Load, Overload, and Recovery in the Athlete: Select Issues for the Team Physician—A Consensus Statement

Definition

Load, overload and recovery are key issues for team physicians treating and caring for athletes. Load is an inevitable result of athletic conditioning, training and competition. Load in activity may be defined as a stimulus experienced and responded to by an individual prior to, during or after participation. Load creates a demand or stress (both physiological and psychological) and has internal and external components. Load that is safely managed may result in improved athletic capacity and performance, and injury and illness risk reduction.

Overload, as defined in this document, is load that is excessive or not well managed. It will result in anatomical, physiological and/or psychosocial conditions that will manifest as altered performance and injury and illness. Identification and modification of load and minimizing overload have been advocated as central parts of optimal performance and injury and illness and prevention strategies.

Recovery is the period and process during which the body responds to load. Adequate recovery may result in positive adaptations for athletic capacity, performance and injury and illness risk, while inadequate recovery may result in maladaptations for athletic capacity, performance and injury and illness.

Goal

The goal of this document is to help the team physician improve the care of the athlete by understanding load, overload and recovery issues in athletes. To accomplish this goal, the team physician should have knowledge of and be involved with the following:

- Current concepts in load, overload and recovery
- Medical issues related to load, overload and recovery
- Musculoskeletal issues related to load, overload and recovery
- Psychosocial and mental health issues
- The role of measurement and monitoring in load, overload and recovery
- Intervention strategies to reduce overload injury and illness risk
- The role of modalities in recovery

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Summary

This document provides an overview of the concepts of load, overload and recovery, as well as the musculoskeletal and psychosocial issues related to overload injuries and illnesses that are important for the team physician to understand. In addition, understanding the role of wearable devices, technology and other tools used to measure load, overload and recovery is important. Interventions to manage load may improve performance and reduce the risk of overload injuries and illnesses. This document is not intended as a standard of care and should not be interpreted as such. It is only a guide and, as such, is of a general nature, consistent with the reasonable, objective practice of the health care professional. Individual treatment will turn on the specific facts and circumstances presented to the physician. Adequate insurance should be in place to help protect the physician, the athlete, and the sponsoring organization.

This statement was developed by a collaboration of six major professional associations concerned about clinical sports medicine issues; they have committed to forming an ongoing project-based alliance to bring together sports medicine organizations to best serve active people and athletes. The organizations are American Academy of Family Physicians, American Academy of Orthopaedic Surgeons, American College of Sports Medicine, American Medical Society for Sports Medicine, American Orthopaedic Society for Sports Medicine, and the American Osteopathic Academy of Sports Medicine.

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Table 1.
External loads create physical, physiological and psychosocial demands.

Physical	Physiological	Psychosocial
Selected examples		
Jumping	Aerobic/anaerobic	Aesthetic sports
Running	Competition frequency	Coaching dynamic
Off-season conditioning	Environmental	Performance pressure
Throwing	Sleep	Sociocultural context
		Team culture

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Current Concepts in Load, Overload and Recovery

Load

A variety of factors affect the body's response to training load. Excessive training may place the athlete at risk for injury, illness and decreased performance. In some cases, undertraining for the expected demands of activity and/or competition may also leave an athlete susceptible to injury and decreased performance.

Load has been measured by factors such as number of pitches thrown, distance run, length of season, hours of training and/or amount of weight lifted. To determine the point of overload, these measurements are evaluated in association with the types of injury and illness or effect on performance to which they contribute (*e.g.,* pitch count and length of season with upper extremity injuries; hamstring weakness with hamstring muscle injury; lower extremity landing mechanics with knee injury; duration and intensity of exercise with respiratory illness; increased anxiety with decreased performance).

Overload

Overload occurs when the balance between external load and internal load is altered so that the body's adaptive capacity is inadequate, resulting in manifestations of altered performance and injury and/or illness.

There may be an absolute overload, in which even if the body is well conditioned the load is too high (*e.g.*, lifting too much weight). There may also be relative overload, in which the load is normal but the body's capacity is diminished (*e.g.*, running sprints with a hamstring injury).

Current Concepts

Current concepts more completely define factors related to load, overload and recovery. Athletes respond individually to internal and external load; the result of which determines the magnitude of the load stimulus experienced.

- External load is the work completed by the athlete during training and competition. External loads create physical, physiological and psychosocial demands, which are affected by frequency, intensity and duration of the activity, among other factors. Demands may be sport-specific (Table 1).
- Internal loads are individual physical, physiological and psychosocial characteristics that respond to external load. Identical external loads may elicit considerably different internal loads in two athletes with different internal characteristics (*e.g.*, age, sex, body composition, fitness, range of motion (ROM), history of prior injury, psychosocial health). Internal loads vary over time, requiring ongoing monitoring (Table 2).
- Recovery is a process with the goal of optimizing physical, physiological and psychosocial adaptation to internal and external loads (Table 3).

Medical Issues Related to Load, Overload and Recovery

Load and overload may result in medical problems including compromised immune system, illnesses, altered sleep patterns and overtraining (Fig. a and b).

Table 2.
Internal loads are individual characteristics that respond to external load.

Physical	Physiological	Psychosocial
Selected examples (alterations)		
Endurance-Fatigue	Aerobic/anaerobic capacity	Mood states
ROM	Endocrine status	Self-efficacy
Skill mechanics	Heart rate	Sleep patterns
Strength	Heat response	Stress responses
	Metabolic function	

Table 3.
Recovery optimizes adaptation to internal and external loads.

Physical	Physiological	Psychosocial
Selected examples		
Joint stability	Heart rate/HR variability	Mood states
Tissue healing	Blood markers	Motivation
ROM	Hormonal changes	Sleep patterns
Strength	Rate of perceived exertion	Social support
	Immunologic markers	
	Nutritional status	

Medical issues may result from too much load, too intense training or increased training intensity for athletes not properly conditioned to the load stimulus. Some research suggests an increased susceptibility to upper respiratory infection, thought to be related to an immune level response. Athletes at different levels respond to similar loads in varied ways.

Increased load may negatively impact sleep volume and quality. Numerous studies suggest sleep deprivation or poor sleep quality may affect athletic performance, recovery from exercise, cognition, reaction time and mood. Decreased sleep duration and training load increases may increase risk for injury. Poor sleep quality is common in athletes and may be more prevalent leading up to a competition (1).

Sleep deprivation results in autonomic (sympathetic/para-sympathetic) disturbances and could decrease the ability to tolerate load resulting in decreased performance and increased risk of injury and illness. While data remains mixed, the literature suggests "competitive calendar congestion" (concentrating increasing competition exposures into a shorter time frame, or having shorter periods of rest) increases injury risk. Long-distance air travel, especially across time zones, may increase susceptibility to illness or negatively influence athletic performance; however, there has been no demonstrated link to injury risk (2,3).

Overtraining is often characterized by a performance plateau not improved with the usual rest and recovery cycle; it is highly individual with physical symptoms such as elevated heart rate, weight loss, muscle pain/soreness, elevated blood pressure, gastrointestinal distress, delayed recovery from exertion, loss/decrease in appetite, severe fatigue, disturbed sleep, overuse injuries, and immune system deficits. There are physical symptoms of overtraining (including cardiovascular, respiratory, hormonal, and immunologic) as well as associated psychosocial symptoms (see section below).

Cardiovascular

- Resting HR typically decreases with fitness but can be elevated or reduced in overtraining.
- Athletes achievable HR Max will decrease.
- Heart rate variability (HRV), or beat-to-beat variability, has been used as a measure of overload. HRV is decreased in the over-trained athlete in some studies. Others are inconclusive. The interpretation of HRV's association with overtraining is evolving.

Respiratory

- Respiratory exchange ratio is lower in overtraining athletes, as is $\dot{V}O_{2max}$.

Hormonal

- Single hormonal measure cannot be used to diagnose overtraining, but many are affected by acute and chronic training.
- Increased resting norepinephrine may be found in overtraining.
- Cortisol levels may be altered. Current studies are inconclusive; some report elevated levels while others report reduced depending on acuity of exercise and chronicity.
    - Acute strain usually causes an elevation in cortisol while chronic strain usually leads to decreased levels.
- In overtraining there is often a decreased ratio of testosterone (free T) to cortisol. Endogenous testosterone levels often will go down.

Immunity

- IgA levels may increase.
- Enhanced expression of T-cell surface markers (CD45 RO+) has been reported.

Enzymes and Blood Markers

- Creatine Kinase (CK), Urea, Uric Acid and Ammonia may become elevated.
    - CK is a marker of mechanical muscular strain. CK is affected by intensity and duration of exercise,

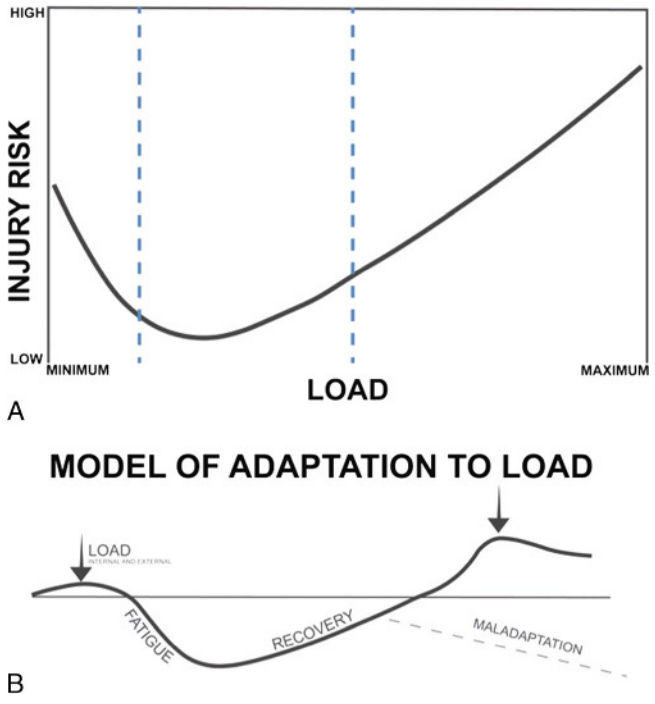

Figure: (A) Relationship between load and injury risk. (B) Proposed model of adaptation to load.

as well as some genetic factors. Elevations can be small or large and are not necessarily directly associated with overtraining.
    - Urea is a marker of protein catabolism and stimulated gluconeogenesis from increased training load and levels can be elevated in overload situations.
- Lactate levels at sub-maximal effort are lower in overtraining.

It is essential the team physician:

- Understand medical issues, such as sleep disturbance, immune dysfunction and overtraining, result from load, overload and recovery.

It is desirable the team physician:

- Be involved in the management of medical illnesses affected by load, overload and recovery.
- Work with the athletic care network to manage medical manifestations of overload.
- Work with the athlete care network to enable acute adjustments to the training and competition loads for athletes if internal overload factors are unfavorable.

Musculoskeletal Issues Related to Load, Overload and Recovery

Pathophysiology

Overload injuries occur when the athlete is inadequately prepared for the stress the muscle-tendon-bone units to manage training and competition.

Mechanical stresses on either soft tissue or bone that exceed the ability to protect/restore the damage resulting from excessive load will result in microscopic or macroscopic damage. Positive adaptations result in strengthening the soft tissue or the bone. Maladaptations may result in muscle injury/tendinopathy or bone stress injuries.

Bone Stress Injury (BSI)

- Bone stress injuries result from limited time for recovery causing imbalance of osteoclast and osteoblast activity.
- When bone homeostasis is not maintained due to abrupt or persistent training or competition stress, the ability of the osteoblasts to lay down new bone is exceeded by the resorptive activity of the osteoclasts in remodeling the cortex. This results in cortical weakening that manifests first as stress reaction with the spectrum continuing to stress fracture and ultimately, acute fracture if not addressed.

Physeal Injury

- The physis is particularly susceptible to load and overload injuries in the skeletally immature athlete.
- Traction loads and repetitive tensile loads to the apophysis may also result in injury.

Muscle Injury

- Myocytes will also respond adversely to chronic overload. This overload leads to reduced muscular force development and reduced contraction velocity.

Tendinopathy

- Tendinopathy can occur when tenocytes are unable to manage and recover from an excessive load.
- When abrupt or persistent load is applied to tendon in excess of the healing capacity of the fibroblasts and tenocytes, tendon breakdown manifests as tendinopathy.
- Tendon units crossing two joints appear to be particularly susceptible due to constant functioning in eccentric mode.

Injuries

Musculoskeletal injuries are impacted by internal and external load factors and may be modified by internal characteristics. Several studies have shown overload or sudden change in load is associated with increased injury risk. Examples include:

- BSI of the lower extremity
    - External load: volume and intensity of running, running surface, shoewear
    - Internal load: energy balance, muscle strength and balance
    - Internal characteristics: age, sex, anatomical alignment, history of stress injury
- Hamstring tendinopathy
    - External load: volume and intensity of training, change in training volume, sprinting
    - Internal load: hamstring flexibility and strength
    - Internal characteristics: previous lower extremity injury
- Patellofemoral injury
    - External load: running, jumping sport
    - Internal load: core strength, quadriceps flexibility and strength, hamstring flexibility
    - Internal characteristics: hip and knee alignment, sex
- Youth shoulder injuries
    - External load: age-appropriate pitch/serve count, length of season, repetitive overhead motion while in pain or fatigued, inadequate recovery, frequency of competition
    - Internal load: poor mechanics, core weakness, scapular motion and shoulder ROM
    - Internal characteristics: open physes, hip and knee alignment
- Youth elbow injuries
    - External load: age-appropriate pitch/serve count, length of season, pitching with pain or fatigue, frequency of competition
    - Internal load: poor mechanics, core weakness, quadriceps strength
    - Internal characteristics: open physes, hip and knee alignment

It is essential the team physician:

- Understand the influence of internal and external load and internal characteristics on musculoskeletal injuries.

It is desirable the team physician:

- Utilize the concepts of load and overload in diagnosing and managing musculoskeletal injuries.
- Understand the sport- and age-specific implications of overload injuries.
- Educate the athletic care network (4) concerning the predisposing factors that result in overload.
- Work with the athlete care network to enable acute adjustments to the training and competition loads for athletes if internal overload factors are unfavorable.

Psychosocial and Mental Health Issues

Psychosocial factors and issues are present in athletic injuries and illnesses and their recovery (2,5). The load or stress that athletes experience during training can have psychosocial and physical components. In both cases, load can result in positive adaptations and/or maladaptations. While the physical demands or load of training are seen as a stress, the experience of training can produce additional stressors, such as acute fatigue, pain, susceptibility to illness and emotional symptoms. Non-training loads can impose stress on athletes and may be either internal (*e.g.,* pre-existing or emerging clinical level emotional symptoms) or external (*e.g.,* psychosocial and/or interaction difficulties, academic struggles, general adjustment issues). There can be significant interpersonal and intrapersonal-variability in response to loads that may reflect factors such as age, sex, fitness level, fatigue level, metabolic or hormonal status, and genetic factors. The athlete's subjective responses, including Rate of Perceived Exertion and mood, have been shown to have superior sensitivity and consistency over some objective measures in determining acute and chronic changes in athlete wellbeing related to load (6).

Psychosocial Issues Related to Overload

Psychosocial overload occurs when load overwhelms coping resources. Poor management of loads and/or recovery can interact with sport-related and non-sport-related major and minor life stress events and create significant maladjustment. Sport-related stress can include inadequate rest cycle, musculoskeletal pain and concern over capability or progress. These stressors can interact with personality variables which may include anxiety, somaticizing tendency, mood problems, motivation and maladaptive coping.

Finding the optimal balance point between load stress and recovery is important. Imbalance often results in overtraining. Psychosocial symptoms of overtraining can include loss of confidence, fatigue, apathy, irritability, emotional or motivational changes, sadness, anger/hostility, confusion, concentration difficulties and boredom.

Psychosocial Issues Related to Recovery

Recovery strategies to address internal and external load to re-establish physiological and psychological balance include: developing resilience strategies to help minimize the impact of negative life events, educating athletes in stress management techniques to minimize effects of stress, reducing training load and/or competition load and intensity, implementing periodic stress assessments and addressing sleep dysfunction (7). All of these strategies could inform adjustment of an athlete's training and/or competition loads.

It is essential the team physician:

- Understand the psychological components of load, overload and recovery.

It is desirable the team physician:

- Be involved in the management of psychological issues related to load, overload and recovery.
- Be involved in referral to the mental health network as indicated.
- Understand maladaptations and injury and illness due to load and overload may be influenced by sport and non-sport stressors.
- Work with the athlete care network to monitor load by implementing subjective load measures of internal overload factors.
- Work with the athlete care network to enable acute adjustments to the training and competition loads for athletes if internal overload factors are unfavorable.

The Role of Measurement and Monitoring in Load, Overload and Recovery

There are varying levels of accuracy in tools and technology developed to measure load, overload and recovery. Even with accurate measurement of internal and external load, further research is necessary to determine their utility in improving athletic performance and reducing risk of injury and illness in sport.

There are a variety of measurement techniques, including new technologies and wearable devices. Categories include:

- *Laboratory*: blood work (*e.g.*, cortisol, CK, hemoglobin, ferritin, iron, testosterone, lactate, vitamin D, white blood cell count); urinalysis (*e.g.*, hydration status)
- *Questionnaires*: psychological (*e.g.*, POMS, REST-Q Sport, Pittsburgh Sleep Quality Index, scales that measure stress), perceived exertion (*e.g.*, RPE), wellness scales (*e.g.*, muscle soreness scale), nutritional (*e.g.*, food journal)
- *Non-wearable technologies*: force plates, $\dot{V}O_{2max}$, imaging (*e.g.*, MRI, ultrasound), isokinetic testing, equipment/devices to measure velocity and power (*e.g.*, Wingate test), video analysis systems, internal/external measurements of core temperature (*e.g.*, ingestive thermometer)
- *Wearable technologies*: Global Positioning System (GPS), heart rate monitors, HRV devices, velocity (accelerometers), wearable motion-capture devices (*e.g.*, wrist-worn and clothing-based technology)

While there is broad interest in these technologies and devices, more research is needed for many of these to understand their application. Main limitations include:

- Limited large-scale, independent, longitudinal data

- The need to place devices at specific anatomical locations
- Movement artifact
- Frequency of data sampling
- Monitoring of a few selected variables (as opposed to a suite of variables)
- Lack of measurement of environmental factors (*e.g.*, temperature, humidity, altitude, UV radiation)
- Inconsistencies and accuracy in algorithms that collect, analyze and distribute data
- Variability of data interpretation by interested parties, including athletes, coaches, researchers and medical personnel
- Inability to transmit data indoors, underwater, and in built-up areas; and interference from other physiological responses (*e.g.*, vasoconstriction, hypovolemia).

It is essential the team physician understand:

- There are components of load, overload and recovery that are measurable.

It is desirable the team physician understand:

- Further research is necessary to determine the utility of tools and technology in improving athletic performance and reducing risk of injury and illness in sport.
- The categories of measurement techniques.
- Limitations in the data obtained from the technology, particularly in its accuracy.
- Limitations in the interpretation of the data.
- The need to work with the athletic care network to effectively monitor athletes using technology that provides valid and reliable information.
- To work with the athlete care network to enable acute adjustments to the training and competition loads for athletes if internal overload factors are unfavorable.

Intervention Strategies

Intervention strategies may decrease overload factors and improve recovery. There are tactics that can be applied to manage internal and external load and overload.

- An effective tactic to manage external load is a customized periodization program with monitoring (1).
- An effective tactic to manage internal load is an ongoing training program that addresses physical, physiological and psychosocial demands.

Training

The role of this program is designed to modify the athlete's response (the internal load) to the imposed external load. The athletic care network may employ a variety of strategies to evaluate load to improve performance and decrease injury and illness.

Athletes with excessive exposure to external load may be more susceptible to both injury and illness due to their internal characteristics, level of conditioning and coping resources. Athletes with inadequate exposure to external load may also be at a higher risk. Newer studies suggest the balance between acute and chronic training loads, or the acute:chronic workload ratio (8), may be an important determinant of injuries.

Load and overload can be managed by training strategies, including modifying volume and intensity, adding variety to avoid monotony, providing emotional support and allowing for rest and recovery. Examples include:

- Optimizing sleep, nutrition (3,9) and mental health
- Limiting weekly hours of training or mileage
- Enforcing a pitch/serve count and recovery periods in overhead athletes
- Limiting number of games and tournaments and allowing for recovery between competition
- Implementing neuromuscular training programs (*e.g.*, FIFA 11)
- Following rules and recommendations of national, state and/or local governing bodies regarding play and recovery

It is essential the team physician understand:

- Intervention strategies may decrease overload factors and improve recovery.

It is desirable the team physician:

- Be involved in the planning and implementation of intervention strategies related to load, overload and recovery.
- Understand the concepts of load management as part of training strategies for optimal athlete response, such as acute:chronic workload ratio, competitive calendar congestion, training variety and periodization.
- Educate the athletic care network on intervention strategies.
- Work with the athlete care network to enable acute adjustments to the training and competition loads for athletes if internal overload factors are unfavorable.

The Role of Modalities in Recovery

Recovery is best accomplished with a comprehensive, multifaceted approach that addresses musculoskeletal, medical and psychological issues.

Many types of modalities are passive treatments and are utilized as adjuncts in aiding recovery. More research is needed to understand their efficacy. Categories include:

- Physical modalities
  - Electricity
  - Thermal Agents
  - Electromagnetic Agents
- Mechanical Agents (*e.g.*, hydrotherapy)
- Stretching
- Traction
- Massage/Soft Tissue Manipulation/Myofascial Release
- Compression
- Taping

It is essential the team physician understand:

- Modalities are frequently utilized as adjuncts to treatment in recovery.
- Limited data exists on the efficacy of modalities utilized in recovery.

It is desirable the team physician understand:

- The benefits of a comprehensive, multifaceted approach to address musculoskeletal, medical and psychological issues in recovery.

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