MUSCLE FATIGUE

Prof. Dr. Alfredo CÓRDOVA
Chair of Physiology
University of Valladolid

Sustained physical exercise inexorably leads to a reduction in the ability to produce voluntary force. This is referred to as "muscle fatigue", which manifests itself as an impairment of muscle function and/or a reduction in the ability of the central nervous system to activate muscles.

It is evident that exercise fatigue has become a common phenomenon among athletes, students, office workers and urban fitness groups. Fatigue is primarily an uncomfortable physiological phenomenon caused by the body's inability to maintain exercise intensity. Therefore, exercise-induced fatigue, i.e. fatigue due to physical loading, is a possible consequence that can increase the likelihood of injury.

It is more common to find that unaccustomed or highly demanding muscle exertion can lead to significant muscle fatigue accompanied by muscle damage. As a cause of this situation, in addition to the mechanical component involved, it is suggested that metabolic deficiencies may play an important role in muscle damage when metabolic stress exceeds mechanical stress.

Indicators of muscle damage are various, such as the effect of repetitive exercise, gender differences, impact on neuromuscular function and thus damage to the contractile machinery, fibre types, impaired metabolism and inflammatory response. All of these will be determinant in the recovery process.

In addition, a higher incidence of specific infections has been observed in situations of fatigue due to intense training sessions or strenuous competitions. All this is accompanied by a general situation of stress with cortisol accumulation as the maximum exponent of accumulated stress.

Prolonged exercise can also, in itself, stimulate cortisol release as a normal metabolic control mechanism. Stress"-induced cortisol secretion can also suppress immune function.
On the other hand, in older people, all of whom have a greater or lesser degree of sarcopenia. Sarcopenia is a progressive physiological development characterised by a decrease in muscle strength, muscle mass and eventually physical performance.

When these situations are prolonged (either by exercise or by ageing itself), an anabolic (testosterone)/catabolic (cortisol) imbalance is produced, i.e. destruction phenomena predominate over regeneration phenomena.

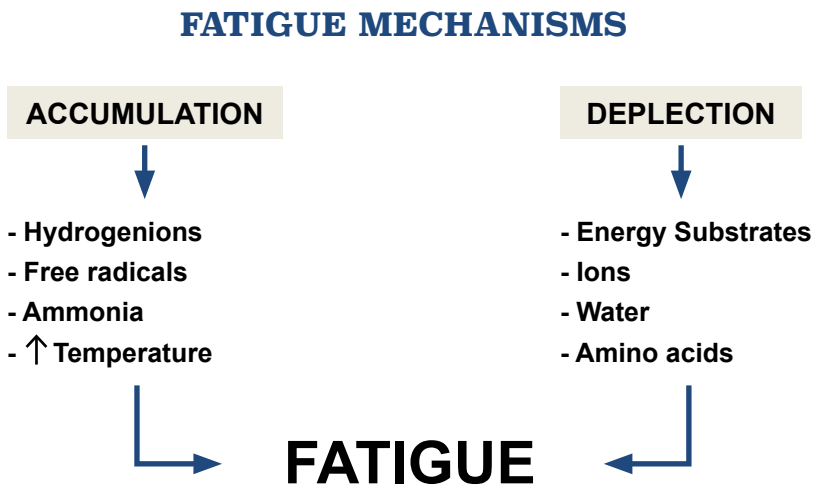
These debilitating effects leading to increased physical demands are accompanied by perceived fatigue. This includes increased perception of exertion and exercise-induced pain.

Aetiology

Fatigue can be the consequence of different situations, mainly exercise overload, work and rest, mental factors and factors arising from illness. The occurrence of exercise fatigue is mainly related to the excessive energy consumption caused by physical demand, which promotes the transformation of energy and energy metabolism and leads to the excessive accumulation of a number of fatigue-related metabolites. In general terms we could say that it is due to numerous causes, but more specifically it could be due to:

- Depletion of energy reserves
- Accumulation of intermediate and terminal substances of metabolism.
- Hydroelectric disturbances
- Inhibition of enzyme activity
- Displacement of electrolytes
- Decrease in hormone levels
- Changes in muscle cell organs
- Inhibitory processes at central nervous system level
- Cellular regulation of the various organ systems.
- Poor nutrition

If we were to put it in terms of what may be lacking or what accumulates, the main causes of fatigue are: proton accumulation in the muscle cell (decreased pH), depletion of energy sources (e.g. phosphocreatine and glycogen), accumulation of ammonia and lactic acid in the blood and tissues, osmotic pressure imbalance, oxidative stress (increased level of reactive oxygen species (ROS)), muscle damage and changes in neurotransmitter synthesis, such as increased serotonin and decreased dopamine.



Acidosis has been considered an important factor in fatigue. Intracellular acidosis leads to inhibition of energy metabolism. In this regard, remember that the key enzymes in glycogenolysis and glycolysis are phosphorylase and phosphofructokinase, respectively. These enzymes are inhibited at low pH.

Recovery

Recovery can be defined as the compensation of fatigue. Recovery strategies should focus on reversing or minimising these sources of fatigue, ranging from the use of physical activity itself to nutritional aspects, both in terms of diet and supplementation with natural products that accelerate the process.

Recovery can be active, that which takes place immediately after the end of the activity or during the next training session. Its effects are the reduction of muscular pain, restoration of the capacity for muscular contraction, lowering of the core temperature, sensation of a state of well-being, etc.

Passive recovery refers to post-exercise inactivity without doing anything extraordinary and leading to an intrinsic return to a state of homeostasis after intense physical activity.
However, the beneficial effects of nutraceuticals as recovery aids are now evident. In this sense, there are several substances that act on recovery, but they all have in common the acceleration of the process. Nutritional supplementation is key after exercise as it increases the muscle's sensitivity to nutritional stimuli, helping to restore energy elements before the next session to ensure adequate physical performance. If recovery is more effective, then it is conceivable that the training load can be increased at a faster rate for greater adaptation to training. Nutrients can attenuate the catabolic stress hormone response and help prevent further protein degradation, thus accelerating protein accretion.

Recovery therefore involves the restoration of energy and nutrient stores, a return to normal physiological function, a reduction in muscle soreness and the disappearance of psychological symptoms associated with fatigue.
From a physiological point of view, in the field of training, certain times are established for recovery to be effective.

Nutritional therapeutic approach

Chronic/prophylactic nutritional supplementation or supplementation in conjunction with a periodised training programme may facilitate strategies to enable increased work capacity. Reducing the symptoms of muscle damage may improve compliance with the exercise programme in trained, untrained, or older adults, who may perceive muscle stiffness as a negative outcome of fatigue.

The decision on the nutritional strategy to be employed should take into account the biological activity of the substance to be used. Several studies have shown that both foods and some natural products (nutraceuticals) have a high medicinal and health value in the treatment and prevention of fatigue. Many nutraceuticals have antioxidant, anti-fatigue and anti-ageing effects, which can also improve exercise capacity and prevent systemic diseases.

Any nutrient deficiency can lead to a decrease in physical and mental capacity.

Different types and combinations of nutrients are used in order to stimulate anabolic hormones as a muscle recovery mechanism. Arginine and branched chain amino acids are important in this process. BCAAs, because they promote muscle protein synthesis.

From an energetic point of view, creatine and carnitine play an important role. L-carnitine is essential for intermediary metabolism and its main function is to act as a carrier for the transport of fatty acids to the mitochondrial matrix where β-oxidation takes place. Ultimately, L-carnitine scavenges free radicals (ROS). Creatine produces increases in lean mass, strength and power.

A key (non-essential) amino acid in recovery is glutamine for its immune modulating role. Furthermore, citrulline together with arginine induces vascular protection through the production of NO, suppressing endothelial damage. In addition, citrulline reduces serum concentrations of IL-6, TNF-α and C-reactive protein (CRP), which increase with physical exercise. It also promotes aerobic metabolism by decreasing levels of acidosis.

Of course, the contribution of vitamins and minerals to recovery is obvious, given their role as regulators of recovery, given their role as metabolic regulators.