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A study on a postural optimization for bicycle's exercise based on electromyography

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Abstract: Against the background of various social issues such as rising crude oil prices, global heating, and diseases associated with adult lifestyle habits, the role of bicycle has been reviewed. In fact, many types of bicycle have been developed, and have been in widespread use all over the country. Various frame size is prepared for the physical size of user and, additionally we can alter the position of bicycle by adjusting the posture of a handle and a saddle. Adjusting position of bicycle against rider's physical properties before exercise makes it possible to improve efficiency of cycle exercise. In this paper, we present an optimization method of determination of saddle height of the bicycle by the use of physical information processing. Especially, we focused on electromyography of leg during cycle exercise and employed both of First Fourier Transformation and analysis of principle components as physical data processing method. In order to accomplish the optimization method of the posture of bicycle exercise, firstly it is necessary to set evaluation standards that we can quantitatively evaluate the performances due to the different settings of saddle height. This paper shows the system structure, introduces our data processing method, and discusses the results of our experiments.

Keywords: Electromyography, First Fourier Transformation, Posture optimization, Cycle exercise, Information Processing.

I. INTRODUCTION

In these days, lifestyle-related diseases, middle-aged health problems mainly caused by the lack of exercises have been a growing concern as a social issue. Besides, reduction of carbon-dioxide emissions against global warming, and increment of the cost of fossil fuels have received considerable attention in recent years. These situations have led to the revision of effectiveness of bicycle, in fact, many types of bicycles including compact folding type and/or electric motor-driven type have been developed by lots of major companies and used in all over the world.

Cycling is currently becoming one of the most popular exercises for physical fitness and recreation for the people who are not specifically trained. From physical load efficiency, briskness, and convenience, the bicycle has also been proactively used in the welfares including rehabilitation. Performance in cycling is affected by a variety of factors, including aerobic and anaerobic capacity, muscular strength and endurance, and body composition [1]. However there is a lack of interests in the importance of the position of bicycle, and its available method have been blurred and given empirically. Within our inquiry, there are few researches evaluating the posture of cycle exercise based on biological information. If it becomes possible to easily make the settings of bicycle better for users, we can use bicycle more effectively and healthfully. And then, this study aims to accomplish the optimization method of the bicycle position based on user's individual physical data. In order to achieve our purpose, firstly we have to reveal what is the good position of the bicycle?

The purpose of this study is to establish an intelligent algorithm to search the bicycle position which can ensure individual best performance. In order to accomplish them, firstly we have to set evaluation standards that we can quantitatively evaluate user's performance during cycling exercise. And then leg electromyography during bicycle exercise has been employed as biological data because these information can be measured non-invasively and tell us the active statements of muscle [2,3]. The following muscles are selected as measurement objects because we can easily patch electrodes on them; vastus lateralis, vastus medialis, gastrocnemius, and biceps femoris. In the following sections, this paper shows the system structure and the graphical user interface we have developed, and shows the experimental results and discusses about them.

II. METHOD

2-1. System structure

Fig. 1 shows a schematic diagram of our developed system, in which it is composed of a computer, a measurement instrument device of electromyography, and a fixed cycle trainer. This computer is running on Windows XP operating system and installed Visual Basic

2005 in order to construct a real-time instrumentation system. The role of this computer is to measure leg electromyography and controls an automation device which is able to change the height of saddle in 1 kHz sampling frequency. And a graphical user interface is displayed on its screen. We can monitor information of the height of saddle and the leg electromyography of examinee during our experimental measurement.

The saddle control device we have developed is described in Fig. 1, which is composed of a DC servo motor, worm and rack gears, and aluminum covers. As a consequence these gears' combination yields an effect of gravity compensation of this saddle height control device. We applied a common PD control law to control the DC servo motor and its feedback gains are empirically determined. To reduce the noise of linear potentiometer, a software filter is employed. The following equation (1) shows the PD control law and the equation (2) is for the software filter used in our system, where the variable i shows the driving current, K_P and K_D are the feedback gains, x is raw data of the saddle height detected by the linear potentiometer, and z is the filtered saddle height. Especially α is 0.4 which is empirically determined as filter permeability.

$$i = K_P(x_r - z) + K_D(-\dot{z}) \tag{1}$$

$$z_n = \alpha x_n + (1-\alpha) z_{n-1} \tag{2}$$

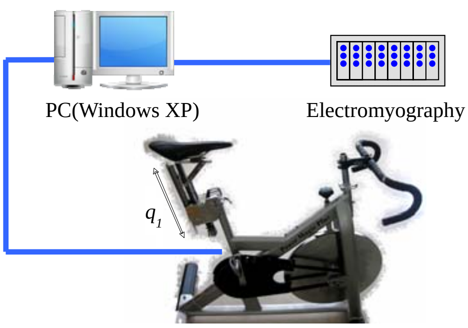

Fig. 1 Automatic saddle height control system muscles

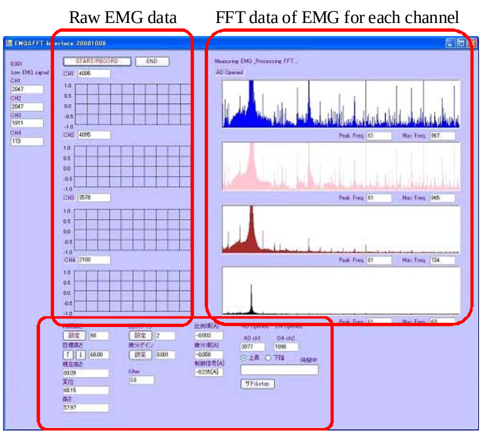

Fig. 2 Graphical user interface

2-2. Human interface

Fig. 2 shows the graphical user interface, which is designed by the basis of dialog base programming of Visual Basic 2005. The computer displaying this user interface on its monitor has to do real-time processing for the saddle height control and the measurement of electromyography. Because of this, we adopted some Windows APIs to realize real-time processing.

Surface electromyography is so called EMG, which is well known as bio-instrumentation system and is a non-invasive technique commonly used to obtain information on muscle activity. And studies of EMG are well accepted by the research community and spreading in sport and clinical physiology as assessment tools.

Generally, muscles generate about 0.5 mV of electric potential when they contract even insensible movement such as eyewink and so on. In short, EMG is sensitive amplification equipment. By using this instrument we can easily know muscular active statement with no effect of HUM noises of 60Hz. In order to distinguish each muscular active during cycling exercise, we patched four electrodes on vastus lateralis, vastus medialis, gastrocnemius, and biceps femoris respectively as shown in Fig. 3. The computer retrieves the output signals from EMG through 12 bit AD/DA conversion board, and transforms these frequency data to electro power spectrum data by using First Fourier Transformation (FFT) method. This translated data is displayed on the graphical user interface with respect to each channel. Table 1 shows our EMG measurement conditions.

2-3. Information processing and experimental conditions

This study experiments with a subject who is an experienced cycling player with more than 10 years athletic career, and measures his EMG by fixing rotation

Table 1 Measurement conditions of electromyograph

Sampling Freq.	1KHz
Lo cut	10Hz
Hi cut	1KHz
A/D resolution	12Bit

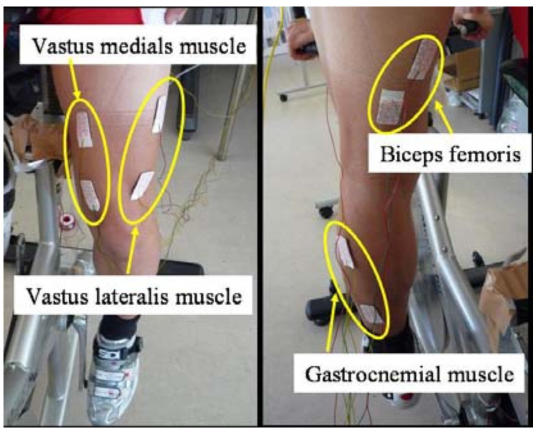

Fig. 3 Measurement muscles of EMG

Table 1 Correlation matrix between four measured muscles

	Vastus medialis muscle	Vastus lateralis muscle	Biceps femoris muscle	Gastrocnemial muscle
Vastus medialis muscle	1			
Vastus lateralis muscle	-0.8834	1		
Biceps femoris muscle	0.9622	-0.9776	1	
Gastrocnemial muscle	-0.8935	0.9998	-0.9820	1

speed of the pedal at 90 rpm. The measurement is performed by following procedures.

1. After starting the pedaling exercise for a while, measurer pushes "start/record" button on the measurement software in Fig. 2 to get the subject's EMG data with the bio-instrumentation system.
2. Measurer pushes the "stop" button to terminate the measurement after the elapse of predetermined time. On the termination of this operation, time series of EMG for each channel both raw data and power spectrum data transformed through FFT are saved as CSV files in a given directory on PC.
3. By putting the files into MS-Excel, changes of EMG are examined by relying on statistics mainly using principal component analysis (PCA).

This study uses FFT to examine the change of muscle activity according to the height of saddle [4]. The system of this study needs on-line and interactive processing to fine-tune the height of saddle quickly. Therefore this study thought FFT is the most suitable technique due to the ability of high computational speed.

As the experimental condition, we collects EMG data of 40 patterns that are obtained at 0.5mm different heights of saddle within the range from 660.5mm to 660.5mm, and each pattern is changed after a lapse of 30 seconds. Here to minimize the effect of muscular fatigue, the measurement time is divided into four and each measurement is given 300 consecutive seconds. The reason giving such the range of height is as follows; the subject has felt 670.0mm as his good position, so we decide to give the measuring range within 10.0mm above or below on the basis of 670.0mm. Similarly, range of motion in automatic saddle height control device is designed by considering generally recommended saddle height. It has well known that length of leg × 0.875 derives a proper saddle height.

In general, professional cycling players have adjusted the height of saddle under 1.0 mm scale, so we give 0.5 mm differences of height to grasp the change of EMG roughly. As an example obtained by the experiment, the time series of EMG and power spectrum of vastus medials muscle at 657.0 mm are shown in Fig. 5 and Fig. 6 respectively. The power spectrum is obtained through FFT in each 1024 milliseconds, so one measurement pattern consists of 30 data of power spectrum distribution. To analyze the muscle activities, this study averages 30 data, and obtains 40 patterns for each muscle, i.e. 160 patterns.

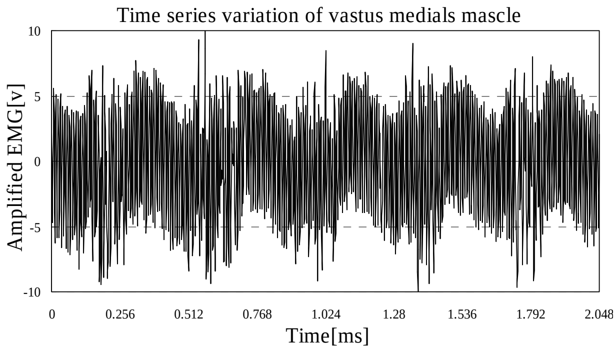

Fig. 4 An example of time series of EMG

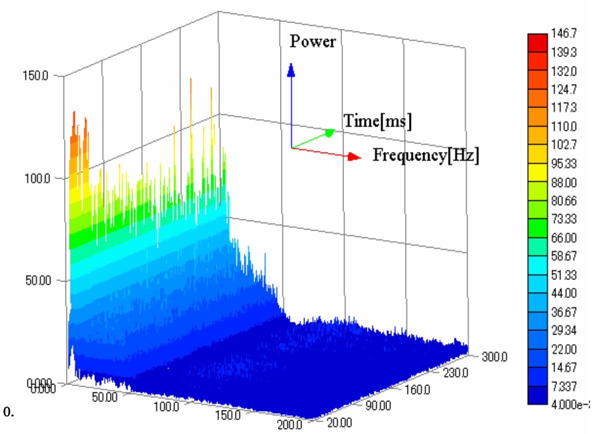

Fig. 5 An example of power spectrum of EMG

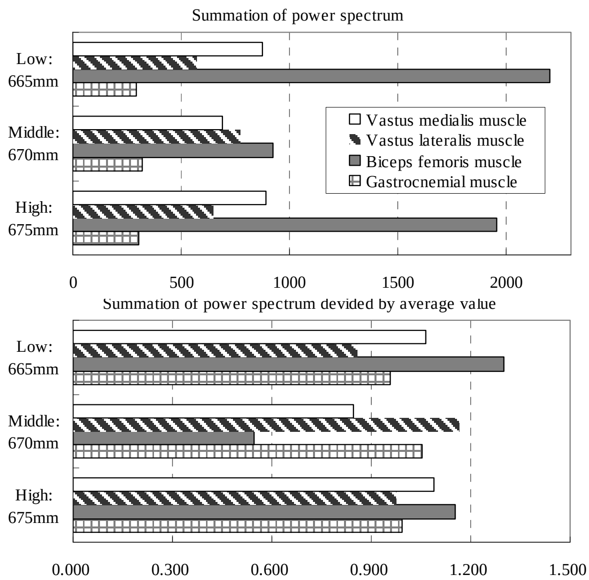

Fig. 6 Summation of maximum power spectrum

Table 2 Characteristic values in PCA

	Characteristic value	Contribution ratio	Cumulative contribution ratio
1st PC	1.8744	46.86%	46.86%
2nd PC	1.1781	29.45%	76.31%
3rd PC	0.6173	15.43%	91.74%
4th PC	0.3303	8.26%	100.00%

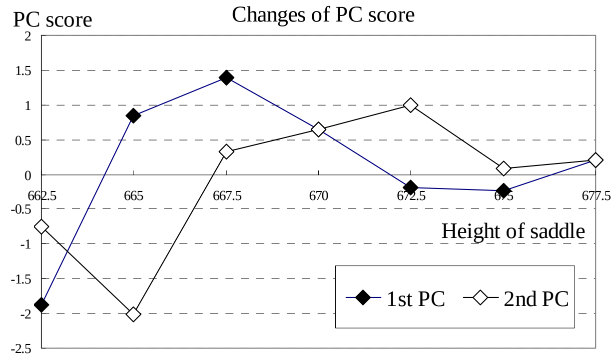

Fig. 7 Changes of PC score from 662.5 to 677.5 mm

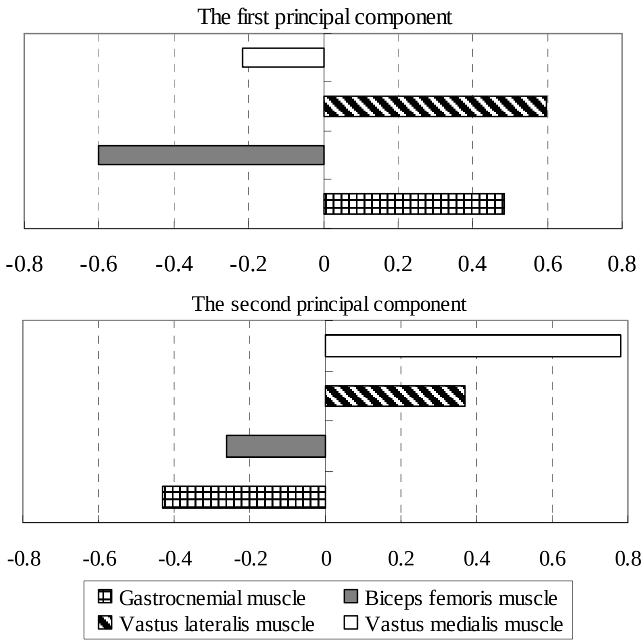

Fig. 8 The first and second principal components

III. Results

The experimental results had shown remarkable differences on the maximum power spectrum depending on the height of saddle, so this paper analyzes variation with time of the maximum power spectrum. This study addresses only the magnitude without the discussion of exact frequency value because most of maximum values are observed in near 1 Hz (see Fig. 5). Summation of the maximum power spectrum at each muscle is shown in Fig. 6, and Fig. 6 shows the differences of magnitude depending on the size of muscle (upper figure is expressed by absolute number, and the lower is after standardization). At first, this study performed correlation analysis, and the result is shown in Table 1. Here we can see the typical positive and negative correlations for all coefficient values, and especially the correlation coefficient value close to 1.0 between gastrocnemial muscle and vastus lateralis muscle can be said as the notable conclusion.

Next, this paper applied PCA to examine the changes of maximum power spectrum. Traditionally, PCA has been performed on the symmetric covariance matrix or on the symmetric correlation matrix. Based on the result shown in Fig. 6, this study shows only the result of correlation matrix that is like a covariance matrix but first the variables, i.e. the columns have been standardized. The results of PCA are shown in Fig. 7 and 8, and the result in Table. 2 are evaluated by the subject and an expert in muscle. The PC scores have varied quite a bit through the heights, so Fig. 8 shows the values averaged within 1.0 mm above or below on the each basis height in Fig. 7 (662.5 mm, 665.0 mm and so on), i.e. the each value in Fig. 7 is five-points average.

IV. Conclusion

From the results of analysis, biceps femoris muscle showed characteristic changes as shown in Fig.6 and 7. Particularly in Fig. 7, the middle position had the lower power spectrum than about the half at high and low position. According to one assumption, the magnitude of power spectrum represents the amount of muscle activity can be said that the position with low power spectrum in biceps femoris muscle is the moderate height of saddle. In Fig. 8, the eigenvector coefficients in 1st PC denoted the approximately-same tendency of the changes in Fig. 6 and 7, but it might be an important consideration that the magnitude of each element is different. As future works, this study will describe fuzzy logic rules [5] based on muscle activity.

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