SPECTRAL ANALYSIS OF SURFACE EMG OF ISOKINETIC VOLUNTARY CONTRACTION UNDER FATIGUE PROTOCOL

Lanyi Xu, Fa-Shen Li[1] and Youlian Hong[2]
School of Life Science and [1]School of Physical Science
Lanzhou University, Lanzhou, Gansu, People's Republic of China
[2]Department of Sports Science and Physical Education
The Chinese University of Hong Kong, Hong Kong SAR

The objective of this study was to extract the indices of muscle fatigue from surface electromyographic signal sEMG. Five male subjects participated in the study. . The sEMG of biceps and triceps was measured when subjects performed consecutive right elbow flexion and extension at the required contraction levels until the contraction levels could no longer be maintained. The significant findings of this particular study are that the difference of the mean frequency of sEMG between non-fatigued and fatigued muscle increases with the speed of contraction. This phenomenon has potential for further study.

KEY WORDS: EMG, spectral analysis, fatigue, muscle

INTRODUCTION: For some considerable time, use of the surface electromyographic signal (sEMG) has been a technique to determine levels of muscle activation and fatigue. It has been found that the mean amplitude of sEMG increases and the mean frequency decreases, as muscle becomes fatigued under isometric voluntary contraction (DeVries, 1968; Patrofsky, 1982). However, study of the features of sEMG under dynamic contraction (i.e. non-isometric and non-constant force contracting) is relatively rare (Potvin, 1997). Therefore, the purpose of this study is to extract the indices of muscle fatigue from sEMG. However, the dynamic contraction is often involved in actual situations, especially in the study of sport science. The characteristics of sEMG under dynamic contraction are different from those of isometric contractions. In the case of a dynamic contraction, the sEMG is non-stationary, while during isometric contraction, it is stationary. Furthermore, the amplitude of sEMG is dependent primarily on three factors. They are the contracting levels, the subject's skin impedance and finally, contracting speed. Therefore there is some hesitation in judging whether or not the muscle is fatigued if only the amplitude was used as an indicator of fatigue. To avoid this ambiguity, the inherent disadvantage of amplitude analysis, spectral analysis (i.e. the frequency component analysis) was utilized in this study. The data obtained through this research would have great potential for application in the study of sport science.

METHODS: The subjects selected for this study included five male subjects aged 20±2 years. Each subject took the same protocol three times with one-hour rest between two consecutive tests. The subject was required to sit on the measurement chair of KIN-COM machine. At the commencement of the test, the right arm of the subject was positioned on the dynamometer for contracting force measurement with forearm horizontally. The angle between the forearm and upper arm was 110° . The subject performed Concentric/Concentric contraction of elbow at required speed (isokinetic) and torque (isotonic) levels. The sEMG of biceps and triceps was measured with 3M Red-Dot Ag/$AgCl_2$ electrodes with differential connection mode. The signal was then amplified and A/D converted (sampling rate 2,000/sec, with CODAS data acquisition card) into digital form to be stored in computer hard disk for analysis. The subjects were asked to perform consecutive right elbow flexion and extension at the required contraction levels until the contraction levels could no longer be maintained.

Since the sEMG under the dynamic contraction is non-stationary, it was divided into five consecutive segments for each contraction. In each segment, the sEMG can be considered to be a quasi-stationary signal, so that the traditional method for stationary random signal analysis can be applied for spectral estimation. The stationary length of the sEMG in one segment can be measured with Run-test (Bendat, et. al., 1971), with a level of significance of

5 percent. The signal was tested with intervals of variable length. It was required for stationary component that 95 percent of the intervals pass this test. It was found that the segment length of 0.2s agree with above requirement, therefore each contraction was subdivided into five segments. To obtain better resolution of the frequency spectrum, the auto-regressive spectral estimation method (Kay et al., 1981) was used via MATLAB5.3 software (Mathworks Inc., USA).

RESULTS AND DISCUSSION:

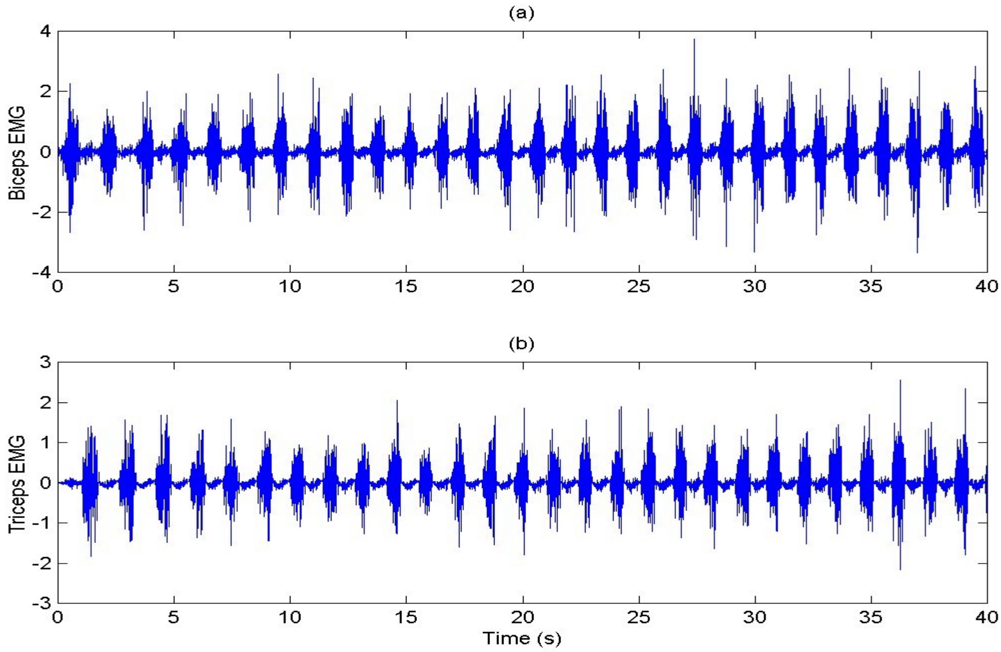

Figure 1 - The sEMG signals selected from one of tests. (a) the sEMG of biceps; (b) the sEMG of triceps muscle.

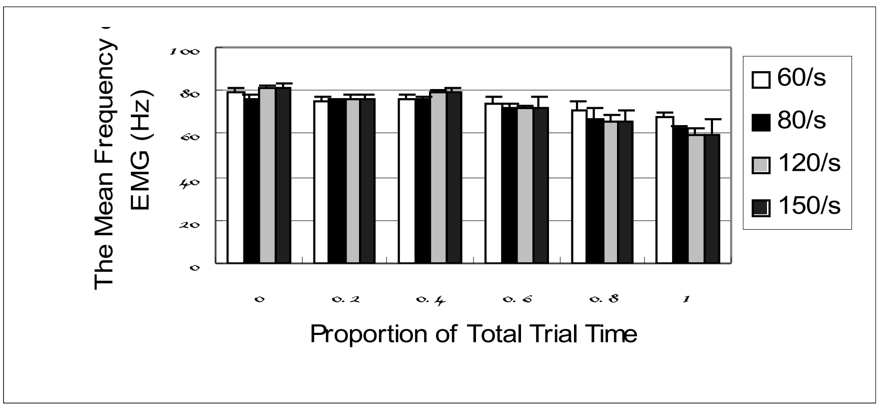

Figure 2 - The Mean frequency of EMG under Isokinetic contraction at difference contracting speeds and fatigue levels; where the contracting speed are 60^0/s, 80^0/s, 100^0/s and 150^0/s, respectively.

Figure 1 shows a segment of sEMG in one of the tests and Figure 2 shows the mean frequencies of EMG signals at different contracting speeds. Fig.3 shows the mean frequency of sEMG in each contraction at different time segments and different contracting speeds. It can be seen from Figure 2 that the mean frequency decreases continuously as the time of muscle contraction increases, i.e. muscle becomes more and more fatigued. This is consistent with the results under isometric contraction. Figure 3 indicates the mean frequency of sEMG of non-fatigued and fatigued at different muscle length. It can be seen that, on average, the mean frequency of sEMG increases as muscle length decreases. The phenomenon has been explained by Potvin (Potvin, J.R., 1997). The significant findings of this particular study are that the difference of the mean frequency of sEMG between non-fatigued and fatigued muscle increases with the speed of contraction. This phenomenon has potential for further study.

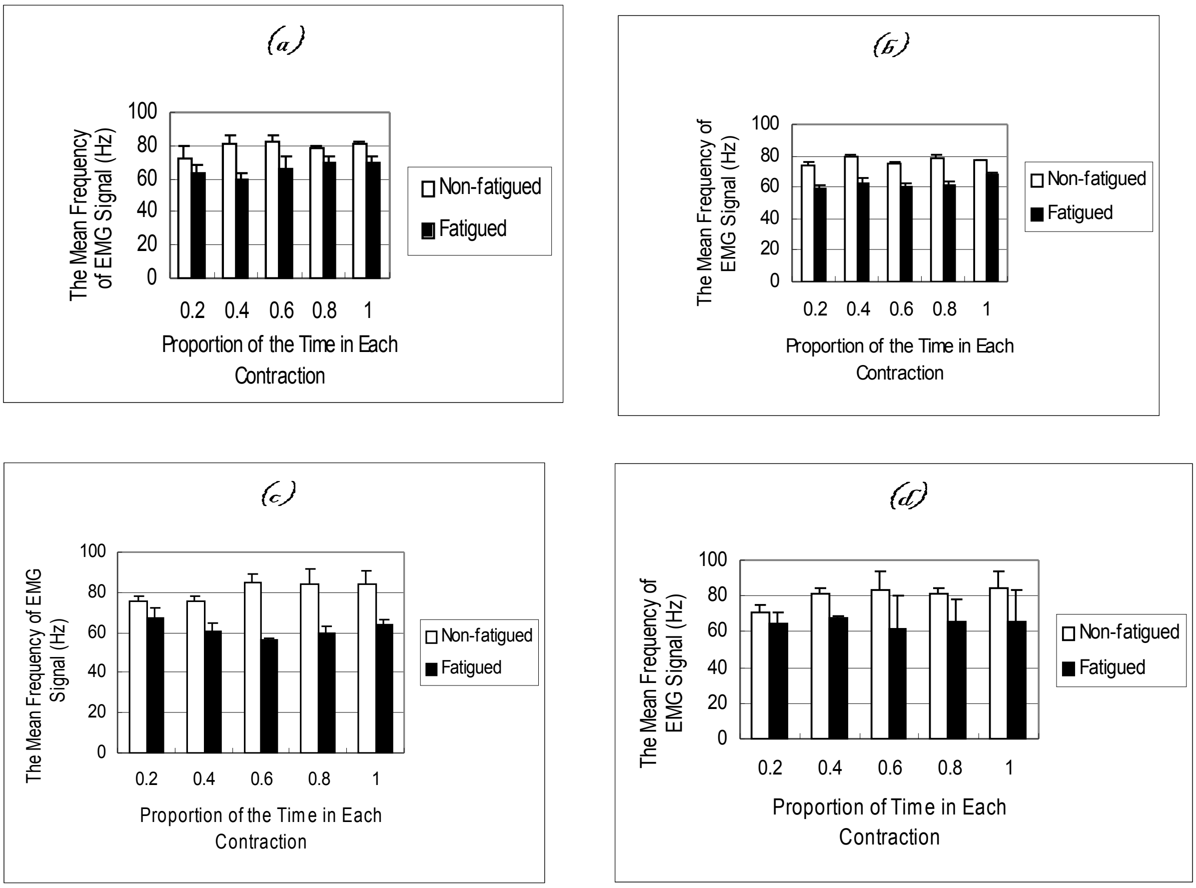

Figure 3 - The mean frequency of sEMG in each contraction at different time segment and different contracting speeds; (a), (b), (c) and (d) are correspondent to 60°/s, 80°/s, 120°/s and 150°/s, respectively

REFERENCES:

DeVries, H.A. (1968). Efficiency of electrical activity as a physiological measure of functional state of muscle tissue. *American Journal of Physiology and Medicine,* **47**, 10-22.

Petrofsky, J.S., Glaser, R.M., et. al. (1982). Evaluation of the amplitude and frequency components of the surface EMG as an index of muscle fatigue. *Ergonomics,* **25**, 213-223.

Potvin, J.R. (1997). Effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. *Journal of Applied Physiology,* **82**, 144-151.

Kay, S.M. & Marple, S.L. (1981). *Spectrum Analysis—A Modern Perspective*. Proc. IEEE. **69**, 1380-1419.

Bendat, J.S. Piersol, A.G. (1971). *Random Data; Analysis and Measurement Procedures*. New York: Interscience.