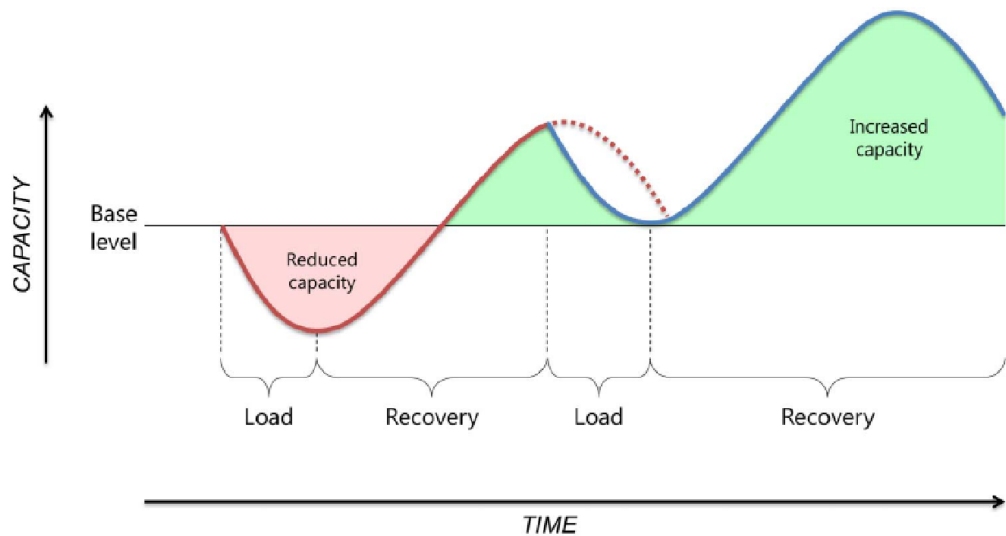


1. Introduction to training load monitoring

Introduction

The main objective of training is to optimize the athlete's performance, which is obtained by prescribing a suitable training load and appropriate recovery, provoking subsequent performance adaptations (Coutts, 2001). Addressing the basic principles of human adaptation to external environments, it should be noted that the organism maintains a stable state of equilibrium called *homeostasis*, which is only disturbed when a stimulus or stress is enacted upon it, thus altering it (García Manso, 1999a). Within this context, it is understood that physical activity is interpreted by the organism as physiological stress (Borresen & Lambert, 2008). Therefore, for an organism to achieve increased performance, it must be exposed systemically to new stimuli (training) that provoke specific reactions (adaptations) in different physiological systems (Borresen & Lambert, 2008; González Badillo and Ribas Serna, 2002). These stimuli constitute the training load (González Badillo and Ribas Serna, 2002). This training load imposed on the athlete will provoke a decrease in his performance level or a reduction of his basal capacity. After a certain amount of time has passed after applying the stimulus, the organism starts to recover above the performance level that was initially present. This phenomenon has been named General Adaptation Syndrome, a term coined by the Neurophysiologist Hans Seyle (figure 1).

Figure 1: Biological adaptation caused by a stimulus or load cycle and subsequent recovery period



Source: Adapted from Meeusen. Taken from Soligard et al. (2016).

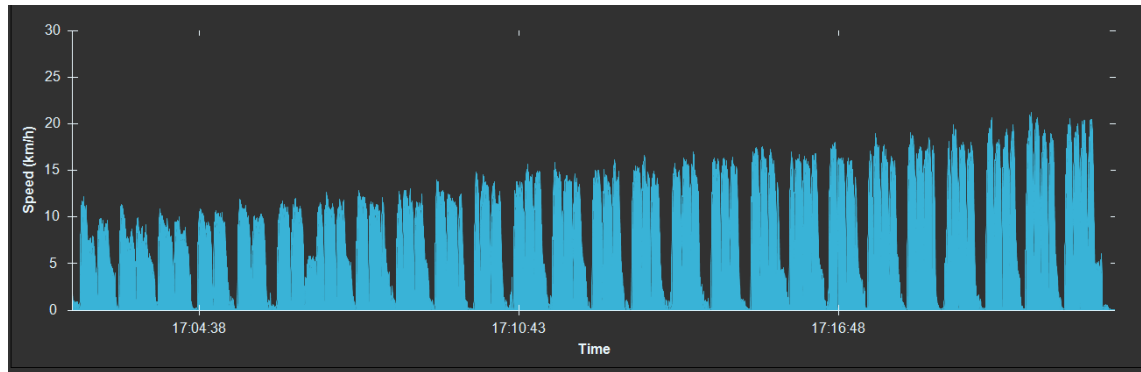
Training load

As indicated, the training load refers to the stress or stimulus to which the athlete is subjected during the training process (García Manso, 1999b). According to Verkhoshansky (1990), the load is the muscular work that implies by itself the training potential derived from the athlete's condition, which produces a training effect that stimulates the adaptation process. Additionally, in sports, the stimulus or training load has a series of components, amongst which volume, intensity and frequency of training can be highlighted (Davies & Knibbs, 1971; Wenger & Bell, 1986). These components are considered very influential on the adaptation response that may develop within the athlete's organism, which could cause an increase in athletic performance should it result in a positive adaptation (Mujika, 2006).

On the other hand, González Badillo and Ribas Serna (2002) define training load as the collection of biological and psychological demands (internal load) caused by activities performed during training (external load). In these terms, training load can be divided into two: external load and internal load. External load corresponds to the stimulus the athlete executes while internal load represents the physiological response (homeostatic alteration) and the Rate of Perceived Exertion [RPE] that said stimulus generates in the subject, the external load being the primary factor that determines internal load (Impellizzeri et al., 2005). For example, performing a progressive maximal intermittent endurance test (in the example in figure 2, *Intermittent Fitness Test 30-15*) assumes an

external load for the athlete that is represented in terms of speed, that is, speed is a measure of the activity's external load.

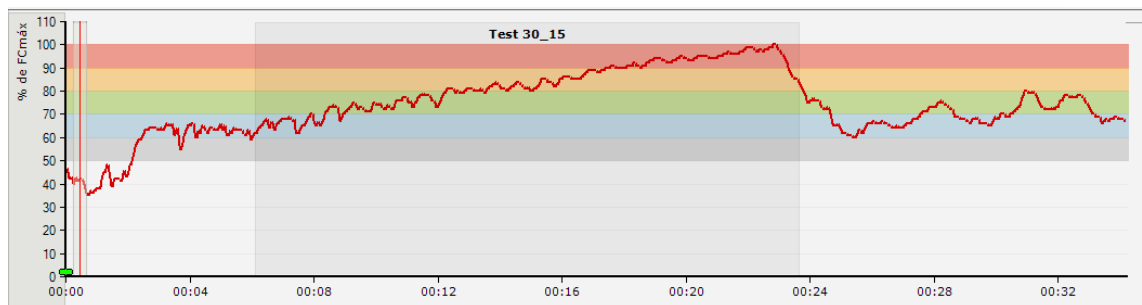
Figure 2: An athlete's moving speed while performing a progressive maximal intermittent endurance test



Source: Prepared by the author

This external load generates stress or internal impact on the athlete. In this specific case, we have used heart rate responses to represent this internal load, although many other additional parameters can be considered (blood lactate, sweat, oxygen consumption levels, etc.) (figure 3). Heart rate response thus supposes a measure of internal load.

Figure 3: Heart rate response expressed as the maximum individual percentage while performing the progressive maximal endurance test.

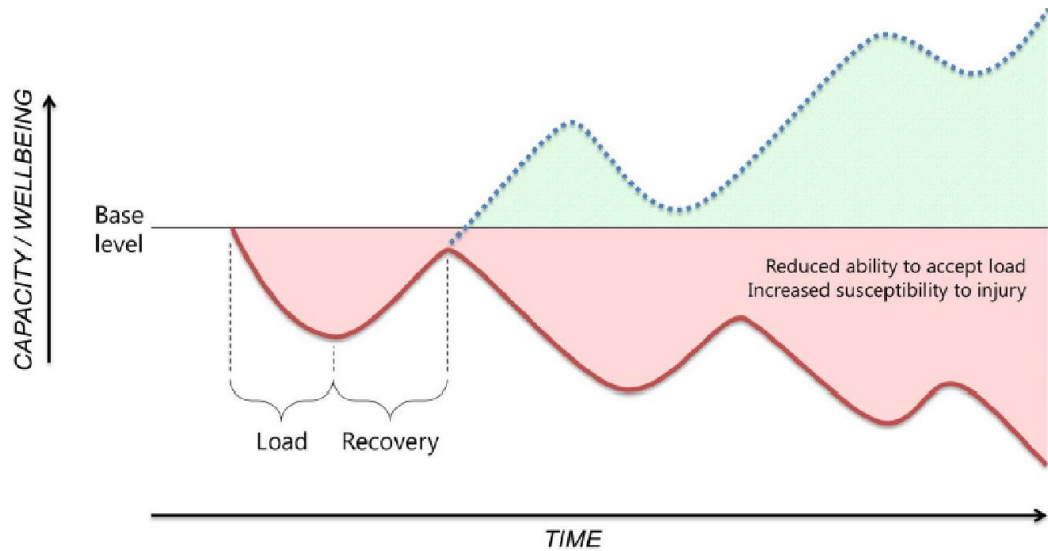


Source: Prepared by the author

It is important to mention that other factors such as genetic condition or the athlete's level can influence (Bouchard & Rankinen, 2001) the athlete's response (internal load) when performing a specific activity (external load). In this way, as a consequence of biological adaptation to training

stimuli, a decrease in performance can occur, as can be observed in figure 4.

Figure 4: Increase or decrease in performance based on biological adaptation

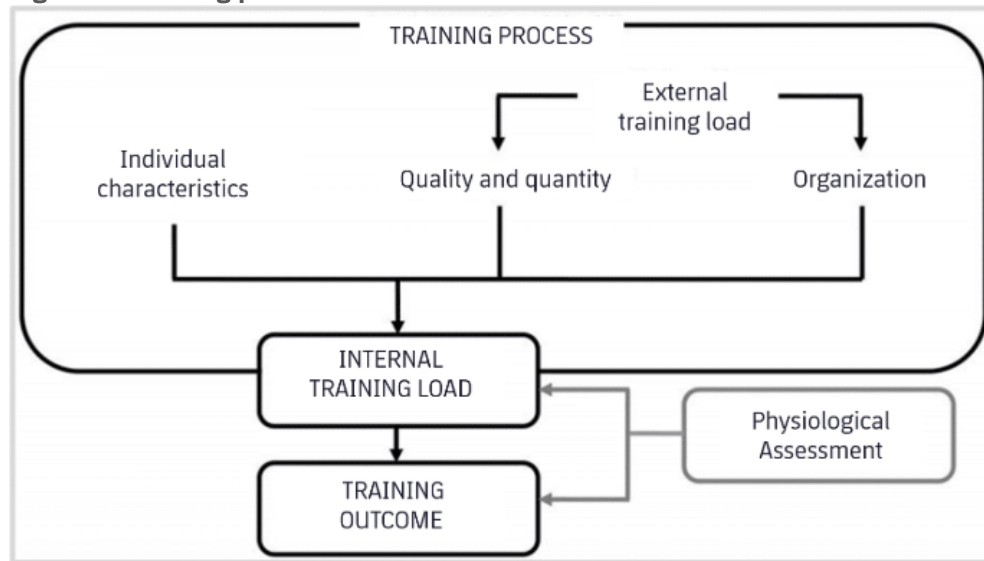


Note: The graph shows inadequate biological adaptation in red, in the event of an excessive load cycle and/or inadequate recovery period. In green, on the other hand, we see adequate biological adaptation, which increases the athlete's performance.

Source: Adapted from Meeusen. Taken from Soligard et al. (2016).

Knowledge of these criteria leads us to the conclusion that performance must be measured two-fold, taking into account all activities that are performed during the training process (figure 5) but also the biological impact that they have on the athlete (González Badillo and Ribas Serna, 2002). Continuing with this concept, Verkhoshansky (1990) shows that internal training load is determined by content (training specificity and potential), volume (magnitude, intensity, and duration) and organization of the external load (distribution and interconnectivity of loads). Taha & Thomas (2003), on the other hand, indicate that external load is determined by the combination of intensity, duration and frequency of training, although habitually it is simplified by determining volume and intensity (Brink et al., 2010; Flanagan & Merrick, 2002).

Figure 5: Training process



Source: Translated from Impellizzeri et al. (2005). Taken from Castellano and Casamichana (2016).

In order to assess the relationships of cause and effect between the training executed by athletes and physiological and performance adaptations, it is a priority to quantify the training load (Mujika, 2006). According to this author, the load that must be quantified is the "real" load undertaken by the athlete (which may be different from the load proposed by the trainer), which has also been shown to be a measurement linked to the injury index in team sports (Gabbett, 2004; Gabbett & Jenkins, 2011). Unfortunately, there is no universal parameter that can be used to measure the broad range of physiological responses provoked by training stimuli (Petibois et al., 2003).

External training load

The external load represents, therefore, the objective measurement of the workload executed by the subject during his training or competitive activity (Bourdon et al., 2017). Global positioning systems (GPS) are widely used to assess the external load of athletes, as they have demonstrated that they can provide a valid measurement of physical activity profile in team sports (Coutts & Duffield, 2010). These devices record information concerning speed, distance covered, and specific non-locomotor sports activities, thanks to the inertia sensors they are equipped with (Gabbett, 2016). Therefore, external load corresponds to the stimulus executed by the athlete, their observable behavior and the physical demand. Internal load – on the other hand – represents the physiological response (homeostatic alteration) that said stimulus prompts in the individual and that will probably have anatomical, as well as physiological, biomechanical, functional and psychosocial effects on the individual. External load is the primary factor that determines internal load

(Impellizzeri et al., 2005) although, as noted, other individual factors may have an influence. This is precisely the biggest headache for physical trainers, as the correlations proposed by the model regarding the stimulus-response relationship acquire as many nuances as there are players (and moments posed). This is why single performance models are rightly criticized (Impellizzeri et al., 2005), since, although they may respect a similar framework, they become specific when training different individuals and teams.

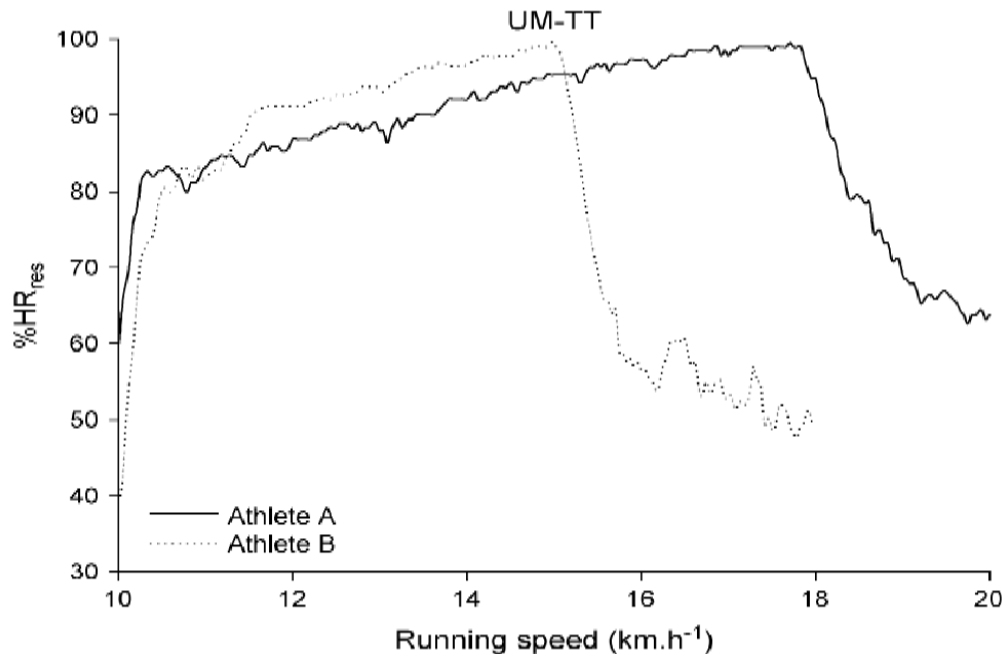
Internal load

Internal load refers to the biological stressors (both physiological and psychological) that are imposed on the athlete during training or competition (Bourdon et al., 2017). One very common way to assess internal load has been by monitoring heart rate (HR) and the rate of perceived exertion (RPE) (Abrantes, Nunes, Maças, Leite and Sampaio, 2012). Determining the maximum heart rate percentage ($\%HR_{max}$) is a common practice (Halouani, Chtourou, Gabbett, Chaouachi and Chamari, 2014; Hill-Haas, Dawson, Impellizzeri and Coutts, 2011) where information can be expanded by the HR-time spent in different intensity zones, determined by the player's $\%HR_{max}$ (Abrantes et al., 2012). Using RPE to monitor internal workload can be a practical and low-cost strategy, as well as a valid and reliable tool for team sports (Impellizzeri, Rampinini, Coutts, Sassi and Marcora, 2004). In this sense, the measured intensity of the session based on rate of perceived exertion is multiplied by the duration of the training (RPE x minutes), obtaining the load value in arbitrary units (AU). It is therefore one of the methods available to monitor and quantify the training load and its components (Gabbett, 2016).

It is interesting to point out that the same external load imposed on two different bodies can lead to different internal loads and, therefore, individual adaptations (Castagna et al., 2011; Impellizzeri et al., 2005 and Manzi et al., 2013). This seems logical when we think of two different subjects (in height, weight, age, etc.), but also players with similar conditional capabilities (Abt & Lovell, 2009) may assimilate the same external load in different ways, which may not be the ideal one for each (due to excess or defect) and, although the implications may be trivial when it comes to a single workload (task, training session or even microcycle), systematically reproducing them may provoke overtraining or a lack of stimulus, moving us away from the optimal performance state and increasing the chances of injury in both cases. For example, in figure 6 we can observe the different responses of internal load for two athletes performing the same activity (Université of Montreal Track Test). At the same speed, they both exhibit a different response in their organism. Athlete B exhibits a heart rate with a superior heart rate reserve (HRres)

at any speed, and he finishes the progressive maximal test before his fellow athlete. The final speed of the test for athlete A is 18 km/h while athlete B's speed is 15 km/h.

Figure 6: Heart rate response (in percentage) in two athletes while performing the Université of Montreal Track Test.



Source: Buchheit (2008).

Knowing this presents an advantage when designing an intervention in team sports (Coutts et al., 2007), although it is evident that the training process becomes more complicated as not all players on a team should be trained in the same manner. This becomes less viable as we move further away from the realm of high performance. The variability of training is, however, a day-to-day reality that must not be cause for fear. However, at the same time, the issue goes further than inherent interindividual variability. Any given player is not the same at two different moments. Intraindividual variability (less noted than interindividual variability) or, put in a different way, the unavoidable evolution of each individual, places the coaching staff in the position of needing to reinterpret or adapt the training process, 'tailoring' it to each player and given period.

Importance of monitoring and quantifying the training load

Detailed knowledge of the determining factors of performance and the athlete's profile is a fundamental prerequisite to optimizing the training load (Reilly, Morris and Whyte, 2009). Quantifying the demands of the

game has always been seen as one of the keys to planning conditioning programs with precision and ensuring the best conditions for the player in his execution during the competition (Rebelo, Brito, Seabra, Oliveira, Drust and Krustup, 2012). Additionally, knowledge of the athlete's mechanical and physiological responses to given exertions becomes essential to improving and understanding the underlying mechanisms to the adaptation process (González Badillo, Rodríguez Rosell, Sánchez Medina, Ribas and López López, 2016).

The numerous and significant technological advances developed in recent years, along with the eagerness of athletes to overcome their own records as well as set new ones, have led to an increase in competitive intensity in most sports disciplines. Elite athletes are often faced with extended training phases with a high frequency of competitions and busy calendars (Malone, Owen, Newton, Mendes, Collins and Gabbett, 2017). To increase the odds of success, trainers apply training loads that challenge the limits of their athletes (Piggott, Newton and McGuigan, 2009).

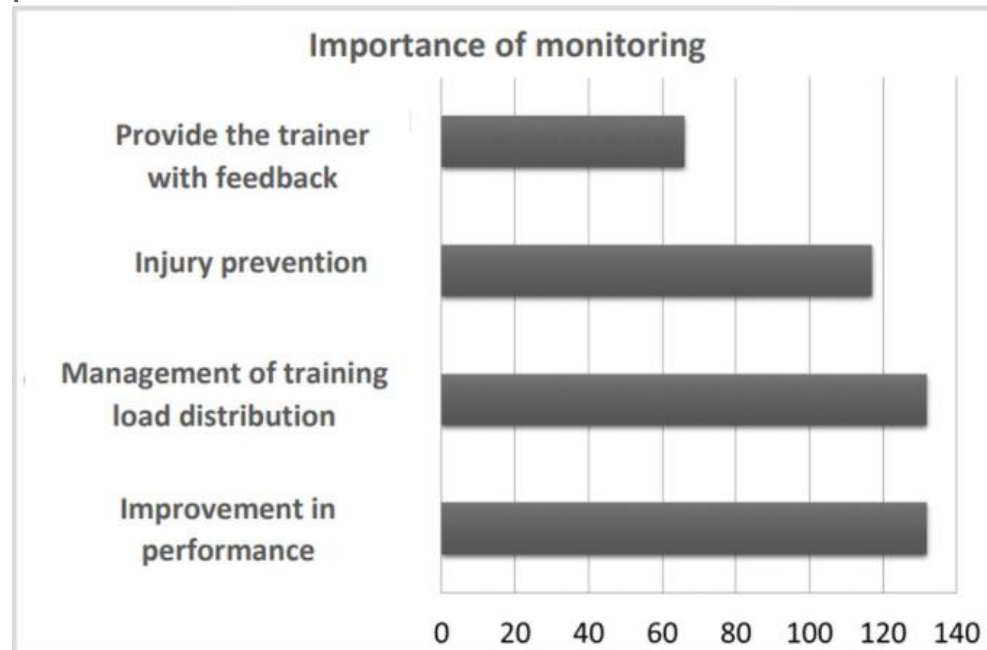
Catering to all of this, coaching staff and physical trainers face the challenge of ensuring an appropriate balance between training stimulus and recovery processes (Campos Vazquez, Mendez Villanueva, Gonzalez Jurado, León Prados, Santalla and Suarez Arrones, 2015), by the monitoring of all the imposed loads at each moment, in order to determine individual adaptation to the program, assess fatigue and minimize the risk of overload, injury and illness (Bourdon et al., 2017).

In Buchheit's (2017) words, the primary objectives of the monitoring process are:

- Provide an objective assessment of the external load in hindsight of any given match or training session.
- Optimize training load patterns.
- Make individual decisions with regards to the training load in order to optimize performance and prevent injury.

Akenhead & Nassis (2016) surveyed 41 professional soccer teams with regards to the reasons or justifications behind the training load monitoring process, subjectively assigning a score to possible reasons. We can observe in figure 7 how the monitoring process is justified as a way to improve athletic performance, to manage the training load, for injury prevention purposes and, finally, by how it provides the coach with objective feedback with regards to the activity executed by the players.

Figure 7: Subjective scoring of the aim or justification for the monitoring process in elite soccer



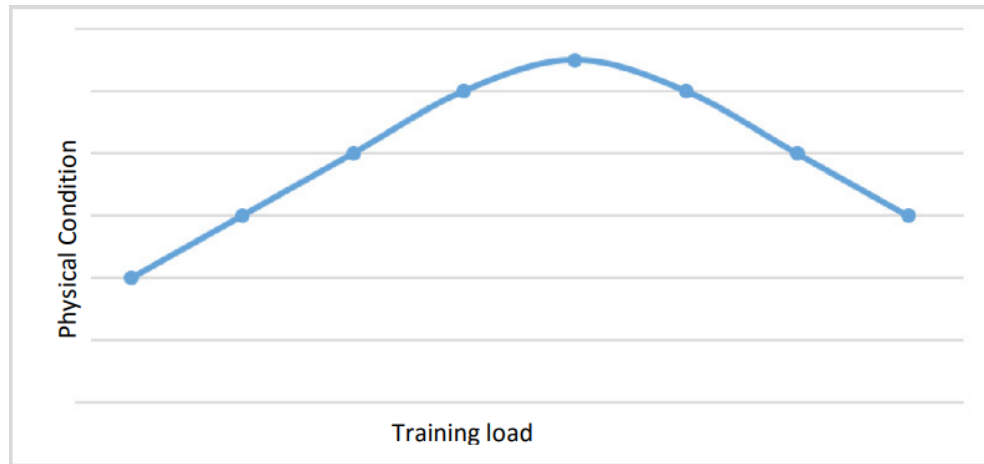
Source: Adapted from Akenhead & Nassis (2016).

Therefore, the benefits provided by monitoring the training load are diverse, but can be summed up into one: this information must help athletes train better. "Training better" will no doubt help – both at the individual and collective levels – to meet one's goals for promoting to health and athletic performance. Although "training better" may seem somewhat subjective and not very specific, as the course progresses we will explain the conditions that must be met to move closer towards what is referred to as "training well". Phrases such as "every chef has his secrets" seem to have justified and validated all past proposals, but today we have scientific evidence regarding certain components of monitoring training loads which we must try to incorporate in our training proposals.

Relationship of load level to performance and injury

The relationship between workload level and achieved performance has an inverted U shape, according to the model proposed by Busso (2003). Therefore, the highest (or nearest) point of the inverted U must be found, that is, the optimal heavy load point that is sufficient and necessary. It is sufficient in the sense of avoiding a lack of stimulus, and is necessary – at the same time – for staying away from overuse, which runs the risk of overload (i.e., a decrease in performance) or in the worst of cases, the onset of an injury (Owen et al., 2015). Gabbett (2016) brings us to the same idea (figure 8).

Figure 8: Relationship between chronic training load and physical condition level

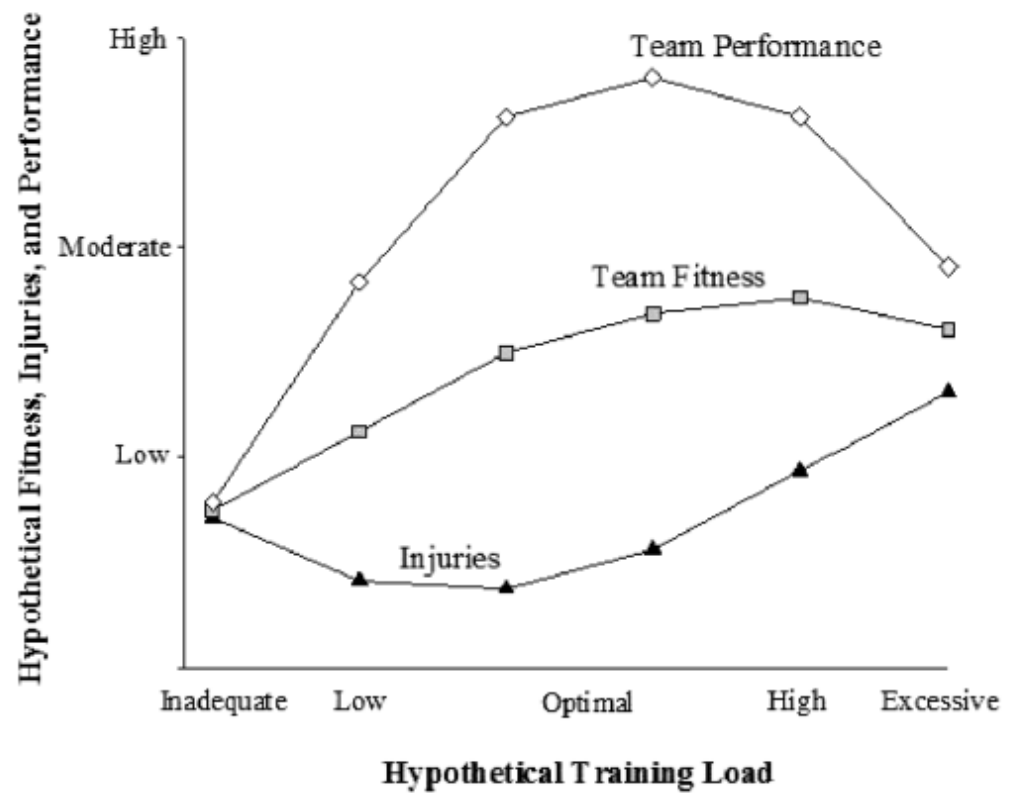


Source: Adapted from Gabbet (2016).

However, not all variables that appear to be linked to the training load level present the same relationship. Therefore, the response of injury incidence in relation to the load level imposed on the athlete presents a U shape (not inverted in this case) with a higher probability of injury when facing very low and very high loads (figure 9). This means that there is a certain load level that reduces the probability of injury with respect to reduced and excessive loads. In this way, the workload exerted by athletes is presented as one of the main factors of injury risk. Therefore, monitoring, analysis and tracking of training loads and competition loads is a very useful strategy when it comes to preventing injury and optimizing performance.

It is not easy, but it is necessary to find the optimal load for each athlete at each moment, as this is also variable and dynamic. A given training load imposed on a single athlete, for instance eight 40-meter sprints with a passive recovery of 30 seconds between them, may generate different effects at different moments. One effect may be that it exceeds the organism's adaptation limits in the first training session of the preseason, or after a period of injury, and yet is tolerated by the athlete at another moment during the competitive season. Therefore, having suitable methodology to monitor, analyze, and manage training load will become key for us to help athletes "train better".

Figure 9: Hypothetical relationship between workload, physical condition or fitness level, injury incidence and performance.



Source: Adapted from Orchard. Taken from Gabbet (2016).

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