PEDALLING KINEMATICS OF CYCLING WITH ROTOR® CRANKS

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The purpose of this study was to investigate the 3-D pedaling kinematics of cycling using a Rotor RSIV and a conventional crank system. Five trained cyclists cycled at their preferred cadence and power output of 300 W using Rotor (ROT) and conventional (CON) cranks. The hip, knee and ankle flexion/extension, shank rotation, foot adduction/abduction, and pedal angle were analyzed employing 3-D kinematics. The range of motion (ROM) using the two crank systems were compared by the Student t-test. The ROM was statistically different ($p<0.05$) between the ROT and CON for movements of hip, knee, ankle, shank, and pedal. No differences in foot ROM were found. The ROT changed the pedaling kinematics of the evaluated cyclists who were not previously adapted to use of the ROT.

KEY WORDS: Cycling, 3-D Kinematics, Rotor Cranks.

INTRODUCTION:

Published studies have verified the effects of different crank systems on maximal and submaximal cycling performance (Martin *et al.*, 2002; Zamparo *et al.*, 2002). However, no studies have specifically investigated the effects of the more sophisticated Rotor Cranks® - ROT. The ROT (Figure 01) is designed to eliminate the dead spot during the pedaling cycle, where theoretically the cyclist does not apply significant effective force for power generation and the bicycle propulsion.

Figure 1: Rotor cranks RS IV kinematics.

The kinematics of the lower limb during the pedaling can be used in the determination of joint overload, and used to describe body segment orientation in response to different stimulus, as example, the changes of bicycle geometry, body positioning, exercise duration and intensity, etc (Faria and Cavanagh, 1978). The aim of this investigation was to examine the 3-D kinematics during pedaling with the ROT. Our study tested the hypothesis that the ROT could modify the pattern of movements of the ankle joint, based on the fact that it seems to be the joint more related to pedaling technique changes, as shown in a previous study (Carpes *et al.*, 2006).

METHOD:

Five trained cyclists volunteered for this study. They do not use ROT before the evaluation. The cyclist's characteristics were (mean ± SD) age 23 ± 4 yr, body mass 79 ± 7 kg, and height 1.83 ± 0.06 m. The cyclists performed two tests in an 18-speed bicycle mounted on a wind-load simulator (Cateye CS 1000, Cateye Co., Japan). The pedaling cadence was continuously monitored using a S725 cadence sensor (Polar Electro, Oy, Finland).
For the evaluation of conventional cranks, the bicycle was equipped with a conventional bottom bracket system (XT, Shimano Corp., Japan), whereas the other test the bicycle was equipped with a Rotor Cranks RSIV (Rotor Technologies, Spain) adjusted in the position 4,

both system with a crank length of 170mm, and in the same cyclists' posture using clipless pedals. For kinematics evaluation, the cyclists were submitted to a protocol of stationary cycling at 300W and preferred cadence (90-100 rpm) during 10 min after standard warm-up at 100W. Three-dimensional kinematics data were acquired using a Peak Motus System (Peak Performance Technologies Inc., Englewood, CO) with two high-speed cameras synchronized, and operating at a sampling rate of 180 Hz. The DLT method was employed to obtain 3-D coordinates from 2-D data from synchronized cameras. The raw 3-D coordinates were filtered using a second-order low-pass Butterworth filter with a cutoff frequency of 6 Hz (Winter, 1990).
Retroeflexives markers were positioned over specific anatomical references of the right lower limb: anterior-superior iliac spine, greater trochanter, lateral femoral epicondyle, anterior face of the patella, tibia tuberosity, calcaneous, lateral tibia epicondyle, II metatarsal, V metatarsal, centre of rotation of the pedal spindle and centre of rotation of the bottom bracket. Metal sticks were used to monitor the tibia movements. The first stick (figure 2, arrow "a") was positioned on the pedal body, and it was used to calculate the pedal angle. Another metallic stick (figure 2, arrow "b") was positioned at 40% of the shank length proximal to the knee joint, aligned to the halux and used to calculate the shank rotation in transverse plane. The flexion/extension projected angles of hip, knee and ankle were computed, as well as the foot adduction/abduction, pedal angle, and crank angle for 10 crank revolutions.

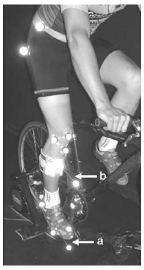

Figure 2: Detail of metallic sticks on the pedal (arrow a), and tibia (arrow b).

The range of motion for each joint movement evaluated was compared employing the Student's t-test following a significance level of 0.05. The statistical package was the Statistica 5.1 (StatSoft Inc., USA).

RESULTS:

Table 1 Range of motion for ROT and CON crank systems. Mean ± SEM. *p<0.05.

Crank system	Hip Sagittal plane	Knee Sagittal plane	Ankle Sagittal plane	Foot Transverse plane	Shank rotation Transverse plane	Pedal Sagittal plane
ROT (°)	39 ± 3*	69 ± 4*	21 ± 2*	6 ± 1	10 ± 1*	43 ± 3*
CON (°)	34 ± 4	57 ± 10	19 ± 4	6 ± 0.4	14 ± 1	37 ± 5

The results from the range of motion (ROM) analysis are presented in the table 1. The differences in the ROM between the two systems were statistically significant for all movements, except for the foot.

DISCUSSION:

The kinematics evaluation indicated that the range of joint motion was changed with the use of ROT. The shift in joint amplitude may be result in changes in the muscle activity related to the downstroke phase, which should explain the better cycling economy reported by previous studies concerning the use of ROT (Lucía *et al*., 2004; Santalla *et al*., 2002). The knee angle is directly related to the crank velocity, and the ROT use can alter this characteristic during the pedaling (López *et al.,* 2005; Lopez *et al.,* 2003). The larger ROM observed for the knee may be related to additional exigency of the muscles responsible for the knee extension during the downstroke phase. As previous described (Herzog *et al*., 1991; Savelberg and Meijer, 2003), the length of lower limb muscles due to the changes in angular displacement may alter the force produced by the related muscles.

The evaluated cyclists presented the pattern of movement expected (Carpes *et al*., 2006). The changes in the ankle angle appears to reflect the changes for knee and hip ROM (López *et al*., 2005), and this fact may also alter the contribution of muscles responsible for the knee extension and extension/flexion of the ankle. The ROM for the shank rotation when the CON crank was evaluated was similar to that observed during the normal gait while for the ROT, the ROM of shank was lesser than that reported during gait (Levinger *et al*., 2005). The movements of the shank rotation may indicate more participation of the muscle *vastus lateralis* in attempt to sustain the knee movement along the crank system and influence the observed differences found in the muscular torque. The ROM of the shank may also influence *varus* and *valgus* knee loads during downstroke and upstroke phase, respectively. This movement presents a complex analysis, because previous study (Levinger *et al*., 2005) has showed that the shank movement presents high variability among subjects.

These observations about changes in the ROM of selected movements can affect the capacity of force production, which also is highly dependent upon muscle length (Faria and Cavanagh, 1978; Guimarães *et al.*, 1994). Nevertheless, these inferences in pedaling technique requires further study employing specific protocols for the evaluation of the pedal forces, torque output, and muscle activity.

CONCLUSION:

Our results indicated that the ROT affects the lower limb kinematics. The foot, fixed to the pedal by the cycling shoes, does not alter pedaling kinematics**.** However, all the other selected joints and movement evaluated demonstrated changes regarding the joint range of motion. Studies are being developed by our group for evaluation of the muscle activity responses to the ROT use in trained cyclists.

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