**Belen, Habrard et al. 2007 – The performance and efficiency**

Belen, L.; Habrard, M.; Micallef, J. P.; Le Gallais, D. (2007):

## The performance and efficiency of cycling with a carbon fiber eccentric chainring during incremental exercise.

In: *J Sports Med Phys Fitness* 47 (1), S. 40–45.

*Abstract:*

AIM

The aim of this study was to compare cycling performance and efficiency of a carbon fiber eccentric chainring (EC) versus a metallic standard chainring (SC) during an incremental exercise. The main feature of EC was that crank-arm length changed as a function of the crank angle, being maximal during the pushing phase and minimal during the recovery one. Because of its design, cycling with EC was expected to develop higher torque during the downstroke, and lower torque during the upstroke, thus increasing mechanical efficiency and requiring lower cardioventilatory solicitation at submaximal exercise intensities.

METHODS

Eleven male subjects performed two incremental cycle tests in a randomized order using EC and SC successively. Cardioventilatory data were recorded every minute using an automated breath-by-breath system. Blood samples were taken at rest, exhaustion, 5 and 15 minutes of recovery to access lactate concentrations, [LA], mmol . L(-1) .

RESULTS

The subjects reached significantly lower maximal speed at volitional exhaustion with EC compared with SC (39.4+/-2.5 versus 41.5+/-2.9 km . h(-1), respectively; P<0.05). Analysis of variance revealed significantly higher values for oxygen uptake and carbon dioxide production during incremental exercise with EC (P<0.05). Lastly, [LA] at exhaustion were similar with the two chainrings.

CONCLUSIONS

The carbon fiber EC tested in this study failed to enhance cycling performance and efficiency throughout an incremental exercise. This indicated that carbon fibers did not exhibited its expected mechanical advantage.

**Cordova, Latasa et al. 2014 – Physiological Responses during Cycling**

Cordova, Alfredo; Latasa, Iban; Seco, Jesus; Villa, Gerardo; Rodriguez-Falces, Javier (2014):

## Physiological Responses during Cycling With Oval Chainrings (Q-Ring) and Circular Chainrings.

In: *Journal of sports science & medicine* 13 (2), S. 410–416.

*Abstract:*

The aim of this study was to compare the physiological responses of cyclists using round (C-ring) or oval (Q-ring) chainrings during an incremental test until exhaustion. Following a randomized design, twelve male elite cyclists [age (mean ± SD): 21.1 ± 2.1 yr; VO2max: 78.1 ± 5.3 mLÂ·kg(-1)min(-1)] performed two incremental maximal tests separated by 48 h (one with C-rings, the other with Q-rings). Starting at 100 W, the workload was increased by 25 W every 3 min until volitional exhaustion. Maximal heart rate, power output and oxygen consumption were compared. Blood lactate was monitored throughout the test. After the incremental test, 4 intermittent 20-s maximal sprints with a 60-s recovery period in between were performed. Maximal isometric voluntary contractions were performed at rest and immediately after each 20-s maximal sprint, and the force and EMG RMS amplitude were recorded from the vastus medialis and vastus lateralis muscles. For the incremental exercise test, no significant differences were found in the maximal power output (P=0.12), oxygen

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consumption (P=0.39), and heart rate (P=0.32) between Q-rings and C-rings. Throughout the incremental test, lactate levels were comparable when using both the C-rings and Q-rings (P=0.47). During the short sprints, power output was 2.5-6.5% greater for Q-rings than for C-rings (P=0.22). The decline in EMG RMS amplitude observed during the incremental tests was comparable for Q-rings and C-rings (0.42). These findings indicate that the oval chainring design, presented here as "Q-rings", did not significantly influence the physiological response to an incremental exercise test as compared to a conventional chainring. Key pointsDuring the incremental exercise test, no significant differences were found in power output, oxygen consumption or heart rate between oval "Q-rings" and conventional chainrings.Over the course of the incremental test, blood lactate levels were comparable for the oval "Q-rings" and conventional chainrings.During the short sprints performed after the incremental test, there were no statistical differences in power production between oval "Q-rings" and conventional chainrings.

**Cullen, Andrew et al. 1992 – Efficiency of trained cyclists using**

Cullen, L. K.; Andrew, K.; Lair, K. R.; Widger, M. J.; Timson, B. F. (1992):

## Efficiency of trained cyclists using circular and noncircular chainrings.

In: *Int J Sports Med* 13 (3), S. 264–269. DOI: 10.1055/s-2007-1021264.

*Abstract:*

The purpose of this study was to determine oxygen consumption (VO2), heart rate (HR) response, and rating of perceived exertion (RPE) of trained cyclists using noncircular and circular chainrings over a range of gears and pedal cadences. The subjects included 7 male cyclists (6 USCF licensed riders, 1 national qualifying triathlete). Each subject rode his own bicycle mounted on a wind-trainer at gears of 5.92 and 7.33 meters with noncircular and circular chainrings at pedal cadences of 50, 70, and 90 rpm. VO2, HR, RPE, and respiratory exchange ratio (RER) measurements were made during each of the 12 rides. Mean percent VO2max for each condition ranged from 28.7 +/- 2.1% with the 5.92 meter gear at 50 rpm to 83.4 +/- 4.3% using the 7.33 meter gear at 90 rpm. The results indicate no significant difference in any of the parameters measured between the two chainrings for any of the experimental conditions. The data indicate that the noncircular chainrings used in this study were not more efficient than the standard circular chainring for trained cyclists.

**Dagnese, Carpes et al. 2011 – Effects of a noncircular chainring**

Dagnese, Frederico; Carpes, Felipe P.; Martins, Elisandro de Assis; Stefanyshyn, Darren; Mota, Carlos Bolli (2011):

## Effects of a noncircular chainring system on muscle activation during cycling.

In: *J Electromyogr Kinesiol* 21 (1), S. 13–17. DOI: 10.1016/j.jelekin.2010.02.005.

*Abstract:*

Previous studies evaluated cycling with noncircular chainrings and suggested that changes in muscle activation would occur in response to altered pedaling mechanics throughout the crank arm revolution. However, no previous study addressed this question. The aim of this study was to compare the magnitude of muscular activity between a conventional and a noncircular crank system during an incremental maximal cycling test. Seven mountain-bike trained cyclists completed two incremental maximal tests, separated by 48 h, one for each crank system. Each test started with a workload of 100 W and was increased by 30 W every minute until exhaustion. Power output, pedaling cadence and heart rate were monitored and compared between the crank systems using paired t-tests. Surface EMG was recorded from the right rectus femoris, vastus medialis, biceps femoris and gastrocnemius medialis. EMG was compared using a general linear model considering as factors the crank system and workload with post hoc analysis at $\alpha=0.05$. RMS presented effect of workload, but no effect of crank system was found for the muscles analyzed. The present results do not support effects of the noncircular crank system on variables of performance and muscle activation during incremental cycling in trained mountain bike cyclists.

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**Hue, Galy et al. 2001 – Enhancing cycling performance using**

Hue, O.; Galy, O.; Hertogh, C.; Casties, J. F.; Préfaut, C. (2001):

## Enhancing cycling performance using an eccentric chainring.

In: *Med Sci Sports Exerc* 33 (6), S. 1006–1010.

*Abstract:*

PURPOSE AND METHODS

This study was designed to compare the physiological responses and performance of well trained cyclists riding with two different chainring designs, round or eccentric, during a brief and intense cycling exercise: an "all-out" 1-km laboratory test. The eccentrically designed chainring was made of two crank arms sliding into each other, with the inside arm fixed on the center of the arm of a circular chainring and the outside arm sliding along the inside and revolving around an elliptical cam. This design increases crank arm length at the downstroke and decreases it during the upstroke, thus increasing and decreasing the torque. In terms of the chainring's revolution, the crank arm length at 0 degrees and 180 degrees is similar to the arm length of circular chainrings (175 mm). However, during the downstroke (0-180 degrees ), it increases to its maximum length of 200 mm at 90 degrees and then returns to its original length of 175 mm at 180 degrees. During the upstroke, it decreases to a minimum length of 150 mm at 270 degrees and then increases to 175 mm at 360 degrees. Eleven cyclists performed an all-out 1-km laboratory test using each chainring. The study was conducted over two consecutive weeks with the order of chainring use randomized. During all trials, ventilatory data were collected every minute using an automated breath-by-breath system. Heart rate was measured using a telemetry system.

RESULTS

None of the cardiorespiratory variables showed significant differences between chainring trials. Performance, however, was significantly improved using the eccentric design (64.25 +/- 1.05 vs 69.08 +/- 1.38 s, P < 0.004, with the eccentric and the round design, respectively).

CONCLUSION

We concluded that the eccentric chainring significantly improved the cycling performance during an all-out 1-km test. Further testing with indoor cycling specialists performing on a velodrome would be helpful to define the maximal possibilities of such a chainring.

**Hue, Chamari et al. 2007 – The use of an eccentric**

Hue, Olivier; Chamari, Karim; Damiani, Michael; Blonc, Stephen; Hertogh, Claude (2007):

## The use of an eccentric chainring during an outdoor 1 km all-out cycling test.

In: *J Sci Med Sport* 10 (3), S. 180–186. DOI: 10.1016/j.jsams.2006.05.028.

*Abstract:*

This study assessed whether an eccentric chainring that increases crank arm length at the downstroke and decreases it during the upstroke improves performance in a track cycling event: the 1000m time trial. It also determined whether selected physical and physiological variables and the velocity profile are associated with eccentric chainring performance. Twelve cyclists performed an outdoor 1000m time trial on a 333m banked, cement-surfaced track using two different chainrings, round and eccentric, in randomised order. The important findings of this study were that (1) performance did not significantly differ between chainrings; (2) neither the physiological variables (lactate and heart rate) nor the velocity profile (lap times) were affected by use of the eccentric design; (3) when time was saved with the eccentric chainring, it was significantly correlated with estimated lower limb muscle volume (r=-0.605), circumference (r=-0.739), estimated calf muscle volume (r=-0.772) and cross-sectional area (r=-0.745). Moreover, estimated lower limb muscle volume (r=-0.703), estimated calf muscle volume (r=-0.772) and cross-sectional area (r=-0.871) significantly predicted performance with the eccentric chainring. The physical variables associated with eccentric chainring performance were muscle anthropometric parameters. We have interpreted our results cautiously and suggest that the subjects who had greater lower limb muscle volume and greater calf muscle volume, seem to have had a significant advantage in performing with the eccentric chainring. Further testing with track specialists

performing at national or international level would be helpful to define the maximal possibilities of this chainring.

**Hue, Racinais et al. 2008 – Does an eccentric chainring improve**

Hue, Olivier; Racinais, Sébastien; Chamari, Karim; Damiani, Michael; Hertogh, Claude; Blonc, Stephen (2008):

## Does an eccentric chainring improve conventional parameters of neuromuscular power?

In: *Journal of science and medicine in sport / Sports Medicine Australia* 11 (3), S. 264–270. DOI: 10.1016/j.jsams.2007.06.004.

*Abstract:*

This study compared the conventional parameters of anaerobic cycling power in physically active non-cyclists using the Pro-Race system and a traditional chainring. The force-velocity test was chosen for this purpose because it is the shortest validated cycling laboratory test in which each parameter of maximal anaerobic power can be estimated. The power output (W(max)) and the force at which W(max) is produced (F(opt)) were significantly improved with the eccentric chainring (1100+/-227W versus 1006+/-197W and 1.39+/-0.15N/kg body mass versus 1.13+/-0.16N/kg body mass with the eccentric and round designs, respectively; P<0.006 and P<0.0004, respectively). The power gained (delta power) was significantly correlated with the eccentric chainring F(opt) (r=0.649; P<0.05), the mid-thigh circumference (r=0.685; P<0.05), the estimated lean thigh volume (r=0.765; P<0.01) and the estimated lean lower limb volume (r=0.665; P<0.05). We concluded that the eccentric chainring significantly improved the estimated anaerobic power output during a force-velocity test by increasing the force component, F(opt). Cautious interpretation of our results suggests that the subjects with physical attributes that contribute to developing high forces may have a significant advantage in performing with the eccentric chainring.

**Hull, Williams et al. 1992 – Physiological response to cycling**

Hull, M. L.; Williams, M.; Williams, K.; Kautz, S. (1992):

## Physiological response to cycling with both circular and noncircular chainrings.

In: *Med Sci Sports Exerc* 24 (10), S. 1114–1122.

*Abstract:*

The purpose of this study was to compare physiological variables of endurance-trained cyclists riding with four different chainring designs: round, Shimano Biopace, and two engineered ellipse designs. The ellipse designated Eng10 had the crank arm oriented 10 degrees forward of the major (i.e. longer) axis. Eighty degrees further forward, along the minor axis, was the crank arm orientation for the second ellipse, Eng90. With the major to minor axis ratio of 22.9 cm/16.8 cm (1.36), both ellipses imposed a crank angular velocity variation of 27% relative to the highest velocity assuming constant chain velocity. Best described as a skewed ellipse (i.e., major and minor axes not perpendicular), the Biopace had a major to minor axis ratio of 1.09 thus giving a crank angular velocity variation of 8%. Eleven male cyclists rode at a high (80% of maximum VO2) and a low (60% of maximum VO2) workrate using each chainring. The study was conducted over four consecutive days with the presentation order of the chainrings randomized. Open circuit spirometry was used to collect continuous respiratory data. Heart rate, blood lactate, and cadence values also were measured. None of the physiological variables including rates of oxygen consumption showed significant differences among the chainrings. Thus, the gross efficiency of cycling was not improved by any of the noncircular chainrings. For cycling events where efficiency is a determinant of performance, the noncircular chainrings do not offer any advantage over round chainrings.

**Kautz, Hull et al. 1994 – A comparison of muscular mechanical**

Kautz, S. A.; Hull, M. L.; Neptune, R. R. (1994):

## A comparison of muscular mechanical energy expenditure and internal work in cycling.

In: *J Biomech* 27 (12), S. 1459–1467.

*Abstract:*

The hypothesis that the sum of the absolute changes in mechanical energy (internal work) is correlated with the muscular mechanical energy expenditure (MMEE) was tested using two elliptical chainrings, one that reduced and one that increased the internal work (compared to circular). Upper and lower bounds were put on the extra MMEE (work done by net joint torques in excess of the external work) with respect to the effect of intercompensation between joint torques due to biarticular muscles. This was done by having two measures of MMEE, one that allowed no intercompensation and one that allowed complete intercompensation between joints spanned by biarticular muscles. Energy analysis showed no correlation between internal work and the two measures of MMEE. When compared to circular, the chainring that reduced internal work increased MMEE, and phases of increased crank velocity associated with the elliptical shape resulted in increased power absorbed by the upstroke leg as it was accelerated against gravity. The resulting negative work necessitated additional positive work. Thus, the hypothesis that the internal work is correlated with MMEE was found to be invalid, and the total mechanical work done cannot be estimated by summing the internal and external work. Changes in the dynamics of cycling caused by a non-circular chainring may affect performance and must be considered during the non-circular chainring design process.

**Mateo-March, Fernández-Peña et al. 2014 – Does a non-circular chainring improve**

Mateo-March, Manuel; Fernández-Peña, Eneko; Blasco-Lafarga, Cristina; Morente-Sánchez, Jaime; Zabala, Mikel (2014):

## Does a non-circular chainring improve performance in the bicycle motocross cycling start sprint?

In: *Journal of sports science & medicine* 13 (1), S. 97–104.

*Abstract:*

Maximising power output during the initial acceleration phase of a bicycle motocross (BMX) race increases the chance to lead the group for the rest of the race. The purpose of this study was to investigate the effect of non-circular chainrings (Q-ring) on performance during the initial acceleration phase of a BMX race. Sixteen male cyclists (Spanish National BMX team) performed two counterbalanced and randomized initial sprints (3.95s), using Q- ring vs. circular chainring, on a BMX track. The sample was divided into two different groups according to their performance (Elite; n = 8 vs. Cadet; n = 8). Elite group covered a greater distance using Q-ring (+0.26 m, p = 0.02; D = 0.23), whilst the improvement for the Cadet (+0.04 m) was not significant (p = 0.87; D = -0.02). Also, there was no significant difference in power output for the Elite group, while the Cadet group revealed larger peak power with the circular chainring. Neither lactate level, nor heart rate showed significant differences due to the different chainring used. The non-circular chainring improved the initial acceleration capacity only in the Elite riders. Key PointsThis work provides novel results demonstrating very significant improvements in the sprint performance of BMX cycling discipline using a non-circular chainring system.This study seeks a practical application from scientific analysisAll data are obtained in a real context of high competition using a sample comprised by the National Spanish Team.Some variables influencing performance as subjects' physical fitness are discussed.Technical equipment approved by International Cycling Union is studied to check its potentially beneficial influence on performance.



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**Neptune, Herzog 2000 – Adaptation of muscle coordination**

Neptune, R. R.; Herzog, W. (2000):

## Adaptation of muscle coordination to altered task mechanics during steady-state cycling.

In: *J Biomech* 33 (2), S. 165–172.


*Abstract:*

The objective of this work was to increase our understanding of how motor patterns are produced during movement tasks by quantifying adaptations in muscle coordination in response to altered task mechanics. We used pedaling as our movement paradigm because it is a constrained cyclical movement that allows for a controlled investigation of test conditions such as movement speed and effort. Altered task mechanics were introduced using an elliptical chainring. The kinematics of the crank were changed from a relatively constant angular velocity using a circular chainring to a widely varying angular velocity using an elliptical chainring. Kinetic, kinematic and muscle activity data were collected from eight competitive cyclists using three different chainrings--one circular and two different orientations of an elliptical chainring. We tested the hypotheses that muscle coordination patterns (EMG timing and magnitude), specifically the regions of active muscle force production, would shift towards regions in the crank cycle in which the crank angular velocity, and hence muscle contraction speeds, were favorable to produce muscle power as defined by the skeletal muscle power-velocity relationship. The results showed that our hypothesis with regards to timing was not supported. Although there were statistically significant shifts in muscle timing, the shifts were minor in absolute terms and appeared to be the result of the muscles accounting for the activation dynamics associated with muscle force development (i.e. the delay in muscle force rise and decay). But, significant changes in the magnitude of muscle EMG during regions of slow crank angular velocity for the tibialis anterior and rectus femoris were observed. Thus, the nervous system used adaptations to the muscle EMG magnitude, rather than the timing, to adapt to the altered task mechanics. The results also suggested that cyclists might work on the descending limb of the power-velocity relationship when pedaling at 90 rpm and sub-maximal power output. This finding might have important implications for preferred pedaling rate selection.


**Peiffer, Abbiss 2010 – The influence of elliptical chainrings**

Peiffer, Jeremiah J.; Abbiss, Chris R. (2010):

## The influence of elliptical chainrings on 10 km cycling time trial performance.

In: *Int J Sports Physiol Perform* 5 (4), S. 459–468.


*Abstract:*

The use of elliptical chainrings (also called chainwheels or sprockets) has gained considerable interest in the amateur and professional cycling community. Nevertheless, we are unaware of any scientific studies that have examined the performance benefits of using elliptical chainrings during an actual performance trial. Therefore, this study examined the influence of elliptical chainring use on physiological and performance parameters during a 10 km cycling time trial. Nine male cyclists completed, in a counterbalanced order, three 10 km cycling time trials using either a standard chainring or an elliptical chainring at two distinct settings. An attempt was made to blind the cyclists to the type of chainring used until the completion of the study. During the 10 km time trial, power output and heart rate were recorded at a frequency of 1 Hz and RPE was measured at 3, 6, and 8.5 km. Total power output was not different (P = .40) between the circular (340 ± 30 W) or either elliptical chainring condition (342 ± 29 W and 341 ± 31 W). Similarly, no differences (P = .73) in 2 km mean power output were observed between conditions. Further, no differences in RPE were observed between conditions measured at 3, 6, and 8.5 km. Heart rate was significantly greater (P = .02) using the less aggressive elliptical setting (174 ± 10 bpm) compared with the circular setting (171 ± 9 bpm). Elliptical chainrings do not appear to provide a performance benefit over traditional circular chainrings during a mid-distance time trial.

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### Rankin, Neptune 2008 – A theoretical analysis

Rankin, Jeffery W.; Neptune, Richard R. (2008):

## A theoretical analysis of an optimal chainring shape to maximize crank power during isokinetic pedaling.

In: *J Biomech* 41 (7), S. 1494–1502. DOI: 10.1016/j.jbiomech.2008.02.015.

*Abstract:*

Previous studies have sought to improve cycling performance by altering various aspects of the pedaling motion using novel crank-pedal mechanisms and non-circular chainrings. However, most designs have been based on empirical data and very few have provided significant improvements in cycling performance. The purpose of this study was to use a theoretical framework that included a detailed musculoskeletal model driven by individual muscle actuators, forward dynamic simulations and design optimization to determine if cycling performance (i.e., maximal power output) could be improved by optimizing the chainring shape to maximize average crank power during isokinetic pedaling conditions. The optimization identified a consistent non-circular chainring shape at pedaling rates of 60, 90 and 120 rpm with an average eccentricity of 1.29 that increased crank power by an average of 2.9% compared to a conventional circular chainring. The increase in average crank power was the result of the optimal chainrings slowing down the crank velocity during the downstroke (power phase) to allow muscles to generate power longer and produce more external work. The data also showed that chainrings with higher eccentricity increased negative muscle work following the power phase due to muscle activation-deactivation dynamics. Thus, the chainring shape that maximized average crank power balanced these competing demands by providing enough eccentricity to increase the external work generated by muscles during the power phase while minimizing negative work during the subsequent recovery phase.

### Ratel, Duché et al. 2004 – Physiological responses during cycling

Ratel, Sébastien; Duché, Pascale; Hautier, Christophe A.; Williams, Craig A.; Bedu, Mario (2004):

## Physiological responses during cycling with noncircular "Harmonic" and circular chainrings.

In: *Eur. J. Appl. Physiol.* 91 (1), S. 100–104. DOI: 10.1007/s00421-003-0937-9.

*Abstract:*

The aim of the present study was to compare physiological data obtained during cycling using a noncircular "Harmonic" chainring versus a standard circular chainring over a range of speeds and slopes in endurance-trained cyclists. Thirteen male subnational cyclists (16-45 years) performed two maximal graded exercises on their own bicycle: one with a circular chainring, the other with a Harmonic chainring with the same gearwheel (52 teeth). The two chainrings were randomly assigned to avoid learning effects. The tests were carried out on a simulator. Speeds and/or slopes were increased every 2 min 30 s until exhaustion of the subject. Ventilation, oxygen uptake, carbon dioxide output, respiratory exchange ratio, and heart rate were continuously measured during the tests. Blood lactate concentration was measured during the last 30 s of each level. No significant difference was observed in any of the submaximal parameters measured during the tests ( $P>0.05$). Similarly, maximal values were not statistically different ( $P>0.05$). In conclusion, although the design of the Harmonic chainring was based on optimization analysis, comparison of the physiological response in this study did not translate into an advantage of the Harmonic over circular chainring during submaximal and maximal pedaling in trained cyclists.

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**Strutzenberger, Wunsch et al. 2014 – Effect of chainring ovality**

Strutzenberger, Gerda; Wunsch, Tobias; Kroell, Josef; Dastl, Jacqueline; Schwameder, Hermann (2014):

## Effect of chainring ovality on joint power during cycling at different workloads and cadences.

In: *Sports biomechanics / International Society of Biomechanics in Sports* 13 (2), S. 97–108. DOI: 10.1080/14763141.2014.908946.

*Abstract:*

Non-circular chainrings theoretically enhance cycling performance by increasing effective chainring diameter and varying crank velocity, but research has failed to consistently reproduce the benefits in cycling trials. The aim of this study was (1) to investigate the effect of different chainring shapes on sagittal knee joint moment and sagittal lower limb joint powers and (2) to investigate whether alterations are affected by cadence and workload. Fourteen elite cyclists cycled in six conditions (70, 90 and 110 rpm, each at 180 and 300 W), for 2 min each, using three chainrings of different ovalities (1.0-1.215). Kinematic data and pedal forces were collected. For most conditions, only the chainring with the highest ovality (1.215) was characterised by smaller sagittal knee joint moments, smaller relative sagittal knee joint power contribution and larger relative sagittal hip joint power contribution, which suggests a change from maximising efficiency to maximising power production. Effect sizes increased with higher cadences, but not with higher workload. This study has application for athletes, clinicians and sports equipment industry as a non-circular chainring can change joint-specific power generation and decrease knee joint moment, but certain ovality seems to be necessary to provoke this effect.