Detecting the velocity of the muscle contraction

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Abstract

The dynamics of skeletal muscle mechanical response cannot be measured selectively and non-invasively using existing methods. Therefore new, selective and non-invasive method (Tensiomyography) that provide information about skeletal muscle contractile properties, like: speed of muscle contraction, time needed for relaxation after contraction, recruitment pattern and muscle potentiation/fatigue, was developed. Method uses alter approach and detects thickening of the muscle belly. A result of the measurements speaks about intrinsic properties of the muscle belly without being affected by connective and passive surrounding tissue. Importance of the time parameters of the muscle contraction is of the essential value studying muscle illnesses, rehabilitation processes, training dimensioning and muscle adaptation. Measuring setup and equipment needed were developed to hit commercial and laboratory environment and offers easy-to-operate universal diagnostic tool.

1 Introduction

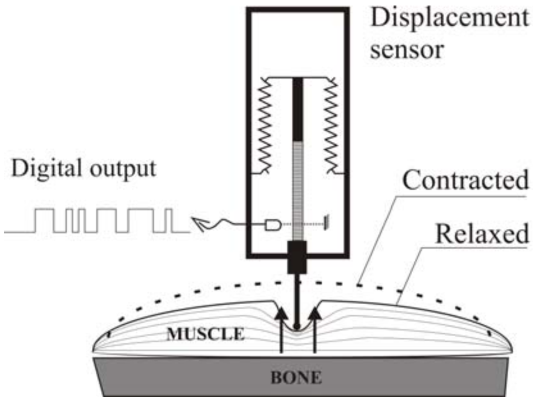
Skeletal muscles' velocity of the contraction is beside muscle force another very important parameter and speaks about quality of the muscle tissue. As such it is very difficult to detect because of the subjective standardization of the measurement protocol and muscle specifics that could affect the results. To avoid those impediments new methodology (Tensiomyography - TMG) was developed and evaluated during last few years.

Considering constant muscle volume the longitudinal and transversal changes in muscle structure during contraction are closely related. Already in 17th century few individuals could hear the sound of muscle contraction at very low hearing frequencies. Vollaston in 1810 was the first to link muscle sound with muscle force and announce that muscle sound is at about 14 – 36 Hz, which was later found as the right conclusion. This was the beginning of the oldest method, called Mechanomyography or shorter MMG. Later new sub-methods of MMG method were developed (Phonomyogram, Vibromyogram, Soundmyogram, Acoustomyogram) distinguishing on the sensor nature. Thickening of muscle belly was observed with laser beam (Orizio et al., 1999 and 2000), lateral vibrations of muscle fibres were observed with accelerometer (Zhang et al., 1992 and Orizio, 1993) or microphones (Barry et al., 1985; Maton et al., 1990).

TMG method uses displacement sensor for selective detection of transversal muscle deformations on electrical stimulation (Figure 1). Such approach lowers the variability rate and raises the quality of the information detected. Method was introduced (Valenčič, 1990) and evaluated with histochemical results (Dahmane et al. 2000), muscle force and torque (Šimunič, 2003) and EMG (Krševan, 2002). In this study we will present just few possibilities of methods' application in top sports. Analyses of lateral and functional symmetry, muscle adaptation on specific sport or exercise, muscle potentiation and fatigue and muscle recovery from injury.

2 Results

The presented findings were results of the already published or unpublished preliminary work. The main idea is to give few different aspects on using the TMG method in sport area. Method was found to be easy to use and universal tool for objective detection of muscles' contractile properties. Results are noiseless and therefore automatically interpreted using standard parameter definition (Figure 2).



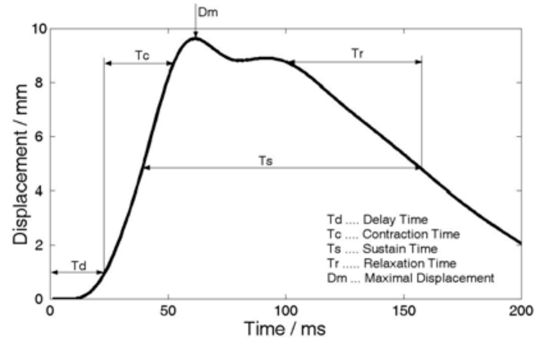
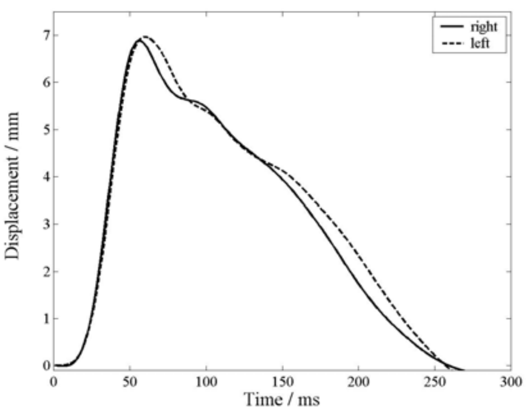


Figure 1: Principle of the TMG method. Electrical twitch evokes muscle contraction resulting also in thickening of the muscle belly that is measured by the displacement sensor. Displacement sensor is positioned perpendicularly to the skin surface above the muscle belly and the tip of the sensor is pressed to the muscle, slightly deforming the muscle belly.

Figure 2: TMG parameter definition. Delay time describes responsiveness of the nervous system, contraction time was found significantly related to muscle composition, sustain and relaxation time describes reverse dynamics of the calcium pumps in sarcoplasmic retikulum and maximal displacement describes muscle volume and tone.

2.1 Lateral and functional symmetry

Acquiring TMG parameters from supramaximal muscle response with electrodes and sensor positioning takes about 2 minutes. Therefore in maximum 30 minutes all the essential superficial muscles could be measured and their results are ready for further analyses.



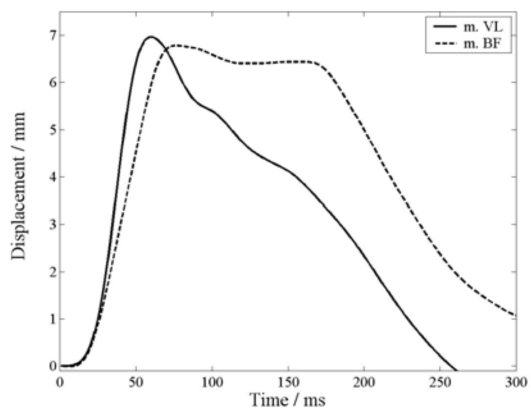


Figure 3: Lateral symmetry of the *vastus lateralis* muscle measured on basketball player. Symmetry rate is almost perfect, 96%.

Figure 4: Functional symmetry of knee joint between vastus lateralis (VL) and biceps femoris (BF) measure also on basketball player. Symmetry rate is 58% as contraction time for VL is 23ms and for BF 38ms. Also additional asymmetry is present in sustain time.

Calculating lateral symmetry from all five TMG parameters enables us to compare the same muscle on different lateral sides of the body. Evaluating the lateral symmetry with single number makes comparison much easier as the importance of all five parameters are not always the same depending on subjects' sport activity or health. Usual lateral symmetry rate is above 85% (Figure 3) no matter on sport activity. In some typical asymmetric sports (golf, hockey, etc.) also lower lateral symmetry rate is present and than we have to deicide whether to keep this asymmetry or to minimize it incorporating specific training program to do so.

Functional symmetry could be calculated as symmetry between antagonistic muscle pairs (*biceps brachii* and *triceps brachii*) or as symmetry between synergistic muscles (*vastus lateralis* and *vastus medialis*). Maximal displacement depends not just on muscle tone also on muscle volume and therefore we have to ignore this parameter from calculating functional symmetry. Functional symmetry rate is usually above 65% and lower values indicate potential danger for injury, reflect sports' asymmetry or past injuries (Figure 4). Athlete involved in periodic and explosive sport should have not just powerful but also fast muscles and no muscle should step out in any way significantly.

2.2 Potentiation of the response

Muscle potentiation is commonly known as acutely stronger twitch response after short bursts of voluntary or elicited contractions. In translation to sport activities we could understand this as a stronger response of the muscle after short intensive physical stimulus, like some explosive action. We have tested muscles' response before and after three sets of four-second maximal voluntary contraction (Figure 5) and demonstrate the transitoriness of the phenomena (Figure 6).

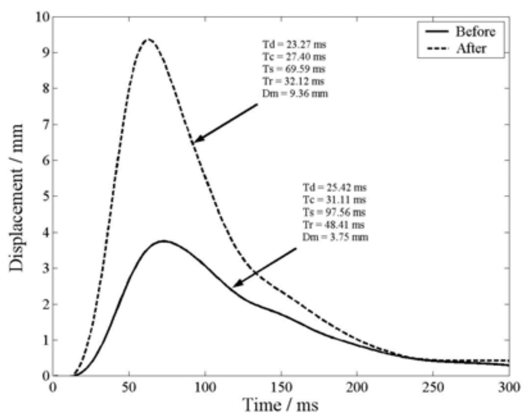


Figure 5: TMG response and parameters of *biceps brachii* muscle before and after short intensive exercise bursts. All four time parameters diminishes and Dm increases significantly.

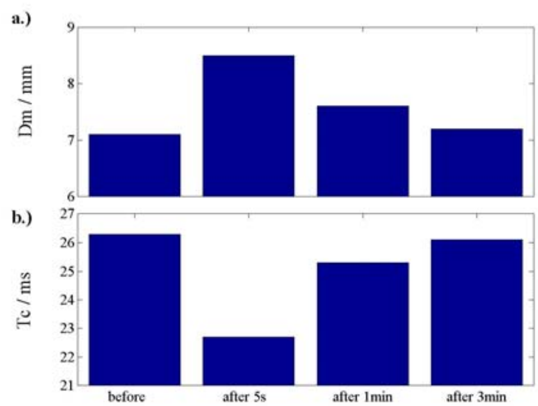


Figure 6: Chronological view of the potentiation phenomena, which completely disappears after 3 minutes of rest. Muscle *vastus lateralis* was tested before and three times after the exercise. Dm of the response increases (a) and Tc decreases (b).

2.3 Muscle fatigue

Prolonging the short exercise needed to trigger potentiation of the response causes muscle fatigue. That makes potentiation and fatigue parallel processes with potentiation overcoming fatigue in the first period of time and *vice versa* in the second part. Knowing the exact point at which this happen is the key for the successful training dimensioning. Two points of view on this issue are popular. Dimensioning training process from the rest period point of view or from the number of sets point of view. On both issues we must seek answers and TMG testing offers us answer in general. On Figure 7 muscle recovery after complete exhaustion is demonstrated using selective intermittent electrical stimulation as the fatigue protocol. On Figure 8 tracking of TMG parameters Td and Tc is presented where also potentiation in the first part is visible.

2.4 Muscle adaptation

Skeletal muscle tends to adapt on certain long-term training process. Few parameters of such adaptation could be assessed with TMG method, like muscle tone, contractile parameters and resistance to fatigue. Athletes involved in the measuring protocol were top track and field sprinters in their everyday training process of the whole 22-week training period. At the end of this period they all started to compete and their peak performance at that time was expected and confirmed by 30 meters flying sprint test. TMG results of the last 13 weeks are presented on Figure 9 were we could see that at the end of training period muscles didn't become significantly faster but are far more synchronized. This is important as the measured muscles are all very involved in the sprinting event and inter-muscle synchronization is expected.

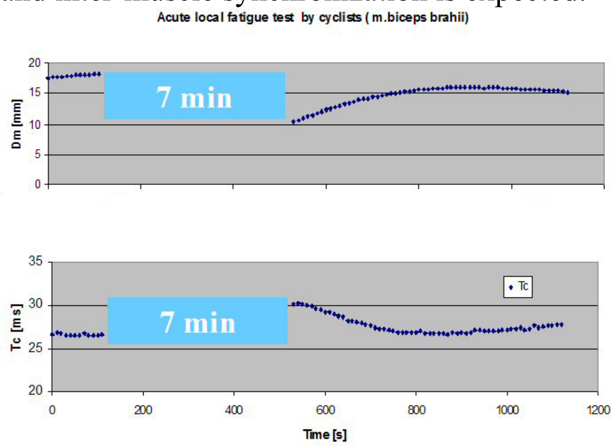


Figure 7: Changes in Dm and Tc TMG parameters after acute fatigue of biceps *brachii muscle* using intermittent stimulation fatigue protocol. TMG response was detected every 15s for two minutes before the fatiguing protocol and for ten minutes after it. It is evident that five minutes was enough for both parameters to recover on its initial value. Dm dropped for 55% and Tc increased for 16%.

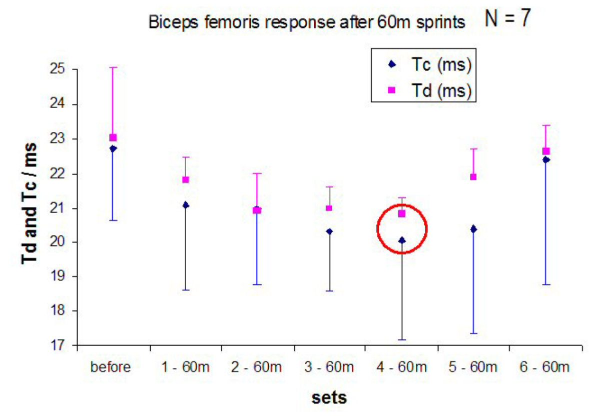


Figure 8: Changes of the Td and Tc parameters after six sets of 60m sprints. Seven subjects performed six sprints and after each one TMG response was obtained from *biceps femoris* muscle. After first, second, third and fourth attempt potentiation overcomes fatigue. After the fifth set muscles' fatigue becomes visible and even increases after sixth set.

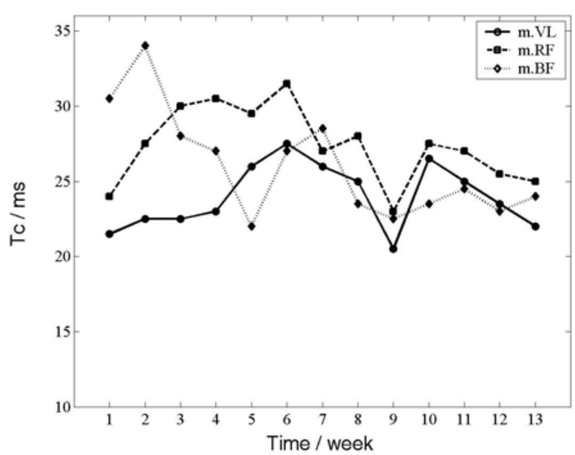


Figure 9: Chronological analysis of *biceps femoris*, *rectus femoris* and *vastus lateralis* muscles' contraction time in six elite sprinters. Last 13 weeks of the overall study are presented. Contraction time was extracted to monitor inter-muscle synchronization regarding to actual peak performance of athletes. On week 13 they achieved the best results in sprinting events and the competition period started.

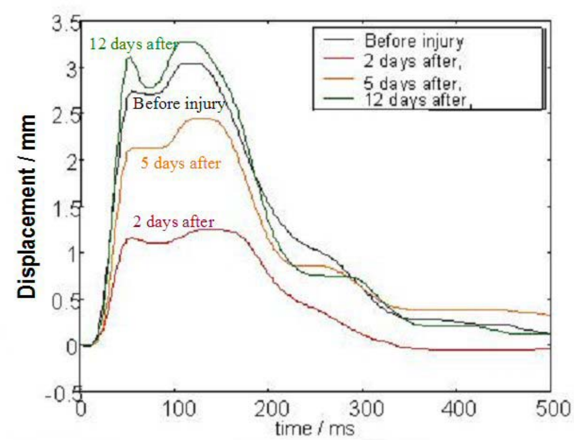


Figure 10: Time tracking of the rehabilitation process of the *biceps femoris* muscle injury in football player. Local muscle strain in *biceps femoris* muscle happened during football game. The player was measured three days before injury and later on second, fifth and twelfth day after injury. Muscle was fully recovered after twelfth day.

2.5 Muscle recovery

Muscle injuries are very common in top sport and hamstring muscles are often subject to the strain or rupture. More than 70% of all hamstring injuries hit the *biceps femoris* muscle as the muscle is almost twice as fast as *semitendinosus* or *semimembranosus*. Football player – attacker was diagnosed as very fast on *biceps femoris* muscle (Tc = 22ms) but with very low muscle volume. All other key muscles' contraction times were around 20ms and therefore fast moves were expected during football play. He was warned to build muscle mass on *biceps femoris* muscle. Three days after TMG assessment his muscle was strained during the football game. The rehabilitation process of the muscle was closely measured to see the objective and safe timing for his next game. On the Figure 10 we could see that on the second day the activation of the muscle was much lower owing to inhibition and on twelfth day after the injury of the muscle *biceps femoris* was fully recovered and the player was ready for he next game. Regarding to the TMG results players rehabilitation process was in that time optimized and shortened so the contractile properties stayed unchanged.

3 Conclusions

In this work TMG method and its usefulness was presented. Many different applications were pointed out and preliminary data presented. Method could be used in various studies on superficial skeletal muscles depending on sport that subject is involved in to. Variability was previously checked and could be minimized down to 5% considering measuring standards set by team of experts involved in methods development (Šimunič, 2001).

4 Literature

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