A LOW-COST METHOD FOR REAL-TIME EVALUATION OF MEDIAN FREQUENCY DURING CYCLIC CONTRACTIONS

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The appropriate exercise intensity can be used to improve physical strength as well as to prevent musculoskeletal injuries, and scientific analysis can evaluate the effectiveness of resistance training. The goal of the study was to test a low-cost method for real-time evaluation of median frequency (MDF) during cyclic contractions. Surface electromyography (sEMG) is an objective, non-invasive and pain-free method for assessing and monitoring muscle fatigue in humans performing resistance exercise. In the study, we provided a low-cost method for real-time evaluation of MDF during cyclic contractions. For a well designed program that controls the accumulation of fatigue, local muscle fatigue must be quantified.

KEY WORDS: median frequency, cyclic contraction, EMG.

INTRODUCTION: Resistance training has become a popular way to improve athletic ability and to promote health. Muscular strength and muscular endurance are vital to our health and to our ability to perform athletics and daily activities. The muscle contractions during the cyclic contraction is highly effective in developing strength, but it can put joints, soft tissue and the body's muscule at risk for injury from repetitive overuse and cumulative muscle fatigue, so controlling cumulative muscle fatigue from repetitive training is important. The appropriate exercise intensity can be used to improve physical strength as well as to prevent musculoskeletal injuries, and objective scientific tests can evaluate the effectiveness of resistance training.

Methods for assessing the electrical manifestations of muscle fatigue during movement analysis have been reported in many papers (Linnamo, Bottas & Komi, 2000; Gefen, Ravid, Itzchak & Arcan, 2002; Sbriccoli, Bazzucchi, Rosponi, Bernardi, Vito, & Felici, 2003; Danuta, Tomasz, & Karina, 2004; Kyle & David, 2008). The shift of the surface electromyographic (sEMG) power spectrum to lower frequencies during sustained isometric contractions is well known and is generally accepted as the relationship between frequency and conduction, a sign of local muscle fatigue. It has been suggested that, as a muscle tires, the shift in the power density frequency spectrum of sEMG to lower frequencies is caused by two major factors: a decrease in the muscle fiber conduction velocity, and a change in the motor unit (MU) firing situation. Thus, the median frequency (MDF) of the power spectrum can be considered a sensitive measure of muscle fatigue.

A sound program of resistance training will develop major muscles for strength and endurance, and also will protect the body from injury. Therefore, it is important to evaluate the conditions of the muscles during the program. The goal of the study was to test a low-cost method for real-time evaluation of MDF during cyclic contractions.

METHODS: During the experimental procedure, ten subjects were tested on a leg-extension machine (PL2000, Paramount Fitness Corp., USA). Before the cyclic contraction, the subject sat erect on the seat with the back and hips pressed evenly against their respective pads. The position in the machine must allow the knees to be in line with the axis of rotation of the machine. The foot was held in a neutral position. The weight of the lifting was controlled to be equal to 60% maximal voluntary contraction (MVC) for each subject and had been previously determined for each subject individually. The subjects repeated lifting at a frequency of twenty times per minute, following a cyclic beep from the interface of experimental control, and were instructed to keep the movements as smooth as possible. Exercise was stopped at

the moment when the subject, because of muscle fatigue, was not able to reach full extension within the time allowed.

The sEMG data were recorded simultaneously from three quadriceps muscles—*m. rectus femoris* (RF), *m. vastus lateralis* (VL), *m. vastus medialis* (VM) —using three discrete EMG pre-amplifiers (MA-416, Motion Lab Systems Inc., USA) and a data acquisition device (USB-6009, National Instruments Corp., USA). For this purpose, the sEMG electrodes were placed over the midline of the muscle belly. These sites were cleaned with alcohol pads in order to minimize the skin resistance. A photo snesor CNY70 was used to segment the periods of the whole cyclic contraction. The sensor was placed by the side of the loading ingot. The raw sEMG signals and photo signal were recorded at the sampling rate of 1000 Hz (Figure 1).

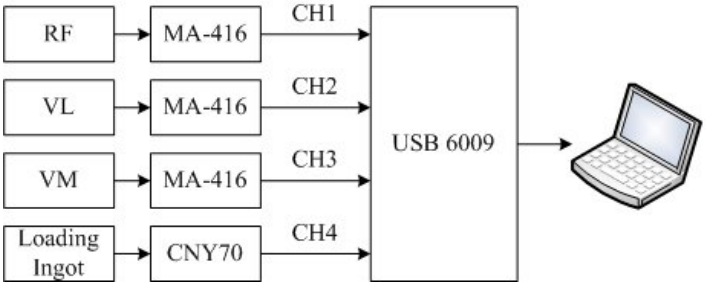

Figure 1: Block diagram of the recording setup (RF: rectus femoris, VL: vastus lateralis, VM: vastus medialis).

All signal processing was performed using custom programs written with LabVIEW programming software (Ver. 8.6, National Instruments Corp., USA). The sEMG data were filtered for the frequency range of 20-500 Hz by a fourth-order Butterworth filter. Then the MDF values were calculated for each contraction. The MDF (f_{med}) of the power spectral density P(f) is defined as:

$$\int_0^{f_{med}} P(f)df = \int_{f_{med}}^{\infty} P(f)df = \frac{1}{2}\int_0^{\infty} P(f)df$$

RESULTS: The user interface of signal processing can display the results of real-time calculations. The lower left of interface was the signal of the photo sensor (CNY70) and the lower right of interface showed the MDF values of the real-time analysis. Besides, three columns display raw sEMG signals of three electrodes, corresponding power spectrum and corresponding MDFs (Figure 2).

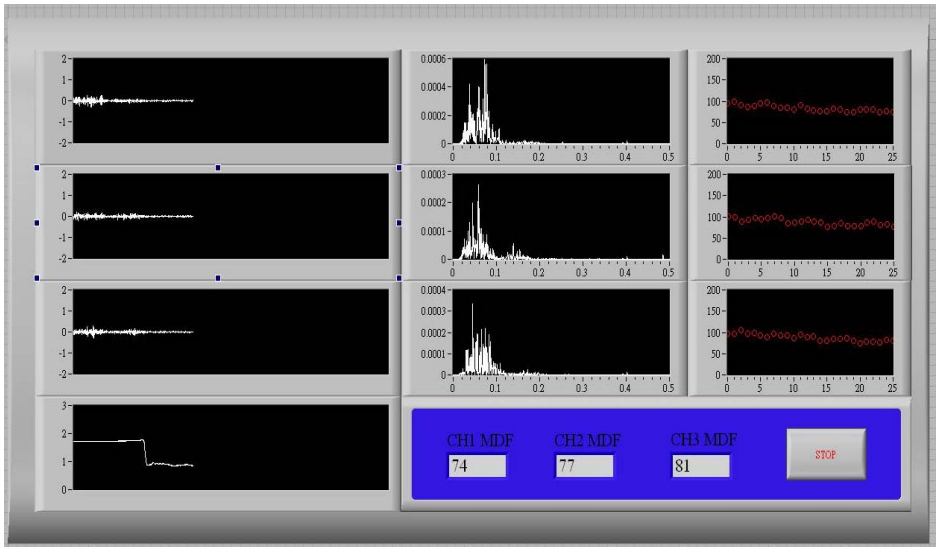

Figure 2: The user interface of signal processing (the first column: raw sEMG signals and photo signal; the second column: corresponding power spectrum; the third column: MDF series)

DISCUSSION: The MDF data were stored into the computer by using ASCII text format. It is convenient for the users because they can plot the figure by using some software packages (Figure 3).

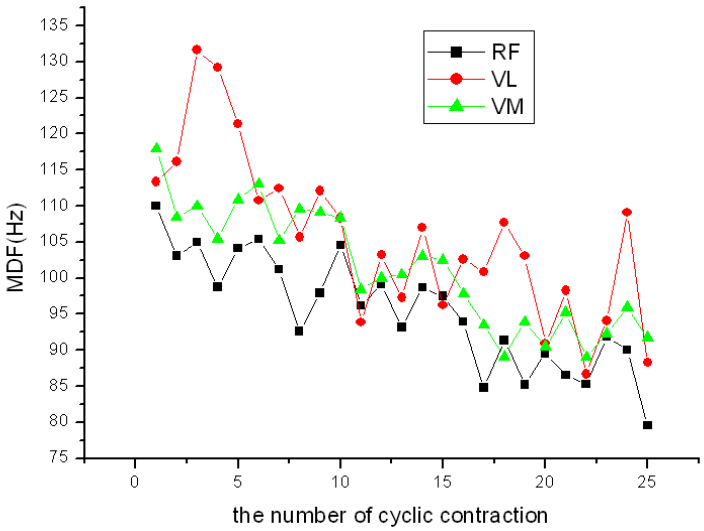

Figure 3: The MDF data of one subject

Many studies had reported various findings about the relationship between EMG and muscle fatigue in the past though. However, only few researches can use real-time monitor to the fatigue condition of the muscle. It may be important to efficaciously improve the effects of training and to prevent athletes from sport injuries.

CONCLUSION: Surface EMG is an objective, non-invasive and pain-free technique for assessing and monitoring muscle fatigue in humans performing resistance exercise. For the majority of people starting out in a program for resistance training, the body needs a certain period of time to adjust to the demands of the training, so a resistance program will vary with the individual's needs. In the study, we provided a low-cost method for real-time evaluation of MDF during cyclic contractions. For a well designed program that controls the accumulation of fatigue, local muscle fatigue must be quantified.

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