EXPLORING THE DIFFERENCES IN SURFACE ELECTROMYOGRAPHIC SIGNAL BETWEEN MYOFASCIAL-PAIN AND NORMAL GROUPS

Feature Extraction through Wavelet Denoising and Decomposition

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Abstract: Upper-back myofascial pain is an increasingly significant syndrome associated with frequent computer using. However, the changes in neuromuscular functions incurred by myofascial pain are still under-discovered. This study aims to discover the changes in neuromuscular function on the taut band through signal analysis of surface electromyography. We first developed a fully automatic algorithm to detect the duration of an epoch of muscle contraction. Following that, the features of epochs in both time-domain and frequency-domain were extracted from the 13 patients to compare with the measurement from 13 normal subjects. The higher contraction strength with lower median frequency found in the patient group is similar to the reported changes with muscle fatigue. The signal was further analyzed by wavelet energy of 17 levels. The result shows that the energy measured from the patients exceeds that from the normal group at the low frequency band, suggesting that an increasing synchronization level of motor unit recruitment may cause the drop in the median frequency and the increase in contraction strength.

1 INTRODUCTION

Nowadays due to the popularity of using computer and increasing working stress, myofascial pain (MFP) has been a common occupational hazard. The number of people with this syndrome seeking medical treatment is increasing abruptly. Although there are various inferences for the etiology of MFP, the investigation into any induced changes in neuromuscular functions is rare.

The detected signal form surface electromyography (SEMG) is called the interference pattern (IP), which provides considerably more diagnostic information than that of the motor unit action potential (MUAP) along. The IP is commonly used to predict the muscle force and evaluate the muscular motor functions in several fields such as rehabilitation, and sport and geriatric medicine. The popularity of application of SEMG in clinics is due to non-invasiveness. Past efforts to analyze SEMG signals were mainly based on the feature extractions in time (Fricton et al., 1985) or frequency domain (Hagberg and Kvarnstrom, 1984) separately. These methods do not take both time and frequency variation into account in an optimal sense. However, since the IP is comprised of the summation of MUAP trains from all active motor units within the surface electrode recording range; as a result of that, the variations in MUAP shapes and sizes are averaged. In addition, the SEMG signal is non-stationary as its statistical properties change over time and usually contaminated with random noises. All these factors can lead to a loss of key motor control information contained in the signal. Therefore, the non-stationery nature of SEMG signal associated with the large subject-dependent variances in its parametric measures hinder practitioners from interpreting their clinical findings.

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The wavelet transform (WT) is an efficient tool for multi-resolution analysis of non-stationary and fast transient signals. These properties make it especially suitable to study the neurophysiological signals. Numerous WT applications in biosignal analysis have been proposed, including for EMG analysis (Arikidis et al., 2002, Kumar et al., 2003).

In our previous study (Jiang and Kuo, 2008), we have developed a wavelet denosing method that can automatically detect the occurrence of SEMG epochs and render more consistent and stable epoch strength. Based on this denoising method, this study further applies feature extraction and analysis of SEMG signal in both time and frequency domain to explore the changes in neuromuscular function with MPF.

2 MATERIALS AND METHODS

2.1 SEMG Measurement

We recruited two groups of participants with the age ranged from 30 to 50 years old. One was the patient group and the other is normal group. Table 1 provides the descriptive information of the participants. In order to make a consistent condition, only the right-handed participants were selected.

The active electrodes MA-411 were attached on the taut-band loci at the right side of the upper back to measure the SEMG signal. The analogue signal was amplified up to 3800 times and band-passed (20Hz to 3,000Hz) by MA-411 and then digitized with 5000 kHz sampling rate by instruNet 100 data acquisition card and transferred to computer for further analysis.

The participant conducted only five repetitive trials. For each trial, participants lay down on their stomach steadily for standby at the first three beats and lifted both their arms toward the ceiling on the 4th beat with their maximal force, released the hold on the 5th beat. One beat last one second, so each trial last for 5 seconds.

Table 1: Descriptive information about participants.

Variable	patient group	normal group
Number	13	13
age (years)	41.2±6.2	39.5±7.3
weight (kg)	58.6±7.5	59.3±8.7

2.2 Denoising and Epoch Detection

The overall procedure to detect the occurrences of 1-sec epoch for each contraction is summarized in Figure 1. According to our previous comparative study, we first applied *Universal-soft* denoising method to yield the reconstructed signal with the best signal quality. Following that, the 1st differentiation of the denoised signal was calculated to detect the abrupt spikes, contained in each epoch. Finally, the dominate spike, indicating the central location of the epoch, was detected by using our developed multi-resolution thresholding algorithm based on statistical clustering process. The principle of the algorithm is based on the existence of an optimal threshold that should separate the population into two groups with maximal between-class variance. This concept was originally proposed by Otsu for image segmentation (Otsu, 1979). However, the distribution of the SEMG signal derivatives is not like an image histogram with definite discrete levels. To circumvent this problem of indefinite derivatives, we developed a novel auto-thresholding algorithm with multi-resolution concept. The algorithm is described in detail in the reference(Jiang and Kuo, 2008).

Once the central location of the epoch is determined, then the duration can be spread symmetrically toward both side of it within 1 sec. (each side contains 2500 sampling points). The following feature analysis was subject to the detected epochs.

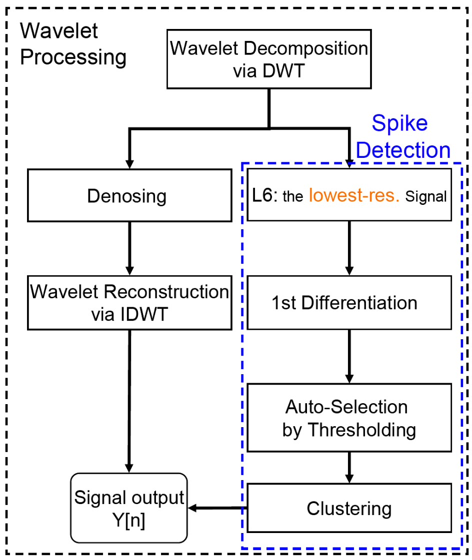

Figure 1: Wavelet processing.

2.3 SEMG Analysis

Three features were extracted from the SEMG activity for group comparisons to examine the

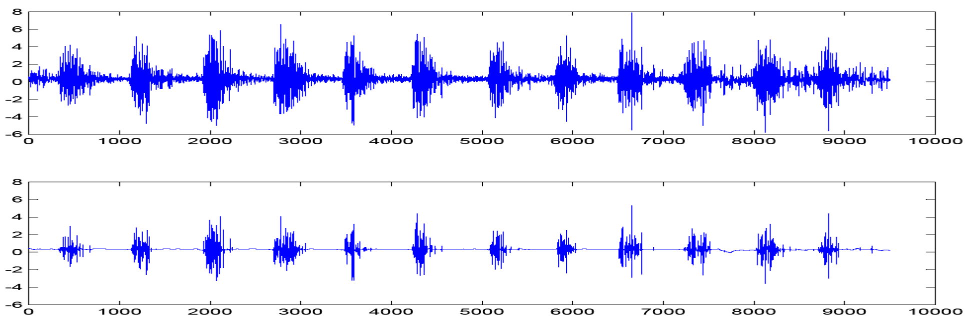

Figure 2: Top panel shows the original SEMG signal from the muscle contraction at a constant pace and the corresponding signal after denoising shown in the bottom panel.

difference between normal and MFP contraction. They are described separately in detail as follows.

- Root mean square (RMS) of a SEMG epoch is an index to evaluate the strength of the corresponding muscle contraction. It can be calculated as the summation of amplitude square within an epoch according to

$$RMS = \{|m(t)|\} = 1/T[\int_{t}^{t+T} m^2(t)dt]^{1/2} \quad (1)$$

- Median frequency (MDF) is a common parameter derived from the power spectrum density (PSD) of SEMG signal to evaluate the activity of muscle fiber recruitment and conduction. The definition of MDF is the frequency where the area of the PSD is exactly half of total area of the PSD as

$$\int_{0}^{MDF} PSD(f)df = \frac{1}{2}\int_{0}^{\infty} PSD(f)df \quad (2)$$

- Wavelet energy is a quantifier commonly used to evaluate signal strength in a specific frequency band through wavelet decomposition. The wavelet energy (Ej) at level j is defined as the summation of the power of the “detail” coefficient (dj[m]).

$$E_j = \sum_{m=1}^{n} (d_j[m])^2 \quad (3)$$

We further made a plot of wavelet energy (E_j) versus decomposition level (j) and fitted the plot into a curve using a non-linear regression model.

3 RESULTS AND DISCUSSIONS

The results are described from two aspects as follows.

3.1 Denoised Signal and Detected Epochs

The effect of the denoising process for the SEMG signal is illustrated in Figure 2. It can be found that the denoised signal still keeps the epoch location and preserves the features.

An example of the detection of the occurrences of SEMG epoch is given in Figure 3.

3.2 Group Comparison of SEMG Features

The analysis in the time domain shows that the RMS from the patient group is slightly higher than that of normal group. The power-spectrum analysis shows that the MDF from the patient group is lower than that of normal group. Table 2 summarizes the results of those analyses.

From the results of the comparative study, it is evident that the SEMG signal from the MPF participants tends to have greater RMS amplitudes than that from the normal subjects. This result agrees with the finding of the previous study (Fricton et al., 1985, Hagberg and Kvarnstrom, 1984). The decreasing median frequency observed in the power spectral density of the SEMG from MPF subjects is similar to a fall in median frequency during muscle fatigue (Hagberg and Kvarnstrom, 1984).

The result of wavelet analysis (Figure 4) shows an increasing energy gap between patient and normal groups as the decomposition level increases, especially beyond level 8.

Table 2: Comparison of the SEMG features between two groups.

Variable	patient group	normal group
RMS (volt)	0.98±0.07	0.94±0.13
MDF (Hz)	966.6±28.7	975.8±20.7

Our finding in increasing energy difference in the lower-frequency-band is in accord with the finding of previous approach regarding muscle fatigue (Kumar et al., 2003). The WT of a signal provides a multiresolutional decomposition of the signal for the analysis of signal components at different scales in the time domain. The energy in the higher decomposition level is contributed by the signal in the coarser resolution or within the lower frequency-band. In addition, the greater wavelet energy derived from MPF SEMG signal than that from the normal SEMG signal in the lower-frequency-band could be a reflection of the drop in the median frequency of the spectral analysis.

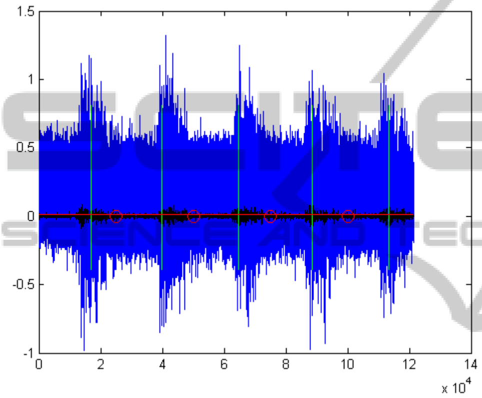

Figure 3: The detected center of the epoch for each contraction is indicated as the green bar.

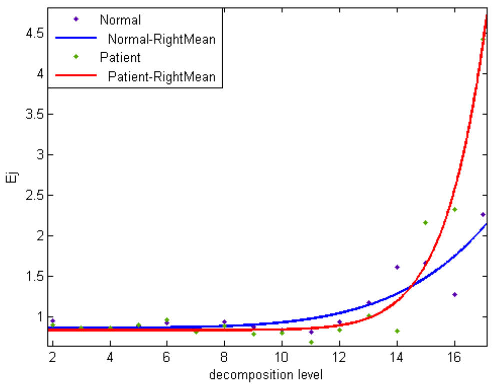

Figure 4: The trend of difference in the wavelet energy between the MDF patients and the normal subjects across the 17 frequency levels.

4 CONCLUSIONS

In recent years, Upper-back myofascial pain (MP) is increasingly found to be associated with consistent computer using. We postulate that MP could be due to muscle fatigue caused by long-lasting computer usage. However, the effect of MP on the muscle function is unclear. Therefore in this study we tried to use the wavelet energy to analyze differences in SEMG signal between MP and normal groups.

Results either in the time domain or in the frequency domain show similar changes found in muscle fatigue. Wavelet analysis further explores that these changes may be attributed to the increasing difference towards the lower frequency-band, as the result of the increasing synchronization level of motor units recruitment. These finding may suggest that the changes in neuromuscular function associated with myofascial pain can be induced by a long-term muscle fatigue.

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