RECOVERY PROCESS AFTER PHYSICAL EXERCISE - MEANS OF RECOVERY

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Abstract
Playing a sports game at a competitive level requires considerable physical effort that can only be sustained by excellent physical condition. The effort provided during both training and official competitions must be permanently in the attention of the specialised coach, who should be primarily concerned with preventing excessive fatigue in athletes. A clinical form of chronic pathological fatigue (an imbalance of the whole body, which strongly affects both the physical and mental spheres) is caused by overtraining. Modern means of tracking physical parameters in real time allow the coach to correctly dose exercise intensity as well as the frequency and length of the necessary breaks. The coach also has modern means of restoring the functional systems used during exercise, while being aware that these systems recover at different time intervals. The correct relationship between the recovery process and the recovery time of energy sources is essential in the effectiveness of the athlete's body recovery technique. The proper load-recovery ratio is the key to the training process, and the decision on the recovery procedure will affect the physical condition of athletes. In the recovery process, specialists can use relaxation techniques, oxygenation, negative air ionisation, active or passive rest, medication, alkaline diet, massage, sauna, acupuncture, acupressure, thermotherapy, cold compression/therapy, vibration therapy, electrostimulation and lymphatic drainage.
Keywords: *exercise, fatigue, physical recovery, training session.*

Introduction

"Efforts to promote physical activity have focused on identifying determinants and designing interventions that might effectively promote regular physical activity" (Seefeldt et al., 2012, p. 143). Any physical activity is followed by the onset of fatigue, which requires a recovery action so that the human body returns to the state of comfort.

Exercise recovery is a process of regeneration and rebalancing of the body after intense, repeated and continuous physical activity. The recovery process aims to eliminate the state of fatigue and restore the initial bio-motor and mental power of the body, which is affected by the sustained effort made during training and official matches. It is even possible to bring the involved systems to a higher level in the overcompensation phase (Bota, 2000).

The goal of recovery is not limited to the action of fully rebalancing the potential effort of athletes but is also coupled with the effect of overcompensation - the only phenomena that provide extra adaptation without which progress cannot be achieved (Bota, 2002).

Shortening the fatigue or compensation processes of the functional systems can be done by using guided forms of recovery. The coach is responsible for several methodological operations, while the other members of the multidisciplinary team (doctor, psychologist, etc.) are responsible for specialised issues that contribute to superior sports performance.

Physical effort in sport

Both physical and mental efforts take place without interruption.

Any coach has a huge influence on the physical and psychological development of trained athletes (Short & Short, 2005; Gustafsson et al., 2017; Barcza-Renner et al., 2016), and the professional background is very important in this regard.

It is for sure that a positive influence and supportive social interactions in the athletes'

environment have the potential to enhance their performance and development (Bianco & Eklund, 2001). Negative social exchanges (due to rejection or neglect) can hinder progress and lead to a detrimental athletic experience (Newsom et al., 2005).

In sport, short bursts of intense anaerobic alactic exercise alternate with anaerobic lactic and mixed (anaerobic and aerobic) exercise. During a sports game, the ratio of these types of training differs.

Mixed (or combined) training uses the energy released by both aerobic and anaerobic processes; it lasts between 1 and 3 minutes, and its intensity is 80-100% of the mechanical equivalent of an individual's maximal oxygen consumption (Doboşi & Zamora, 2009). These authors also indicate three other types of exercise as follows:

- isotonic exercise, which involves isotonic contractions that occur when the muscle moves the segments where its insertion points are located;
- isometric exercise, which involves isometric contractions that result from the shortening of contractile elements simultaneously with the passive elongation of non-contractile elements; changes occur in muscle tension, which increases;
- auxotonic exercise, which involves auxotonic contractions, namely combinations of isotonic and isometric contractions that commonly occur in physical activity.

Sports training and obviously competition require a high level of activation of the nervous system. Intensified reflexes, improved coordination and decreased reaction time are the effects of increased excitability of the central nervous system. Hyperexcitability of the nervous system results in increased visual and acoustic acuity. Coordination and balance functions are also significantly improved (Drăgan, 2002). The need for permanent oxygen supply to the muscles during exercise is very high, which leads to a very intense transport of gases and energy substances.

Vesterinen et al. (2013) believe that heart rate variability can predict individual adaptation to endurance training in recreational runners. Heart rate variability is an important tool for observing the individual response to exercise in sports medicine and is increasingly used to monitor professional athletes (Plews et al., 2013). Aubert et al. (2003) demonstrate that heart rate variability can be very important in assessing the training status of athletes. A heart rate of 128 beats per minute for men and 138 beats per minute for women represents a total sum of oxygen of about 50% of an athlete's maximal consumption (Doboşi & Zamora, 2009).

Resting heart rate can reach values between 180 and 190 beats per minute during training or official sports games. Under the influence of official game stakes, the pulse is generally faster after competition compared to its values after training, although the exercise volume and intensity are higher during training (Bota, 2002). The literature (Gladwell, 2011; Predoiu et al., 2019) mentions a range between 115 and 145 beats per minute when the best performance is achieved. At over 145 beats per minute, complex motor skills begin to decline, which makes it difficult to do something with only one hand. When the number of beats per minute exceeds 175, the visual field narrows, cognitive processing ability is affected and behaviour becomes more/unusually aggressive.

At the same time, blood pressure after training or competition shows similar changes: systolic blood pressure increases after exercise reaching values of 160-180 mm Hg, while diastolic blood pressure remains relatively constant, with small increases or insignificant decreases. An important problem is breathing or external respiration, which shows many changes during both training sessions and official games. Athletes often perform their actions in apnoea (with their chests blocked). After a high-intensity exercise, at the first moment of respite, the athlete feels the need to partially or totally liquidate the oxygen debt. Thus, the respiratory rate is relatively low, and pulmonary ventilation can vary (within a time interval of about one minute) from zero (in apnoea) to a hyperventilation level. At the end of exercise (training or official game), during

the oxygen debt liquidation, there is usually an increase in the parameters of pulmonary ventilation (for 20-30 minutes) after breathing returns to normal. (Drăgan, 2002)

An inadequately trained athlete who gets stressed far beyond their functional limits will experience, for example, symptoms such as fatigue (visible through the pallor of the face), excessive sweating, arrhythmic and shallow breathing, dizziness, sudden increase in heart rate and large reduction in maximum oxygen consumption. On the other hand, too low levels of stress and anxiety also have a negative impact on athletes, affecting their intersegmental coordination, topographical memory and reaction time (Cojocaru et al., 2015a), and these aspects are directly related to their on-field performance (Cojocaru et al., 2015b).

The occurrence of these symptoms (or only some of them) will attract attention and will force the physician-coach dyad to take the necessary measures to review the training plan and exercise dosage.

Fatigue

Fatigue has been a permanent concern of experts, being therefore defined in many specialised works.

Fatigue is the reversible diminution of the physical and/or mental performance capacity, which allows however to continue the exercise, but with a considerable energy cost and a decrease in motor precision (Weineck, 1992).

Fatigue is a psychophysiological activity with a certain length and intensity, which produces a protective inhibitory reaction in the central nervous system (Drăgan, 2002).

Fatigue strictly depends on the physical condition of each athlete and is directly proportional to it. Performing a complex exercise for a long time is due to good physical condition. Fatigue resistance can be assessed through vigilance and reaction time tasks (Igorov et al., 2016; Grigore et al., 2014).

According to Drăgan (2002), *there are two types of fatigue*:

- *physiological fatigue, which occurs after an exercise that does not exceed the normal limits of the body's functional capacity and is manifested at the muscular level;*
- *pathological fatigue, which occurs after an exercise that exceeds the functional limits of the human body and is manifested at both the peripheral and central levels.*

THERE ARE MAJOR DIFFERENCES BETWEEN RECOVERY PERIODS AFTER FATIGUE OR EXHAUSTION.

Physiological fatigue has two main components: muscle fatigue or acute peripheral fatigue; neuropsychological fatigue or acute central fatigue.

Muscle fatigue

Frequent and lasting muscle contractions cause a disturbance in the body's physical and chemical balance. This results in the onset of muscle fatigue, a process that takes place over time and is directly influenced by the exercise duration and intensity.

According to Drăgan (2002), the energy-related causes that can lead to muscle fatigue are the following: depletion of muscle CP reserves in the case of alactic and lactic exercises (0- 45 seconds); depletion of muscle CP reserves and increased lactic concentration (short endurance - 45 seconds to 2 minutes); increased lactic concentration and liver ammonia (medium endurance - 2 to 10 minutes); depletion of muscle glycogen (long endurance - types I and II - between 10-35-90 minutes); depletion of muscle glycogen (long endurance - types III and IV - 90 minutes to over 6 hours).

Muscle fatigue can be identified in several ways, either objectively or subjectively. Objective aspects: increased muscle tone at rest; decreased muscle tone during exercise; considerably reduced physical performance; insomnia; decreased strength. Subjective aspects: movements performed with difficulty; a feeling of weakness throughout the body; an intention to abandon the exercise; the need for rest. These behaviours are observable in athletes and can be measured by analysing their frequency per unit time, duration and intensity - the "magnitude" of behaviours (Pelin et al., 2018).

Neuropsychological fatigue

The onset of this type of fatigue is caused by complex physiological mechanisms such as: lower blood sugar; accumulation of amino acids in the brain with a disruptive effect on neurons; increased neuropsychological stress (including in the case of goalkeepers). Mental fatigue affects the accuracy of different routines and motor performance in sport (Teodorescu et al., 2013).

It is relatively easy to recognise the onset of acute central fatigue, given that this process has some distinct aspects such as: decreased coordination ability; reduced performance capacity; disturbed function of psychological regulation phenomena; delayed motor reaction. The onset of mental fatigue can be prevented through neuropsychological and metabolic recovery. Specialists should pay special attention to mental fatigue as a dimension that enables the achievement of peak performance in sport (Pelin et al., 2020).

Acute fatigue entails a major difference in the body's ability to promptly respond to an exercise demand (Drăgan, 2002). Overuse may involve: muscle pain - physical distress after exercise, which can be acute (immediately after exercise) or delayed (1-2 days after exercise); muscle crack - caused by a muscle contracture; heartburn - manifested by extrasystoles and cardiorespiratory arrest, followed by death; neurological, vegetative and sensory disorders: gait disorders; stance disorders; coordination and balance disorders; visual, auditory and vestibular disorders; psychomotor disorders. Overtraining leads to a difficult state of pathological fatigue, which has an immediate harmful effect on the whole body. The onset of this form of chronic fatigue is due to overloading the central nervous system: excitation processes - through the volume, intensity and complexity of the means of training; inhibition processes - through prolonged monotony of training; both processes simultaneously through sudden changes in techniques, tasks or team positions.

Topic Addressed

Recovery

The following factors influence the recovery process (Drăgan, 1978):

- type of motor task (recovery occurs faster after dynamic than static exercise);
- task duration: a long task close to the anaerobic threshold induces the depletion of glycogen stores within 40-60 seconds; a task close to the aerobic threshold allows the complete restoration of neuromotor activity within 40-60 minutes, and recovery is fully achieved within 48 hours through a mixed diet rich in carbohydrates;
- increased intensity of motor activity: causes lactic acid and oxygen damage, and recovery takes several days;
- task sequence: requires careful planning of recovery intervals between exercises;
- task frequency: depends on the duration, intensity and frequency of various stimuli;
- training level: allows adaptation to specific and non-specific tasks, the homeostasis disruption having a constant dynamic;
- heredity and the role of environmental factors.

The restoration of functional systems used during exercise occurs at different times, for example, cardiorespiratory parameters recover within a few minutes, while metabolic parameters recover within a few days. It is important for coaches to remember the relationship between the recovery process and the recovery time of energy sources (Table 1).

Table 1. Relationship between the recovery process and the recovery time of energy sources (Bota, 2002)

Process	Recovery time	
	Minimum	Maximum
Phosphagen recovery (ATP and CP)	2 min	5 min
Oxygen debt repayment	3 min	5 min
Repayment of oxygen-lactic debt	30 min	60 min
Restoring oxygen supply	10-15 sec	60 sec
Muscle glycogen resynthesis	10 h after continuous effort	24-48 hours
Hepatic glycogen resynthesis	unknown	12-24 hours
Removal of lactic acid from muscles and blood	30 min in active recovery	1 hour
Removal of lactic acid from muscles and blood	60 min in passive recovery	2 hours

The nature and amount of the task can be changed by varying the load according to the number of repetitions and the time allowed between them; weekly frequency and overall recovery time contribute to charactering both the task and the exercise. Given the evidence that muscle chains exist and have the ability to transmit contraction forces, one can assume that, when the anatomical or functional integrity of a muscle chain is impaired, the repercussions occur not only locally but also across the entire muscle chain (do Rosário et al., 2012). Therefore, according to the muscle chains theory that is based on clinical assessment, a new perspective opens up in the physiotherapeutic practice, with great chances of recovery.

Recovery can be achieved in the short-, medium- or long-term, as it is linked to adaptation and overcompensation processes, which are variable in duration and characteristics.

Nowadays, there is only one winning solution: to train longer and more intensely using all the elements of an individual's characteristics. One of the secrets of the new training strategy is that any loading dynamic has its own recovery dose.

For the good development of the activity, the coach can use two categories of procedures (Bota, 2002), namely methodological (preventive) and basic ones (methods, means, techniques). Preventive methodological procedures are based on the principle of systematic alternation of periods of training with those of rest and body recovery. Prevention measures underlying recovery consist of streamlining and optimising both the schedule and placement of demands at the appropriate time intervals. These are strictly necessary for the recovery of consumed resources as well as for the use of a training strategy able to solve efficiently and qualitatively the proposed objectives.

Recovery needs to be practised and addresses intact mechanisms in morphological and functional terms. Guided recovery does not replace natural (physiological) recovery but rather complements, strengthens and accelerates it.

Recovery, just as exercise, is an individual process, given that several factors need to be taken into account, for instance: age; gender; level of training; environmental conditions; sports branch; level of stress; nature and duration of the exercise.

The means of psychological training, which represent a special category of recovery, are actually another component of training. After consulting sports psychologists and receiving their support, coaches choose the means of psychological training among the techniques and methods of psychotherapy and psychohygiene. These are: relaxation techniques; concentration techniques; autosuggestion techniques; suggestion techniques.

Means that accelerate neuropsychological recovery: psychotherapy (conversation, yoga, etc.); (natural or artificial) oxygenation; (natural or artificial) negative air ionisation; active or passive rest; massage; medication (Drăgan, 1994).

Means that accelerate neuromuscular recovery: hot hydrotherapy, sauna, massage; autogenic training, yoga, acupuncture, acupressure; active or passive rest; diet (alkaline, water-sucrose, mineralised,

vitaminised); pharmacology (glucose, glycol, Na, K, P, Mg, vitamins B and C, muscle relaxants, carnitine, etc.).

Means that accelerate endocrine-metabolic recovery: (natural or artificial) oxygenation, negative air ionisation; neuromuscular relaxation techniques; hydro-electrolytic rebalancing; massage, acupuncture; medication (piracetam, vitamins, etc.).

Means that accelerate cardiorespiratory recovery: (natural or artificial) oxygenation; hydro-electrolytic rebalancing; active or passive rest; hot hydrotherapy; sauna (15 min/week), massage (daily); alkaline, carb and vitamin diet; medication (P, Na, K, Mg, Ca, glucose, vitamins B, C and E, tyrosine).

Basic means of recovery according to the nature of the exercise (Drăgan, 1994):

1. Anaerobic exercise (up to 2 minutes): neuromuscular recovery; neuropsychological recovery; endocrine-metabolic recovery;
2. Aerobic exercise (up to 3 minutes): metabolic recovery; cardiorespiratory recovery; neuromuscular recovery.
3. Mixed exercise: neuropsychological recovery; cardiorespiratory recovery; metabolic recovery; neuromuscular recovery.
4. Neuropsychological exercise: neuropsychological recovery; neuromuscular recovery.

The means of recovery are implemented according to their accessibility and effectiveness.

In addition to the classic means of recovery mentioned above, professional sports use modern ways of fast muscle recovery based on special technologies. Of them, the best known and commonly used are: thermotherapy or high-temperature therapy; cold compression (compression and low temperature therapy); percussion therapy or vibration therapy; electrostimulation (uses low-intensity electrical impulses); lymphatic drainage.

Thermotherapy. Heat therapy, in addition to increasing blood flow, metabolism and elasticity of connective tissue, relieves most of the pain. This procedure is especially helpful for athletes because the injury percentage is higher among them. Thermotherapy is mainly recommended after workouts or sports competitions and proves to be the best option for treating muscle pain (Malanga et al., 2015). This therapeutic method is excellent for reducing joint stiffness and relieving muscle spasm. An effective intervention is thought to be performed approximately 48-72 hours after the injury. During therapy, blood vessels dilate and blood flow increases. This relaxes the muscles and reduces the feeling of muscle fatigue. With the return of blood circulation to normal parameters, the supply of oxygen and nutrients increases, and lactic acid is eliminated.

Percussion therapy. In the clinical, medical and rehabilitation fields, vibration technology has become increasingly important, specialists using direct and indirect vibration therapy (Cochrane, 2013). This revolutionary treatment reduces contractures and is a muscle relaxant. It acts deeply in the muscle through fast and repetitive vibration impulses that will stimulate blood circulation. Vibrations improve venous and lymphatic circulation and help muscles to quickly return to their original shape, reducing recovery time. Percussion therapy is found to be much more effective than manual massage.

Cold therapy. The physiological effects of this therapy "include reductions in pain, blood flow, edema, inflammation, muscle spasm, and metabolic demand. There is limited evidence from randomized clinical trials (RCTs) supporting the use of cold therapy following acute musculoskeletal injury and delayed-onset muscle soreness (DOMS)." (Malanga et al., 2015, p. 57) This procedure is performed for a period no longer than 3 minutes by enveloping the body with steam at low temperature. It should be noted that thermal shock is avoided due to the extremely dry air.

Electrostimulation (passive gymnastics). Transcutaneous neural stimulation (TNS) relieves pain after surgery and can be used with other physical modalities to recover more quickly after sports injuries. Patients who used TNS after knee surgery, for example, "had shorter hospital stays and needed less narcotic pain relief" (Smith, 2016, p. 46). TNS acts on the muscles by

introducing isometric contractions with an effect on increasing metabolism and muscle tone. Passive gymnastics uses devices that produce muscle movements without the need to perform voluntary muscle activity. As a result of using these devices, blood circulation is improved, on the one hand, and on the other hand, muscle toning is obtained. "Athletes with injuries or pain are being wired in a whole new way today, as transcutaneous neural stimulation is used for rehabilitation and analgesia." (Schultz, 2016, p. 116) At the same time, it has therapeutic benefits. A powerful electrostimulator can be used for relaxing massages, muscle contractions, muscle pain or lower back pain.

Lymphatic drainage. Lymphatic drainage can be manual or simple. Manual lymphatic drainage is performed by a qualified therapist, while simple lymphatic drainage is a technique that can be used at home. In this latter case, the person who plans to do this type of drainage should learn it from a specialist, because it is essential to know which area to massage and how much pressure to use (Eske, 2022).

Conclusion

Exercise recovery is a major component of sports training, which uses rational and targeted natural and/or artificial medical or pedagogical means from the external and/or internal environment of the body in order to restore homeostasis before exercise and especially to maintain it through functional overcompensation.

In the recovery process of athletes (and not only), specialists can use relaxation techniques (Schultz, Jacobson), (natural or artificial) oxygenation, negative air ionisation, active or passive rest, medication, alkaline diet, massage, sauna, acupuncture, acupressure, thermotherapy, cold compression/therapy, vibration therapy, electrostimulation and lymphatic drainage. Specialists should inform athletes about both the need to properly recover on a scientific basis and the means that can be used to achieve this. Athletes need to be aware that recovery is both physiological (anaerobic or aerobic fatigue) and psychological (stress, anxiety).

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