USE OF NEUROMUSCULAR FATIGUE IN DETERMINATION OF OPTIMAL CYCLING PEDALLING RATE FOR FEEDBACK TRAINING

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The objective of this study were 1) to find out the individual optimal pedalling rate in non-cyclist during pedalling exercise and 2) to assess the effectiveness of the feedback training program on cadence acquisition. Three sessions of the criterion exercise, composed of warm-up exercise and main exercise were performed on the Cateye cyclosimulator on which an on-road bike with SRM powermeter was mounted for pedalling rate and power determinations. During the criterion exercise, the myoelectric signals were recorded by the surface electromyography (EMG) technique. An increase of the integrated EMG (iEMG) as a function of time was found in each session of the pedalling rate. There was significant improvement in pedalling rate error reduction in the experiment group.

KEY WORDS: cycling, pedalling rate, neuromuscular fatigue, integrated electromyogram

INTRODUCTION: In the sport of cycling, the pedalling effectiveness is a complex function of mechanics, muscle physiology and pedal force vector orientation. Both recreational enthusiasts and competitors desire to maximize their performance. Pedalling rate is one of the works out variables in the cycling training schedule. Leg speed is another component of fitness (Barker, 1997). The athletes can maximize the potential according to the characteristic of their neuromuscular type in their working muscle. Generally, experienced cyclists prefer a comparatively higher pedalling rate of approximately 90rpm or more (Takaishi, Yasuda, Ono, & Moritani, 1995). Takaishi and his co-worker found that a pedalling rate at which the minimal neuromuscular fatigue was around 70rpm in non-cyclist.
Neuromuscular fatigue in the working muscles rather than the economy of metabolism is closely related to the preferred pedalling rate of the subject for on-road cycling. So that, optimal pedalling rate could be acted as a baseline or starting point for training of leg speed. In this study, a practical solution was given for training of pedalling rate of the subjects. After the optimal pedalling rate of each individual athlete was determined, a feedback training program was provided to enhance the learning effect. The method of training which was easy to use and handle by the coach and athlete could be applied in the future training. The purposes of this study were to find out the optimal pedalling rate in each non-cyclist during pedalling exercise based on the rate of neuromuscular fatigue and to determine the effectiveness of the feedback training program on pedalling rate modification.

METHODS: Eighteen healthy subjects, without any cycling competition experience, were taken part in this study. Mean height, body mass, and age were 170.44 (SD 5.75) cm, 64.21 (SD 6.74) kg and 20.61 (SD 1.85) years respectively.
Optimal pedalling rate determination. Three sessions of the criterion exercise, composed of warm-up exercise and main exercise were performed on the Cateye cyclosimulator on which an on-road bike with SRM powermeter for pedalling rate and power determination was mounted (Figure 1). The warm-up exercise consisted of 5 minutes of pedalling at 100W and 50W for male and female subjects respectively. The main exercise consisted of 15 minutes of pedalling at individually decided power output, which was displayed on the SRM powercontrol unit (Figure 2). The two exercises were performed consecutively without a break. The intensity of each individual for the main exercise was decided at approximately 70% maximal oxygen uptake (VO_{2max}) while pedalling at 50 rpm according to the YMCA submaximal cycle ergometer tests. Three sessions of exercise was performed in random order at the pedalling rates of 60, 70 and 80 rpm which were displayed on the SRM powercontrol unit for the feedback information of the subjects. At least 3 hours of rest between the sessions was given to the subjects. During the criterion exercise, the myoelectric signals were recorded by the surface electromyography (EMG) technique using

BTS TELEMG system. Two miniature electrodes (Medicotest, silver / silver chloride, P-00-S, 1.5cm contact diameter, 3.5cm inter-electrode distance) were placed over the belly of vastus lateralis muscle of dominant leg and a reference electrode was placed over the pisiform on wrist joint. Before attaching the electrodes, the skin was shaved, and rubbed with alcohol in order to lower the skin resistance. The recorded data were digitized at a sampling rate of 2kHz and the iEMG was calculated every 20s interval. The increase in the iEMG as a function of time, i.e. the iEMG slope, (Moritani, Takaishi, & Matsumoto, 1993) was applied as a criterion to compare the degree of neuromuscular fatigue during cycling exercises with different pedalling rates versus a given intensity of the athletes. The gradient of iEMG slope could reflect the rate of neuromuscular fatigue of the subject at different pedalling rates.

Figure 1 - Photograph shows the subject pedalling on an On-road bike which was mounted on a cyclosimulator. A SRM powermeter system (chainring) was fixed on the bike.

Figure 2 - Photograph shows the SRM powercontrol unit displayed Information.

Feedback training for cadence acquisition. For each subject, based on the minimum iEMG slope, the optimal pedalling rate was selected for the feedback training session. The training program was last for ten days and each of the training session was last for 20 minutes. Thus, in the first five minutes of each training session for the experiment group would be without any feedback. Also, because it was important that the subjects not become dependent upon the feedback. This was removed gradually, according to the schedule on Table 1, that resulted in progressively less feedback over the ten-day period. Table 1 shows the detail breakdown of feedback duration in 10 training days.

Table 1 Detail Breakdown of Feedback Duration in 10 Training Sessions

Day	Duration with feedback	Duration without feedback
1 to 5	2.5 minutes	2.5 minutes
6 to 7	1.5 minutes	3.5 minutes
8 to 10	0.5 minute	4.5 minutes

There was no feedback information to the subjects during the pre-test, post-test and retention test.
Statistical evaluation of data was accomplished by using a two-way analysis of variance (ANOVA) with one repeat measure with time. When a significant F-value was achieved, Fisher's LSD test was used to locate the pairwise differences between means. The level of significance was set at $p < 0.05$.
During the fifteen minute ride, the percentage time of cadence error that deviated from the optimal cadence one rpm or more was used to analyze the performance of the subjects.

RESULTS: The mean absolute VO_{2max} of the subjects was found to be 3.16L/min. The average exercise intensity of prolonged exercise for the individuals, which was decided at the intensity corresponding to 70% VO_{2max}. Figure 3 shows a typical set of data indicating the changes in iEMG as a function of time and the differences of the iEMG slope in each pedalling rate treatment. With each period of exercise, the iEMG increased linearly. Each line shows the regression line fitted mathematically. All the regression lines were considered having a significant level ($p<0.05$).

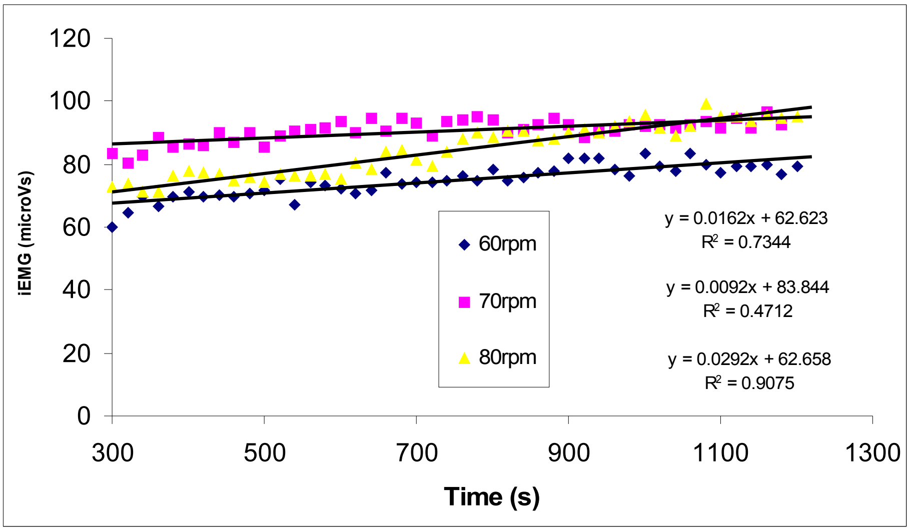

Figure 3 - A typical set of data for the changes in integrated electromyogram pattern as a function of time at 60rpm, 70rpm and 80rpm for a single subject.

Table 2 Distribution of Optimal Pedalling Rate of Subjects

Pedalling rate (rpm)	No. of subject	Average iEMG slope (μV)
60	8	0.015
70	4	0.026
80	6	0.019

Table 2 is a summary of result of the number of subjects using their optimal pedalling rate in feedback training. Also the average value of iEMG slope in different pedalling rate is shown.

Table 3 Time Percentage of Cadence Error Deviated from Optimal Cadence by more than One rpm during Pre-, Post-, and Retention Tests in Control and Experiment Groups

Percentage (%)	Control	Experiment		p
Pre-test	81.2 (SE 6.19)	81.6 (SE 5.14)	Group	0.002
Post-test	80.0 (SE 6.26)	34.1 (SE 3.35)*	Time	0.000
Retention test	78.7 (SE 6.86)	52.7 (SE 8.90)*	Group x Time	0.001

*Significant decrease in pedalling rate error pre-test ($p<0.05$).

There was no significant difference between the pre-test time percentage means of the experiment and control groups. Table 3 shows the results of the feedback training on cadence skill acquisition. There was a significant effect of the training for the experiment group but not for the control group. There were significant differences of pre-test, post-test pair and pre-test, retention test pair. The time percentage of cadence error in post-test and retention test in the experiment group were significantly less than the control group. There was no significant difference in the post-test and retention test.

DISCUSSION: In this study surface electromyography was used to quantify the total activity of vastus lateralis muscle. A progressive increase in iEMG occurred when muscle contractions were sustained at a constant force output (Maton, 1981). An increase of the iEMG as a function of time was obtained for each session of the pedalling rate treatment in each subject. These results were similar to those findings by Takaishi and his co-workers. The reason for the increased iEMG was the progressive recruitment of an additional motor unit. Also, an increase of firing rates of an already recruited motor unit may take place to compensate for impaired force generation caused by some peripheral factors such as the decrease of intra-muscular pH owing to the increase in lactic acid (Takaishi, Yasuda, & Moritani 1994). Based on the above phenomenon, this optimal pedalling rate could be acted as a baseline or starting point for training.

This training protocol could provide a scientific means to let the subject learn a particular pedalling rate. The results obtained indicated that the subjects of experiment group learned their respective optimal pedalling rate in ten day training. Subjects' performances in cadence acquisition improved considerably. The ability were maintained in the post-test and in the retention test. These results were similar to the findings of previous cycling feedback studies (Sanderson & Cavanagh, 1990; Broker, Gregor, & Schmidt, 1993). Although there was a progressive removal of the feedback over the period of the training sessions, the performance of subjects in the experiment group was maintained. Under the guidance hypothesis, frequent administration of feedback could promote learner dependency on the feedback. Relative to every-trial feedback schedules, infrequent feedback that encouraged these processes, although weaker in its effect on performance during acquisition, has often been found to enhance learning (Broker, Gregor, & Schmidt, 1993). There was no significance difference of outcomes in the post-test and retention test since removal of feedback was introduced during the acquisition phase.

CONCLUSIONS: An increase of the iEMG as a function of time was obtained for each session of the pedalling rate treatment in each subject.

The time percentage of cadence error in post-test and retention test were significantly less than the pre-test result of the experiment group.

The use of this feedback training assisted the experiment group to make use of kinesthetic variable to control the new pattern pedalling skill. The subjects have learned to modify an existing pedalling pattern of during cycling and that the new pattern did not disappear even the feedback was removed. The use of a biomechanical variable, pedalling rate, in real time was an effective mode of information feedback.

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