EFFECT OF NONCIRCULAR O-SYMETRIC CHAINRING ON MUSCULAR ACTIVATION DURING STEADY-STATE PEDALLING

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The purpose of this preliminary study was to compare the surface EMG level activity of seven muscles (gluteus maximus, rectus femoris, vastus medialis, tibialis anterior, gastrocnemius medialis and soleus) while pedalling with circular and noncircular ring (O-Symetric). Five cyclists rode at 2 power output levels (150 - 200 W) and 3 different pedalling cadences (70 ï 90 ï 110 rpm) on SRM ergotrainer. Unlike the other muscles, gluteus maximus and vastus medialis were more recruited while pedalling with O-Symetric ring (~5-15%) only at the lowest cadence (70 rpm). These neuromuscular behaviours might be related to the increase in time of the power crank sector induced by the O-Symetric design. However, this substantial advantage didnôt appear as benefical for higher crank velocities, probably due to muscle activation-deactivation dynamics.

KEY WORDS: cycling; surface electromyography; non circular chainring, pedalling cadence

INTRODUCTION: Non-circular chainrings, *i.e.* Q-rings (Rotor, www.rotorbike.com) or O-Symetric ring (Stronglight, www.O-Symetric.com) are often used by top-level road professional cyclists, as did Bradley Wiggins and Chris Froome during their winning Tour de France 2012 and 2013. The O-Symetric chainring shape can be described as a skewed ellipse where major and minor axes are not perpendicular. These two patented designs reduce the radius and the effort needed to get through what is commonly called the top and bottom ñdead spotò in everyoneôs pedal stroke, and increase the usable radius during the power portion of the downstroke of the crank. Despite the manufacturerôs claims that this powerful tool improve power production by 7-10%, many studies found no significant advantages for maximal aerobic power, maximal oxygen uptake, gross efficiency and time-trial cycling performance (Ratel et al. 2004; Jobson et al. 2009; Peiffer et al. 2010; Dagnese et al. 2011), except for the power output generated during short sprints of 8-20 s (Cordova et al. 2014, Hintzy et al. 2000). It has been suggested that this improvement (2-8%) could be related to changes of muscular activity in response to altered pedalling mechanics throughout the crank arm revolution. In this line, with using a dynamic optimisation framework, Rankin and Hull (2008) showed that the slowing down of the crank velocity during the downstroke with non-circular chainring allow muscles to generate produce more external work, and thus increased the crank power during maximal sprint performed at 60, 90 and 110 rpm by ~3%. However, several studies showed that EMG activity level was unchanged by the use of elliptical chainring (Neptune et al., 2000), oval Q-rings (Dagnese et al. 2011), or O-Symetric ring (Horvais et al., 2007). Nevertheless, the subject during these researches pedalled only with one high pedalling cadence (90, 106 and 80 rpm, respectively). Thus, the potential effect of noncircular ring at lower cadences remains yet unknown. The aim of this preliminary study was to compare the level of muscular activity of the main muscles involved during submaximal exercises performed with circular and O-Symetric ring with varying pedalling cadences.

METHODS: Five cyclists (24 ± 7 years; 1.78 ± 0.04 m; 67 ± 7 kg) who had none practice with noncircular chainring, pedalled at two power output levels (150 - 200 W) with using 3 different pedalling cadences (70 ï 90 ï 110 rpm), on a SRM ergotrainer (SRM, Jülich, Germany) which has been matched to each subjectôs preferred position and alternatively equipped with 52 tooths rings, circular (Shimano) and non-circular O-Symetric (Figure 1). To prevent muscular fatigue, each pedalling exercise lasted one minute for data collection, separated by 2 min of recovery, (plus ~20 min for the change of chain ring). In addition, each subject performed three 10 s sprints against different resistive loads to evaluate maximal cycling performance. The subjects were instructed to keep the same body position (trunk flexion and hands position on handlebar) throughout the pedalling session. All pedalling conditions (2 chainrings x 2 power output levels x 3 pedalling cadences) were randomized to minimize fatigue-related effects.

Data collection: Power output (PO) and pedalling cadence (CAD) were measured continuously at 1 Hz throughout the pedalling session and stored in the SRM power unit control. Surface electromyographic signals (sEMG) of Gluteus Maximus (GM), Rectus Femoris (RF), Vastus Medialis (VL), Biceps Femoris (BF), Gastrocnemius Medialis (GAS), Soleus (SOL) and Tibialis Anterior (TA) of right and left lower limbs were measured simultaneously by fourtheen Trigno wireless sensors (dimensions: 37 x 26 x 15 mm, 15g) which consist of two dry bar electrodes (10 x 1 mm) spaced by 10 mm (Trigno Lab, Delsys Inc., Natick, U.S.A). Electrode skin areas were shaved, rubbed with an abrasive paste, and cleaned with an alcohol solution. The EMG sensors were attached to the skin with a double-sided adhesive interface tailored to match the contours of the sensor. They were placed on the middle of the muscleǿs belly and arranged in the direction of the muscle fibres, following the recommendations of De Luca (1997). The attachment of sensors was secured with specific adhesive tape and by the wearing of cycling leg warmer. sEMG signals were sampled at 1000 Hz, filtered using a band-pass filtered (10-500 Hz), converted in digital format using a 16-bit multi-channel PowerLab 16/35 hardware and analysed with the LabChart software 8.0 (AD Instruments, Australia). Muscular activation of each muscle was quantified during 20 consecutives pedalling crank cycles, by the mean root mean square of EMG signal (RMS) of the two limbs, and was expressed in % of the RMS value (3 consecutives cranks cycles) measured during the three sprints performed with circular ring.

Statistical analysis: Data are presented as mean ± SD. Wilcoxon signed no parametric tests were used to examine difference in PO, CAD and muscular activation between circular and O-Symetric (OSY) rings. All criteria of significance were chosen at $p < 0.05$.

Figure 1: The O-Symetric ring

RESULTS: Maximal PO and optimal CAD (at PO_{max}) during sprints were not significant different between the OSY and circular ring (980 ± 95 vs 934 ± 34 W and 137 ± 22 vs 140 ± 11 rpm, respectively). There was also no significant differences between the two rings for each submaximal paired pedalling trial. Figure 2 shows the normalized RMS values of the seven muscles studied during the four pedalling trials performed at 70 rpm. The muscular activation of the GM and VM were significantly higher at 150 and 200 W, respectively, during pedalling with OSY ring. Although it was not significant, RF, BF and SOL activation tend to be lower with OSY while TA and GAS seems remain at the same level. Similar adaptations in EMG activity have been observed at 90 and 100 rpm but none attained the level of significance. The muscular activation of each muscle was also not different during the sprint between the OSY and circular ring.

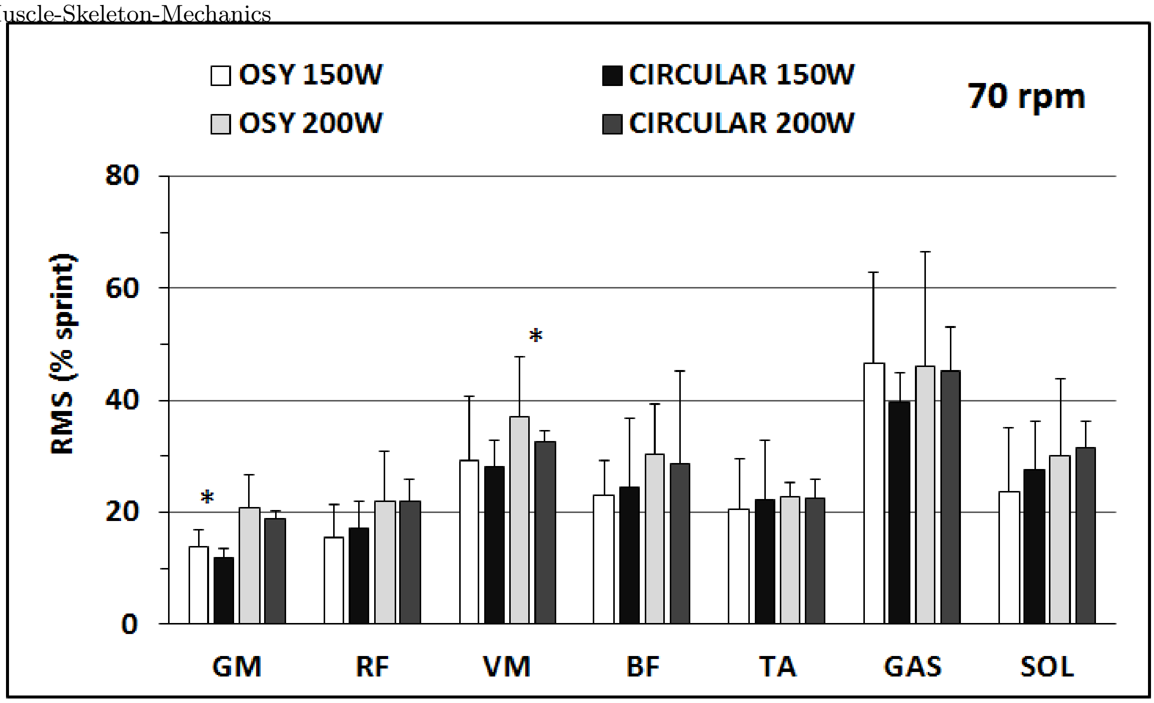

Figure 2: Muscular activation when pedalling with O-Symetric (OSY) and circular ring at 150 and 200 W with the lowest cadence (70 rpm).* Significant differences are presented for GM at 150 W (p =0.04) 0.04) and for VM at 250W (p =0.04).

DISCUSSION: Like previous studies (Cordova et al. 2011, Horvais et al. 2007, Neptune et al., 2008), we found no significant differences of muscular activation for all muscles at higher pedalling cadence (90 and 110 rpm). However, when the cyclists pedalled with at 70 rpm, the O-Symetric ring enhanced slight increases of muscular activation of GM and VM (~5-15%), the two main muscles power producer during the crank cycle (Raasch & Zajac, 1999). These results must to be interpreted with cautiously because of the small number of subjects (n=5).
These neuromuscular adaptations could be related to the fact that the usable time during the power crank sector is increased by the slowing down of the crank velocity during the downstroke due to the skewed ellipse of the O-Symetric shape. From their dynamic optimisation framework, Rankin and Hull (2008) showed that pedalling with a noncircular chairing at 60 rpm increased theoretically more the work of GM and vastii muscles (up to 5 J) between 315 and 135° of crank cycle. Moreover, they suggested that the optimal eccentricity of the shape of noncircular chainring, *i.e* the ratio of major to minor axes length, for increasing the crank power during sprints performed at 60-120 rpm by 3%, is comprised between 1.24 and 1.35, which is very close to the eccentricity of O-Symetric (1.25). However, this substantial advantage seems not to be benefit for high crank velocity, and thus could explained partly why we didnâ observed any significant difference in muscular activation and power production during sprints. The reason of this phenomenon would be related to muscle activation-deactivation dynamics or others unknown mechanisms.
Although the O-Symetric design is viewed to reduce the effort needed to get through the top and bottom transition, the activation level of RF, BF, GAS muscles involved during these critical phases, were not significantly altered for all pedalling cadences. Nevertheless, the lack of significant changes can be due once again to the small group size and also to the relative higher inter-subject variability of EMG signals (Figure 1).

CONCLUSION: This study showed that the muscular activation of the mono-articular hip and knee extensor muscles is slightly increased while submaximal cycling at low pedalling cadence (70 rpm) with a noncircular ring, i.e. O-Symetric. For the near future, these results must to be confirmed by increasing the number of subjects, and completed by measuring kinetic (pedal forces), kinematic (joint angles), cycling economy (gross efficiency) and performance (time trial test predate to long-time exhaustion exercise) in order to conclude definitively to the real effect of O-Symetric ring, and therefore to give the best advices for cyclists and triathletes.

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