WHITE PAPER THE SCIENCE BEHIND NON-CIRCULAR CHAINRINGS
Since the origin of the bicycle more than a century ago, improving pedaling efficiency has long been identified as an area warranting research. **Nobody applies constant**, even force throughout the pedal stroke, and as a result, curiosity tended toward the pedal stroke’s biomechanics. Studies focused on revising traditional circular chainrings to take advantage of the areas where the most force is applied during the pedal stroke by creating a variable drive radius, thereby giving a greater forward momentum to the bicycle, and reducing the **“dead spots.”** Chainrings that could vary drivetrain resistance in line with the legs’ ability (or lack thereof) to deliver power would make pedaling more effective, efficient and a more natural process.
Researchers concluded that an elliptical design would take advantage of maximum power generation and compensate for the least-productive part (dead spot) of a complete pedal rotation. The merits of elliptical chainring design depended upon three primary factors: orientation, ovalization, and form. The orientation factor took into account the angle between the centerline of the cranks and the largest diameter of the chainring. Ovalization is defined as the ratio between the largest and smallest diameters of the chainring. The form factor indicated the curves shaping the perimeter of the chainring, such as arcs and ovals, angles or flat sections, and ellipses.

Early design concepts that emerged consequently failed because improper orientation, ovalization, or form factor (or all three) produced irregular pedal rotations that led to pain-causing stress on the knees. A successful design would orient the chainring around riders’ unique pedaling characteristics relative to both the ovalization and form factors. Design features would have to include subtle but efficient ovality: smallest diameter at weakest point of pedal stroke, maximum diameter at strongest point of pedal stroke, and adjustability to ensure minimum diameter related to the start of pedal stroke and maximum diameter related to peak power.
The primary goals for non-circular chainrings focused on minimizing the negative effects of dead spots during a rider’s pedal stroke while maximizing power output. Additional claims boasted by savvy design included increased endurance, reduced joint strain, reduced fatigue to muscle fibers, lower heart rate and oxygen consumption, improved climbing and cruising, and increased power output. Critics were quick to take issue, and research to debunk such claims ensued. One peer-reviewed publication investigated the use of non-circular chainrings (in this case Rotor Q-Rings) compared to round chainrings during a four-week adaptation period proved these claims to be true. The results of the research found:

- **Q-Rings** were faster, with an average gain of 1.6 sec and 0.7 km/h (1.8%).
- **Q-Rings** generated more power, with average increase of 26.7 W (6.2%)
- Reduced oxygen consumption and heart rate in submaximal tests with Q-Rings.
- An immediate performance increase on switching from round rings to Q-Rings.
- An immediate performance reduction on switching back to round chainrings.

The scientific findings of this study seemed to indicate that a superior chainring design would indeed positively impact performance\(^{(1)}\).

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Research and tests succeeded in proving performance values of non-circular chainrings in various controlled environments but some cyclists competing in high-stakes events, like Grand Tours, world championships and the Olympics, resisted change. Their main concern was switching to something different from what they’d become accustomed to riding all their lives. Despite strong scientific evidence, these cyclists viewed switching to non-circular chainrings as a risk. Then a convincing win in 2008 by the Spanish rider, Carlos Sastre, who won the Tour de France on non-circular chainrings (specifically Q-Rings), confirmed their acceptance among this class of racer. More high-profile races and other landmark victories were won on non-circular chainrings in the disciplines of mountain biking, cyclocross, and both off-road and Ironman triathlon.

Those earlier versions of non-circular chainrings that featured improper orientation, ovalization, and form factors are still cited by doubters unconvinced that non-circular chainrings could have an impact on performance. However a robust force of early-adopters and consequent early majority consumers have thrust non-circular chainrings into mainstream consciousness.
Riding and racing “by feel” has since been replaced by the pursuit of data that bears proof that performance can be improved. Researchers and innovators seized that trend and zeroed in on pedaling efficiency as an area for improvement and performance gains. They believed that by redesigning a chainring’s shape to compensate for the least-productive zone of a pedal stroke while maximizing the power output in the most-productive zone, non-circular chainrings would possess desirable benefits such as shaving seconds off a race, increasing power output, and reducing strain on joints. Skeptics who doubted these virtues were quieted by science, which proved such claims to be true and helped repair a reputation previously damaged by bad design and consequent market failure. The appeal of non-circular chainrings—once touted by a handful of early-adopters-turned-loyalists broadened as more podiums were reached and validated what science had already proven.