A PRACTICAL APPROACH TO MANAGING PATELLAR TENDINOPATHY IN THE COMPETING ATHLETE

IS IT POSSIBLE TO QUANTIFY TENDON LOADS IN REHABILITATION?

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INTRODUCTION

Patellar tendinopathy (PT) is one of the most common injuries in jumping sports. A higher prevalence has been observed in elite compared to youth and recreational athletes[20,38,76], with substantial impact in elite volleyball (45%), basketball (32%) and track and field (23%)[38]. High jumping demands and a better jumping ability have been associated with PT,[69,71] but its real burden is unknown. Epidemiology studies usually capture only time-loss injuries[3], however most athletes with PT at the elite level keep training and competing with ongoing symptoms for long periods of time. Although high training loads are necessary for high performance, staying on the right side of the fine line between performance enhancement and injury risk remains a challenge for athletes.

What is the best approach to managing patellar tendinopathy in-season?

Exercise-based rehabilitation and load management remain the gold-standard for the management of PT[41,43], although its application at the highest level is a challenge. Studies have explored different exercise protocols and modalities in recreational athletes[41], but their effectiveness in competitive athletes remains unclear[72].

Patellar tendinopathy is still perceived by athletes and coaches as a benign condition that allows training and competing even when the athlete is in pain, but it can cause decreased performance. Pain management strategies and short-term adjunct therapies like extracorporeal shockwave therapy, platelet rich plasma and corticosteroid injections are therefore widespread at the elite level[31,39,46,70], but their benefit for long-term tendon health and pain is still questionable[12,31,51,68].

Although recommendations are available for the management of PT in season[11,57,59,67], their practical application is commonly hindered by the contextual factors of the competitive environment; high load demands, tight calendars, time constraints, contractual obligations and financial interests among others. Hence,

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two main approaches are commonly used by on-field clinicians for the management of tendinopathy in the competitive environment:

a. The rehabilitator approach

As with any other injury, athletes with PT need to follow a rehabilitation plan led by the medical staff. Specific exercises (commonly isometric, eccentric and heavy slow resistance)[31,41,59] are the core of the program, as well the athlete reduces load with an individual training plan. Painful activities are limited, sometimes including training and competition, until pain free function is completely restored. Some issues with this approach are:

- Decreasing training load usually improves pain in the short term but will progressively cause de-training, therefore performance can become increasingly compromised and more time will be needed to return to the previous level.[34]
- Rehabilitation exercises are usually less the demands for sports tasks, so they may be useful for pain management but insufficient to generate the necessary adaptations if not combined with sport-specific stimuli.[23]
- While this approach is easier in individual sports where training is always customized to the athlete by nature, it is more difficult in team sports where the injured athlete must adhere to a group training program.

b. The load management approach

PT is seen as an 'overload issue', so training load management is the key. Athletes and coaches learn to manage their training volume and intensity according to pain and the training program is adjusted. In most cases, athletes are never removed from the group completely; they train with some pain or dysfunction and often use adjunct therapies to mitigate pain. Specific tendon exercises are used as an 'extra'.

Some common problems with this approach are:

- An athlete 'used to pain' may develop alternative motor strategies, potentially affecting performance and overloading other elements of the kinetic chain[28,52].
- Adjustments in training load might be useful and allow the athlete to compete in the short term but will fail to maintain the tendon and kinetic chain requirements for performing at the highest level in the long term.
- Athletes using adjunct therapies may see quick improvements in pain[12] and their adherence to long-term exercise programs may be compromised.

Can patellar tendinopathy be better managed in the elite athlete?

The intricacies of professional sport have unique contexts that demand a more flexible approach than standard treatment protocols and magic recipes. The best program for PT is the one that can be adapted to the context and has the athlete buy-in, even if the program itself is not ideal tendon rehab. At the highest level, training and performance are always the priority and must be the primary consideration when designing an injury recovery program. The most challenging aspect is to balance the pressure and interests of everyone while also protecting the athlete's health. This requires a clear long-term perspective, wise expectation management and shared decision-making[16,44].

The usual vicious circle of PT in the athlete is characterized by pain, muscle inhibition, weakness and alteration of the motor patterns[14,29,50,58]. Many effective strategies exist to manage pain and muscle inhibition in the short term, including adjunct therapies[12,56]; however, weakness and motor pattern compensations can only be effectively addressed through long-term exercise programs, and athletes may not have the patience and the commitment to adhere to a program without immediate results. Paradoxically, adjunct therapies aimed at providing windows of opportunity to allow the athlete to work harder without pain, are often a major hindrance since with absence of pain comes lack of motivation to comply with exercise programs and potentially further tissue overload. A wise balance between short- and long-term strategies is usually the key to progress safely without compromising the athlete's

health while still performing. Nevertheless, athletes need to be aware that there is no quick fix with tendons. Tendinopathy symptoms may have to be managed throughout the season and any tangible improvement may take weeks or months[14], often without a clear time for pain-free sport.

The dynamic approach: managing load management

1. IDENTIFY TRIGGERS THAT INITIATE PAIN

Many extrinsic and intrinsic factors have been associated with PT[47,61,69]. Most intrinsic factors are non-modifiable and affect tendon load capacity (e.g. tendon pathology) while most extrinsic factors are related to load and therefore modifiable. Each athlete may present with a unique cluster of risk factors and the most relevant for each case must be identified and properly addressed with the program.

Tendinopathy is multifactorial; thus, it is challenging to identify the key factors,[6] especially in elite athletes that are constantly pushing physiological boundaries. A comprehensive analysis covering not only sport-related issues, but the multiple biopsychosocial factors is needed to reach a complete understanding of the situation[44]. Since tendons respond slowly to intervention[34], the analysis needs to focus not only on the last few days before injury, but on the previous weeks, months and even years. Special attention should be put on the relationship between acute and chronic training workloads[22,24] and on certain subtle but sometimes relevant changes that may affect the tendon (e.g., new training surface, a new exercise in the gym, other injuries, etc.).

The identification of the most relevant triggering factors and their interaction decides the strategy needed for each individual[6,69]. If an external factor like faulty

Table 1

a *EXAMPLE OF TENDON-RELATED LOADS FOR DIFFERENT DRILLS ACROSS SPORTS*

	Nil Demand	*Low Demand*	*Medium Demand*	*High Demand*
High jump	*Upper body and core gym session*	*Running drills*	*Double leg plyometrics (low hurdles)*	*High jump take-off technic*
Football	*Pool session*	*Passing drills without opposition.*	*Positional game attacking task (midfielders)*	*Reduced space game with full opposition*
Basketball	*Free shots*	*Full court drills*	*Defensive drills*	*Quarter court training*
Rugby	*Upper body gym*	*Extended Game Play (All players)*	*High Ball Receives (Backs)*	*Lineout Jumping (Forwards)*
Handball	*Penalty shooting*	*Positional defensive drills (outside defender)*	*5:1 defense game (top defender)*	*Defensive drills 6v6 (full backs)*
Volleyball	*Forearm passing drills*	*Serve receive drills*	*Blocking technique drills*	*Spiking drills*

b *EXAMPLES OF TENDON LOAD FOR A SPECIFIC TRAINING SESSION (FOOTBALL PLAYER)*

Task	*Tendon load demand*	*Min*	*RPE*	*Tendon load*
Jogging	*Low=1*	*5*	*3*	*15*
Mobility and ball drills	*Nil=0*	*15*	*4*	*60*
Passing drills	*Low=1*	*10*	*3*	*30*
Rondo (outsider)	*Low=1*	*15*	*5*	*75*
Possession game 7v6 reduced space	*High=3*	*30*	*7*	*630*
Free kicks	*High=2*	*10*	*5*	*100*
			TOTAL LOAD FOR THE SESSION	*910*

Table 1: Tendon-related training loads. 1a. Examples of nil, low, moderate and high demand sessions for the patellar tendon in different sports. 1b. Example of tendon load during a training session for a football player (defensive midfielder). RPE: Rate of perceived exertion.

> ***Patellar tendinopathy is usually characterized by pain and loss of function. While pain has traditionally been the main target of the rehabilitation process, loss of function that affects performance is often the main concern in the competing athlete.***

equipment, a recent change in shoes or a spike in load is identified, then the highest priority is to target it. Increasing the tendon capacity should be the main focus if no external factor is identified and an internal factor like a coexisting metabolic disease or biomechanical alterations are contributing. Frequently, the perfect storm happens when an inappropriate load is applied to a tendon with a temporary decreased capacity, e.g. a training session on a harder surface in an athlete who just came from a lay-off period due to illness or injury. In these cases, strategies targeting the removal or modification of the identified inciting event together with a program to increase tendon capacity in the mid-long term are needed.

Coaches and athletes provide valuable information and their perspectives on training-related factors are critical. Key factors like the periodization of plyometric sessions within the training cycle, specific sport technique or training errors are better understood by coaches, and modification may have more impact than any well-designed exercise program.

2. QUANTIFY TRAINING AND REHABILITATION LOADS

High training loads are essential for high performance[24]. As tendinopathy is a load driven process, quantifying the amount of sport-related load a pathological tendon sustains is required for the optimal management of PT in the competing athlete.

Two major sources of load may affect the tendon:

1. load from training and competition, which may be harmful to the tendon especially in sports with high jumping volumes[11,22];
2. load applied to the tendon through rehabilitation exercises, which is intended to be protective for the tendon by promoting tendon adaptation and pain modulation[7,10].

Load from training: the 'harmful' load

Nowadays, it's easy to quantify training loads for most sports via wearable devices that measure the volume, the speed or the number of jumps, contacts or accelerations[9,40,62,64]. While these devices have improved the understanding of training loads in elite sports, it is still very difficult to quantify the amount of load on specific tissues during sport activities. The patellar tendon is known to sustain high loads especially during jumps, deceleration and change of direction (COD)[15,17,28,30,63]. However, how this load is sustained by pathological tendons is unknown and pain usually leads to typical compensatory motor strategies in athletes with PT[18,28,52].

The general training load parameters should be examined when quantifying training load for an athlete with PT, specifically the volume and intensity of jumping, deceleration and COD. Many elite clubs and institutions have the technology and resources to process these data while more traditional ways can still be used when technology is not available. Recording the number and type of jumps, the subjective perception of intensity and the total training volume are methods that have been used in individual sports for decades as an estimation of load at the tendon. For team sports, registering and planning specific tendon loads on an individual basis is more challenging due to the unpredictability of the game and the dynamic interaction with opponents and teammates[65].

A more practical approach could be to categorize all training activities according to their estimated patellar tendon demands, which would be specific to each sport, context and training model (Table 1a). Each activity would then be assigned a tendon load demand score (e.g. nil=0, low demand=1, moderate=2 and high=3) and the total load for a given session would be calculated by multiplying the load demand score by the volume (No. of minutes/jumps) and the athlete rate of perceived exertion (RPE) of each task on a 0 to 10 scale (Table 1b). An athlete with PT could then be scheduled to participate in training according to the 'risk' of the different tasks for each session and not only based on generic volume and intensity parameters.

Rehabilitation load: the protective load

Patellar tendinopathy is usually characterized by pain and loss of function. While pain has traditionally been the main target of the rehabilitation process, loss of function that affects performance is often the main concern in the competing athlete. Multiple factors like the loss of muscle strength, alterations in the kinetic chain and the presence of pain may be responsible for the loss of athletic function in the athlete with PT[14,34,43,48]. However, tendinopathic tendons are known to present with altered mechanical and material properties (strain, stiffness, cross sectional area and Young's modulus)[77,78] that jeopardize their capacity to transmit and absorb high forces. Resistance exercises are known to induce changes in tendon mechanical properties enhancing its capacity to tolerate high loads[7,32,35,42], which has been associated with better clinical

outcomes in PT[79]. Quantifying the load from rehabilitation exercises in clinical practice is, however, unexplored territory and theoretical models are scarce[21,75]. Isometric, concentric, eccentric, energy storage and plyometric exercises are supposed to load the tendon in a progressive sequence[10,43], but the amount of load sustained at the tendon for each modality and type of exercise has not been quantified. Despite the excessive focus on the most effective exercise modality for tendinopathy (isometric vs eccentric vs heavy slow resistance)[13,27,41], it appears that overall load magnitude is more relevant for the tendon than the muscle contraction type, with higher loads generating significantly larger mechanical adaptations[2,5,7,42,48,74]. In the elite athlete with a good muscle strength and power, the ultimate goal often involves challenging tendon capacity boundaries. A combination of targeted high-load exercises rather than a sequence of progression or a single exercise modality may be needed to reach optimal loads in these cases[4,26].

Higher loads can be achieved adding repetitions, external load or modifying speed of the most common patellar tendon exercises. However, not only the standard rehabilitation exercises are used; other exercises are sometimes empirically chosen according to their emphasis on the tendon, their difficulty or the sport-specificity based on the available equipment and the preferences of the athlete and the practitioner. Each exercise poses a unique load on the tendon[21,75,53], but how all factors interact to enhance tendon adaptation is still unknown. Some exercises may pose a great load on the muscle-tendon unit while others are more focused on the kinetic chain, with great inter- and intra-individual variability[53], especially in presence of pain. A qualitative approach that identifies the main domains influencing patellar tendon load is proposed below to quantify and categorize different exercises for a better optimization of the exercise programs in the competing athlete.

Strength based vs jump-based exercises.

In the jumping athlete, plyometric and strength training are essential elements of the training program, and both demand an optimal tendon health for enhancing performance. However, strength and jump-based exercises are known to load the tendon on different manners; while strength exercises produce high tensile forces at the tendon (which are known to improve its mechanical properties as long as they are heavy, slow and sustained[32,35,36,42]), plyometric training requires the tendon to act like a spring absorbing and releasing energy at very high loading rates. Different activities pose different types of load on the patellar tendon[17,21,55,75]; while the absolute tensile load is similar between most strength and jump exercises, the loading rate can be up to 40 times higher for the jumps[17,30,54]. However, plyometric exercises have shown lower tendon adaptive responses compared to resistance training[7,8,37].

Strength exercises with a special focus on generating high tensile forces are therefore required to prepare the tendon for the mechanical demands needed when high jumping volumes and intensities are needed. They may also be beneficial to address muscle inhibition due to the high neural demands provided they are heavy enough[25,73]. A combination of strength and jump-based exercises has shown feasible to address tendon function while enhancing adaptive responses when there is no time for progression as in the recreational athlete[26,60]. Hence, quantifying the type and amount of load at the tendon of different exercises could help optimize exercise prescription and load management in the competing athlete.

Tendon exercise rating: the Silvan Exercise Score for PT (SES-PT)

Exercise prescription in tendinopathy has traditionally been based on protocols from scientific studies (e.g., Alfredson protocol[82], heavy slow resistance[83]), but when the demands are as high as in the competing athlete, standard protocols fall short of athletic needs. As we are still unable to quantify specific tendon loads for most exercises, exercise selection and load progressions are often subjective.

Recent studies have attempted to quantify the load that Achilles tendon[80] and patellar tendons[81] sustain during some of the most common rehabilitation exercises according to their loading magnitude, duration and rate. However, these studies are the result of theoretical models and only describe a limited number of exercises compared to what is used in competitive athletes. For that reason, we propose a practical tool (the Silvan Exercise Score for PT or SES-PT) to estimate the tendon load based on a series of exercise features to

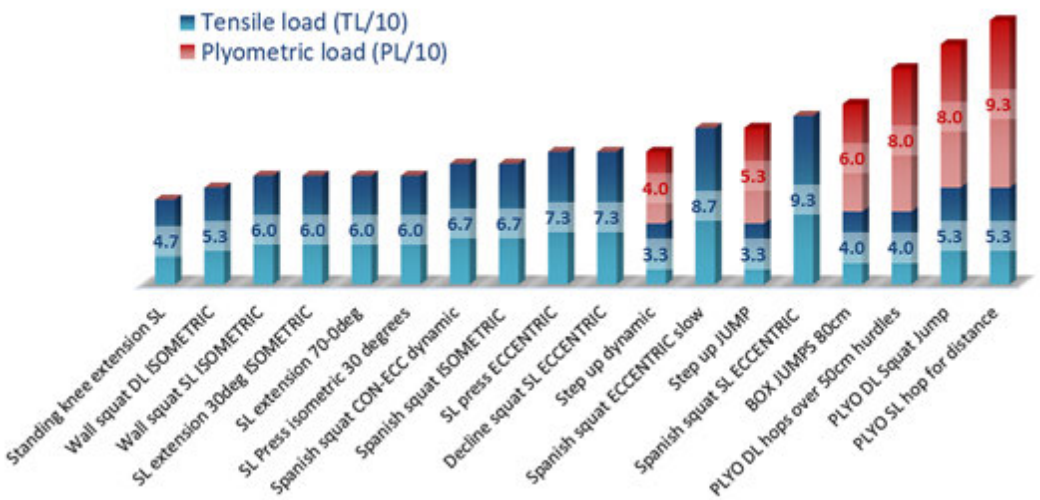

Figure 1: List of common patellar tendon exercises displayed according to the SES-PT score. Tensile load (TL) and Plyometric load (PL) are adjusted to a maximum of 10 points. SL: Single leg. DL: Double leg. Deg: Degrees. CON: Concentric. ECC: Eccentric. PLYO: Plyometrics.

Table 2

		NIL (0 points)	LOW (1 point)	MODERATE (2 points)	HIGH (3 points)	EXAMPLE: Step-up Jump
	TENSILE LOAD DOMAINS					
1	Dominant muscle contraction type		Isometric	Concentric	Eccentric	2 points
2	Time under tension (per rep)	<1 sec	1-2 sec	2-5sec	>5sec	0 points
3	Estimated Quadriceps % MVC	<50%	50-70%	70-90%	>90%	1 point
4	Lengthening of MTU	No lengthening	Minimal	Moderate	Maximal	0 points
5	Specificity to the tendon	Non- specific	Multi-joint double leg	Multi-joint single leg	Single joint single leg	2 points
					TENSILE LOAD SCORE	**5/15 points (3.3/10)**
	PLYOMETRIC LOAD DOMAINS					
6	Kinetic chain implication	Null	Knee dominant	Knee + hip or ankle	Whole kinetic chain	3 points
7	Ground contact	No contact	Focus on take off	Focus on landing	Jump + land	1 point
8	Breaking forces	No breaking forces	Minimal	Moderate	Maximal	1 point
9	Knee flexion at landing	No landing	0-10°	10-30°	>30°	1 point
10	Sports specificity	Non- specific	Include some components	Resembles sports specific tasks	Maximal sport demand	2 points
					PLYOMETRIC LOAD SCORE	**8/15 points (5.3/10)**

Table 2: Tendon exercise rating score table, with an example for the Step-up jump exercise. Characteristics for each domain are detailed by columns according to their impact at the tendon from nil to high. Total Tensile load and Plyometric load scores are calculated by summing up the score of domains 1 to 5 and 6 to 10 respectively (maximum 15 points) and rounded to 10 points for the final score. MVC: Maximum voluntary contraction. MTU: muscle-tendon unit. DI: Double leg. SL: Single leg

provide objective criteria and help with exercise selection and progression.

A total of 10 relevant exercise features were defined based on the authors' clinical experience and the available evidence. Categories #1 to #5 for strength-oriented exercises: (1) type of muscle contraction, (2) time under tension, (3) % of quadriceps maximum voluntary contraction (MVC), (4) lengthening of the muscle-tendon unit (MTU), and (5) specificity to the tendon[1,7,26,32,48,66,75]; and categories #6 to #10 for jump-oriented exercises: (6) implication of the kinetic chain, (7) ground contact type, (8) breaking forces, (9) knee angle at landing, and (10) sport-specificity[17,28,33,43,55]. For each feature, different exercise variations were defined and categorized in a scale of 0 to 3 according to their impact in the patellar tendon (Nil= 0, Low= 1; Moderate= 2; High= 3). An example can be found in Table 2.

Following these criteria, any exercise (existing or new) can be categorized assigning 0 to 3 points for each one of the 10 features, up to a maximum of 30 points (15 for tensile load and 15 for plyometric load), indicating how much strength or

Table 3

	What to monitor	How to monitor	Why to monitor
Primary elements (in all cases)	*Pain*	*3-4 repetitions of the provocative test (SL decline squat/SL hops) before warming up each day. Pain to be scored in a 0-10 scale.*	*Pain during provocative activities is the gold standard for monitoring tendon response to load.*
	Tendon-related training load	*A detailed training diary with the content of each session according to its tendon impact (0-3), the duration (min) and the athlete's perceived intensity (0-10) of each task. Wearable devices data if available.*	*Daily quantification of specific tendon-related training loads helps knowing how the tendon responds to different training modalities.*
	Rehabilitation load	*Tendon tensile load (TL) and plyometric load (PL) for different rehab exercises must be registered longitudinally based on the tendon exercise rating score.*	*Quantification of tendon load for different exercises may help optimizing exercise prescription during rehabilitation.*
Secondary elements (optional on a case-by-case basis)	*Training-related pain*	*Time to warm up until pain settles (min)*	*Some athletes find it useful as an indicator of tendon wellbeing as an alternative to the provocative test.*
	Strength training sessions	*Tendon exercise rating score to be applied also for gym exercises, especially for strength-based sports.*	*Adding extra 'tendon exercises' to the normal strength program may overload the tendon. All exercises potentially involving the knee need to be quantified.*
	High intensity jumps sessions	*Register daily training content*	*Periodization within the training cycle is important as they are the most damaging for the tendon and the athlete may need more time for recovery.*
	Interactions between training sessions	*Register daily training content*	*Different training modalities within the same day or session may have negative interactions and prompt a pain response*
	Movement quality	*Biomechanics analysis/ observation*	*Compensatory motor patterns may affect tendon loading and overload the kinetic chain*
	Recovery and fatigue	*Wellness questionnaires, sleep quality index*	*Fatigue, lack of recovery and poor sleep can impair tendon recovery*

Table 3: What to monitor in an athlete with patellar tendinopathy.

jump-oriented an exercise is. This way, different exercises can be compared to optimize exercise selection and help clinical reasoning for load progressions (Figure 1). In cases where high loads are needed (e.g. the jumping athlete), scoring exercises may help to design and select the most demanding ones instead of adding load to the standard exercises, optimizing time and resources.

Once the exercises are scored, the same system can be used to monitor the load of the rehabilitation exercises to help plan and adjust loads during the process. When several exercises are used in the same session, we can multiply the number of repetitions of each exercise by its score, obtaining an arbitrary number that may serve as a guide for load progressions throughout rehabilitation.

3. MONITORING THE ATHLETE

The key for the management of PT in the competitive athlete is an effective monitoring of the daily response to load. Tendons are known to have a delayed pain response of 24-48h, so a pain rating score (0-10) in response to a provocative test (e.g. decline single leg squat) is widely used for monitoring PT[10,49,67,45]. However, athletes may need more demanding tests to provoke pain; single leg hops, drop jump or squat jumps are good options for monitoring pain in these cases. The test should be done daily before training so that the program can be adjusted according to this pain response. Unlike the recreational athlete, the elite athlete needs to be monitored on a daily basis. There are multiple factors that can influence a tendon pain response

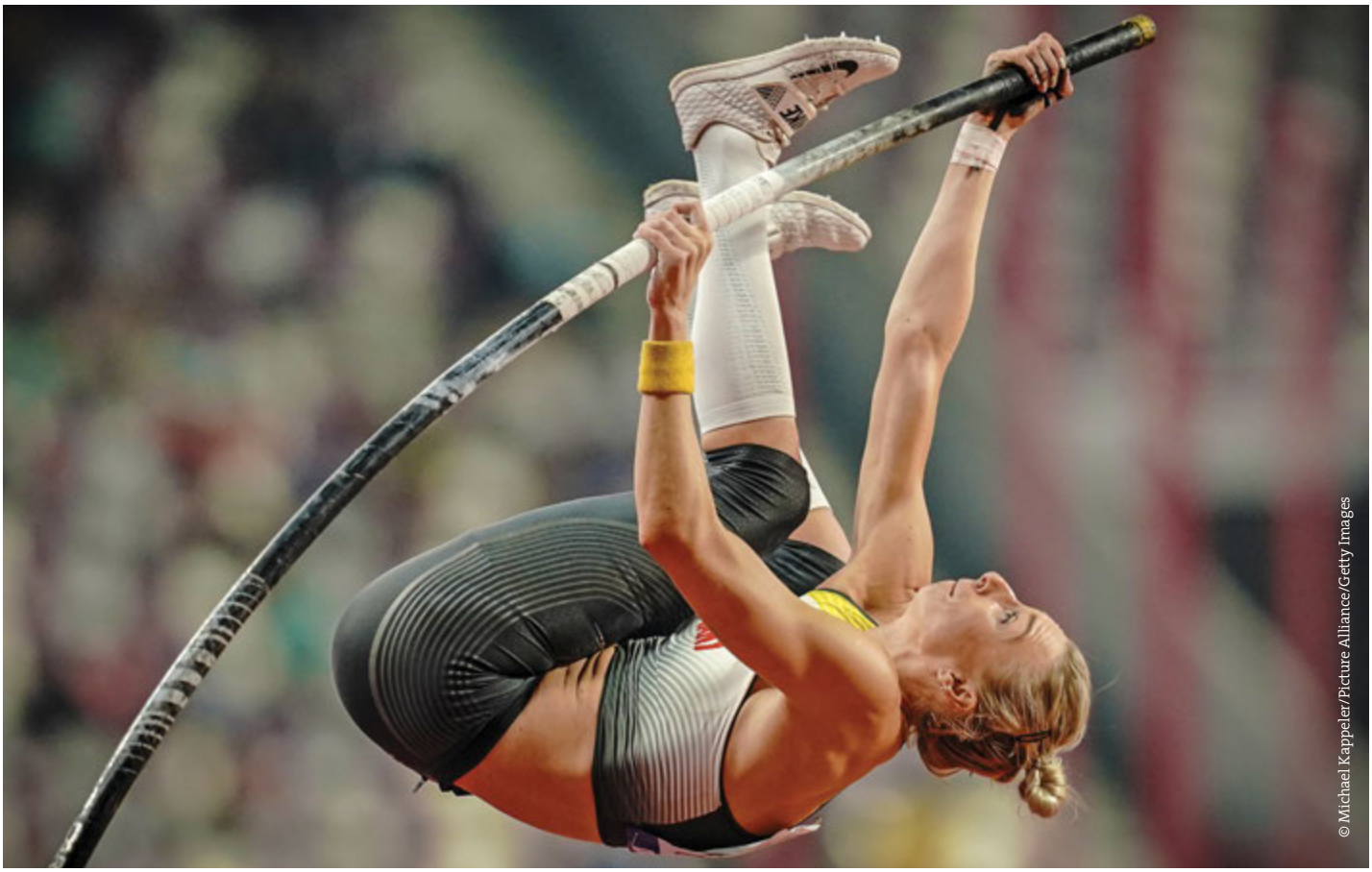

Image: Illustration.

that cannot be overlooked; the type of load, the interaction between different training contents, acute and cumulative fatigue or specific one-off loads.

For example, if pain is exacerbated every time an athlete (1) trains on a specific surface or (2) does a specific training session or (3) has insufficient sleep, that specific variable needs to be included in the monitoring template. Some fundamental elements need to be monitored together with some secondary ones that need to be selected on a case-by-case basis (Table 3). Creativity and flexibility are needed in such a challenging context and although many confounding factors may interfere, monitoring needs to be kept simple to be useful. Program adjustments must be based on regular feedback and analysis to find out what needs to be monitored and what interventions are more effective on a case-by-case basis.

PRACTICAL APPLICATIONS

Competitive sports are dynamic and complex systems, and one size will never fit all. Patellar tendinopathy is always a challenge for the athlete, the medical practitioner and the technical staff, so performance, health and coaching need to be integrated and work collaboratively[16,23,44].

This approach is intended to provide a practical framework for the management of the competitive athlete with PT based on sound clinical reasoning and load quantification. Understanding what exercise characteristics produce better tendon adaptations and how high load magnitudes can be achieved without interfering other aspects of training is key in the athlete.

A clear element of subjectivity may exist in selecting the domains for the quantification of tensile and plyometric loads (others could have been considered), as well as for defining its characteristics and scoring exercises and training activities. However, beyond its scientific validity, clinical models are intended to be practical and open for customization as long as they facilitate the management of PT rehabilitation.

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