

Summary of Preliminary Report on the Performance Enhancements provided by ROTOR Q-Rings

Foreword

This document is an abridged version of a larger study. For more detailed information, please refer to the original study 'Preliminary Report in Q-Rings: ANALYSIS OF PHYSIOLOGICAL AND BIOMECHANICAL EFFECTS OF OVAL VARIABLE GEARED CHAINRINGS (Q-RINGS) IN COMPARISON TO CONVENTIONAL CIRCULAR CHAINRINGS.' By Dr. D. Alfredo Cordova Martinez, et al, ESCUELA UNIVERSITARIA DE FISIOTERAPIA

Introduction

There have been many studies focusing on analysing the efficiency and activity of muscles during pedalling in past years. Most focus on physiological factors, mainly determinate issues for sport performance such as oxygen consumption (VO₂ max), heart rate, aerobic and lactic thresholds, lactate concentration and mechanical efficiency. In regards to pedalling mechanics, Ericsson and Nisell¹ proved that Pedalling strength is not constant during the pedalling cycle. (see illustration on the right) This is demonstrated in that the tangential

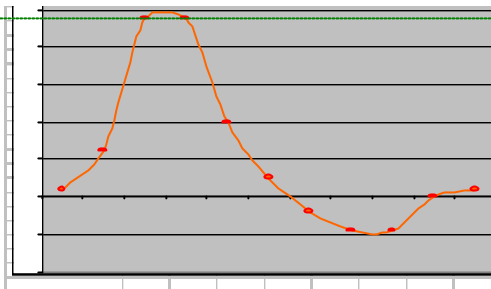


Figure 1, leg strength approximation during pedal stroke

Merknad [P1]: Pablo, Figure 1 is an approximation of the static leg force during the pedal stroke. Could you adjust this graph to be true to the dynamic pedalling situation? OR better yet, fill it with data you know to be true from the spincan tests. (I have yet to work out how to get the program to display the first data row as the X axis categories.)

force is at its greatest when the cranks are close to horizontal alignment. They remark the existence of two points in the tangential force cycle, being these the Upper Dead Spot (UDS) and the Lower Dead Spot (LDS), both placed at cranks vertical alignment.

There have been several proposals of non circular chainrings to improve performance, most of which accelerated the up and down stroke. With, "Shimano Biopace", the maximum angular speed occurred when the angle of the cranks was at 66° and 246° from UDS. "Eng 10" chainrings maximum speed was obtained at 100° and 280° from the UDS. Both these chainrings had the particularity that the crank arms were placed so that the diameter perpendicular to the crank arms was the smallest and the parallel diameter the largest. In the 1980's another elliptical chainring called "O.Symetric Harmonic" was developed with which the crank arms were placed perpendicular to the greatest diameter. Authors of studies on these chainrings indicate that with their design, pedalling effort is harmonized. However, they conclude that even though these chainrings were designed to optimize pedalling, no advantages were obtained in the cyclist's physiological response, compared with conventional circular chainrings.

Today, Rotor Componentes Tecnológicos, S.L., has developed a new type of oval chainring "Variable Gear chainrings (Q-rings)". Q-Rings imitate pedalling biomechanics of Rotor Cranks during pedal down stroke, when cyclist generates their greatest power. In this region the Q-ring progressively increases the immediate gear, according to leg's immediate capacity. After the power stroke Q-rings reduce the immediate gear ratio to pass through the Dead Spots, acting similarly to a smaller circular chainring, reducing stress on the knees. Q-rings place maximum gear moment when the pedal is around 15-20° below the

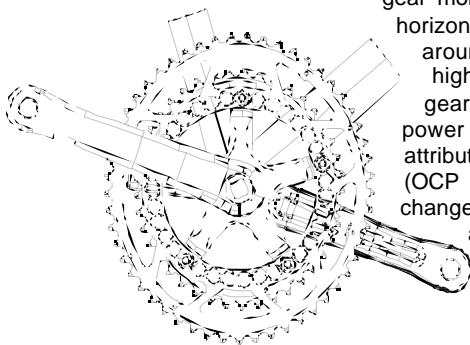


Figure 2: conventional cranks fitted with Q-Rings

horizontal axis on the downstroke, given the fact that it is around horizontal axis where tangential forces are higher. Based upon this, Q-rings place the maximum gear of the oval in such a way as to optimize cyclist's power delivery. Additionally, Q-rings have the unique attribute of allowing for the orientation of their ovalization (OCP System - Optimum Chaining Position) to be changed in regards to the crank, so the angle of delay in attaining the maximum effective gear can be adjusted for every cyclist. This is because each cyclist applies his maximum strength at a defined moment (which is individual to each cyclist) in the pedalling cycle: the maximum torque point (MTP).

¹ Ericsson MO, Nisell R. Efficiency of pedal forces during ergometer cycling. Int J Sports Med 9: 118-122, 1988

Aims

Because they reduce the intensity of the Dead Spot, Q-rings contribute to an increase in pedalling efficiency and, therefore, lead to an improvement in performance. As such, this should be reflected in athletes physiological responses (cyclists, triathletes, duathletes, etc.) while training and competing, as well as in trials or lab and/or field physiological tests. Considering all this information, the aim of this study is to compare physiological data from sub-maximal and maximal tests, to ascertain the degree of benefit Q-Rings offer.

Material

For lab tests a trainer from the brand Computrainer™ was used, which manages the resistance at the rear wheel by computer². An application called SPINSCAN was linked to the cyclotrainer, allowing for analysis of each riders pedalling style, which sped up the Q-Ring setup process. Each cyclist used his own bicycle for the test with one rear wheel (the one subject to resistance) being used at a set pressure (8 atmospheres) for each test. Each bicycle was fitted with a pair of OQC (Q-rings) or NCC (Normal or Circular Chainrings), depending on the correspondent test.

For analytic validation we used an auto-analyzer for blood determinates and another for biochemicals. Lactate measurements were made, using a micro-method system "Lactate Pro" and Sterile lancets, which is accurate to 3%. Likewise, at the same time measurements were taken with an "Accusport" photometric blood analyser, using pure blood samples. This method has a good correlation, $r=0.90$ & $r=0.97$, in determinations related to YSI 1500 analyzer (reference analyzer used for the validations). Recordings of the test subject's Heart Rates were taken and saved continuously using a heart rate monitor (Polar – Xtrainer Plus). Gas composition was monitored breath by breath for the duration of the tests (Medical Graphics System CPX-Plus).

Method

8 volunteer Elite-sub23 amateur cyclists were used as test subjects in this study. The study was held at the beginning of their 2006 training season. The average age of test subjects was 21,1 +/-2.1, weight 69.3 +/- 8,4 Kg., height 175.8 +/-5.9 and Max VO₂ 70.5 +/-5.3 (ml.Kg-1min-1). Clinical backgrounds were collected and physical examinations were carried out before tests were done. Additionally, blood specimens were taken for study, in order to ascertain the physical condition and biological profile of every tester, and to exclude any subject who could display any characteristics violating the criteria of the UCI-2005 Medical Committee

On the same day of lab tests, blood specimens were taken from each athlete, before and just after the maximum effort test in order to determine changes in blood variables. Smaller samples were taken before the start of the test, and 1,3 and 5 minutes after finishing it, in order to obtain the maximum lactate levels.

Variables calculated on the test were oxygen consumption (VO₂), ventilation (VE), Oxygen Ventilatory Equivalent (VE – VO₂ – 1), respiratory quotient (RER). Subsequently, ventilatory thresholds were measured, attending to the increase of VE/VO₂-1 without the increase of VE/VC0₂-1 criteria for the VT₁, and increase of VE/VO₂-1 in parallel to the increase for VE/VC0₂-1, to obtain the VT₂.

Tests were carried out in three sessions of two days for all test subjects, in different weeks. During the first and third week, tests were carried out in two consecutive days. For the first day half the test group used OQC (this group first pedalled on their bicycles with NCC on the trainer in order to obtain SPINSCAN results with which the OQC were regulated for their bikes.) and the other half using NCC, and on the second day vice versa. Protocol held consisted of 20 minutes warm-up on the trainer, and after that a load of 200W (watts) for 4 minutes, prior to the incremental test. The progressive incremental test started at 200W, and from the 5th minute on, 10 watts were added per minute till the tests subject's exhaustion. Gearing used by cyclists was free, but their cadence stayed around 85 - 95 RPM. During the test 4 blood specimens were

² Tests carried out on this trainer can only be seen as indicative of how QRings will perform in the real world

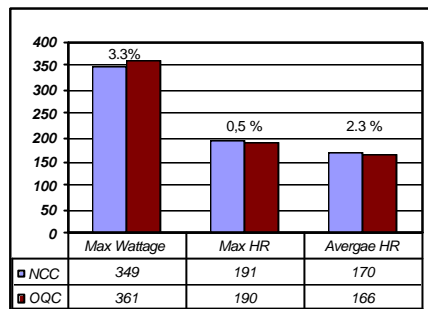
taken from their fingertip in order to measure lactate levels, with time and heart rate data being recorded at the same time. After 15 minutes recovery pedalling without drivetrain resistance at 130 heartbeats per minute, the test subject made four 20/40 sprint cycles. Blood specimens were taken just before sprints started and at the 1st and 3rd minute after the 20/40's, to record lactate levels.

During the second week, tests were also done over two consecutive days, in the same way as the first tests. Time schedules and conditions were as identical as possible to those of the previous week for every cyclist. The first test, consisting of a sub-maximum trial at 90% MHR, was carried out after warming-up for 20 minutes on the trainer. This 90% was calculated using the previous week's test results. Trials consisted of constant pedalling at 90% W_{max} for the maximum possible time. As with the protocol from previous week, blood specimens were taken at the end of the trial in order to obtain lactic acidemia. We must remark that during first day, if the test subject endured this test for over 25 minutes, he was stopped, scoring heart rate and lactate. On the second day of testing, tests were ceased when the test subject continued 8 minutes over his time from the previous day, at which point the subjects heart rate and lactic acidemia were recorded.

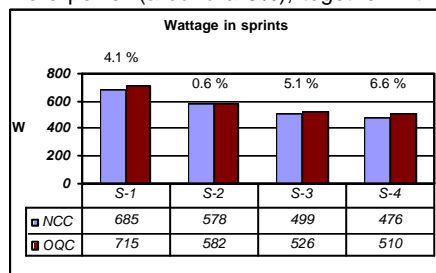
Results

Data presented is the arithmetic average of every moment analyzed, for the scores taken with OQC and NCC. Results are displayed in Graphs 1, 2 and 3. For explanation of the results, statistical variations of results were not considered, due to this being a preliminary study, so more attention was focused on evidential biological tendencies. Obviously, for a bigger group of test subjects and with control of parameters considered as optimal, it would be necessary to do a statistical analysis of the results, so they could be properly published in a scientific publication.

It is observed in the results that when cyclists made the test with OQC they produced slightly more power (around a 3%), together with a slightly lower heart rate (around a 2%) during the progressive incremental test (graph 1).



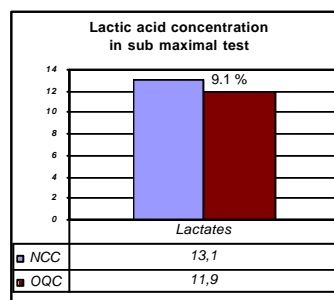
Graph 1. Analyzed Variables (W, HR-Max, X-HR) on Incremental Maximum Test with OQC & NCC.



Graph 2. Analyzed variables (La-Max, HR-Max) on 90% sustained power test (90% of power showed on incremental test) generated with OQC & NCC.

For the repetitive 20/40 exertion/recovery cycles, Three of the four tests (first, third and fourth) showed that power production was higher with OQC than with NCC (graph 3). In the second sprint, the same results were recorded with NCC as OQC.

Regardless which chainrings were used, (OQC or NCC) maximum levels of Heart rate and oxygen consumption (VO_2 Max) saw no change, which seems logical because they were tested when every individual had to keep on pedalling until his maximum (until exhaustion).



Graph 3. Analyzed Variables (W, HRmax, X-HR) on consecutive short sprints, Developer with OQR & NCC.

Discussion and Preliminary Conclusions

Not finding differences on Maximum Oxygen Consumption ($V_{O2\ max}$) is not considered relevant, because is a maximal test no variations on this aspect were expected, as has been described by previous ovalized chainring studies. Nevertheless, relevant facts are found. The most significant in this preliminary study has been to observe that when cyclists underwent the 90% of their established maximum test (average of all measures obtained with OQC and NCC), they were able to maintain the effort level they were required to for longer when using OQC. Additionally, in the sprints done after the maximum effort test, those cyclist using OQC were able to generate (although only slightly) more power on each of the sprints, in comparison when they were using NCC.

Another remarkable fact of this study is that after the 90% power maximum effort test a lower lactic acid production was observed at the end of the test, even when same heart rate was reached. This fact can be understood as an indicator of a lower metabolic requirement when using OQC in comparison with the NCC requirements, moreover when it pertains to a longer time of exertion at a 90% of the maximum power.

The fact that during repetitive sprints a higher power generation was scored by the OQR compared to NCC, could also be understood as a higher biomechanical efficiency indicator, together with the previously mentioned higher metabolic efficiency. This is seen in that on the same maximum test consisting of 4 sprints, a power production of 4% higher was seen with OQC tests. Even when this difference is small, in the world of high level competition they could be decisive for the final rankings, especially in situations of continuous or frequent maximum exertion, seen in disciplines such as time trials.

Given the fact that no difference on Oxygen Consumption was found between the chainring types, this could suggest that physiological demands were non significant, which would be coincident with previous studies findings that internal work to move the legs could be not independent from external work. But in our study, even when no relevant variations in maximum heart rate and maximum oxygen consumption are detected, a lower lactic acid production was observed in the 90% sustained load test. Coinciding with this, an improvement in mechanical efficiency was observed in a study carried out by Santalla et al.³. Analyzing Rotor Crank system. These authors explain this in that when the leg is on the pushing phase from the highest position, it could help the other leg's work, which is involved in maximum descendent force application.

Normally legs are accelerated and decelerated by the muscles, resulting in an increase and decrease of the energy supplied. But with OQR power delivery seems to be more continuous, with less variations, (which is confirmed by the cyclist who made the test's impressions), which could explain why lactate production is lessened in some fashion simply by the contribution of a continuous and harmonic pedalling. This changes on the energy flow for the external work, incise on the requirements for the internal work mentioned before.

Altogether, we think that, for experienced cyclists whose muscle coordination is already perfect, the use of a chainring providing certain energy savings could be beneficial, specially on trials where a maximum effort is required as in time trials, sprints, spurts (????) and climbs/ uphill. Apparently, regulation settings of Q-rings could be the key for the differences in performance obtained.

All the same, we consider necessary a complementary electromyographic study (EMG), together with a metabolic study analyzing biomechanical factor affected by physical activity, both lab test as the presented and field test (for example a training ride of 3-4 hours). This study could provide valuable information in order to verify improvement and pedalling efficiency, under which circumstances it could be beneficial or not, so pedalling optimization could be customized. Q-rings' uniqueness regarding their regulation options can contribute to creating a more precise view of physiological, metabolic and biomechanical variations arising from non circular chainring use.

³ Santalla A, Manzano JM, Perez M, Lucia A. A new pedalling design: the Rotor--effects on cycling performance. *Med Sci Sports Exerc.* 34: 1854-1858, 2002