ANALYSIS OF PEDALING TECHNIQUE DURING A MAXIMAL CYCLING EXERCISE

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The purpose of this study was to analyze the effects of the fatigue process during a maximal cycling exercise on the pedaling technique. Eight elite competitive male cyclists were evaluated in a two days protocol. On day 1, the cyclists were submitted to a VO_{2MAX} test, and on day 2, they cycled to exhaustion on a cycle ergometer equipped with two 2-D pedals dynamometer to measure the forces applied on the pedals. The workload was set at 100% of their VO_{2MAX}, as measured on day 1. The resultant and effective forces were calculated from normal and tangential forces to obtain the index of effectiveness (IE). No differences were observed in the IE throughout the entire test. This study suggests that under a fatigue protocol, elite cyclists are able to sustain the IE, which can be an important strategy in order to sustain the power output.

KEY WORDS: fatigue, pedal forces, index of effectiveness.

INTRODUCTION:

Through the evaluation of the magnitude and orientation of pedal forces it is possible to determine the cyclist's pedaling technique (Too, 1990). The index of effectiveness (IE) is defined as the ratio between the crank perpendicular component (effective force) and the total force applied on the pedal (resultant force). It has been used to describe the pedaling technique (Gregor et al., 1991; LaFortune & Cavanagh, 1993), and in the process of learning and training of competitive cyclists (Sanderson & Cavanagh, 1990). Several studies have investigated changes in pedaling technique when cadence, saddle position, and/or power output are modified, but few studies addressed the effects of fatigue process on pedal forces (Ericson & Nisell, 1988; Sanderson & Black, 2003). Amoroso et al. (1993) have measured the forces applied on the pedals of 11 cyclists pedaling with a constant work load (300 W). The subjects were encouraged to pedal for as long as possible. The results indicated that there was an increase of the maximal peak of the normal force and a reduction of tangential force, but no changes were observed for resultant and effective forces throughout the test. Considering the high exercise intensity experienced by the cyclists during competitions, and the importance of improving the forces applied on the pedals, the purpose of this study was to analyze the effects of the fatigue process during a maximal cycling exercise on the pedaling technique. Our study tested the hypothesis that the fatigue process should modify the pedaling technique by means of the analysis of the index of effectiveness.

METHOD:

Data Collection: Eight elite competitive male cyclists (USCF Category 3 or higher) from the Austin (Texas) area were recruited. Their characteristics are presented in the Table 1. The experiment followed a two days protocol. On Day 1, each cyclist performed a VO_{2MAX} test and a familiarization trial (cycling to fatigue). This occurred at least one week prior to the cycling fatigue test. On Day 2, the participants cycled up to exhaustion on a cycle ergometer Lode Excalibur Sport V2.0 (Groningen, Netherlands) equipped with two 2-D pedals dynamometer (Newmiller et al., 1981) to measure the normal and tangential components of the sagital pedal force (Coyle et al., 1991). The cyclists pedaled at a previous selected workload corresponding to 100% of their VO_{2MAX}, as measured on Day 1. They all received vigorous verbal encouragement throughout the fatigue test, which lasted between 4 and 10 min. VO_{2MAX} and the fatigue test were finished when the cadence dropped below 80 revolutions per minute (RPM) or when the subjects felt they could not continue. The kinematics data were used to calculate the crank and pedal angle. This data were sampled at 120 Hz continuously using six cameras (Vicon Motion Analysis system 612, Oxford Metrics, Oxford, UK). A marker on the center of the pedal was used to define one complete cycle, the beginning (at top-dead-center of the cycle), and end (return to top-dead-center). The kinetics data were sampled at 1080 Hz throughout the entire test using the Vicon system and recorded simultaneously with kinematic data.

Table 1: Characteristics (mean ± SD) for age, weight, VO_{2MAX}, and HR_{MAX} of the cyclists.

Subject	Age (years)	Weight (kg)	VO_{2MAX} ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR_{MAX} (bpm)
S1	35	82.7	58.27	167
S2	25	74.2	64.10	190
S3	41	70.5	55.47	154
S4	32	83.6	63.47	172
S5	25	71.1	63.02	189
S6	35	70.1	59.06	179
S7	34	73.2	57.24	185
S8	26	62.3	67.09	190
Mean	30.6	73.5	61.0	173
SD	5.80	6.96	4.01	13.05

Data Analysis: The resultant and effective forces were calculated from normal and tangential forces to obtain the index of effectiveness (IE). The data analysis was calculated from entire test cycles and divided in intervals of 10% of the whole test. All data were analyzed using MATLAB® software (The MathWorks, Natick, MA). The IE throughout entire trial was compared employing ANOVA one-way for repeat measurements considering a significance level of 0.05. The data variability was calculated by means of the coefficient of variation (ratio of standard-deviation and the mean). The statistical analyses were performed using SPSS version 12.0 (SPSS Inc, Chicago, Illinois).

RESULTS:

The mean and standard deviation of IE throughout the entire test are depicted in the Figure 1. There were no significant differences between the intervals.

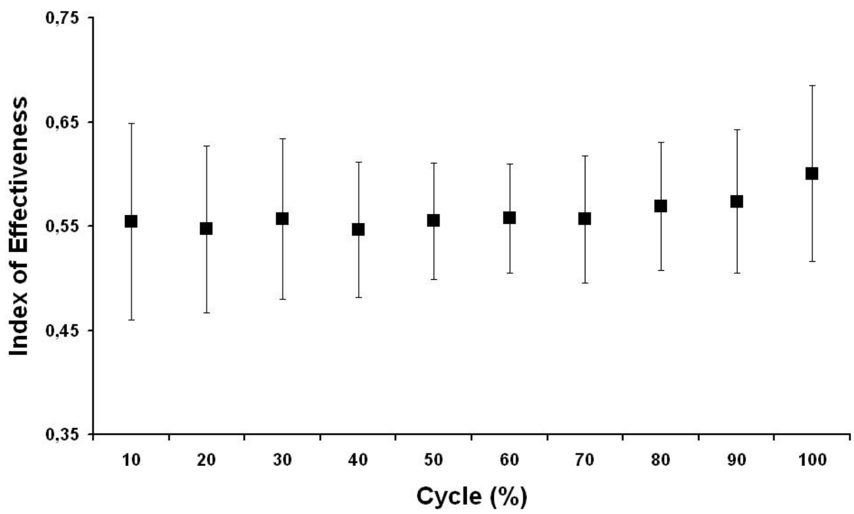

Figure 1: Mean and standard deviation of the index of effectiveness for each period of 10% of the entire the fatigue protocol.

In order to verify the variability of the IE along the test the coefficient of variation was calculate and are presented in Figure 2. No significant differences were observed for this coefficient during the entire test.

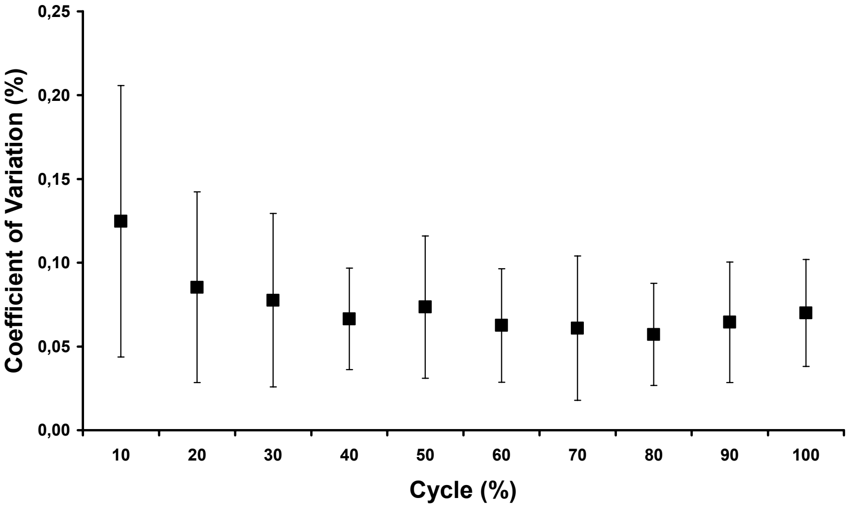

Figure 2: Mean and standard deviation of the coefficient of variation for each period of 10% of the entire the fatigue protocol.

DISCUSSION:

The aim of this study was to analyze the effects of the fatigue process during a maximal cycling test on the pedaling technique. The consequences of a fatigue process may be the failure to maintain optimal mechanics and the necessity of muscle's adaptations to maximize efficiency under stressful conditions (Amoroso et al., 1993). We expected that fatigue should therefore change the force production of cyclists, changing the IE throughout the fatigue test. However, no differences were found for the IE throughout the cycling test, showing that cyclists were able to adapt under stressful conditions in order to maintain their IE. The large variability among the subjects seems to show that elite cyclists have different techniques, and this might have influenced the results of the present study. Previous studies (Amoroso et al., 1993) have not found differences for the effective force when comparing fatigued and non-fatigued subjects, which implies that the rider does not overcome fatigue by becoming more effective in pedaling strategy. As our results showed the same pattern from previous studies, we suggest that the improvement of the pedaling technique is not a strategy used by cyclists in order to sustain the exercise under fatigue conditions. Sanderson and Black (2003) found differences in the angular impulse of the effective force during the propulsive phase between the beginning and the end of cycling test to exhaustion pedaling at an intensity of about 80% of the maximal power output. Sanderson and Black (2003) reported that in their test, the cyclists increased the component of force that produces negative torque (negative angular impulse of effective force) during the recovery phase. Their results indicate that during fatigue the cyclists became less effective during the recovery phase, contrary to the propulsion phase, where they were able to increase the effective force. We should speculate that would have an increase of the activity of the knee extensor muscles in the propulsion phase with no change in metabolic cost.

CONCLUSION:

This study suggests that, under fatigue, elite well-trained cyclists are able to sustain the pedaling effectiveness, which can be an important strategy in order to sustain the power output during strenuous exercise.

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