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ABSTRACT: The biomechanical characteristics such as force and velocity of skeletal muscles, are of great importance in sport and medicine. These characteristics are significantly influenced by acute physical exercise. The problem is how to access the influence of the exercise by simple and non-invasive measurement method. The two main contractile properties, relative force and velocity of the biceps brachii muscle, are assessed by measurement based on magnetic displacement sensor measuring the muscle belly response. The measurements were performed in set of 10 healthy male individuals from 21 to 32 years old. Bipolar electrodes are applied in order to elicited single muscle response. The time response of muscle contraction is analysed, typical parameters are extracted and evaluated by statistical methods. Variability of the new method is compared to method that is widely used. With proper evaluation of the measuring results influence of measuring errors can be lower. It has been estimated by previous study that variability of displacement sensor with electrical stimulation (ES) is 15-33% and 5-16% for maximal voluntary contraction (MVC). The measurements were performed before exercise and repeated 2, 4, 6 10 and 20 minutes after physical exercise. The maximal fatigue due to exercise of biceps brachii muscle were achieved by dominant concentric volitional contraction of m. biceps brachii under condition that the arm is loadrd by weight of 6 kg. The time of exercise slightly varied for each individual. The fatigue was achieved after about 3 up to 5 minutes of activity.

The threshold of stimulating voltage, contraction time, sustain time, and half relaxation time are analysed as parameters of responses. The results show significant increase of stimulating threshold voltages and decrease of contraction time and sustain times. In half relaxation time, significant changes are not detected. In time interval between 5 and 7 minutes the parameters are achieved the stationary value.

This result and the method proposed might be relevant as a procedure of the on line follow up of sportsman during a process of active training and it might give the valuable data to trainer how to plan the process of warming up before of competitions.

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INFLUENCE OF ACUTE PHYSICAL EXERCISE ON TWITCH RESPONSE ELICITED BY STIMULATION OF SKELETAL MUSCLES IN MAN

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Key words: Biomechanics, skeletal muscle, sport medicine, electrical stimulation, and tensiomyography

INTRODUCTION

Acute physical activity can have various effects on skeletal muscle, ranging from subcellular damage of muscle fibres to stretch-induced muscle injures – strains. Symptoms associated with delayed-onset muscle soreness are an increase in plasma enzymes (e.g. creatine kinase), myoglobin and protein metabolites from injured muscles; structural damage to subcellular components of muscle fibres; and temporary increases in muscle weakness, as reported in references /1,2/. Most of the symptoms are possible to investigate by invasive techniques and therefore are not suitable for daily use in active sportsmen. It is the purpose of the proposed non-invasive biomechanical method to

estimate the range of time parameter changes in twitch response due to acute exercise.
Physical activity activate both metabolic and mechanical events that may damage muscle and, beside the metabolic factor lead to changes of biomechanical properties of the skeletal muscles. Because eccentric contractions are associated with high forces and possible damage in acute experiment the dominant concentric volitional exercise has been applied in order to avoid possible muscle damage.

MATERIAL AND METHODS

A simple method for the measurement of skeletal muscle contraction has been used /3/. The method is based on the assumption that radial muscle belly displacement detected by a magnetic sensor is proportional to muscle force. The muscle belly displacement is the globulisation or the rounding of the

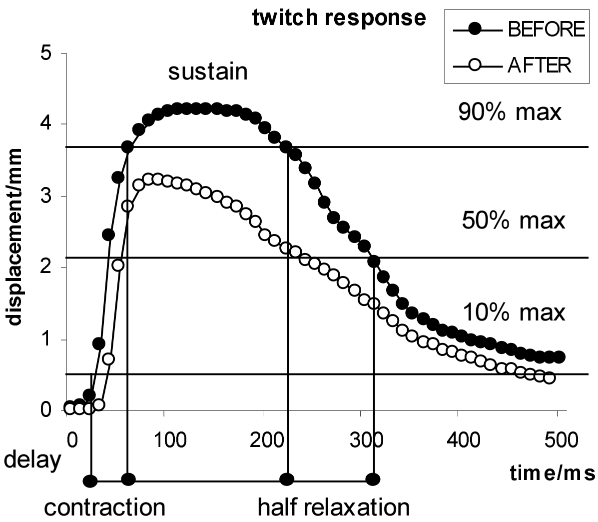

Figure 1. Changes in twitch responses muscle biceps brachii before and after physical dominant concentric exercise. Delay, contraction, sustain a relaxation time are extracted from the time response on single electrical stimuli (duration 1ms, amplitude 40 V above e threshold). These parameters are statistically evaluated for set of 10 healthy individuals.

muscle surface due to contraction. The procedure has been evaluated in healthy subjects /3/, subject after above knee amputation /4/ and denervated pretibial muscle group. It has been shown that the method can be applied as a substitute for mechanical brace measurement systems that are based on force transducers. With the method proposed one can measure the action of a single muscle within a given muscle group.

The transducer is mechanically constructed on a supporting frame with a micromanipulator for the precise positioning of the displacement transducer directly on the belly of the muscle. Subject is sitting or lying on a table during the experiment.
Ten healthy subjects, aged 21 to 32 were measured by

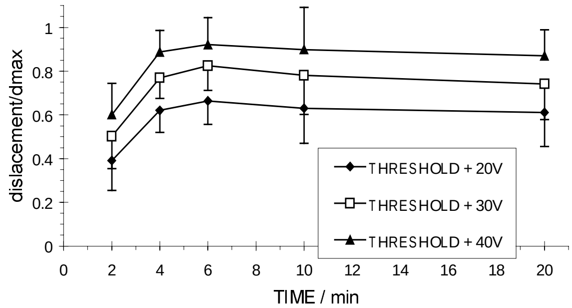

Figure 2 Changes in normalised displacement 2, 4, 6 10 and 20 minutes after physical exercise of m. biceps brachii. Threshold voltages are determined for each subject individually.

the system in isometric conditions during the experiment the subjects sat comfortably on a special chair. The forearm was fixed to the mechanical brace with an initial elbow flexion of 90 degrees. The displacement sensor was positioned at the surface of the belly of the m. biceps brachii where the maximal enlargement (globulisation) of the belly was observed as the muscle contracted. This position needed to be determined individually because of individual anatomical differences. In the experiment single-twitch stimuli were used in order to study the dynamic response of the muscle. The stimulation was provided cutanously by two surface electrodes (radius of 5 cm). The positive electrode was placed over the muscle up to 5 cm above the measuring point and the negative one up

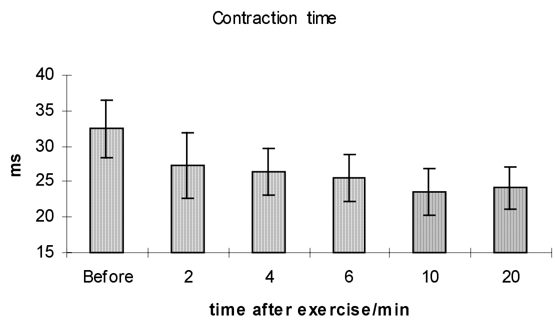

Figure 3. After dominant concentric exercise the contraction time is significantly shorter-for about 20%. ($p < 0,05$).

to 5 cm below the measuring point. The duration of the stimuli was adjusted to 1 ms and the voltage amplitude was gradually increased from up to 40 V above threshold muscle contraction response. The significance of differences between time parameters of both groups was tested by the two-sample Student's t-Test. A *P*-value lower than 0.05 was considered statically significant.

RESULTS

A typical changes in twitch muscle sponses before (filed dots) and after physical dominant concentric exercise (non-filed circles) are shown in Fig. 1. Delay, contraction, sustain an relaxation time are measured as time intervals between moment when the response has the value of10%, 50% and 90% of maximal displacement. Maximum response was measured at single electrical stimuli (duration 1ms, amplitude 40 V above threshold). These parameters are statistically evaluated for 10 healthy individuals. From the time curves it is evident a decrease of maximal response after exercise, shortening of contraction time and sustain time. The half relaxation time is not changed significantly. The measurements were performed before exercise and repeated 2, 4, 6 10 and 20 minutes after physical exercise of m. biceps brachii in condition when the arm is load by weight up to 6 kg. The time of exercise slightly varied in each individual. The fatigue was achieved after about 3 up to 5 minutes of activity.
The results show significant increase of stimulating threshold voltages and decrease of maximal displacement. In time interval between 5 and 6 minutes the parameters achieve the stationary value as illustrated in Fig 2. Contraction time is consedered as an important parameter describing the biomechanical characteristic of skeletal muscle. We found that this parameter varied significantly for different muscles from 20 ms for m. vastus lateralis and up to 60 ms in m. biceps femoris. In case of m. biceps brachii the average Contraction time is about 32 ms. After dominant concentric exercises the activation time is significantly declined for about 20%. ($p < 0,05$, n =10, with a Student's t-Test, Paired). Fig. 3.
After acute excercise of m. biceps brachii the sustain time is for all individuals significantly declined ($p < 0,05$, n =10, with a Student's t-Test, Paired) Fig 4.
One may assume that the sustain time is related to with the active process of crossbridge cycling, the possibility of interaction between the crossbridges and the thin filaments increases by volitional excercising. The net result is the changes in activation and sustain time. Beside these effects no significant changes were detected in half relaxation time.

DISCUSSION

These experimental findings are not in agreement with our expectations. After acute exercising and therefore fatiguing contraction, the usual result is increase of contraction time and sustain time, and prolongation in the relaxation time of a twitch. The twitch duration is usually increased after fatigue. This is presumably associated with biochemically mediated reduction in

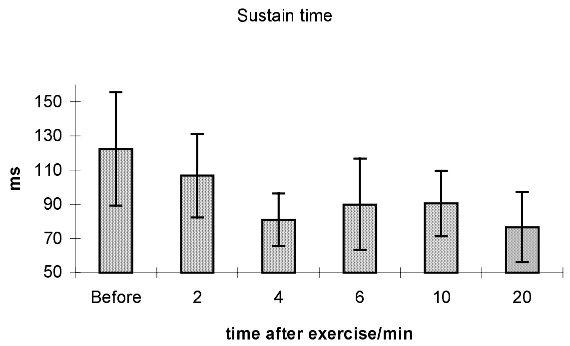

Figure 4. After dominant concentric exercise the sustain time is significantly shorter-for about 25%. ($p < 0,05$).

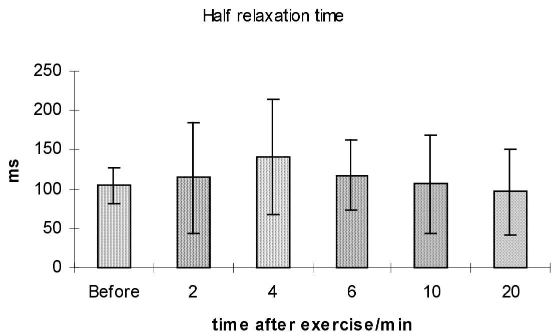

Figure 5. Half relaxation time does not changed significantly after acute exercise of m. biceps brachii is not enough fatiguable to elicit expected effects in twitch response.

relaxation rate. In our experiment it is possible that short lasting volitional concentric dominant movement The next possible, perhaps the most reasonable reason for the contradictory results in twitch duration is posttetanic potentiation. The magnitude of the twitch force is extremely variable and depends on contraction history of the muscle. The posttetanic potentiation of twitch response can be substantial and can be elicited by both voluntary contractions and electrical stimulation. Potentiation of submaximal force occurs in all three types of motor units (Types S-slow, FR-fatigue resistant and FF- fast fatigue). When motor units were activated with a stimulus that elicited a submaximal tetanic force, the average potentiation was greater among the fast-twitch motor units then in the slow-twitch motor units (Gordon, Enoka, Stuart, 1990). Because posttetanic potentiation and fatigue occur concurrently, beginning from the onset of contraction; the twitch response after exercising depends on distribution of different motor units in particular skeletal muscle. For the experiment proposed in m. biceps brachii we might conclude that particular

skeletal muscle consist dominantly of fast-twitch motor units. This is in agreement with data obtained by the histological examinations.
In the next experiments we have to repeat the same protocol of measurement in the muscle which typically consists of types S and FR motor units (i.e. m. biceps femoris). We can conclude that the method based in detection of muscle belly displacement is a simple and non-invasive way, suitable for the study of contractive properties of practically any skeletal muscle in man.

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