Dynamic EMG Processing in Describing Muscle Activities during Isokinetics

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ABSTRACT

A dynamic EMG processing method combined with a biomechanical model to describe the muscle activities during isokinetics is proposed. This new approach transfers the EMG signals into two components to depict the spatial summation and the temporal summation separately [1]. A good correlation of the EMG and muscle force predicted from a biomechanical model is presented. In low speed isokinetic movement, the muscle strength change is dominated by the number of fibers change (spatial summation variation). However, in high speed isokinetic movement, the muscle strength change is contributed by both the number of fibers change (spatial summation variation) and the frequency change of nerve impulses in each fiber (temporal summation variation).

INTRODUCTION

Many problems associated with musculoskeletal system have been extensively discussed between the EMG signals and muscle activities. Most of the investigations have been demonstrated that a linear or nonlinear relationships exist between EMG and muscle force when effort is isometric and in the mid-range of effort. Although there are a lot of unanswered questions, the isometric study provides a gross quantification of EMG and muscle force. During isokinetic study, most of the investigators provided no information of the relationship between EMG and muscle force. This study presents a dynamic EMG processing method combined with a biomechanical model to describe the muscle activities during isokinetics.

METHOD

Cybex II is used for the isokinetic movement. The knee joint torque and position angle recorded from analog output system of Cybex II and a surface EMG signal of the quadriceps acquired by the MEDELEC MS91a are simultaneously converted to digital signals in the PC/AT at 1.25 KHz sampling rate (Figure 1). Having reference to the position angle between 0° and 90°, we first accurately extract the EMG waveform segment of extension motion. After multiplying the extracted waveform with a rectangular time window, a fast Fourier transformation is made. Repeating calculation of a number of Fourier spectrum by shifting the time window, we can dynamically estimate a series of the dominate frequency (Fd) and its corresponding magnitude (Am) in different extension angles (Figure 2). Their definition is shown in the following formula.

$$P(Fd) \geq P(f) \quad \text{for } 0 \leq f \leq Fmax,$$

$$Am = P(Fd)$$

where P(f) is the fast Fourier transformation of windowed signal and Fmax is the maximum frequency after Fourier transformation.

From the viewpoint of physiology, the summation (adding individual muscle twitches together to make strong and concerted muscle force) occurs in two different ways : (1) spatial summation by increasing the number of motor units contracting simultaneously, and (2) temporal summation by increasing the frequency of contraction of individual motor units. Hence, Fd is related to temporal summation and Am is related to spatial summation. By directly averaging the Am and Fd in different angles, we can derive a curve which is closely related to the muscle force predicted from a knee joint biomechanical model [2].

RESULTS

Figure 3 shows a curve derived from our dynamic EMG processing method in different extension angles during isokinetics and a curve of quadriceps muscle force predicted by a biomechanical model. A good correlation of these two curves is presented. The results of different isokinetic angular velocity in 60°, 120° and 180° per second are illustrated in Figure 4. In low speed the Fd curve is approximately constant, the muscle strength change is dominated by the number of fibers change (spatial summation variation). However, in high speed the muscle strength change is contributed by both the frequency change of nerve impulses in each fiber (temporal summation variation) and the number of fibers change (spatial summation variation).

DISCUSSION/CONCLUSION

The isometric study of the muscle contraction can be considered as a special case of the

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isokinetics without angular motion (no segmental angular velocity). According to the results, the temporal summation remains constant in no or low speed motion. Therefore, the spatial summation is the only factor to be considered in analyzing the relationship between the EMG and muscle force during isometrics. That's why a linear or nonlinear relationships exist between EMG and muscle force can be easily depicted for isometrics. However, in general condition such relationships are difficult to obtain in the regular movement including isokinetics. To further explore and understand the relationship between EMG and muscle force during human movement, we propose a dynamic EMG processing scheme for isokinetic study. However, without knowing the exact combination of Am and Fd, we cannot provide further information of the EMG quantification during high speed isokinetic movement. To quantify the EMG, a better combination of Am and Fd (not just a simple average presented in this study) and its role needs to be further studied.

REFERENCES

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[2] C.K. Cheng, H.C. Shang, and S.H. Wei, "Knee Model in Predicting Muscle Forces With EMG Validation during Isokinetics," Hong Kong Sports Medicine Conference, pp. 13, 1989.

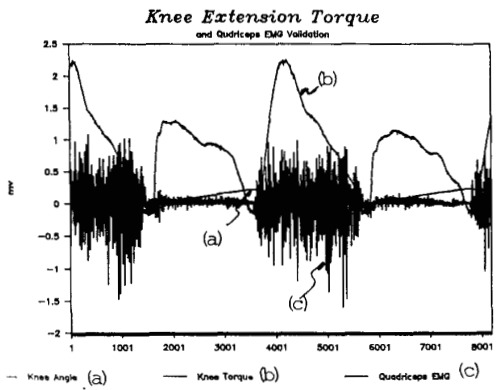

Figure 1: (a) Flexion angle obtained from Cybex II.
(b) Torque value obtained from Cybex II.
(c) Corresponding EMG signal.

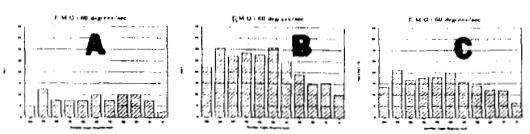

Figure 2: (a) Fd : Dominated Frequency.
(b) Am : Corresponding Magnitude of Fd.
(c) (Fd + Am) / 2.

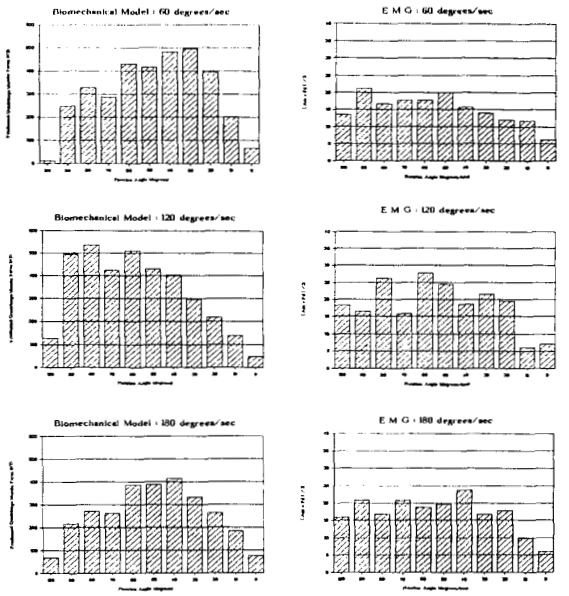

Figure 3: A comparison between estimated EMG results and muscle forces predicted by the biomechanical model during different isokinetic speeds.

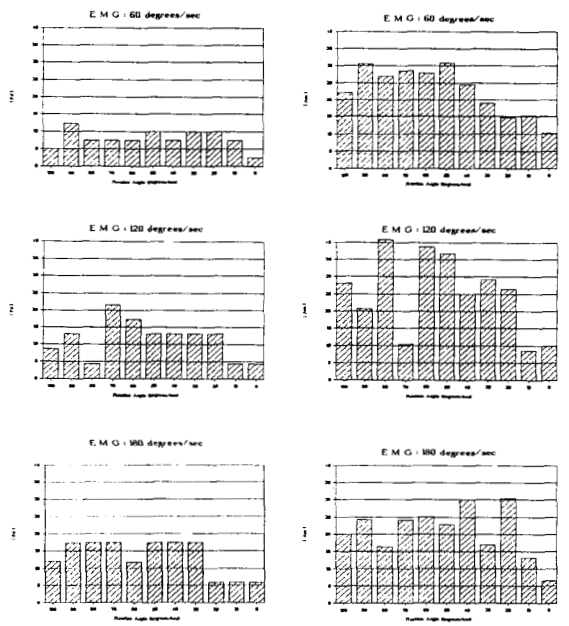

Figure 4: Left Column and Right Column are the results of Fd and Am, respectively, during different isokinetic speeds.