3.5 ± 0.5	3.9 ± 0.7*		
% HR_{max} mean	68.8 ± 1.5	74.8 ± 2.8*		
	Mean per Match			
	Elite (n = 21 weeks)	Sub-elite (w = 19 weeks)		
Quantification Official Matches				
DE match (m)	9.876 ± 404	10.552 ± 582*		
DE match > 19.8 km/h^{-1} (m)	822 ± 131	1.183 ± 112*		

*Significantly different ($p < .05$) when compared to Elite level results. TTT: total training time; % HR max: percentage of the maximum heart rate; RPE: rate of perceived exertion; DE Match: distance covered in official match.

Source: Gómez Díaz, A. J., Bradley, P. S., Díaz, A., & Pallarés, J. G. (2013)

Figure 6: Correlation between the main study variables

1	2	3	4	5	6	7
1. TTT (min)	.52**	-.08	.78**	-.04	.17	.23
2. TTT > 85% HR_{max} (min)		.80**	.82**	.55**	-.03	-.51**
3. % of TTT High Intensity (%)			.45**	.63**	-.20	.44*
4. RPE mean				.32*	.20	.43*
5. % HR_{max} mean					.40*	.65*
6. DE match						.77**
7. DE match > 19.8 km/h^{-1}						

* p < .01; * * p < .001. TTT: total training time; % HR_{max}: percentage of the maximum heart rate; RPE: rate of perceived exertion; DE Match: distance covered in official match.

Source: Gómez Díaz, A. J., Bradley, P. S., Díaz, A., & Pallarés, J. G. (2013)

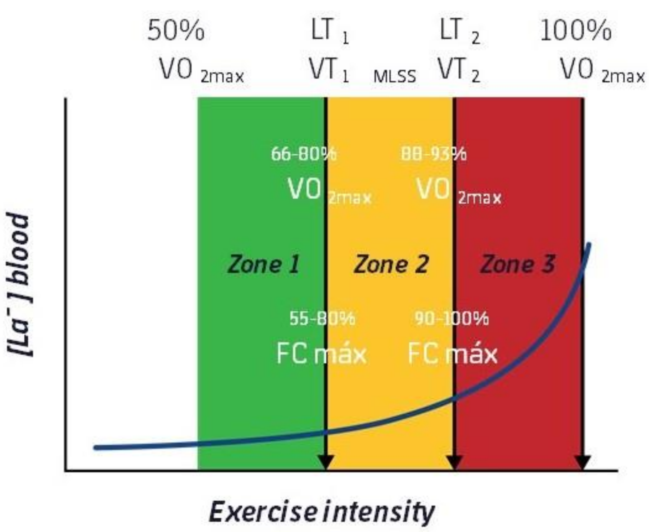
Correlation between the main study variables

From this study and its data, we can observe a high correlation of internal load parameters TTE> 85 % HR max. with other internal load variables such as RPE and also external load parameters such as distance traveled at high intensity in competition, among others.

Maximum oxygen consumption (VO2 max)

The traditional methods used to measure VO_2 max make its everyday use in training impossible. Furthermore it is currently impossible to use in competitive settings in team sports. Some authors have determined that HR monitoring is an adequate indicator of exercise intensity due to its close relationship with VO_2 max (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Likewise, this parameter has been commonly used to measure intensity in team sports:

Figure 7: Training Zones



Source: Muñoz, 2014, https://goo.gl/dKp6Dt

In the same way that the average HR in a soccer match is estimated to be 85 % of the maximum HR, the average oxygen consumption in a soccer match can be indirectly estimated to be 70 % of VO_2 max.

However, team sports present some specific characteristics such as the intermittent and submaximal nature of actions. This intermittent structure of the game, together with thermal or emotional stress that may occur during the competition, could alter the linear relationship between HR and VO_2 (Casamichana, San Román, Calleja, and Castellano, 2015).

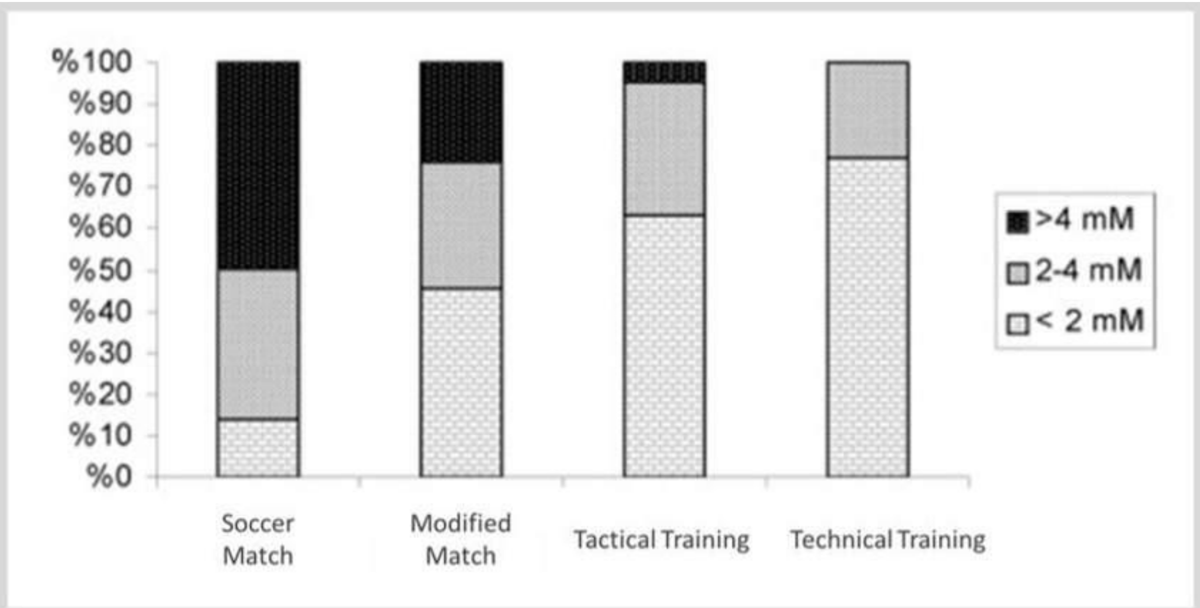
Blood lactate concentration

Another measurement taken to quantify the athlete's internal load is blood lactate concentration, normally measured using different portable analyzers, that have made its evaluation during training and competition possible.

In general terms, both the variables of VO_2 max and sanguineous lactate anaerobic threshold can be used to explain performance in endurance sports, but can also be used in team sports. Since sanguineous lactate is associated with the physiological load, this can be correlated with an athlete's heart rate to assess the internal load.

Bearing in mind that scientific studies (specifically in soccer) have shown that lactate concentrations are between 4 and 6 mM during a match, the 2 mM lactate line is normally used as an aerobic threshold, while the 4 mM lactate line is used to indicate the start of the anaerobic threshold. From these assessments there are different internal load magnitudes for different contents in training sessions and matches:

Figure 8



Source: Eniseler, 2005, page 801. Journal of Strength and Conditioning.

Percentage of heart rates recorded below, between and above the heart rates corresponding to the 2- and 4-mM reference lactate lines during different soccer training activities.

Rate of Perceived Exertion (RPE)

RPE is probably the most economical and easy to use, non-invasive method that collects individual information from the player during or at the end of the sporting activity itself. RPE scales (Borg, 1982) are quantified by athletes attributing a subjective perception of physiological stress based on perceived exertion.

Traditionally, the Borg-RPE scale included scores between 6 and 20. However this was modified to a scale of 1-10 for better understanding, once results and academic assessments became more familiar with it.

Figure 9: Relationship between rate of perceived exertion and training zones

RPE TRAINING ZONES

BORG RPE	MODIFIED RPE	BREATHING	TRAINING ZONE	% of MHR	TYPE
6	0	No exertion	1	50% - 60%	Warm-Up
7		Very light			
8	1				
9					
10	2	Notice breathing deeper, but still comfortable. Conversations possible.	2	60% - 70%	Recovery
11					
12	3				
13		Aware of breathing harder; more difficult to hold conversation	3	70% - 80%	Aerobic
14	4				
15	5	Starting to breathe hard & getting uncomfortable	4	80% - 90%	Anaerobic
16	6				
17	7	Deep & forceful breathing, uncomfortable, don't want to talk	5	90% - 100%	VO2 Max
18	8				
19	9	Extremely hard			
20	10	Maximum exertion			

Source: Daley, 2011, https://goo.gl/cDUcui

Through this method's subjective analysis, necessary information is provided by the player as they use said scale, which consists of asking the player to score numerically (from 0-10 when using the modified Borg Scale) how hard the session was for them. Using that score, the training load is then easily calculated by multiplying this subjective value of exertion by the duration of the session in minutes.

As an example, we will provide information about a soccer match, in which a player indicates (quantitatively) a level of fatigue/tiredness with a RPE of 10, and at training on day -3 with a RPE of 6. As shown below, based on the same duration, different loads are calculated:

Match = 95 min x 10 RPE = 950 load units
Training -3 = 95 min x 6 RPE = 570 load units
(60 % of match load)

The Borg scale is also used to identify the type of work that has been done during the session, as it can be used to classify the intended focus and preferences throughout a given session. Thus:

- The first three levels of the scale correspond to a preferably aerobic training.
- Below the aerobic threshold, between three and seven is considered the mixed zone (between the aerobic and anaerobic thresholds).
- From a score of seven onwards, the training is predominantly anaerobic.

Self-Perception of Health (SPH)

Wellbeing questionnaires have become relevant in team sports and high performance sports. Increasingly there is greater interest in the athlete's self-perception and how this relates to training and competition stimuli. Recent research in these sports demonstrates that there is a close relationship between the impact of training and the athlete's state of well-being and mood.

McLean, Coutts, Kelly, McGuigan and Cormack (2010), in rugby, and Morgan, O'Connor, Ellickson and Bradley (1998), in athletics, researched wellbeing questionnaires. They evaluated five main sections in the questionnaires: athlete's perception of fatigue, sleep quality, muscle soreness, stress levels and mood. For the assessment of each, they used a scale from 1 to 5 (lower to higher wellbeing):

Figure 10: Example of a wellbeing questionnaire

	5	4	3	2	1	Record Score
FATIGUE	Very fresh	Fresh	Normal	More tired than normal	Always tired	
SLEEP QUALITY	Very restful	Good	Difficulty falling asleep	Restless sleep	Insomnia	
GENERAL MUSCLE SORENESS	Feeling great	Feeling good	Normal	Increase in soreness/tightness	Very sore	
STRESS LEVELS	Very relaxed	Relaxed	Normal	Feeling stressed	Highly stressed	
MOOD	Very positive mood	A generally good mood	Less interested in others &/or activities than usual	Snappiness at team-mates, family and co-workers	Highly annoyed/ irritable/down	

Source: Morgan, O'Connor, Ellickson, and Bradley (as cited in Andoni, 2016, https://goo.gl/pWy5aV).

Methods: Resources for monitoring external load

Currently, GPS technology and accelerometers have been used in team sports to quantify the movement demands on athletes in training and competition situations. These devices are non-invasive, small and light-weight, they are individual and are not excessively expensive. Thus they continue to be highly successful at monitoring conditional capabilities in the field.

In an effort to classify and clarify the different variables that are obtained using said technologies, in a recent study (Fernández, Medina Leal, Gómez, Arias Vicente, and Gavaldà Mestre, 2016) in the area of athletic performance at FC Barcelona the variables were divided into the following groups, which in turn can be used for all team sports:

Table 1: Description of the selected physical variables divided into three groups: locomotor, metabolic and mechanical

Locomotor variables:
Distance covered (DIS)
Sprints (SPR)
High speed running (HSR)
Max speed (MAX)

Metabolic variables:
Average metabolic power (AMP)
High metabolic load distance (HMLD)
High metabolic efforts (HEF)
Energy expended by the player per second per kg, measured in W/kg
Distance traveled by the player when the metabolic power is> 25.5 W/kg
The number of movements or efforts undertaken in producing HMLD
Total distance covered during a session or matches
Number of times over 5.5 m/s for more than 1
Meters covered when speed is > 5.5 m/s
Maximum speed reached by the player

Mechanical variables:
Fatigue index (FAI)
Dynamic stress load (DSL)
Total loading (TLO)
Accelerations (ACC)
Decelerations (DEC)
Step balance (STE)
Accumulated DSL from the total session volume, in terms of speed (DSL/SPI)
Total number of impacts, based on the total number of impacts, based on accelerometer values over 2 g
The total of the forces on the player over the entire session based only on accelerometer data
Number of increases of speed during at least 0.5 s (> 3m/s^2)
Number of decreases of speed during at least 0.5 s (> 3m/s^2)
Ratio of left step impacts to the sum of left and right step impacts

Source: Description of physical variables. (Adapted from Fernández, Medina Leal, Gómez, Arias Vicente, and Gavaldà Mestre, 2016)

Based on these variables, reports are created about training exercises, training sessions, microcycles and evolution by player or group of players.

Figure 11: Example Wimu Conditional session and training exercises report

Source: Prepared by the author

Other external load monitoring resources can be obtained using multi-camera system video recording. Normally, each of the players is assigned a point prior to training or competition, and from there a series of variables that can be conditional and also technical-tactical in the case of team sports are studied.

As a summary, in the following table we outline the main variables looked at in our soccer competition matches using the multi-camera system.

Figure 12: Example of Mediacoach individual player report Eventing, accumulated technical data

Eventing

Summary of accumulated data

	Mean	Total		Mean	Total
Goals scored	0,09	1	Shots	0,54	6
Goal assist	0,00	0	Shot assists	0,63	7
Total passes	69,58	777	Good passes	61,52	687
Recovered balls	5,73	64	Lost balls	12,54	140
Fouls received	1,88	21	Fouls committed	0,99	11
Yellow cards	0,00	0	Red cards	0,00	0
Off-sides	0,00	0	Standings	0,00	0

Source: Prepared by the author.

Figure 13: Example of Mediacoach tactical report Distances between lines of players, breadth and depth

Source: Prepared by the author.

Adjuvant Training. Monitoring strength training

In the theory and practice of high performance team sports training, there are two established training methods within structured training.

Firstly, there is *optimizing training*, which covers the programming, design, execution and control of training tasks, and aims to optimize the performance of the athlete in all competitions that they participate in throughout their athletic life.

Secondly, there is *adjuvant training*, which works as a complement to the former. This includes all the practices that allow the athlete not only to achieve a state of success and to protect their health–which means the tasks set by the optimizing training each day can be carried out (Seirul-lo, 2017)–but also to strengthen the elements, structures and systems required by each specialty and that facilitate the athlete progressing towards the desired level of performance. This training is as important as optimizing training, however, sometimes its practice is underestimated, as it does not directly affect the athletes' performance.

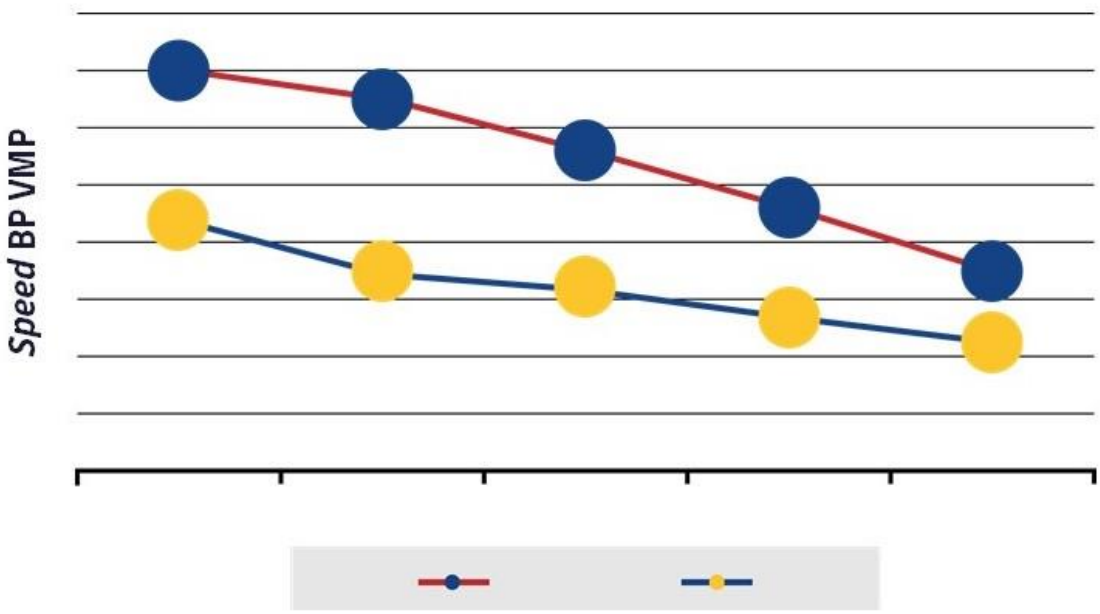
VBST (*velocity based strength training*) is used as part of adjuvant training and to monitor strength training. VBST utilizes different technology, such as accelerometers or linear or inertial *encoders* to measure the speed of movement in an exercise. From the information on the speed of movement, both the coach and the athlete can observe performance immediately and obtain specific and real *feedback*, in order to adjust the training.

Traditionally, strength training has been monitored using absolute weight (in kg) or relative weight (based on repetition maximum or % 1RM). However, in a more recent trend, researchers such as Sánchez Medina and González Badillo (2011) state that coaches should prescribe strength training based on the speed of movement focusing mainly on two variables:

- The average velocity of the first or best repetition.
- The maximum percentage of velocity loss for a repetition with regards to the best repetition of the set. Example: If the percentage of loss within a set is greater than 15%, the feedback is not positive and the set should end. This is very important, since it allows us to observe and limit the athlete's fatigue during any movement.

In the end, with regards to high performance, the player's improvement is achieved by optimizing strength and, therefore, the speed of execution and power. If we want athletes to move a load faster (an external load or their own body weight), then more strength is being applied in less time and, consequently, that improvement in the speed of execution will be accompanied by an improvement of strength and power.

Figure 14: Difference between two training tests with different loads for the same exercise (half squat HS) in a professional soccer player

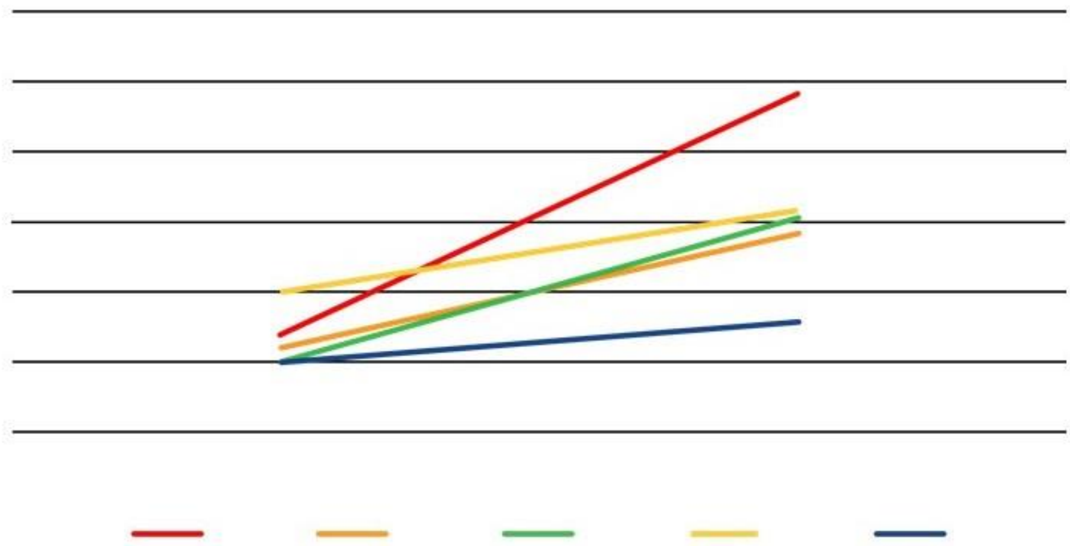


Source: Gómez, 2017 (prepared by the author)

Ultimately, and according to Jovanovic and Flanagan (2014), a series of benefits will be obtained from monitoring velocity in strength training:

- Develop an individual load-velocity profile per athlete and movement.
- Use this load-velocity profile to predict and monitor changes in maximum strength.
- Use velocity monitoring to control the effects of fatigue in strength training.
- Use velocity monitoring for immediate performance feedback to reach the maximum level of effort in certain exercises and utilize it as a training stimulus to achieve greater adaptation.

Figure 15: Velocity improvement with different loads for the same exercise (half squat HS) in a group of professional soccer players



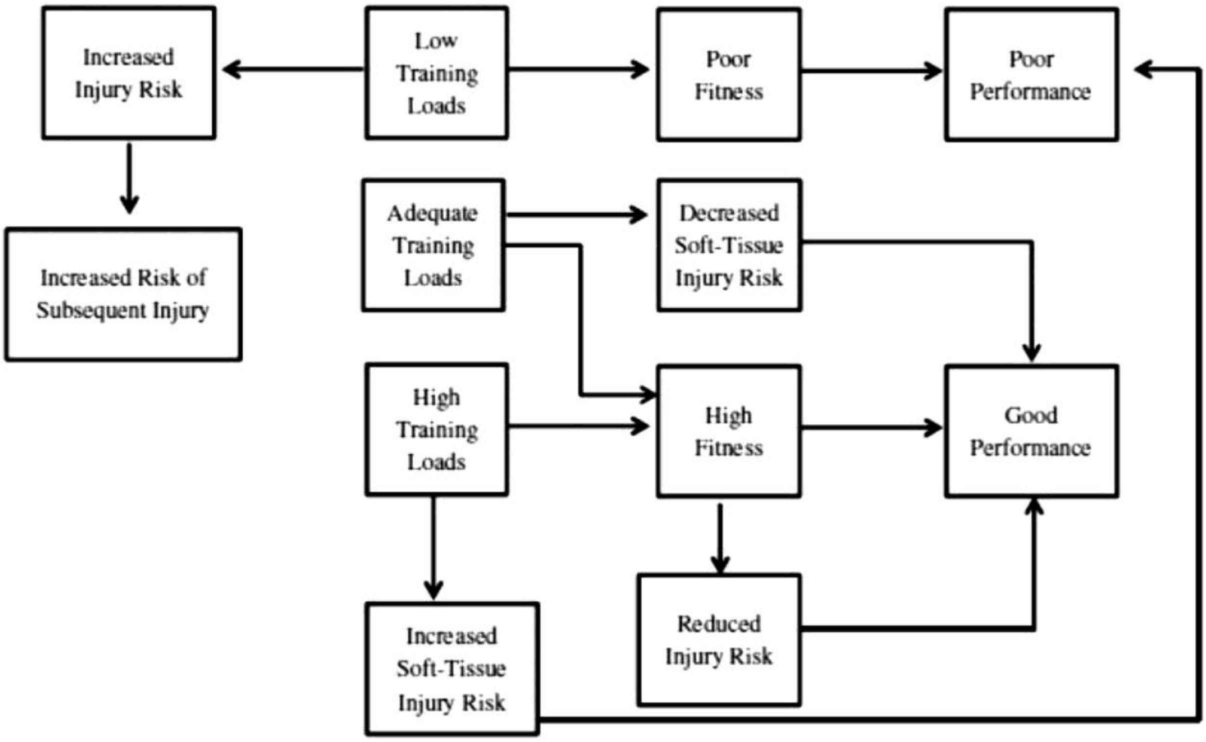
Source: Gómez, 2017 (prepared by the author)

Objectives: optimizing performance and reducing injury risk

As discussed at the start of this unit, the main objectives of high performance team sports are performance optimization and injury prevention. Professional soccer teams with fewer injuries per season perform better in national leagues, in the top leagues in Europe and in European Cup competitions (Hägglund et al., 2013). Hence we have to take into account factors that facilitate injury prevention.

In our opinion, the best prevention comes from a good state of physical preparation, appropriate load control and an optimal dose of competition. In this regard, well-known researchers in this field such as Tim Gabbett (2016), from Australia, provide the evidence and implication of preventive work in load control, outlining the following conclusions on the relationships between the level of physical condition, training load and injury risk in team athletes:

Figure 16: Relationship between physical qualities, training load and injury risk in team sports players



Source: Gabett, 2016, https://goo.gl/ThPfUe

It seems that a high chronic load has a positive influence on injury prevention.

- An adequate level of physical fitness is associated with reduced injury risk.
- Insufficient training increases injury risk, in addition to facilitating a loss of physical fitness.
- Reducing workloads is not always the best way to protect against injuries.
- Non-contact injuries may be caused by an inappropriate training program.
- Excessive and rapid increases in training loads are likely responsible for a high percentage of soft tissue injuries.

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