CYCLING BIOMECHANICS

The Biomechanics of Q-Factor

Stance Width, Knee Loading, and How eMTB Motors Compare to Analog Mountain Bikes

Prepared for TGI Cycling

July 2026

Contents

1. Summary

Q-factor, the horizontal distance between the outer faces of a bike's two crank arms, and by extension the width at which a rider's feet are held apart while pedaling [1], is one of the least-discussed yet most biomechanically consequential dimensions of a bicycle. It sets the rider's stance width, which in turn influences the alignment of the hip, knee, and ankle through every one of the roughly 5,000 pedal revolutions in an hour of riding. For the knee in particular, stance width changes how load is distributed across the joint.

This matters more now than ever because mid-drive electric mountain bike (eMTB) motors sit between the cranks, and the width of the motor housing tends to push the cranks (and therefore the feet) farther apart than on an analog bike. The controlled biomechanics literature is consistent in the direction of the effect: increasing Q-factor increases frontal-plane knee loading, specifically the peak knee abduction moment (KAbM) and medial-compartment contact force. [2] [3] The magnitudes observed on real bikes are smaller than the extremes used in laboratory studies, but the direction is well established and clinically relevant for riders with knee sensitivity.

The practical finding of this paper is that the specified eMTB motors cluster around Q-factors of roughly 170–188 mm, while the analog bikes from popular brands like Transition, Santa Cruz, Trek, Specialized, and Pivot, built around SRAM Eagle and Shimano XT/XTR cranksets, cluster around 168–178 mm. The two groups overlap, but eMTBs skew wider, with Bosch's full-power Performance Line CX (especially Gen 5) at the wide end and lightweight units such as TQ, Fazua, and Bosch's SX reaching into analog territory. A notable exception runs the other way: maxon's compact Air S, as implemented on bikes like the Dirtlab Paratu and Instinctiv Ocelot, achieves a Q-factor starting at just 155 mm, narrower than almost any analog mountain bike and closer to a road bike, proving that motor design, not the mere presence of a motor, drives Q-factor. For most riders, the difference is unnoticeable; for riders with a history of medial knee pain, patellofemoral issues, or wide-stance sensitivity, it is a fit variable worth managing deliberately, and aftermarket narrow cranks can partly address it.

Note: this document is an educational synthesis of published research and manufacturer specifications for general information; it is not medical advice. Riders with knee pain or injury should consult a physician, physical therapist, or professional bike fitter.

2. Defining Q-Factor, Stance Width, and Tread

Q-factor is measured as the horizontal distance between the outboard faces of the two crank arms where the pedals thread in. [1] The related rider-facing quantity is stance width, the lateral separation of the feet, which equals Q-factor plus any additional offset from the pedal spindle length and cleat position. Historically, the same dimension was called “tread,” borrowing from over a century of bicycle design vocabulary. [4] Q-factor is set primarily by the crankset and bottom-bracket system; on an eMTB, the motor housing is an additional, dominant constraint because the cranks must clear it. [5]

A useful anchor: road cranksets typically produce a Q-factor of 145-150 mm, while mountain-bike cranksets are roughly 20 mm wider, commonly 168–178 mm, to clear wider tires and chainstays and to accommodate boost hub spacing. [5] [6] This width difference is why the same rider often feels “more bow-legged” on a mountain bike than on a road bike, and why the incremental widening imposed by some eMTB motors is worth examining rather than dismissing.

An important measurement caveat runs through this topic: a bike's Q-factor is a property of the fitted crankset, not the frame or, strictly, the motor alone. The same crank model is used across all frame sizes of a given bike, so Q-factor does not change with frame size even when crank-arm length does. [5] Manufacturers also rarely publish Q-factor directly, so many of the figures in this paper are drawn from component makers, bike-fitting specialists, and aftermarket crank manufacturers who measure it explicitly. When a range is given, it reflects crank and offset options rather than measurement uncertainty.

3. The Biomechanics of Stance Width at the Knee

3.1 The frontal-plane knee-loading mechanism

The knee is loaded in three planes, but stance width acts most directly in the frontal plane via the knee abduction moment (KAbM). KAbM is a well-validated surrogate for the load passing through the medial (inner) compartment of the knee; in gait research, it increases with the severity of medial knee osteoarthritis. [2] In walking, widening the step reduces KAbM, which is why "wider stance" gait retraining is used to offload arthritic knees. Cycling, importantly, behaves in the opposite direction.

In a controlled laboratory study using instrumented pedals and 3-D motion capture, Thorsen and colleagues tested four Q-factor conditions (150, 192, 234, and 276 mm) across three workrates and found that increasing Q-factor increased peak KAbM during stationary cycling. [2] A follow-up musculoskeletal-simulation study by the same group estimated joint contact forces directly and found that a wide Q-factor (276 mm) significantly increased medial-compartment contact force relative to a narrow setting (150 mm), whereas total and tibiofemoral contact forces were not significantly changed; the increase was attributed to a longer frontal-plane moment arm of the pedal reaction force. [3] Regression analysis showed that KAbM and knee-extension moment together explained about 87% of the variance in medial contact force. [3]

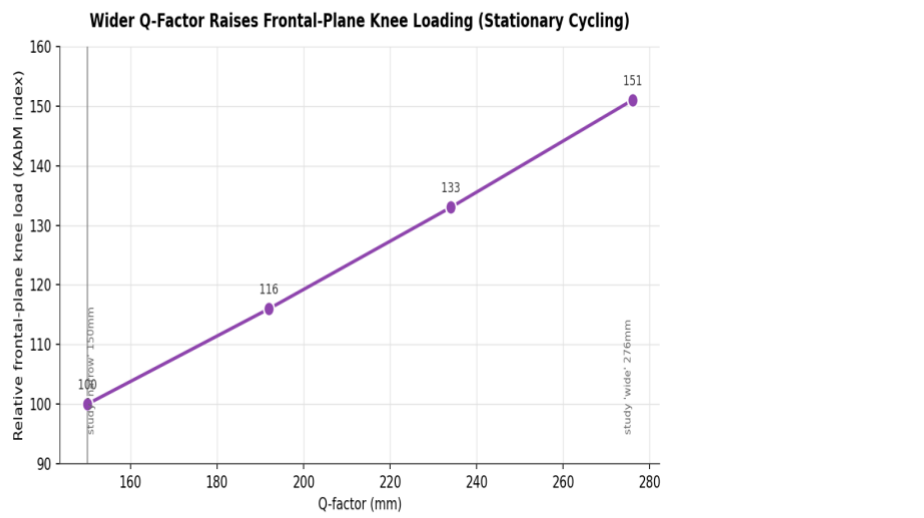

Figure 1. Schematic of the reported dose–response: increasing Q-factor progressively raised frontal-plane knee loading (KAbM) and medial-compartment contact force in controlled cycling studies [2,3]. Index values are illustrative of the direction and monotonicity, not exact published magnitudes.

Two nuances keep this honest. First, these studies used Q-factor increments far larger (up to 276 mm) than the differences between real bikes (a spread of roughly 20 mm across the systems compared here), so the on-bike effect is proportionally smaller. Second, the same studies found that a wide Q-factor significantly reduced peak knee-flexor muscle force and did not change peak knee-extensor force [3], so the picture is not uniformly "wider is worse"; it is "wider shifts load toward the medial compartment." For a healthy knee, that shift is typically inconsequential; for a medially sensitive or osteoarthritic knee, it is the specific load one may wish to minimize.

3.2 Efficiency, power, and self-selected width

Beyond joint load, Q-factor has also been studied for performance. The intuition that a narrower stance (closer to the inline track of walking) should improve efficiency has only weak empirical support. Disley and Li examined gross mechanical efficiency and muscle activation across Q-factors and found small effects, with a self-selected width not necessarily matching the metabolically optimal one. [7] [8] The broader literature is candid that comparatively little research has isolated an "ideal" Q-factor, because most bike-fit science has concentrated on saddle height and aerodynamics. [4] The reasonable reading is that for most riders, moderate differences in Q-factor have minor efficiency consequences, and comfort, joint health, and stability should drive the choice rather than a hypothetical wattage gain.

3.3 Individual variation: anatomy, sex, and history

Optimal stance width is individual. Hip width, femur length, tibial alignment (varus/valgus), foot progression angle, and prior injury all influence where a given Q-factor places the knee. Bike-fitting practitioners note that women, who differ from men in pelvic geometry and hip mechanics, are often fitted using data derived predominantly from male cohorts, which may not represent them well. [9] Clinically, a stance that is too wide for a rider's anatomy can produce medial knee pain and a sensation of the legs bowing outward, while a stance that is too narrow can crowd the pedal stroke. [10] This individuality is why the group-level Q-factor figures below should guide screening and conversation, not serve as a deterministic predictor.

4. Q-Factor of the Specified eMTB Motors

Because the motor housing sits between the cranks, mid-drive eMTBs generally run wider than analog bikes. However, the newest lightweight and "SL" systems have narrowed the gap, and at least one compact drive undercuts analog bikes entirely. Manufacturers seldom publish Q-factor, so the figures below are compiled from bike-fitting specialists, component makers, and aftermarket crank manufacturers who state it explicitly; the exact number on any given bike depends on the crankset fitted. [5] [11] [12]

- Bosch Performance Line CX (Gen 5): approximately 180 mm with standard cranks and reported as high as ~188 mm with certain crank/clearance setups — the widest of the group, reflecting the Gen 5's larger motor shell. [11] [13]
- Bosch Performance Line CX (Gen 4): roughly 178–180 mm stock; the previous full-power benchmark. [11] [14]
- Bosch Performance Line SX: about 174 mm with standard cranks and reducible toward 160 mm with narrow cranks. Bosch's lightweight unit is among the narrowest full-brand options. [11] [6]
- Shimano EP801: 177 mm as delivered on typical Shimano crank sets, deliberately built narrower than older full-power motors to approach analog width. [15] [6]
- DJI Avinox (M1/M2S): built on an ISIS spindle in the same width class as Bosch's SX/Brose systems, roughly 172–178 mm depending on crank, with aftermarket narrow options available. [11] [12]
- Specialized 2.2 / 3.1 (Brose-derived): roughly 174–178 mm class, with the notable quirk that the motor is offset about 4 mm toward the drive side of the frame centerline, so a symmetric crankset places the stance slightly off-center. [11]
- Fazua Ride 60: a lightweight unit in the ~169–175 mm class (the earlier Fazua Evation measured about 169 mm with narrow aftermarket cranks), overlapping the wider end of analog cranks. [16] [12]
- TQ HPR60: the compact Harmonic Pin-Ring design is among the narrowest motors here, in the ~170–176 mm range and frequently singled out for a stance close to a traditional MTB. [12] [17]
- Maxon Bikedrive Air S (e.g., Dirtlab Paratu, Instinctiv Ocelot): the standout narrow case. Its BLDC internal-rotor motor and single-stage planetary gearhead, with an innovative near-zero-resistance freewheel, yield

a Q-factor that, per Maxon's own specification, starts at just 155 mm. That is significantly narrower than bulkier mid-drive competitors such as the Shimano EP8 (177 mm) or Fazua (171 mm), and closer to a road-bike stance than to a typical eMTB, letting these bikes feel like a normal mountain bike underfoot. [22] [15]

The through-line is that "eMTB" is not a single Q-factor. Full-power Bosch units define the wide end; lightweight TQ and Fazua units and Bosch's SX sit at or near analog width; and maxon's Air S reaches below it, narrower even than a typical analog crankset. A rider sensitive to stance width therefore has motor-selection options, not only crank-swap options.

5. Q-Factor of the Analog Bikes

Mainstream brands like Transition, Santa Cruz, Trek, Specialized, and Pivot do not manufacture their own cranks for their analog mountain bikes; they specify SRAM Eagle or Shimano XT/XTR drivetrains, so the Q-factor of these bikes is effectively the Q-factor of those component standards. [6] [18] This makes the analog side straightforward to characterize from component data:

- SRAM Eagle Transmission (T-Type): the modern standard on many Transition, Santa Cruz, Trek, and Pivot builds is offered in a 168 mm (narrow) and a 174 mm (standard) Q-factor. [18] [19]
- SRAM Eagle DUB / X0/XX SL cranks span roughly 158 mm (race non-boost) to 168–174 mm (boost). [6] [19]
- Shimano XT (12-speed) runs about 172 mm non-boost and 178 mm boost; Shimano XTR ranges from about 162 mm (race) to 174 mm depending on model. [6] [20]
- Across these, analog mountain bikes from the five brands cluster at roughly 168–178 mm, with 172–174 mm the most common modern trail figure. [6]

Because all five brands draw from the same SRAM/Shimano parts bins, the differences between, say, a Santa Cruz Hightower and a Trek Fuel EX in Q-factor are driven by which crankset and chain line (boost vs non-boost, 55 mm wide chain line) the specific build uses, not by brand identity. [18] A rider chasing a narrow stance can often spec or retrofit a 168 mm SRAM crank on any of them.

6. Side-by-Side Comparison

The chart and table below place the specified eMTB motors and the analog crank standards on a common scale. The overlap is real, but the central tendency of the eMTB group sits wider, and the widest options are all full power eMTB motors.

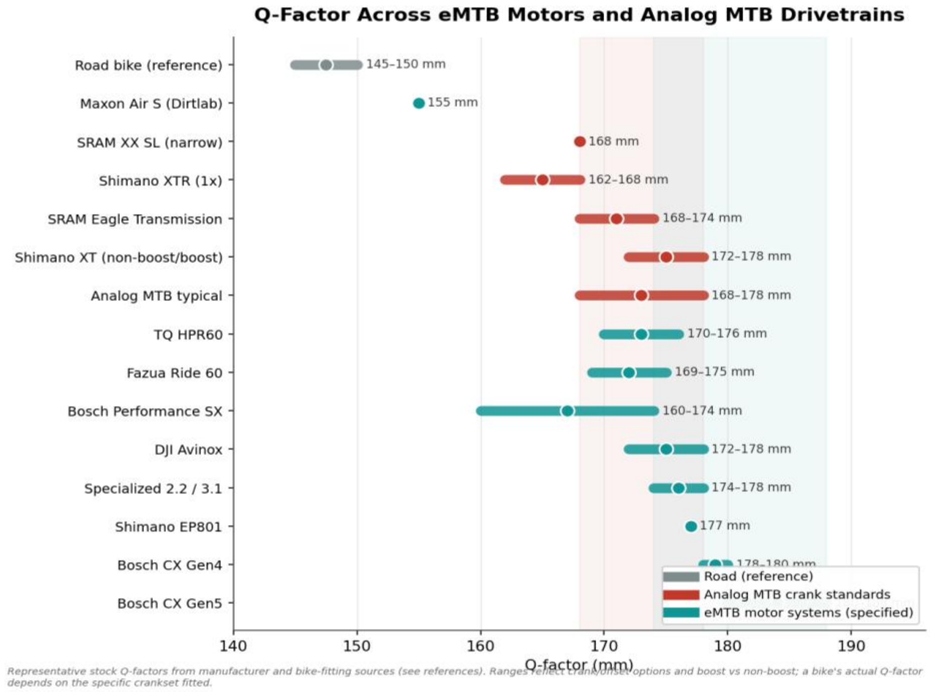

Figure 2. Representative stock Q-factors. Analog MTB crank standards (red) cluster ~168–178 mm; specified eMTB motors (teal) span ~155–188 mm the Maxon Air S the narrow outlier, Bosch CX Gen 5 the wide end; road shown for reference. Ranges reflect crank/offset and boost options [6,11,12,15,18–20,22].

System	Type	Q-factor (mm)	Notes
Road crankset (ref.)	Reference	145–150	Narrow inline stance [6]
SRAM Eagle Transmission	Analog	168 / 174	Narrow or standard option [18,19]
Shimano XT (12s)	Analog	172–178	Non-boost / boost [6,20]
Shimano XTR	Analog	162–174	Race to trail [6]
Analog MTB (5 brands, typical)	Analog	168–178	SRAM/Shimano spec [6]
Maxon Air S (DIRTLAB & Instictiv**)**	eMTB	from 155	Narrowest here; per maxon spec [22]
TQ HPR60	eMTB	~170–176	Narrowest full/light class [12,17]
Fazua Ride 60	eMTB	~169–175	Lightweight, overlaps analog [12,16]
Bosch Performance SX	eMTB	160–174	Narrow w/ narrow cranks [6,11]
DJI Avinox	eMTB	~172–178	ISIS spindle, narrow options [11,12]
Specialized 2.2 / 3.1	eMTB	~174–178	4 mm drive-side offset [11]
Shimano EP801	eMTB	177	Built narrow for a full-power motor [15]
Bosch CX Gen 4	eMTB	178–180	Prior full-power benchmark [11,14]
Bosch CX Gen 5	eMTB	180–188	Widest; larger motor shell [11,13]

Bracketed numbers are reference citations (Section 9). Q-factor depends on the fitted crankset; values are representative stock figures, not the only possible configuration for each system.

7. Practical Implications and Fitting Guidance

For the great majority of riders, the ~10–20 mm of Q-factor spread across these systems is not something the body will flag, and no intervention is warranted. The riders for whom it matters are identifiable: those with a history of medial knee pain, patellofemoral pain, knee osteoarthritis, prior knee surgery, or a clear sensation of over-wide stance. For them, the frontal-plane loading mechanism described in Section 3 is a reason to treat Q-factor as an active fit variable.[2][3]

Several levers exist, from least to most involved:

- Motor/bike selection: if a rider is stance-sensitive and wants an eMTB, steer toward narrower systems; the Maxon Air S (Dirtlab & Instinctiv) is the narrowest at 155 mm, with TQ HPR60, Fazua Ride 60, and Bosch SX also comparatively narrow, rather than the widest full-power units, or toward an analog build with a 168 mm crankset.
- Narrow aftermarket cranks: specialist manufacturers make reduced-Q-factor cranks for most motor systems (for example, ISIS-spindle narrow cranks for Bosch Gen 5, SX, and Avinox), and reduced-Q cranks for analog drivetrains, trimming several millimeters of stance per side. [11] [21]
- Pedal spindle length and cleat position: shorter pedal spindles and inboard cleat setup reduce effective stance width without changing the crankset; lateral cleat wedges can also address frontal-plane alignment.
- Professional bike fit: because optimal width is individual and interacts with alignment and foot mechanics, a fitter measuring the rider through the pedal stroke is the most reliable path, especially post-injury. [9] [10]

It is worth stating the counterpoint plainly: a wider stance is not inherently harmful, and some riders find it stable and comfortable. The evidence supports a targeted rather than universal concern, matching stance width to the individual, with extra attention to knees that are already load-sensitive. [3] [7]

8. Conclusions

Q-factor is a small dimension with a real biomechanical footprint. Controlled research shows that widening it increases frontal-plane knee loading and medial-compartment contact force [2] [3], even though its effect on efficiency appears minor [7] and its ideal value remains individual [9]. Among the systems examined, the specified eMTB motors range from about 170 mm to 188 mm, skewing wider than the 168–178 mm analog cluster defined by the SRAM and Shimano cranksets that Transition, Santa Cruz, Trek, Specialized, and Pivot fit to their bikes. Full-power Bosch units anchor the wide end; lightweight TQ, Fazua, and Bosch SX systems reach down into analog width; and maxon's Air S goes narrower still, starting at 155 mm on bikes like the Dirtlab Paratu, a reminder that motor design, not the motor itself, sets stance width.

For retailers, the key message is informed fitting rather than alarm. The difference is immaterial to most riders and easily managed for the minority it affects through motor choice, narrow cranks, pedal and cleat adjustments, or a professional fit. A shop that can explain why an eMTB may feel wider underfoot and offer concrete remedies when a customer's knees are sensitive turns an obscure spec into exactly the kind of expert, trust-building guidance a boutique brand is built on.

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Q-factor figures for motor systems are compiled from manufacturer technical pages, bike-fitting specialists, and aftermarket crank makers who publish the dimension explicitly, since drive-unit manufacturers seldom list it. Actual Q-factor on any bike depends on the specific crankset fitted and may differ from the representative values here. This paper is educational and not a substitute for professional medical or bike-fitting advice.