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Analysis of the Electromyographic Signal During Rehabilitation Exercises of the Knee Joint

Jakub Krzysztof GRABSKI
Institute of Applied Mechanics, Poznan University of Technology
ul. Jana Pawła II 24, 60-965 Poznań
jakubgrabski@poczta.onet.pl

Sylwia KAZIMIERCZUK
Institute of Applied Mechanics, Poznan University of Technology
ul. Jana Pawła II 24, 60-965 Poznań

Tomasz WALCZAK
Institute of Applied Mechanics, Poznan University of Technology
ul. Jana Pawła II 24, 60-965 Poznań
tomasz.walczak@put.poznan.pl

Abstract

The system of human locomotion is very complex. Generally we can divide it into the skeletal and muscle systems. The muscle system (muscles) enable to move the body which is formed by the skeletal system (bones). Electromyography is a technique of measurement the electrical activity of muscles which is related with shortening or lengthening of muscle fibers (muscle contraction). In the paper analysis of the electromyographic signal (EMG) recorded during knee rehabilitation exercises was conducted. The records of EMG from person after knee injury were compared with records of EMG from healthy person.

Keywords: electromyography, knee rehabilitation, rehabilitative exercises

1. Introduction

The human movement is possible by interaction between three systems: the nervous system, the muscle system and the skeletal system. Each of the aforementioned systems has specified functions for human movement performing. The skeletal system maintains the shape of human body. The joints which are part of the skeletal system enable movement of the body. The movements of the body in the joints are performed by contraction of muscles which are connected to the bones by the tendons. Decisions about human movement are taken in the brain which is part of the nervous system.

The nerves which directly innervate the muscle fibers are located in the vertebrae and they are called alpha motor neuron. The alpha motor neuron, muscle fibers which are innervated by single alpha motor neuron and axons constitute the motor unit. One alpha motor neuron can innervate from several to several thousand muscle fibers. The muscle fibers are grouped together in the muscle fibers bundles (which contain from 10 to 100 muscle fibers).

A single signal which is received by the group of muscle fibers is called motor unit action potential. The disorder propagates along the muscle fibers. Electromyographic signal is a sum of the disorders at the time and the place of electrodes application. There-

fore electromyographic signal depends on many factors (internal and external) which are detailed described in [1].

Electromyography plays more and more important role in medicine, kinesiology rehabilitation, biomechanics, sport and ergonomics [2,5,6]. Many interesting articles on analysis and applications of electromiographic signal can be find in Journal of Electromyography & Kinesiology. Recommendable publication on electromyographic signal, its recording and processing was written by Merletti and Parker [4].

In the paper the results of electromiographic signal recording results during knee rehabilitation exercises with pillow were presented. The main purpose of the paper is to show the relationship between muscle activity and assessing progress of rehabilitation.

2. Description of the knee rehabilitation exercises

Causes of motor organs injury can be divided into internal and external factors. The main internal factors are: anatomical abnormalities, friction forces in the motor system and extensive stretching of tendons. The external factors are associated with training errors (extensive training volume and training intensity, errors in technique of performing exercises).

The main aim of knee rehabilitation exercises is to learn maintaining of the equilibrium state and appropriate technique of the performed exercises [3]. Bad habits in the technique of rehabilitation exercises can result in deepening the disease state. The knee rehabilitation exercises are static exercises with load. There were three knee rehabilitation exercises taking into account in our research: partial squat on the pillow (Fig. 1), one leg partial squat (Fig. 2) and one leg partial squat on the pillow with performing of the semicircle (Fig. 3).

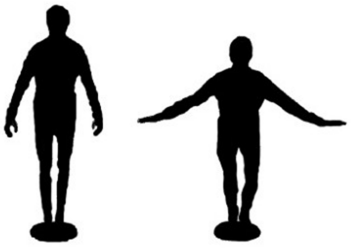

Figure 1. Partial squat on the pillow

Figure 2. One leg partial squat on the pillow

Figure 3. One leg partial squat on the pillow with performing of the semicircle

3. Method of measurements

The measurements were performed using NORAXON electromyographic system and were collected from four muscles on each leg (together eight muscles): the rectus femoris muscle, the vastus medialis muscle, the semitendinosus muscle and the biceps femoris muscle, which were depicted in Fig. 4.

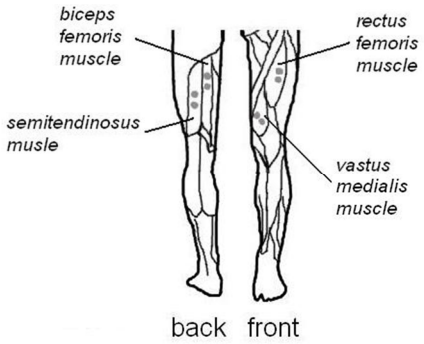

Figure 4. Arrangement of the electrodes on the leg muscles

The EMG signal was recorded for muscles presented in Fig. 4, during described exercises. The raw electromiographic signal is difficult to analyse and therefore various algorithms for its processing are applied. In the paper the RMS algorithm with 100 ms frame was used.

4. Results

The first tested person was a woman who as a result of wrong settings of mechanical axis of the left leg, has a diagnosed injury in her left knee. In this case is extremely import to develop the rectus femoris muscle which is responsible for keeping the kneecap in the correct position. In all considered cases each of experiences performed at least ten times.

In Fig. 5 one can observed big differences between left and right rectus femoris muscle and biceps femoris muscle in the first month of the rehabilitation. The activity partial squat on the pillow in the first month of the rehabilitation of these muscles show that

the left leg is significant weaker than right one. In order to observe the rehabilitation progress similar measurements were done after second month of the rehabilitation (Fig. 6).

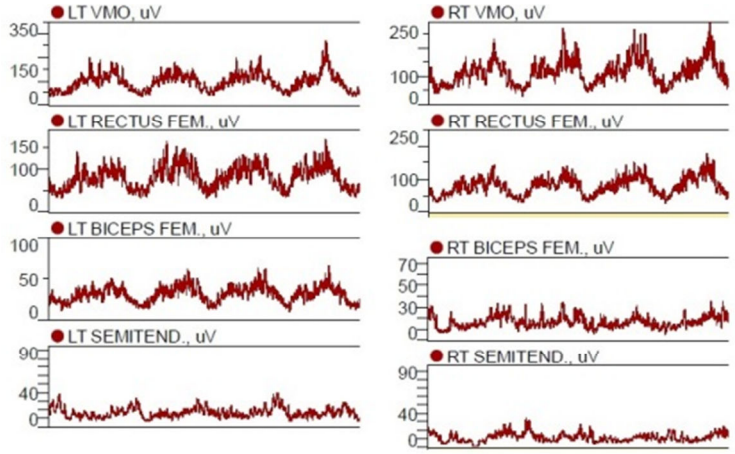

Figure 5. Comparison of the RMS signal for selected muscles of left and right leg during

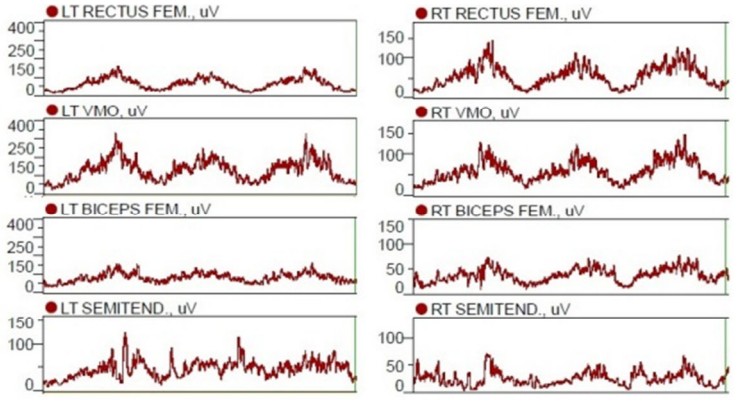

Figure 6. Comparison of the RMS signal for selected muscles of left and right leg during partial squat on the pillow in the second month of the rehabilitation

After two months of the rehabilitation improvement of the left leg could be observed. Significant increase of recorded EMG signal is noticed in the case of the vastus medialis muscle. The difference between left and right muscles activity smaller than the difference in the first month of rehabilitation.

During the one leg squat exercise average activity of muscles is much higher than in the first exercise (Fig. 7). One can conclude that it is difficult to observe find the difference between the healthy leg and the leg with injury. The progress of the rehabilitation in

all considered muscles could be observed analysing graphs presented in Fig. 8. That fact shows efficiency of the used rehabilitation.

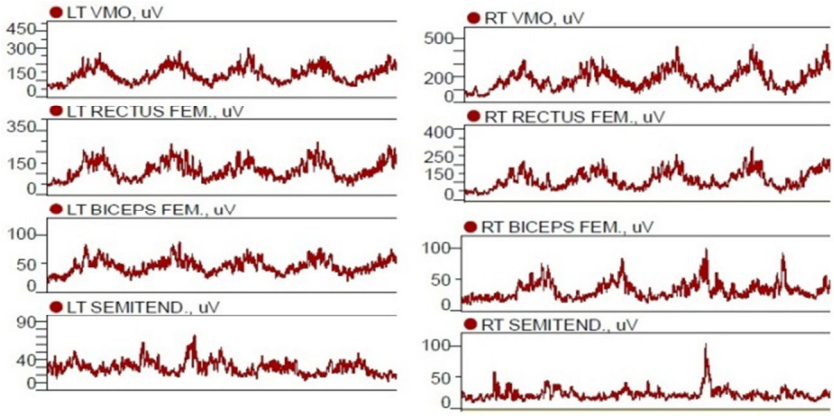

Figure 7. Comparison of the RMS signal for selected muscles of left and right leg during one leg squat on the pillow in the first month of the rehabilitation

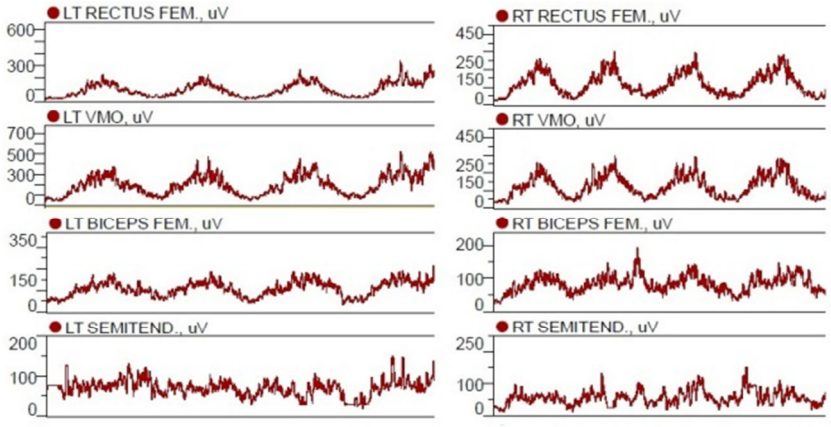

Figure 8. Comparison of the RMS signal for selected muscles of left and right leg during one leg squat on the pillow in the first month of the rehabilitation

The last considered exercise (Fig. 8) is very good indicator which shows whether the muscles are proper protection (stabilization of the knee). In this case one can see disproportion between left and right leg. Shapes of signals from leg with injury are less regular than from healthy one. The vastus medialis muscle, the rectus femoris muscle and the biceps femoris muscle in the left leg have similar activity graph. On the other hand the biceps femoris muscle in the right leg has completely different characteristic. It could be caused by necessity of participating the left biceps femoris in stabilization of the injured knee in that kind of motion.

Records of electromyographic signal for the same exercise but after two months of the rehabilitation was presented in Fig. 10. The average activity of muscles in the left and the right legs is very similar.

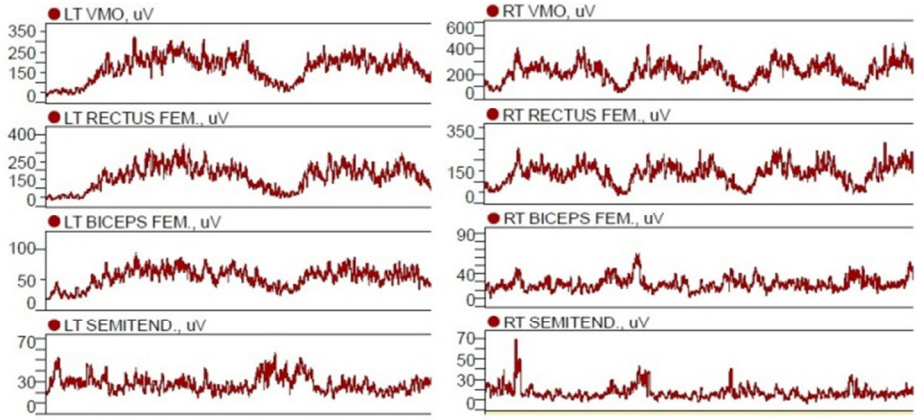

Figure 9. Comparison of the RMS signal for selected muscles of left and right leg during partial one leg squat on the pillow with performing of the semicircle in the first month of the rehabilitation

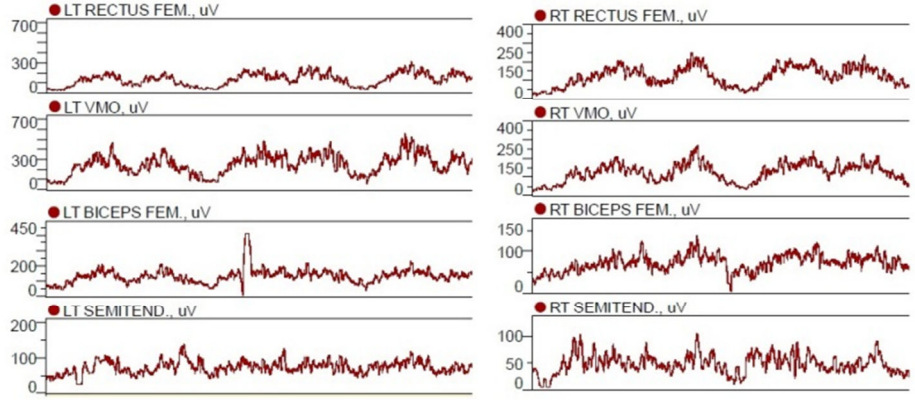

Figure 10. Comparison of the RMS signal for selected muscles of left and right leg during partial one leg squat on the pillow with performing of the semicircle in the second month of the rehabilitation

In Fig. 11-13 records of EMG signal for healthy person were presented. One can observed that in all cases of considered exercises the muscles activity measured for both legs is alike. Work of the considered muscles for left and right leg respectively is much more symmetric than in case of injured person. That kind of signal analysis can be useful for injury prediction.

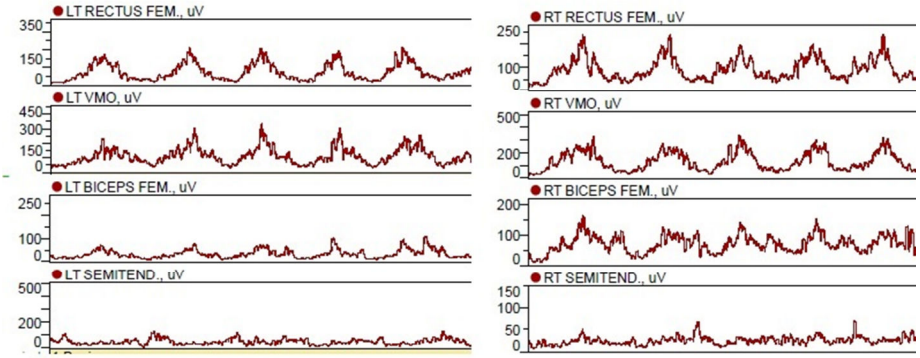

Figure 11. Comparison of the RMS signal for selected muscles of left and right leg during partial squat on the pillow – healthy person

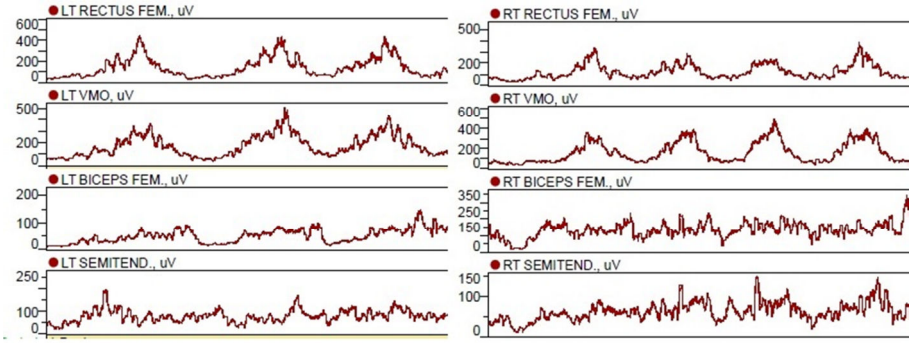

Figure 12. Comparison of the RMS signal for selected muscles of left and right leg during one leg squat on the pillow – healthy person

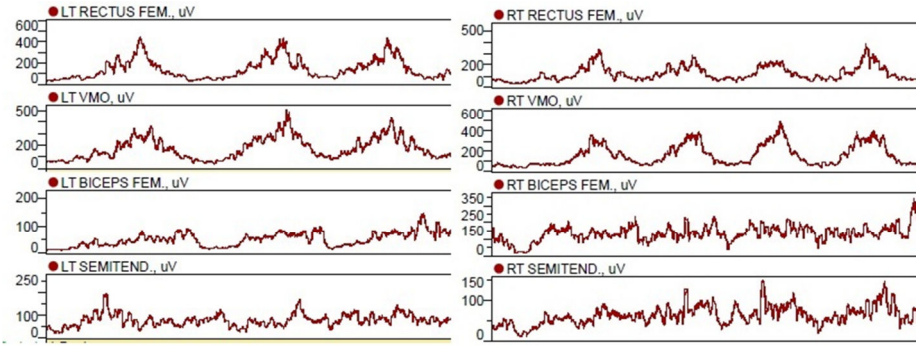

Figure 13. Comparison of the RMS signal for selected muscles of left and right leg during partial one leg squat on the pillow with performing of the semicircle – healthy person

5. Conclusions

The paper presents the electromyographic signal as valuable source of information in the rehabilitation of the knee joint. Injuries of the knee can be manifested by increased activity of some muscle groups which can be seen in electromyographic signal records. Presented results of the research show that progress of the rehabilitation could be in the easily way observed. The difference between muscles activity in healthy and injured leg is well visible. Therefore the electromyographic signal can be a good source of information about progress of the rehabilitation process and potential joints injuries.

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