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Can non-conventional methods support recovery from exercise-induced muscle fatigue in people over 60 years old?

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Abstract
Physical effort contributes to improving the level of physical fitness and fatigue tolerance, however, may cause overtraining and/or chronic fatigue. Recovery is a regenerative process that takes place in every individual and is related to circadian rhythms. The aim of this review was to consider the factors and methods that determine and support the recovery from exercise-induced muscle fatigue especially in older people above 60 years of age. We have searched three online databases: Web of Science, PubMed, and Google Scholar. Based on our narrative review, there are few non-conventional methods (like mindfulness and meditations) that play an important role among numerous non-pharmacological therapies used to enhance or maintain the cognitive function of the body and mind. However, there is still a gap concerning the inclusion of mindfulness meditation as a part of recovery from exercise-induced muscle fatigue.

KEYWORDS: overtraining, recovery, meditations.

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Introduction

The physical effort of different intensities performed by people of all ages undoubtedly contributes to improving the level of physical fitness and fatigue tolerance, but above all, it is a manifestation of care for maintaining good health and functional fitness of older people. Based on statistics showing that the proportion of people over 65 years of age by 2035 will increase by around 10%, this aspect of an active lifestyle is a factor in mitigating the effects of aging. Thus, the maintenance of good health and functional capacity of the elderly reduces the social costs of treatment and rehabilitation of chronically ill patients [11, 62]. The effectiveness and the organism's response to the applied exercise load depend on certain factors. On the one hand, they are directly related to the health status or level of physical fitness, but also to the atmospheric conditions in which exercises are performed or eating habits and behaviors. The disturbances of the internal organism's homeostasis resulting from the exercise stimulus are the cause of the formation of numerous morphofunctional adaptations and an increase in one's exercise capacity. The body's natural reaction to the physical effort is the appearance of fatigue, which protect the body from excessive overload and exhaustion. The strength generated by working muscles is reduced, thus decreasing the effectiveness of work. Despite the development of fatigue, it is possible to continue the effort but to maintain the generated strength additional muscles are engaged, which significantly increases the energy cost of the effort. Physiological mechanisms underlying fatigue concern functional changes within the skeletal muscle itself, structures supplying it with oxygen, metabolic energy sources, but also in the nervous system structures performing coordinating functions and generating electrical impulses. The impact

on each of these elements depends on the type of effort, intensity, age, and gender of the exercising person. Peripheral muscle changes occurring during the exercise of different duration are usually accompanied by central changes located in the nervous system. Peripheral fatigue is caused by the impairment of cell stimulation mechanisms and/or nerve-muscle synapse. It also leads to impairment of electromechanical coupling mechanisms, a decrease in the concentration of energy substrates, decomposition of the contractile apparatus, and damage to the connective tissue of ligaments and tendons. Increased concentrations of adenosinodiphosphate (ADP), inorganic phosphate (P), and hydrogen ions (H^+) are caused by the restriction of oxygen access to working muscles and increased glycolytic metabolism. Additionally, the cardiovascular and respiratory systems are overloaded. The formation of lymphatic edema in working limbs and a decrease in adrenal catecholamine secretion can be observed [60]. During short-term work of high intensity, the occurrence of fatigue changes is additionally caused by slowing down the transmission of the pulse in the nervous system and an increase in the concentration of ammonia from the purine transformations in the cell. This compound increases the activity of glycolytic enzymes, and in the nervous system, it additionally impairs the transmission of stimuli. Studies have shown that elderly people are more resistant to fatigue changes. This is probably due to the disappearance of FT II fibers with age and a higher proportion of oxidative FT I fibers [16, 21]. Tarnopolsky et al. [57] demonstrated that lower muscle glycolytic capacity and more effective lipid metabolism are the factors determining their higher resistance to fatigue in women of all ages. In the study on the rate of muscle regeneration after exercise in people of different ages and genders, Grounds [14] described an age-dependent decrease in the possibility of rapid post-exercise regeneration. He also found, that in the elderly, the long-lasting occurrence of fatigue symptoms led to balance impairments, which increased the risk of their falls.

To cause adaptive changes effective training must be associated with overload and at the same time disproportions between training and regeneration time should be avoided. Lack of sufficient period of recovery in the training process leads to the accumulation of fatigue changes and the development of overtraining. Factors such as cardiopulmonary efficiency, the composition of muscle fibers, hypoxia of working muscles, dehydration, and electrolyte disturbances affect the time of appearance, and persistence of overload changes [29]. The most susceptible to physiological and anatomical overload changes are endurance athletes, young people, and those over 40 years of age. Moreover, women overtrain faster than men [16]. Thus, the coaches should be expected to have an appropriate level of empathy towards over-trained individuals [16, 21].

The consequences of overtraining are common and include numerous physiological pathways, including neuroendocrine, immune, cardiovascular, and musculoskeletal paths. Negative nitrogen balance and amino acid imbalances lead to an increase in blood levels of free tryptophan. It reaches the brain and become a precursor of serotonin neurotransmitter. Increased serotonin concentration is manifested by mood swings, changes in behavior and inhibits motoneuron excitation. This affects the nervous and hormonal regulation in overload conditions [28, 37, 42].

Clinical features of overtraining in different individuals are varied and non-specific. They depend on the specifics of the exercise. The features such as a decrease in the level of physical fitness, fast fatigue during training sessions, anxiety, and decreased body immunity are common to both types of overtraining [30]. In young athletes especially training endurance and speed/power sports, the observed changes are caused by excessive stimulation of the sympathetic nervous system. Sleep disorders, and weight loss, are accompanied by cardiac changes like increased level of resting heart rate (HR) and blood pressure (BP) with simultaneous disruption of orthostatic reactions. In endurance sports, especially in those with a high level of cardiopulmonary and respiratory efficiency and long training experience, the disorders stimulated by the parasympathetic nervous system dominate in the overtraining process. They do not lose weight, their sleep is calm, their resting HR and BP are decreased. Hypoglycemia is a frequent post-workout metabolic disorder. This type of overtraining is difficult to diagnose and treatment lasts even several months. No single test is diagnostic in the assessment of the type and severity of occurring overtraining. The best way of treatment and prevention is prophylaxis, i.e. optimization of the training process and regeneration of the body. From a health-related point of view observation and diagnosis of mood changes, sleep disorders, monitoring the level of physical fitness, stress reduction, and dietary guidance will ensure that the beneficial effects of physical activity are obtained [15, 58].

Conventional recovery

The subject of recovery has been a topic of discussion for years since it accompanies each individual every day. Recovery is a regenerative process, that is related to circadian rhythms. Biological renewal, both daily and

during physical activity, can be supported by a number of conventional and non-conventional measures to optimize physiological rest processes, protect health and maintain or increase the psychophysical capacity of an individual engaged in physical activity, both amateurs, and professionals.

Recovery is defined as the process of restoring the ability to exercise efficiently or the process of restoring homeostasis through the normalization of physiological functions. An important aspect of the analysis of rest after the physical and mental activity is paying attention to the role of the autonomic system. The activity of the sympathetic nervous system prevails during exercise, while the parasympathetic system is at rest [52]. After the physical or mental activity, the nervous system should rest and regenerate. The exhausted sympathetic nervous system manifests by the reduced ability to undertake or maintain effort [3]. Rest aims to balance homeostasis after exercise or taking actions supporting the regenerative process, also by undertaking other efforts called active rest. Post-exercise restitution may take minutes, hours, or days, depending on the intensity and volume of the bout. We should also remember that each individual has its resistance to fatigue and regenerative predisposition. The effectiveness of post-exercise restitution will therefore also depend on the lifestyle of the person undertaking the exercise [52].

Bearing in mind the healthy lifestyle, which correlates with post-exercise restitution, attention should be paid to the following factors:

1. Constant hours of sleep and waking up. Both too short and excessively prolonged sleep may result in the occurrence of many health disorders related to metabolic, depressive, or vascular causes. An appropriate time of sleep (7-8 hours) allows the body to rest and is appropriate to maintain the energy necessary to conduct regular physical activity [11, 26, 27].
2. Healthy nutrition. For the psychophysical well-being, and in particular, with an active lifestyle, a properly composed diet seems an important factor that can provide energy and nutrients based on the guidelines of the newest pyramid of healthy nutrition and physical activity adjusted to age. Fixed eating times are important, therefore, 5 meals a day eaten every 2-3 hours are preferred [18]. Vitamin and mineral supplementation should be considered in some people, while in the elderly, vitamin D_3 supplementation is necessary [13, 35, 62]. The researches confirm that planned nutrition can have a significant impact on sports performance [64].
3. Adequate hydration of the body. Within 24 hours the body should be supplemented with about 40 g of water per 1 kg of body weight [9, 17, 23, 46]. The amount of drunk fluid should depend on the weather conditions, the mode, intensity, and duration of performed exercise. Modern recommendations for drinking water during physical activity are based on starting activity while hydrated, preventing dehydration during ongoing training, and replacing lost fluids after training [2, 36, 44].
4. The ability to cope with the stress of everyday life. Learning the ability to introduce one's body into a state of relaxation, i.e. a pleasant short-term rest, which is experienced as internal relaxation, peace, and carefree [32, 62]. Preferred relaxation techniques are autogenic training, Jacobson's relaxation, or exercises for controlled diaphragmatic breathing [49].
5. Regular physical activity. WHO recommends moderate physical activity for min. 150 minutes (2 hours 30 minutes) a week, at best divided into 30-minute single bouts, performed minimum five times a week. The importance of 30-45 minutes of physical effort is increasingly emphasized. The physical efforts should affect coordination, balance, strength, and include aerobic exercises with an intensity of 60-80% of the predicted maximum heart rate and stretching elements [51].

All the mentioned components of a healthy lifestyle will allow the body to recover faster after exercise. In addition, after physical exercise of a sports nature, it is recommended to perform short light stretching and relaxing exercises and the use of thermotherapy treatments and massage, which accelerate the removal of waste products from the body [52].

One of the modern forms of self-massage, Foam Rolling (using a massage roller), is one of the most effective and simple methods of relaxing the excessively tensed muscular apparatus after training. Used after training, it regenerates, relaxes, and relieves pain from tired muscles [4, 40, 47, 48].

The recommended thermotherapy treatments concern hot or cold treatments. Hydrotherapeutic treatments can be divided into groups concerning induced pressure: hydrostatic (baths), hydrodynamic (showers), or without water pressure (saunas). During recovery the most commonly used water is cold (18-24°C) or cool (25--32°C), which promotes narrowing the blood vessels, increasing the blood pressure, slowing down the heart rate, stimulating the nervous system, reducing sweat secretion, and increasing muscle tension [45, 54]. Neutral (33-36°C) temperatures reduce muscle tension,

enhances relaxation, and sleep quality [45]. The warm (37-38°C) and very warm (39-40°C) treatments are known of increasing blood supply to the skin, lowering blood pressure, accelerating heart activity, stimulating the autonomic nervous system, increasing sweat secretion, relaxing skeletal and smooth muscles, and are also characterized by analgesic, anti-inflammatory and relaxing properties [20, 25, 43, 54, 65].

Individuals that engage in systematic physical exercise are recommended to relax the myofascial tension and improve circulation. One of the possibilities is to take post-exercise contrast showers. The procedure begins with warm water for a few minutes (3-5 minutes) later alternated with several seconds (10-15 seconds) of cold water, ending always in cold water [6].

Another form of effective thermotherapy is a traditional sauna used either as a warm-up or as a regenerating treatment. A sauna bath supports the immunity of the body and accelerates regeneration [41]. However, it should be remembered that as a very stimulus procedure, it can be highly stressful to the body. Some studies even show that the heart effort during sauna treatments can be compared with a single bout of low-intensity exercise [31]. It should be emphasized that "sauna is a specific combination of overheating the body using hot, dry air with periodic, short exposure to high humidity and high electric field intensity, followed by cooling the body with an air bath and cold hydrotherapy treatments (e.g. cold a shower or a cold immersion bath for several seconds)" [53].

Another type of thermotherapy treatment that can complement the recovery process is the infrared sauna. It is much gentler in operation than a traditional sauna, as it has a temperature of 40-50°C and no steam component. This sauna is a great replacement for a traditional sauna and can be used by people with vascular and circulatory sensitivity. It can be used both before a single bout as a form of warm-up and/or after exercise, excluding excessive stress on the cardiac system [41].

Very natural recovery treatment is climatotherapy together with the air and sunbathing treatment included in its scope. Air baths build immunity and seem an appropriate environment for regular physical activity. Heliotherapy (treatment with the sunlight) with a relaxing effect on the body improves mood, but associated with such treatment UVB radiation is involved in the natural synthesis of vitamin D_3 in the skin of a person exposed to this wavelength of the ultraviolet spectrum [24, 60].

Local cryotherapy or warm compresses are other types of treatments with a specific anti-traumatic effect, used successfully by individuals practicing sports. They include gel packs (hot/cold packs). Local muscle cooling before or after exercise can cool down the body structure under heat stress and contribute to increased activation and regeneration of muscle strength. Warm gel packs allow relaxing tensed muscles. It should be remembered that we only use warm compresses on the area free from inflammation. In places, with overload, swelling, heat, redness, and pain we use only cold treatments [19].

Summarizing, it should be remembered that the body recovery process is self-limiting and largely dependent on lifestyle. By introducing biological recovery measures in the form of selected physical treatments e.g. thermotherapy, hydrotherapy, phototherapy, and massage, we act for anti-trauma prevention, supporting the natural process of recovery.

Non-conventional methods

Recovery is associated with better post-workout regeneration of fatigued muscles, tendons, and bones but also with the improvement of processes such as sleep. Sleep quality and post-sleep state is a high priority in quality of life. Insomnia is a relatively frequent sleep disturbance, being more prevalent among women since 40-55% of middle-aged women may show sleep disturbance [7, 38]. It might be caused by excessive stress, overwork, overstrain, or delayed onset muscle soreness (DOMS) felt in muscles several hours strenuous exercise. The phenotypic effect of insomnia might be seen among others in disadvantageous brainwave entrainment. Thus, it seems interesting to focus and recommend such procedures that enhance, among others, the process of falling asleep and sleep it-self. This aspect especially concerns people above 60 years of age. It is now considered whether meditation (a form of disconnection of active consciousness), usually used to and enhance muscle relaxation, can improve sleep quality [12].

Analysis of subjective ratings of sleep and awakening quality derived from the questionnaire of sleep and awakening quality [50], shows that quality of sleep can be significantly improved. Electroencephalographic studies on meditation have shown an overall electroencephalogram slowing (i.e., increased theta and alpha activity) [5]. Thus, meditation may be helpful for individuals who suffer difficulties with switching off the mind when attempting to sleep [39]. However, the large variety of used techniques and the variety of meditator's skills are potential biases [8]. It is assumed that better sleep quality and better muscle relaxation during and after meditation are associated with better

recovery from exercise-induced muscle fatigue, which is slower in older people [55, 34]. There are some drugs − as resveratrol − used to enhance muscle fatigue resistance [1], yet, in this article, we have focused on non-pharmacological treatments.

Non-conventional methods that might support the recovery of exercise-induced muscle fatigue include mind-body interventions affecting bodily functions and symptoms including biofeedback, yoga, Taijiquan, hypnosis, guided imagery, praying, relaxation, and meditation [33]. In classical paper concerning the neuroscience of mindfulness meditation by Tang, Hölzel, and Posner in Nature Reviews Neuroscience meditation is defined as a "form of mental training that aims to improve an individual's core psychological capacities, such as attentional and emotional self-regulation" [56]. Authors emphasize that meditation encompasses a family of complex practices that include mindfulness meditation, mantra meditation, yoga, Taijiquan, and qigong. Given the body kinesthetic criteria, meditation practice (MP) can drop to one of three main subclasses. In the sitting position (zen, yoga, Buddhism), in the lying position (yoga, vipassana, Ma Yuan), or when the movement is involved (circle dances, Taijiquan, whirling dances, yoga, qigong, sustained exercise).

Research on meditation is still at the starting point and searching the Pubmed database using the phrase 'meditation' shows for the last 10 years merely 7,721 records and no more than 2,800 records for the last 5 years. However, the number of results of searching 'meditation' in the Google Scholar database increased from 38,000 in the years 1980-1990 to 213,000 records in the period 2010-2020. This data indicates that the interest in researching meditation is relatively average, but shows an upward trend.

Most meditation techniques are described in detail in numerous scientific articles. However, among the group

Figure 1. Ma Yuan painting of calm water surface, Wikimedia Commons

Figure 2. Ma Yuan painting of restless water surface, Wikimedia Commons

of visualization techniques, Ma Yuan meditation is quite an unknown complex visual imagery technique. Ma Yuan (1160-1225) was a Chinese painter of the Song dynasty specializing in paintings of sea and lake waves (Figures 1, 2).

Ma Yuan meditation technique is a dynamic visualization of wave movements on the water surface in various weather conditions from smooth and calm to aggressive and sharp. These pictures are "only" the starting point to achieve a dynamic form of waving water surface and flowing across. Although this form of painting was very popular in China, only Ma Yuan paintings became an inspiration for meditators. However, it is unknown who was the real author of this meditation technique, yet, it might be assumed that it was the indigenous collective author of Chinese origin.

This meditation is based on anchoring/focusing the attention on the kinesthetic active picture of moving waves and thus switching off/disconnecting the active consciousness. Diving in this space of consciousness helps to distance from competitions and thus calming the emotions. Therefore, it seems important to search for optimal methods that would help to find a balance between appropriate stimulation and silencing. However, according to our best knowledge, there is no evidence concerning the influence of the Ma Yuan meditation technique for recovery and human wellbeing thus making it much more mystery than other well-known meditation practices.

In summary, there is no unequivocal evidence than non-pharmacological treatments enhance recovery from exercise-induced muscle fatigue, yet it is highly possible and therefore should awake our interest and evoke future complex research.

Conflicts of interest

The authors declare no conflict of interest.

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