The effect of human muscle fatigue on muscle electrical activation parameters in elite sport and rehabilitation

Abstract of PhD Thesis

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Introduction

From the perspective of elite sport, fatigue can be an indicator of the quality of a training programme and the effectiveness of the desired training effect, and therefore all coaches and athletes want to know how well they tolerate the training programme, and both professionals and athletes want to know how well they can tolerate fatigue in a competitive situation and thus perform better, for example in a sprint situation where the last metres decide who will win the gold medal. Retired elite athletes have higher rates of certain cancers than the general population. Cancer patients often experience weight loss and loss of muscle mass, which results in reduced physical activity and patient mobility. To slow muscle mass loss, patients often receive physical therapy as part of cancer treatment, with moderate exercise based on the patient's physical abilities. In addition, studies in cancer patients have found that as muscle mass is lost, a shift from slow muscle fibres to fast muscle fibres is observed.

Objective

Understanding the neurological mechanisms behind fatigue is essential to enable athletes to achieve better sports performance and to enable doctors and physiotherapists to provide better quality conservative therapy for rehabilitation. The original question of our series of studies was why middle- and long-distance runners cannot run at significantly higher speeds at the end of the race when they have to sprint - despite the fact that the whole time up to that point there is a dominant aerobic energy expenditure and a concomitant increased activation of the small motor units - than they can run at the maximum speed at rest for short distances. Is it muscle fatigue or is a neural block developing? The aim of our studies was to determine how motor units behave during moderate isometric exercise up to full exhaustion.

Methods

The first study involved 11 university students (G1) and 14 elite athletes (G2). A maximum voluntary contraction (MVC) of 65% was determined for the biceps brachii muscle, and with this load, holding a weight, participants

were required to maintain 90 degrees of isometric elbow flexion in a standing posture until complete exhaustion. EMG activity of the biceps brachii muscle was measured and frequency analysis was performed. In the fatigue protocol, 3 windows were defined: first (W1), middle (W2) and last (W3) 5 s, and MVC frequency analysis was also performed (MAX) between 0 and 260 Hz with frequency bands of 20 Hz.

In our second study, 19 healthy university students participated. After determining the dominant side, we assessed the subjects' single repetition maximum using the GymAware RS device and then calculated 65% and 85% of this. Electrodes were placed on the biceps brachii muscle and the students were asked to hold the weight at 65% and 85% until complete fatigue. Immediately afterwards, subjects performed isometric maximal contraction (Imax). The measured electromyographic record was divided into 3 equal parts and the first, middle and last 3 s (W1, W2, W3) were analysed.

Results

The results of both our studies show that as the protocols progressed in time and the effect of fatigue increased (W1 to W3), the activity of low frequency motor units increased significantly (0-40 Hz), whereas the activity of high frequency motor units (60-260 Hz) decreased significantly in the G1 and G2 groups. It can be concluded that training with constant moderate tension results in increased activation of the lower frequency slow motor units with increasing fatigue, but that increasing fatigue in the lower frequency motor units does not result in an increase in the activation level of the higher frequency fast muscle fibres.

Conclusions

The results show that as the protocol progresses over time and the effect of fatigue increases (W1 to W3), the activity of low frequency motor units is significantly increased (0-40 Hz), whereas the activity of high frequency motor units (60-260 Hz) is significantly decreased in the G1 and G2 groups. It can be concluded that training with constant moderate tension results in increased activation of the lower frequency slow motor units with increasing fatigue,

but that increasing fatigue in the lower frequency motor units does not result in an increase in the activation level of the higher frequency fast muscle fibres. Consequently, since slow motor units are used at moderate loads and will not function even if fast motor units are activated, a higher external load is required. Considering the conversion from slow to fast muscle fibres in cancer patients, in some cases, if the age and physical condition of the patient allows during therapy, higher loads and consequently higher activation levels may be beneficial in terms of reducing the loss of mass of fast muscle fibres.

List of own publications

List of own publications on which this thesis is based:

1. Hegedüs, Ádám ; Tuza, Kornélia ; Katona, Péter ; Kopper, Bence ; Tihanyi, József
Szubmaximális izometrikus kontrakció alatt bekövetkező fáradás hatása a motoros egységek aktivációjára a könyökhajlító izmokban
BIOMECHANICA HUNGARICA 11 : 2 pp. 43-49. , 7 p. (2018)

2. Hegedus, Adam ; Trzaskoma, Lukasz ; Soldos, Peter ; Tuza, Kornelia ; Katona, Peter ; Greger, Zsolt ; Zsarnoczky-Dulhazi, Fanni ; Kopper, Bence ✉

Adaptation of Fatigue Affected Changes in Muscle EMG Frequency Characteristics for the Determination of Training Load in Physical Therapy for Cancer Patients

PATHOLOGY AND ONCOLOGY RESEARCH 26 : 2 pp. 1129-1135. , 7 p. (2020)

3. Hegedüs, Ádám ; Kopper, Bence Ádám

A motoros egységek aktivitásának változása a biceps brachii izomban különböző intenzitású izometriás terhelések hatására [Changes in motor unit activity in the biceps brachii muscle under different intensities of isometric loading]

ORVOSI HETILAP 164 : 10 pp. 376-382. , 7 p. (2023)

List of own publications not directly related to the thesis:

1. Soldos, Peter; Besenyi, Zsuzsanna; Hideghéty, Katalin; Pávics, László; Hegedűs, Ádám; Rácz, Levente; Kopper, Bence

Comparison of Shear Wave Elastography and Dynamometer Test in Muscle Tissue Characterization for Potential Medical and Sport Application
PATHOLOGY AND ONCOLOGY RESEARCH 27 Paper: 1609798 , 11 p. (2021)

2. Sonkodi, Balázs; Hegedűs, Ádám; Kopper, Bence; Berkes, István
Significantly Delayed Medium-Latency Response of the Stretch Reflex in Delayed-Onset Muscle Soreness of the Quadriceps Femoris Muscles Is Indicative of Sensory Neuronal Microdamage