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The sEMG characteristics of the low back muscles during aerobic cycling

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Abstract. More and more people suffer from lumbar muscle strain due to lack of exercise. Cycling serves as both a stylish model of fitness and a training method in exercise and rehabilitation. A few of previous studies have examined the changes in lower extremity muscle activities during indoor cycling, but fewer data pertain to the low back muscles. This study aims to analyze the functional status of erector spinae during cycling by learning the regularity and characteristics of changes in sEMG frequency domain index-mean frequency (MF) within ten minutes. The statistical results showed that the values of 70% subjects fluctuated within the range of (0.04688±0.00125) Hz within the first 30 s and the values raised rapidly to the (150±10) Hz range after the 30 s. Moreover, the values trended to decline slowly in a fluctuating way after a while. However, no obvious regularity was observed among the remaining 30% of the subjects. Results of this study demonstrated that the muscle fatigue with a smaller level of low back began to emerge gradually after 30 s. Moreover, it is evident that cycling can be an incentive to the low back muscles in most people.

Keywords: Cycling, sEMG, MF, erector spinae, muscle fatigue

1. Introduction

Eighty percent of people in modern society, who spend most of their time sitting, have experienced back pain, and 15% of these people have suffered chronic low back pain (LBP). LBP is one of the main causes of labor losses and it is a common musculoskeletal disorder affecting most people at some point in their lives [1]. This lifestyle-related disease is mainly caused by lack of necessary physical exercise. In daily life, cycling is treated as a form of exercise by more and more people. Cycling serves as both a stylish model of fitness and a training method in exercise and rehabilitation. Due to utilizing a reciprocating vertical motion similar to walking, it equivalently plays an important role in fitness and rehabilitation centers [2].

Surface electromyography (sEMG) is the sum of the action potentials generated by the active motor units recorded by electrodes placed on the skin overlying the muscles [3]. It is dependent on numerous factors such as the rate of stimulation of the muscle, size of motor units recruited, morphology of the motor units, electrical properties of the tissues and the presence of any synchronization of the activity

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of different motor units. The rate of stimulation of the muscle and size of active motor units are dependent on the force of contraction required to be produced by the muscle. It is so complex with the character of non-stationary [4]. sEMG provides a non-invasive way to measure the vivo physiological activities of muscles during actions [5].

A few of previous studies have examined the changes in lower extremity muscle activities during indoor aerobic cycling [6–8], but fewer data pertain to the low back muscles. J. Srinivasan and V. Balasubramanian performed the comparison of mean power frequency between the lower back and upper extremity before and after 30 minutes of cycling [2]. During cycling, however, the changes of the functional status of back muscles over time have not been studied. Hence, there are fewer data about the functional changes of back muscles over time.

This study aims to analyze the functional status of back muscles during cycling by learning the regularity and characteristics of changes in sEMG frequency domain index-median frequency (MF) within ten minutes. The study provides certain theoretical basis for people's daily exercise by bike.

2. Methodology

2.1. Subjects

In this study, ten male volunteers (age, 25.5±2.1 years; height, 175.0±3.5 cm; weight, 77.5±10.2 kg) were investigated. All subjects were healthy and had no LBP history. None of them participated in any activities in the past 24 hours before the test. All of them were made fully aware of the experimental details prior to obtaining their consent for participation in the study.

2.2. Procedure

A KLJ-9.1B magnetron exercise bike was utilized to do the experiment. According to the physique differences among the subjects, this study showed different intensities towards the bike. Subjects were instructed to keep the ready posture on the bike with suitable intensities. When the experiment began, the subjects were required to put forth their strength to pedal the bike until the speed reached 40km/h and the speed was maintained within the range of 35-40 km/h for ten minutes.

In this study, the erector spinae was assessed. sEMG signals were recorded using surface electrodes. A pair of Ag-AgCl electrodes were attached to the right erector spinae prominences that were at L2~L3 segment of the vertebra along the longitudinal axis of the erector spinae. Electrode diameter was 0.5 cm and electrode pitch was 3.0cm. The reference electrode was placed on the outside of the vertical between the two electrodes. Before the placement of electrodes, the site was shaved, abraded with sandpaper and cleaned with alcohol to reduce skin impedance which is from 3 MΩ to less than 500 kΩ. As shown in Figure 1, electromyography signals from the subjects were collected using a Shimmer development kit which was provided by Shimmer Corporation of Ireland. The sampling rate was 1000 Hz. The Shimmer collected sEMG continuously for ten minutes and transferred data into a personal computer via Bluetooth wireless transmission in real time. All data collected were stored as .csv file automatically. This file could be opened by Microsoft Excel®, from which the stored sEMG data were decoded.

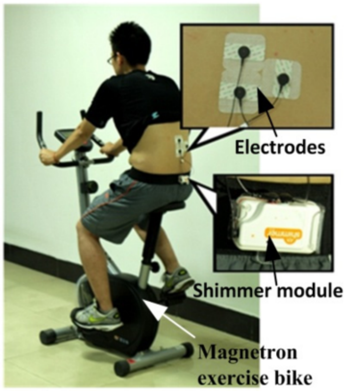

Fig. 1. The subject on the bike riding.

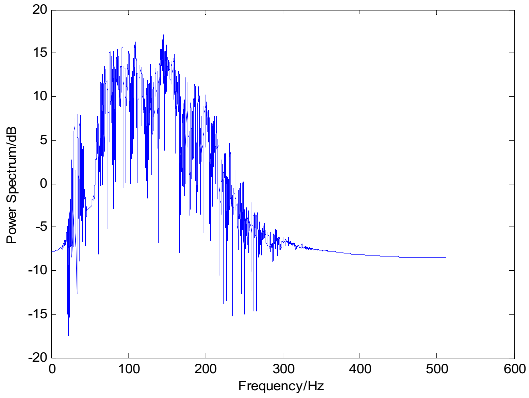

Fig. 2. The power spectrum of sEMG signals.

2.3. Analysis and processing

Raw sEMG signals were filtered using a four-order Butterworth filter with a pass band of 10-500 Hz. A two-order notch filter with a band stop of 49-51Hz was used to eliminate AC line interference. Then signals were analyzed in the frequency domain using power spectrum. The power spectrum of sEMG signals is shown in Figure 2.

In a previous study, it suggests that there is a concomitant change in the power spectrum of sEMG signals during muscle fatigues. There is an increase in the amplitude of the lower frequency band and a relative decrease in the higher frequency band. Thus, it results in the decreasing of MF in the frequency domain [9]. It has been reported that muscle fatigue can be determined based on the reduction of MF [10–12].

In order to investigate the changing laws of the level of erector spinae muscle fatigue over time during cycling, ten minutes were uniformly divided into 20 segments with 30s per segment. For each segment, sEMG signals were used to calculate MF by the following equation:

$$MF = \frac{1}{2}\int_0^{\infty} S(f)\,\mathrm{d}f = \int_0^{MF} S(f)\,\mathrm{d}f = \int_{MF}^{0} S(f)\,\mathrm{d}f \qquad (1)$$

Where, MF means median frequency; *f* is the frequency; *S(f)* is the power spectrum; and *d(f)* is the frequency resolution.

The processing of sEMG signals and the calculation of MF were implemented in MATLAB® R2009b.

3. Results

After ten minutes of cycling, the MF change over time was analyzed. The statistical results showed that about 70% of the subjects presented values fluctuating within the range of (0.04688±0.00125) Hz within the first 30s and the values raised rapidly to the (150±10) Hz range after 30s. Moreover, the values showed a slow decline trend in a fluctuating way after a while (Figure 3). In Figure 3, the average MF of the 70% subjects who expressed obvious fatigue level was showed using the curve.

The horizontal axis represented the time that was divided into 20 segments with 30s per segment, and the vertical axis represented the MF value of each segment. However, the remaining 30% of the subjects did not show obvious regularity. The one-order fitting values of MF calculated for ten subjects after 30s were shown in Figure 4.

In Figure 4, blue triangles mean that the subjects were in the obvious fatigue state, and black circles represent the subjects in the less obvious fatigue state.

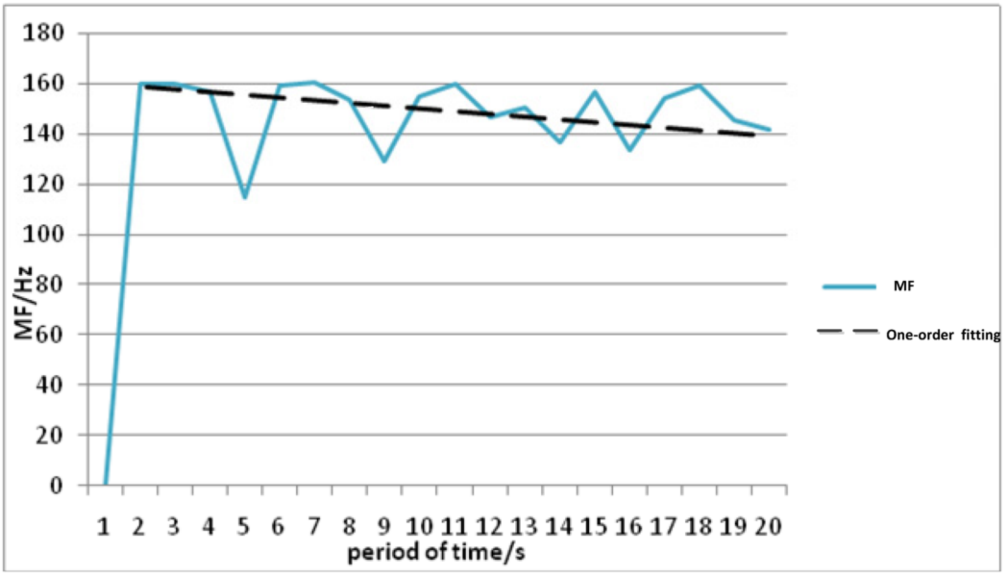

Fig. 3. The MF and one-order fitting of MF.

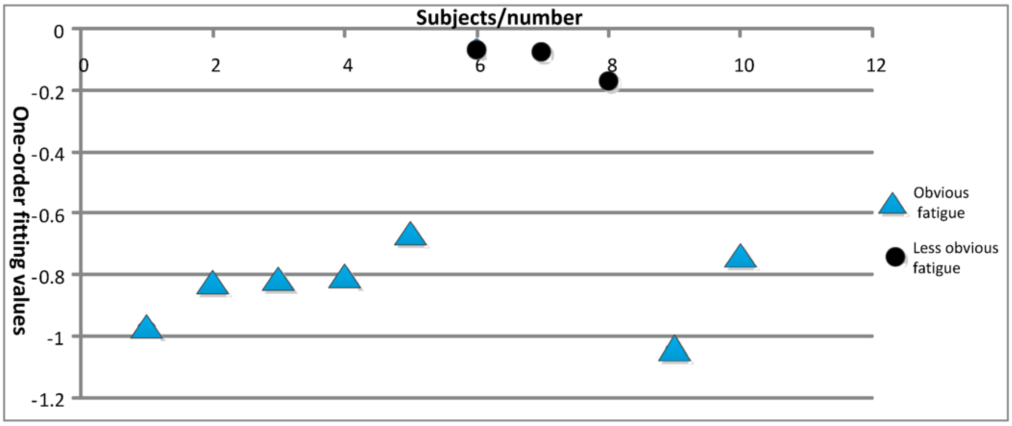

Fig. 4. One-order fitting values of all subjects.

4. Discussion

sEMG that are recorded from the surface of the muscles is one dimensional voltage-time series signals and is also better at reflecting the function of the surface muscles. However, sEMG is seldom used to study the changes of the low back muscles over time during cycling.

The previous conclusion that during muscle fatigue, there is an increase in the amplitude of the lower frequency band and a relative decrease in the higher frequency band in the power spectrum [9] was verified by the power spectrum of sEMG signals, as shown in Figure 2.

The frequency analysis method in which MF is an essential parameter was applied in this study. As shown in Figure 3, the results indicated that the values fluctuated within the range of (0.04688±0.00125) Hz within the first 30 s, and then raised rapidly to the (150±10) Hz range after 30 s. The values trended to decline in a fluctuating way after a while. Figure 4 shows the statistical results. The one-order fitting values of 70% subjects ranged from -1.2 to -0.6, and the values that were more than -0.2 accounted for 30%. Results of this study demonstrated that the muscle fatigue with a smaller level of low back began to emerge gradually after 30s. The reason why the fatigue level among 30% of the subjects was less obvious deserves to be further investigated. The study further illuminates that cycling provides an incentive to the low back muscles in the majority of people.

The decline of MF prompts muscle fatigue. Currently, central and peripheral factors are responsible for the decline of MF during muscle fatigue. Studies have shown that in the aspect of the nerve centre, when different muscles are in the largest voluntary movement, they are accompanied by reduced motor unit discharge frequency. Frequency in the power spectrum declines due to the loss of high frequency components. Peripheral factors are relevant to the metabolic way of the muscle tissue and the form of muscle fibers raises mobilization [13–15].

Studies suggest that fast Fourier transform (FFT) is suitable for static analysis of muscle contraction, but there are more limitations for the dynamic muscle contraction using this algorithm [16]. In the present study, we analyzed the dynamic muscle contraction using FFT. This is the deficiency of the study.

The limitation of this study was the experiment duration. Emissions of sweat had a great effect on the bond between the skin and electrodes after the subjects pedaling for ten minutes so that the reliability of data was not guaranteed. Therefore, the experiment duration was restricted to ten minutes of cycling.

In literature, gender difference in muscle fiber compositions is still discussed controversially. Most studies find no statistically significant differences between genders [17]. Hence, we only chose males for the experiment.

5. Conclusion

This study was designed to analyze the functional status of low back during cycling by learning the regularity and characteristics of changes in sEMG frequency domain index-mean frequency within ten minutes. The results indicated that the muscle fatigue with a smaller level of low back began to emerge gradually after 30 s among 70% of the subjects, but 30% of the subjects were in the less obvious fatigue state.

This study helps us to understand the changes of lumbar muscles over time during cycling. The limitation of this investigation is the experiment duration.

According to the results, it is evident that cycling can be an incentive to the low back muscles in the majority of people. Meanwhile, the results are able to play a guiding role in the exercise by bike.

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