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# Evaluation of Cycling Posture Considering the Difference of Saddle Height with Principal Component Analysis Based on Leg Electromyography

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***Abstract***: The popularity of cycling sports is gradually increasing along with the growing awareness of environmental issues including the people who are not professionally trained and riding on a bicycle for only their physical fitness and holiday's recreation. Many types of bicycles have been developed and have been widely used in our daily life, and these bicycles have various size of frame for user's physical size based on positions, saddle and handle. However there is lack of concern about the importance of bicycle position. This paper quantitatively evaluates the muscular activities during bicycle exercise. The raw electromyographic (EMG) data is converted to power spectrum data by Fast Fourier Translation (FFT), and then it is analyzed by using on-line usage of principal component analysis (PCA). For our fundamental study, we have restricted the freedom degrees about bicycle's position to one, the saddle height and have employed binding shoes in order to fix the pedals of bicycle and the bottoms of rider's feet. As the result of our experiments, the scheme of predict for necessary operation to make saddle height get up the best saddle height of the subject could be derived.

***Keywords*: Bicycle exercise, EMG, FFT, PCA, Saddle height**

## I. INTRODUCTION

In competitive cycling, setting the proper position is extremely important for both performance and injury prevention. The position of bicycle is determined by the settings of saddle and handle. It has already reported that the performance in cycling is affected by various factors, including aerobic and anaerobic capacity, muscular strength and endurance, and body composition [1]. The bicycle position might involve the performance of cycling exercise deeply, because it dominates a basic riding posture and pedaling form. However, the determination standard of bicycle position has not been established and now it is empirically given by user's riding experience. Within our inquiry, there are few researches investigating on the effects of bicycle sittings for performance on the basis of biological information.

This paper aims to establish an evaluation method to search an effective saddle height based on rider's individual physical properties. This paper assumes that the leg muscles are relatively and evenly activated near the rider's best saddle height, so focuses on leg muscular activities during cycling exercise. As measuring objects, this paper selects five leg muscles, lateral vastus (LV), medial vastus (MV), biceps femoris (BS), medial triceps surae (MTS), and lateral triceps surae (LTS), which are thought to be important muscles for cycling exercise. A good position might vary according to each individual's physical description even with similar size and appearance, because their physical features such as the length of body parts and joint flexibility are definitely not the same. If it becomes possible to optimally fit the bicycle position against rider's physical features before riding, we would be able to obtain comfortable cycling life and exercise efficiency with less physical burden. Moreover, if it becomes possible to easily make the optimal settings of bicycle for users, we can use bicycle more effectively and healthfully.

Many researchers have provided a review of the pedaling technique using an EMG approach, and have shown how the pattern of muscle activation during pedaling can be analyzed in terms of muscle activity level and muscle activation timing. This paper firstly constructs an automatic saddle height control system consisting of a computer running on .NET environment, an instrument device of high sensitive amplifier processing EMG, and an available fixed cycle trainer. Then we establish an evaluation method as criterion for rider's pedaling performance with one skillful cyclist. Muscular activations during pedaling exercise of skilled riders are more stable and suitable for evaluate pedaling performance than inexperienced riders. For the same subject, we measure his leg electromyography data during pedaling exercise, and apply both of FFT and PCA to the data. Some experimental results show that our proposal techniques have a possibility to seek the most suitable saddle height of bicycle form rider's physical properties.

## II. RELATED WORKS

The saddle height is defined as the greatest distance from saddle surface to the center of the upper pedal surface in a straight line along saddle pillar and crank [1]. To find an efficient saddle height based on biological reaction, Hamley and Thomas [2] concluded by using oxygen consumption that the most efficient saddle height is 109% of symphysis pubis height (inseam), and other studies including the effort of [3] also confirmed that this method provides optimum aerobic power. Holmes recommended using 109% of inseam for eliciting high performance, and using 25-35 knee angles for injury prevention [4]. Peveler et al. compared a saddle height of 109% of inseam with 25-35 knee angle from the viewpoint of anaerobic power production by using a 30s Wingate test, and showed that using the 25-35 knee angle produces better results than 109 % of inseam [5]. Some studies have shown power decreasing at lower saddle heights, but knee angle was not used [2, 3, 6]. Houtz et al. correlated EMG to exercise on a stationary bicycle with accompanying expertise of joint range studies, and evaluated the efficacy of some of the clinical methods with 3 Subjects, healthy young adult women and experienced bicycle riders [7]. They showed that saddle height does not influence timing of the muscle activity but the exercise is performed with less effort with higher saddle height. Jorge et al. denoted that muscle activity levels bear an inverse relationship to saddle height. Specifically muscular activity bears a complex relationship with saddle height, and quadriceps activity level decreases with higher saddle height. They also showed that muscular activity levels of the quadriceps are influenced by the type of shoes worn, and muscular activity levels increase with soft sole shoes as opposed to cycling shoes with cleats and toeclips [8]. From above mentioned efforts, it is clarified that EMG activity patterns are not strongly related to pedaling conditions, such as load, saddle height and shoe type. The level of muscle activity, however, is significantly affected by pedaling conditions. Ericson quantified the pedaling load induced in the lower limb joints and muscles during bicycle exercise, and studied how these loads changed with adjustments of the bicycle, workload, pedaling rate, saddle height, pedal foot position [9]. He showed that an increased saddle height caused an increase in activity of the gluteus medius, medial hamstring, and gastrocnemius muscles, but the other

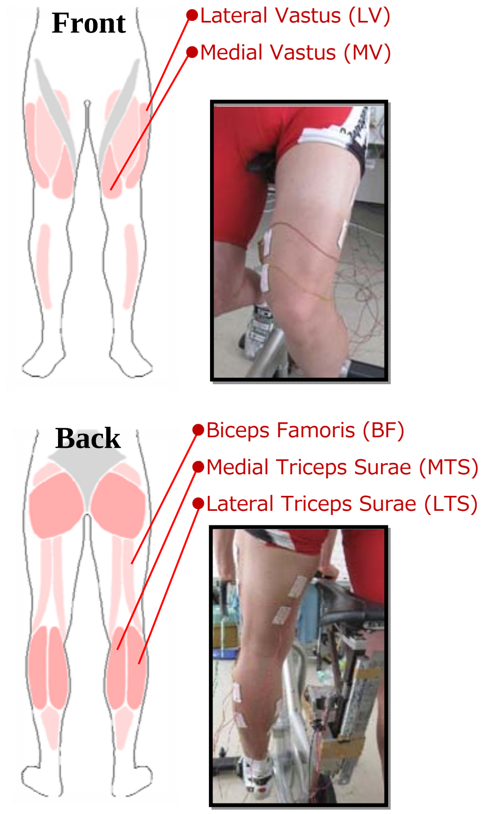


Fig.1. Measuring muscles

muscles were not significantly changed due to changes of saddle height.

## III. METHOD AND EXPERIMENTS

### 1. Definition of criterion

In order to establish a criterion to evaluate subject's pedaling performance, this paper has employed leg electromyographic signals, where five electrodes are patched on the surface of subject's leg as shown in Fig. 1; LV, MV, BS, MTS and LTS. These electromyographic signals are measured at 1000 Hz sampling rate. We assume that these muscles work better in pedaling exercise and these muscular activities can be easily detected by using EMG. Majority of professional cyclists pedal at 90 rpm or greater while riding on a flat road [10], so the electromyography data is measured in pedaling exercise at 90 rpm.

To process raw electromyographic signals, this paper derives power spectrum through FFT, where Hann window function is applied to 64 EMG. In order to evaluate a total amount of power spectrum per one revolution of pedaling, the averaged power spectrum value for 10 per spectrum values is derived, and then used as muscular activity data in this paper. Power spectrum contains some electric noises through entire frequency band, so that we use only the peak value of the averaged power spectrum data as the amount of activity of muscles per unit time during pedaling.

After three times calculation of the muscular activity, PCA is applied to the data obtained. This paper adopts 1st and 2nd principal component (PC) because it is clarified that the total amount of their contribution rate usually exceeds over 84% from the experimental results several times already confirmed by our previous efforts. In order to evaluate the changes of muscular activities in response to the changes of saddle height, we have built an on-line usage algorithm of PCA shown in Fig.2. The saddle height control system can continuously operate PCA processing consisting of data before and after the change of saddle height. The values plotted at PCA score are displayed with different color and shape according to the saddle height, so we can relatively compare plots, i.e., the difference in distribution of two saddle heights as shown in Fig.3. Fig.3 shows the distribution of 1st and 2nd PC scores which is an example of experimental result consisting of two saddle heights, 650mm and 660mm. The difference of distribution and mean value can be found from Fig.3.

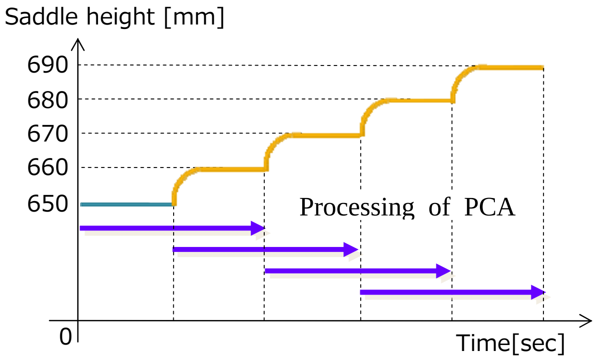


Fig.2. On-line usage of PCA

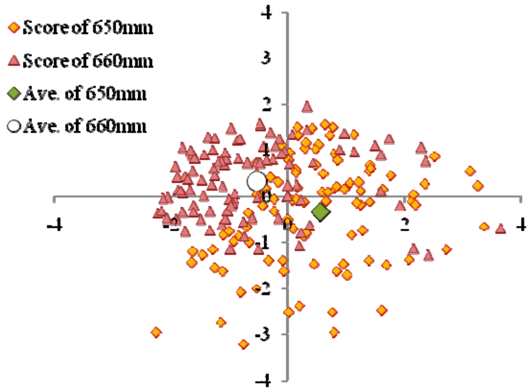


Fig.3. Distribution of 1st and 2nd PC scores

**2. Experiment**

In order to verify the proposed evaluation method using FFT, PCA, and these on-line usage, verification experiments are implemented under the following conditions. The subject is a cyclist, who is the coauthor and has over ten years cycling careers with various road race experiences as Japanese semiprofessional cyclist. Firstly the subject rides on the fixed cycle trainer and sets the handle and saddle height to match his racing bicycle geometry. The subject has felt that his best saddle height is 670.0mm, so this paper performs experiments on the changes of muscle activity at 20mm above or below 670mm, 650-690mm as shown in Fig.2. After patching electrodes on the surface of subject's leg, pedaling exercise begins. The subject firstly pedals on the settings at 650mm, and after 100 calculations of muscle activity, the saddle height rises 10mm. To avoid the effects of fatigue onto electromyographic signals, adequate rests are taken between experiments. For these results, as already shown in Fig.3, we focused on the relative positional relationship between the averaged PC score before and after the change of saddle height.

## IV. RESULTS AND DISCUSSION

The proposed optimization method for the rider's individual most suitable saddle height of a bicycle is based on measuring muscular activities that we had measured. The saddle height derived from the method might bring out certainly rider's muscular strength but there were no concerns about riding comfort. Relationships between each muscle's activities and variance are shown in Fig.4. From Fig.4, this paper can find the saddle height of 660mm minimizes the total number of muscular activities. Considering the dynamic theory of bicycle exercise, law of conservation of momentum can be applied to the relation between rider's physical loads and bicycle's work load. Therefore, the exercise of that the saddle height setting is 660mm stimulated other non-measured muscles. It was impossible to quantitatively and rigorous setting of workload, however the workload were sufficiently low for the subject and shakiness of upper body of the subject were not recognized. Because our multi-high sensitive amplifier can measure 8 channels' signal of EMG at the same time, so gluteus maximus muscle, latissimus dorsi muscle, and musculus trapezius are added as the measure to be measured. If we will include concerns about muscles throughout whole body, then the proper setting of workload of the bicycle corresponding to rider's physical strength. VO2 max, maximal oxygen consumption, is one of the evaluation standard against not only cyclist but also athletes of other endurance sports. An analysis device for expired gas tells us subject's oxygen uptake during cycling exercise in which the workload increases gradually. Adequate load will be derived noninvasively from the measurement of oxygen uptake and VO2 max.

According to the physiologist coauthor, muscle is composed of two different type's muscle fiber. They are fast muscle fiber and slow muscle fiber, and their use rate change corresponding to the workload. We are considering embedding the use rate between fast and slow muscle fibers into PCA analysis. It is assumed that rate of change of muscular fiber use is different due to individual physical characteristics and pedaling skill, and so on. And it has some relations with total contribution ratio of eigenvector calculated in one of processes of PCA.

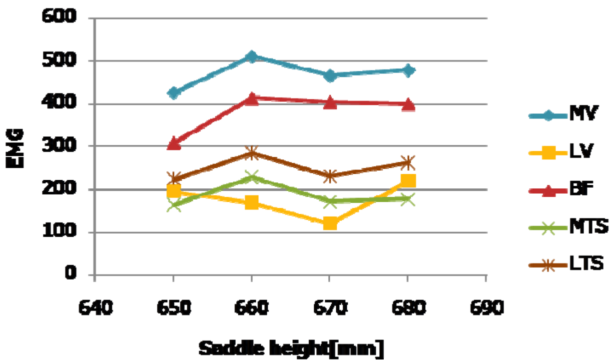


Fig.4. Differences of muscular activity for saddle height

## V. CONCLUSION

This paper assumed that an efficient saddle height enables leg muscles to induce well-balanced action while pedaling. When the saddle is controlled to favorable height after changing higher saddle height, the averaged PC score after changing relatively moved in the first quadrant of coordinate system. Therefore this paper considered that to seek the best saddle height is equal to seek the saddle height to move the average value to the direction of first quadrant on PC score sheet.

The amount of each muscle used by pedaling exercise is different, so electromyographic signals increase depending on the muscle mass. Then this paper employed the use of a correlation matrix in PCA in order to evaluate the muscular activity evenly not influenced by the muscle mass. The feature of correlation matrix is to analyze based on considering the relationship between all values of muscles activity.

The saddle height control system calculates a power spectrum data every 64[msec] and derives muscular activity every 640[msec] in order to consider the muscular fatigue with dynamic change during measurement. It can be found that Wavelet analysis method is better suited for the consideration of the muscular fatigue, because time domain information can be taken account. Then we will use Wavelet transform to evaluate the effects of muscular fatigue.

The decision of saddle height depends on ambiguous human sensibility. By the basis of this concept we will determine to apply Fuzzy logic as a way to seek an effective optimal saddle height.

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