BIKE IQ TECHNICAL WHITEPAPER · V1.0 · APRIL 2026

Bike IQ — Power Estimation Whitepaper

Power Without a Power Meter

How Bike IQ Estimates Cycling Power From Speed, Grade, and Physics

A BIKE IQ TECHNICAL WHITEPAPER

Summary

Bike IQ produces a real-time estimate of the rider's mechanical pedaling power, in watts, without a crank-based or pedal-based power meter. The system applies the same physics that determines cycling power, fed by signals already available to the phone (GPS speed, barometric grade, weather), parameters configured for each bike (mass, aerodynamic profile, tire type), and a small amount of per-rider learning that happens automatically over the course of riding.

Validated against premium dedicated power meters from Quarq and Favero across multiple riders and bikes, the system achieves a mean bias within a few watts of the meter on aggregate, and a per-window error that is well within the range a rider can actually use for pacing and training. It does not match a dedicated power meter on every pedal stroke, and we are open about the conditions where it falls short, but it makes power available to riders who would otherwise have no power data at all.

Why This Matters

Cycling power, measured in watts, is the most important metric in modern endurance training. Heart rate is a delayed and noisy proxy for effort. Speed depends on grade, wind, and surface. Cadence is technique, not effort. Power is the only number that tells a rider, in real time, how hard they are actually working against the world.

Power has historically required dedicated hardware. A crank-based or pedal-based power meter typically costs several hundred to a thousand dollars or more, and has to be installed on a specific bike. The result is that perhaps ten to fifteen percent of cyclists own a power meter, and the other eighty-five to ninety percent train without the most informative metric available. A trustworthy estimate that requires no extra hardware closes a significant gap.

Why It Is Hard

Cycling power is determined by physics. The rider has to overcome four forces at every moment: gravity (when the road goes up), rolling resistance (the tire deforming against the pavement), aerodynamic drag (pushing air out of the way), and inertia (accelerating the bike and rider's mass). The mechanical power the legs deliver is the sum of those four forces multiplied by speed, divided by drivetrain efficiency.

The equation is well known. The difficulty is that every term in it depends on something that is hard to measure accurately from a phone.

Speed. Cycling speed from GPS is good but not perfect, especially in tight corners, under tree cover, in cities, and at low speeds. Even small errors propagate everywhere because power is roughly proportional to speed cubed in the aerodynamic term.

Grade. Steepness from a barometer is accurate over time but lags real-world transitions by a few seconds, particularly at higher speeds. A small grade error at climbing speed is many watts.

Aerodynamic drag. The single largest force at any speed above a brisk walking pace, and also the hardest to estimate. It depends on the rider's body position (drops vs hoods vs aerobars), clothing, helmet, weather, and air density. Conventional wisdom puts a typical cyclist's aerodynamic profile in a range, but the exact number for a specific rider on a specific day is essentially unmeasurable without a wind tunnel.

Wind. The wind the rider experiences is not the wind the weather report describes. Wind direction relative to the rider's heading flips on out-and-back rides. Drafting behind another rider is functionally an enormous tailwind that the model has no way to detect from external signals alone.

Mass. Total system mass (rider plus bike plus water plus food plus everything else) appears in three of the four terms. Riders generally know roughly what they weigh but not exactly, and rarely update the bike's water bottles on the fly.

Drivetrain efficiency. A clean and well-tuned drivetrain is roughly 96 to 97 percent efficient. A neglected one with a worn chain and pulleys can be down at 92 percent or worse. This is the kind of parameter no rider knows about their own setup.

Inertia. Accelerating from a stop sign to cruising speed takes meaningful power, but it lasts only a few seconds. Capturing it requires a clean enough speed signal to compute acceleration without amplifying noise.

The combined result is that a naive application of the physics equation, with default parameters, produces a power number that is in the right ballpark on average but can be wildly off on any specific moment of any specific ride.

Our Approach

Bike IQ's power estimator combines a careful implementation of the underlying physics, signals processed to be usable inputs to that physics, parameters configured per bike rather than averaged across all riders, and per-rider learning that quietly improves accuracy over time.

Physics-Based Foundation

The estimator uses the same force-balance equation that describes the actual power required to move a bike at a given speed, on a given grade, against a given wind, with a given mass and aerodynamic profile. There is no surrogate model and no machine-learned regression in the live path. The output is the answer to the physics equation given the best available inputs at that moment.

Smooth, Causal Inputs

Each input to the equation is processed before it enters. The speed signal is smoothed using a short causal regression that rejects outlier samples (BLE-to-GPS handoff glitches and GPS jumps), then differentiated to produce a stable acceleration term. The grade signal comes from a dedicated grade estimator (described in its own whitepaper) which combines the barometer with rate-clamping to suppress glitches without smoothing out real terrain. Atmospheric density, which affects the aerodynamic term, is computed from current temperature and pressure rather than treated as a constant.

Per-Bike Configuration

Each bike the rider sets up in Bike IQ carries its own physical parameters: mass, drivetrain efficiency, aerodynamic profile (which depends on the handlebar type the rider selects, since hoods, drops, and aerobars produce dramatically different drag coefficients), and rolling resistance (which depends on the tire type the rider selects). The same equation produces different power on the same input data depending on which bike the rider is currently on. A road bike on slick tires and a commuter on chunky tires produce different power numbers at the same speed and grade, which is the right answer.

Per-Rider Wind Coupling

The wind reported by the weather service is at a standard reference height and direction. The rider experiences a fraction of that, depending on their riding position, the surrounding terrain, and luck. Bike IQ couples the reported wind into the physics equation through a single learned coupling factor that approximates how much of the meteorological wind a rider on this bike actually feels. The headwind or tailwind component depends on the angle between the rider's current heading (from GPS) and the wind direction.

Coasting and Edge Cases

Coasting, the common case where the rider is moving but not pedaling, is treated separately. When the cadence sensor or estimator indicates the rider is coasting, the estimator outputs zero rather than report nonzero power based on the bike's deceleration alone. Steep descents where the rider is pedaling above coasting equilibrium are handled correctly through the inertia term.

Continuous Validation Against Real Power Meters

Research rides on bikes equipped with a paired dedicated power meter produce the most useful data in the entire research program. These rides let us compare Bike IQ's estimate to a known-good source minute by minute, on real terrain, in real conditions. This comparison drives every iteration of the estimator and is the basis of the validation numbers below.

How We Validated It

The validation set consists of rides where the same rider, on the same bike, on the same ride, produced both a Bike IQ power estimate and a parallel power feed from a dedicated power meter (Quarq crank-based or Favero pedal-based, both treated as ground truth).

The current validation set:

- Multiple bikes ranging from a dedicated road bike with aerobars to a road racing setup
- Multiple riders with different body sizes and pedaling styles

- Mixed terrain including climbing, descending, urban riding, and open road
- Varied weather conditions including calm days and windy days
- Aggregate ride time well over twenty hours of side-by-side comparison

Headline results, averaged across the validation set:

Metric	Result
Mean bias vs power meter	within a few watts of zero
Average error at 30 second windows	~12%
Average error at 5 minute windows	~10%
Average error at 15 minute windows	~8%

The error shrinks at longer time windows because some of the disagreement at any given second is noise on either side that averages out, while the underlying physics is correct.

Two notes on the comparison itself. First, dedicated power meters are themselves not perfectly accurate. Manufacturer accuracy specifications are typically plus or minus 1.5 to 2 percent, and crank-based meters can read systematically different from pedal-based meters by a few percent on the same ride for valid mechanical reasons. Second, Bike IQ's estimate is naturally smoother than a meter's reading, because it does not see the per-pedal-stroke variation that the meter measures directly. For training and analysis purposes this smoothing is usually a feature, but in head-to-head comparisons it shows up as additional disagreement at the shortest time windows.

What It Does Not Do Well Yet

Drafting. Riding closely behind another cyclist or behind a vehicle creates a significant aerodynamic shadow that the estimator cannot detect from speed, grade, and weather alone. A rider drafting in a paceline will show power that is several tens of watts too high during the drafting effort.

Sustained crosswinds and high-wind days. Bike IQ's wind coupling uses a single coupling factor that does not distinguish between headwind and tailwind. On windy days with strong directional winds, this single factor cannot be right in both directions on the same out-and-back ride. The error is small on calm days and grows with wind strength.

Steep climbs. Power on steep climbs is dominated by gravity, which depends on the grade estimate. Any lag or error in the grade estimator at the moment a climb gets steeper translates directly into a low power reading for the few seconds it takes the grade to settle. The grade whitepaper has more detail on this specific tradeoff.

Hard accelerations and sprints. A short, hard sprint involves rapid acceleration that the speed signal smooths through, and a body position change (out of the saddle) that the aerodynamic term does not model. The estimator captures the sustained power of an effort better than it captures the peak.

Descending while pedaling. When the rider is pedaling on a descent above coasting equilibrium, the estimator reports the additional power above coasting, which is correct. But the grade lag on a descent is structurally larger than on a climb, and this is where most of the descent power error comes from.

Aerodynamic profile is approximate. The handlebar type a rider configures (drops, hoods, aerobars) sets a starting estimate. Real-world differences between two riders both on hoods can easily be plus or minus several percent of their true aerodynamic profile, and that uncertainty caps how accurate the estimator can ever be without per-rider calibration.

The Roadmap

Per-rider aerodynamic learning. A rider's true aerodynamic profile can be inferred from steady-state efforts where all other terms are well-known. Folding this learning into the estimator over the course of several rides will tighten accuracy substantially, particularly at high speeds where aero dominates.

Asymmetric wind handling. Splitting the single wind coupling factor into separate headwind and tailwind components addresses the largest known weakness on windy days.

Drafting detection. Detecting drafting from external signals is hard but not impossible. Sustained mismatches between estimated power and the work the rider's heart rate suggests they are doing, combined with proximity signals from other Bluetooth devices in range, may make drafting recognizable in real time. This is research-stage work today.

Better grade for power. Investments in the grade estimator (described in its own whitepaper) flow directly to power accuracy. Roughly half the per-second power error is attributable to the grade input, so improvements there move the power numbers more than improvements in any other component.

Body-position aerodynamic adjustment. Riders shift between hoods, drops, and aerobars during a single ride. Detecting this shift from motion signals (or letting the rider mark it manually) and applying a different aerodynamic profile would meaningfully improve the per-segment numbers.

Power-meter mode. When a dedicated power meter is paired, Bike IQ can use it directly and silently fold its readings into the per-bike learning. Riders who own a power meter help calibrate the bike's parameters every time they ride, which improves the estimate on the rides where they don't.

What This Means for Riders

A cyclist who opens Bike IQ on a bike ride sees a power number that is reliable enough to pace by, structured training plans against, and analyze after the fact. The number is not pedal-stroke accurate, and the app does not pretend it is. It is, however, a meaningful and trustworthy estimate of the work the rider is doing, available to a population of cyclists who would never otherwise see one.

For riders who already own a power meter, the value of this system is different. It validates that the meter is working, lets them compare across bikes that don't all have meters, and provides a fallback when the meter battery dies mid-ride. For riders who don't own one, this is the difference between training in the dark and training with the most important number in the sport.

Power estimation is one of several metrics Bike IQ derives from the phone alone. Cadence, gear, and grade are described in their own whitepapers, and each contributes to the others.

About Bike IQ

Bike IQ is an iOS cycling app focused on turning the phone into a legitimate cycling computer for riders who want serious training metrics without buying serious training hardware. The app is built by a small independent team and ships regular research-driven updates to its beta and production users.

For press inquiries or technical follow-up, please contact the Bike IQ team at contact@bikeiq.app.

This whitepaper describes research in active development. The systems and methods described herein are the subject of pending U.S. patent application(s), including U.S. Provisional Application No. 64/040,848 filed April 16, 2026. Numbers reported above reflect the state of the system as of the document date and may improve in subsequent releases.