VIII ANTONIO ARRIGO AWARD
Fatigue and sport
Lecture delivered by the winner, Prof. Antonio Dal Monte,
Institute of Sports Science, Italian National Olympic Committee, Rome, Italy

Antonio Dal Monte,
Marcello Faina,
Giovanni Mirri

Institute of Sports Science,
Italian National Olympic Committee,
Rome, Italy

Reprint requests to: Dr M.Faina,
Istituto di Scienza dello Sport, CONI,
Via dei Campi Sportivi 46, 00197 Rome, Italy
E-mail: iss_fisiologia@coni.it

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Introduction

In sport, fatigue may be defined as the onset of a condition of organic and functional exhaustion involving a drop in an athlete’s ability to perform. This situation may occur during an individual competition or during the course of long and intensive training schedules or activities involving competition phases separated by short intervals (e.g., bicycle races conducted in stages).

Sports-related fatigue can thus manifest itself in two forms: acute and chronic.

The athlete’s ability to delay, attenuate or avert the onset of fatigue, by adopting appropriate preventive measures and by following training schedules designed to produce the highest level of organic and functional adaptation, while taking full account of recovery requirements, can be considered as one of the building blocks of performance and one of the factors that makes the difference between a “champion” and a high-level athlete.

Acute fatigue

Acute fatigue is the onset, during a competition, of a more or less marked condition of organic and functional exhaustion. In other words, acute fatigue may be defined as the inability to maintain the required or expected force or power during exertion.

It is essentially determined by a failure of the muscle cells’ ability to contract. The mechanisms that can cause acute fatigue are various and their involvement is closely linked to the type of exertion. To this end, it should be noted that, in accordance with the physiological and biomechanical classification of sports (1), exertion can be classified in relation to 4 categories of activity: 1] short-duration activity; 2] medium-duration activity; 3] long-duration activity; 4] alternating activity.

1] In the first category, which includes activities involving a prevalently anaerobic alactacid (or power) effort, some skilled activities demanding high muscular effort, as well as some combined-effort activities, the main cause of fatigue onset is the depletion of phosphocreatine, which brings about a slowdown in the re-synthesis of ATP. Furthermore, during an effort of high intensity and short duration, the normal outflow of K+ from the active muscle cells – this outflow being stabilised by the energy deficit resulting in a lower activity of the Na+ K+ ATP-dependent membrane pumps – induces an alteration in the membrane potential that brings about a drop in cell excitability (2,3).

When performing the above activities – very short-duration activities, such as jumps, should not be considered in this context as their key feature is their explosive power and metabolism plays no significant role – the ability to maintain exertion at peak power levels is vital to performance and represents an important element when selecting athletes and evaluating their physical conditions.

There exist several tests that appear to be particularly suitable for functional evaluation (4) in the aforementioned activities. For the purposes of evaluation, the key is the ratio between the result of a test investigating explosive force and the result of a 10-15 second explosive force endurance test aimed at investigating the efficiency of the alactacid anaerobic metabolism. It is obvious that the mean value obtained in the endurance test will be lower than the result of the explosive force test. It is also clear that the difference will reflect the decline in performance as fatigue inevitably sets in. The ratio between the results of the two tests, expressed in percentage terms, may be taken to represent the athlete’s
ability to withstand fatigue. Values ≥ 85% may be considered good.

For example, for the purpose of evaluating lower limb muscles, jump tests may be carried out using, as a measurement system, a special conductance pad connected to a stopwatch (Ergojump) or a photoelectric cell system (Optojump). Alternatively, push-out tests on a horizontal press may be performed.

2] In medium-duration activities, which include: i) activities involving mainly lactic acid anaerobic effort, ii) activities involving massive aerobic-anaerobic effort, iii) some skilled activities demanding high muscular effort and muscular effort for specific postural and directional purposes, and iv) so-called combined-effort activities, the main cause of the onset of fatigue is the increase in the intracellular concentration of H⁺ ions resulting from the formation of lactic acid.

In these activities, performance is essentially determined by the tissues' ability to tolerate high concentrations of lactate. Therefore, the evaluation tests (4) used are based both on establishing the ability to maintain maximal levels of strength (ability to withstand explosive force) over a time frame that allows the lactic acid metabolism to become involved (30 to 60 seconds), and on measuring the time to exhaustion during tests conducted at workloads higher than those relating to peak aerobic power. In this case, the duration of the test indicates both the efficiency of the glycolytic system — and hence the capacity to achieve maximum muscle acidosis — and the ability of the organism to tolerate, for as long as possible, lactate in the tissues — hence the efficiency of the buffer systems and of the aerobic mechanism.

3] In long-duration activities, muscle exhaustion can be attributed to a series of factors such as: the depletion of glycogen, hypoglycaemia, and salt and water losses. Furthermore, the production of ammonia (5) and the burning of branch-chain aminoacids for energy purposes (6) modify the equilibrium of the brain neurotransmitters, contributing to fatigue through central-type mechanisms.

To investigate the ability to withstand fatigue in this group of sporting activities, functional evaluation tests (4) are used that rely on the use of modern methods of measuring lactataemia and on advanced instruments, such as miniaturised remote-measuring metabolimeters, able to monitor on-line, both in the laboratory and in the field, the energy cost of exertion and the extent to which the various energy substrates are employed.

4] In activities involving an alternating metabolic effort, including team sports (e.g., soccer, basketball, handball, volleyball, rugby) and sports like tennis, athletes must be able to sustain their competitive performance for varying lengths of time, while maintaining constant their ability repeatedly to perform short actions during which they must yield high levels of muscular power. In these activities the onset of fatigue is due to: 1] a prevalently metabolic feature linked to the ability of the various systems to ensure fast and continuous re-synthesis of phosphocreatine, adequate disposal of the lactate produced, and a continuous supply of energy throughout the performance; 2] a prevalently neuro-muscular feature linked to i) the ability to sustain adequate nerve impulse transmission levels and ii) the muscle fibres' ability to respond to stimulus.

To investigate the ability to withstand fatigue in these activities, functional evaluation (4) is based on alternation or shuttle tests, consisting, respectively, of repeated series of vertical jumps (or push-outs on a horizontal press) and repeated series of sprints with recovery pauses. The parameter monitored is the extent of the progressive reduction in performance.

**Chronic fatigue**

The prerequisites for the achievement of high-level performance are genetic predisposition and the use of appropriate training methods. It is necessary, when drafting a training schedule, to ensure that the workloads administered are able to determine i) the acute biolod changes (adjustments to be made), so that ii) the desired adaptations are induced without producing, in the athlete, a state of iii) overtraining. For the purposes of this paper, overtraining denotes a situation characterised by an imbalance between training and recovery. Between effort and ability to withstand effort, and ultimately between stress and tolerance of stress.

Typically, overtraining comprises two phases: i) a short-term phase — this can be dealt with quickly, even within a few days — which has a favourable prognosis, and results in a temporary reduction in performance output (known as overreaching); and ii) a long-term phase (lasting weeks or even months), involving a rather severe prognosis (this is the phase actually denoted by the term overtraining).

**Overreaching** is a often a normal phase of training that does not jeopardise the supercompensation processes. However, failure on the part of athletes and coaches to recognise overreaching can lead, as a direct consequence of a poor competitive performance, to an inappropriate increase in the training loads, which, rather than sustaining the intended performance improvement can acturally result in the onset of overtraining.

**Overtraining** is a syndrome characterised by an overall state of functional and organic exhaustion where the sharp reduction in performance output is often accompanied by muscle-related symptoms (pain and asthenia), as well as by disorders relating to mood, perception skills, coordination and motivation. Overtraining is caused by irreversible training schedule errors and jeopardises the supercompensation processes.

The genesis of overtraining appears to be essentially linked to downregulation, that is to the onset of an inadequate transmission of ergotropic (catabolic) signals to the target organs; it is this that accounts for feelings of the type expressed in the phrase "I keep stepping on it but nothing happens." From this perspective, the following have been observed: i) a reduction in the noradrenalin and norepinephrine level of the beta-receptors (this would lead to progressive exhaustion of sympathetic secretion); ii) a reduction in the sensitivity of the surrenal cortex to adrenocorticotrophic stimulation with a consequent reduction in the release
of cortisol (this mechanism is thought to play a protective role in preventing a lethal exhaustion of the surnegal glands). Overtraining gives rise to an increased proneness to infections (7). In overtrained athletes, reduced IgA and neutrophils have often been found, along with a deficit in cell-mediated immunity that appears to be correlated with a reduction in the plasma concentration of glutamine, a key substrate for the proper functioning of the entire immune system. Undoubtedly, the early assessment of overreaching and overtraining plays a crucial role in modern sports. To this end, emphasis should be placed on case-history data relating to the athlete’s state of psychophysical wellbeing, and on the detection and observance of certain symptoms and clinical signs, such as loss of appetite, moodiness, muscular pain, weight loss, and the alteration of functional parameters such as heart rate and arterial pressure, measured in the morning on awakening.

In view of the strong need to prevent overtraining while following a correct work plan, scientific research (8-10) has, over the past few years, sought to identify earlier and, above all, more reliable, fatigue symptoms and signs. Particular attention has been paid to the efficient functioning of the endocrine system.

To this end, major emphasis should be placed on studies (11) seeking a correlation between performance and the free-testosterone/cortisol ratio (T/C ratio), as a stable drop in this ratio is considered to be an index of the organism’s increased catabolic phase, and thus of a failure to recover after muscular effort. The main limitation of the use of this marker in the diagnosis of overtraining is its excessive inertia. Very often, by the time the T/C ratio drops, irreversible mistakes have already been made in the training schedule and there is no longer time to “correct” the problem, at least with regard to the sports events for which the training itself was designed. Another method of investigation entails analysing the time pattern of nocturnal catecholamine production (12). It is based on the principle that, during the competitive season (training and competitions), a slight decrease in this parameter, in relation to a basal starting value, is indicative of a positive adaptation. An increase, on the other hand, is considered to denote slowed recovery capacity and a sharp decrease to denote a situation of organic exhaustion.

Analysis of the height variations in the ECG T-wave (13) is another tool used in monitoring the organism’s reactivity and the athlete’s efficiency. An efficient level of conditioning of the cardiovascular system seems indeed to be related to high T-wave voltages in the precordial derivations, while low T-wave voltages would suggest that fatigue is setting in. Variations in T-wave height are thought to represent an altered neurovegetative balance.

Neurovegetative imbalance also appears to be responsible for modifications in the pacemaker activity of the sinoatrial node. In athletes, even in the presence of a basic brachycardia, there is a considerable variability of the R-R interval, which leads to the assumption that in conjunction with hypervagotony there is also a paradoxical sympathetic activation. It has also been suggested that monitoring R-R interval variability (14) may be useful in the study of a condition like overtraining, in which the excessive workload brings about a neurovegetative imbalance, one of the main factors accounting for reduced performance. On the other hand, the athlete’s self-evaluation of his/her own state of psychophysical well-being (feeling of fatigue, muscular pain) is still the most effective method of monitoring overtraining and recovery. The importance of key elements, such as case histories, the clinical “insight” of the sports physician looking after the athlete and, most of all, the coach’s sensitivity, thus appears to be fully acknowledged.

A further instrument for diagnosing overtraining is longitudinal evaluation of the time pattern underlying the specific performance capacities of an individual athlete. Checking the effectiveness of a training schedule through the use of functional evaluation tests administered at regular time intervals is indeed crucial in order to verify that the results actually obtained are in line with the goals being pursued. In this way, it is possible to ascertain whether the athlete’s organism is positively adapting to the training loads and moving towards the supercompensation processes (an essential stage that must be reached by the competitive event) or whether, instead, a stagnation or even a reduction in the performance output has occurred, prompting fears of the onset of an overtraining syndrome.

To this end, the functional evaluation tests used must be absolutely specific and the athlete must be tested in such a way as to stress his/her organism in conditions that are as similar as possible to those occurring during actual competition, in terms of i) activation of the functional systems (cardiorespiratory system and metabolic pathways), ii) neuromuscular effort and iii) execution of the specific technical actions associated with his/her sport. Only by following this process will it be possible to obtain reliable results (4).

It should, however, be noted that methods monitoring overtraining patterns through the administration of evaluation tests tend to be implemented after the training schedule has been fully developed. This leaves little scope for correction, and means that the benefits of adjustments implemented can only be obtained subsequently. Hence the growing importance now attached to the assessment of adjustments, both for the on-line monitoring of training patterns and for the monitoring of recovery times between workloads.

References


