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PERSPECTIVE

Why now? A physiological perspective on the first official sub-2-hour marathon

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Abstract

The first official sub-2-hour marathon provides a unique real-world case for re-examining the determinants of elite marathon performance. This Perspective argues that the key scientific issue is not whether human physiology can theoretically support sub-2-hour running, but how physiological capacity can be preserved and expressed under late-race fatigue. Sabastian Sawe's 1:59:30 performance was marked by a 59:01 second half and, based on available split data, a 27:36 segment from 30 to 40 km, indicating late-race acceleration rather than simple pace maintenance. The wider front-group pattern, with Sawe, Kejelcha, and Kiplimo all completing the second half in approximately 60 min or faster, suggests that the barrier fell within a collective performance environment rather than through an isolated individual effort. The core interpretation is that the post-sub-2 era should be studied through fatigue resistance and race execution: the ability to preserve running economy, substrate availability, neuromuscular control, perceptual regulation, and tactical commitment after prolonged marathon-specific stress. High-rate carbohydrate delivery, gastrointestinal training, advanced footwear technology, buffering strategies, competitive proximity, and performance support systems are therefore interpreted not as separate explanations, but as interacting supports for late-race capacity expression. Advanced footwear likely contributed by reducing energetic cost and amplifying the expression of that capacity, although responses to such technology are variable and independent data on the exact shoe model remain limited. The first official sub-2-hour marathon should therefore be viewed neither as a purely physiological achievement nor as a technology-driven outcome, but as an extraordinary human performance expressed through an increasingly integrated athlete–technology–performance system.

Keywords Marathon · Sub-2-hour marathon · Pacing · Negative split · Fatigue resistance · Running economy · Carbohydrate intake · Gastrointestinal training · Advanced footwear technology · Performance ecosystem

Abbreviations

CHO Carbohydrate
RE Running economy
VO_{2max} Maximal oxygen uptake

Introduction: from prediction to race evidence

For decades, the sub-2-hour marathon represented one of the most compelling symbolic and physiological barriers in sport. To complete 42.195 km in under two hours, an athlete must sustain approximately 21.1 km·h^{-1}, or 2:50 min·km^{-1}, for the entire race. Classical models identified maximal oxygen uptake (VO_{2max}), fractional utilization of VO_{2max}, and running economy (RE) as the core determinants of marathon performance (di Prampero et al. 1986; Joyner 1991; Jones et al. 2021). Subsequent work has expanded this model to include fatigue resistance or durability (Maunder et al. 2021; Jones 2024), pacing regulation and perceptual decision-making (Tucker 2009; Renfree et al. 2014), carbohydrate (CHO) availability and race nutrition (Burke et al. 2011; Jeukendrup 2014), thermoregulation (Nybo et

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al. 2014; Périard et al. 2021), and advanced footwear technology (Hoogkamer et al. 2018; Kipp et al. 2019; Muniz-Pardos et al. 2021, 2025).

A recent integrative framework specifically addressed the determinants required for a record-eligible sub-2-hour marathon and proposed that such a performance would require the coordinated optimization of physiological, technological, nutritional, biomechanical, environmental, and cognitive factors (Grivas 2026). The present Perspective is not intended to re-review those determinants. Instead, it uses the first official sub-2-hour marathon as a post-event race case to examine how elite physiological capacity was preserved and expressed under late-race fatigue. Accordingly, rather than revisiting whether sub-2-hour performance is theoretically possible, this article asks what the race profile reveals about fatigue-resistant capacity expression after 30 km.

This distinction is important. A pre-event framework describes the determinants that may make a sub-2-hour marathon physiologically and technologically possible; a post-event analysis examines how those determinants were expressed under real competitive conditions. The key question is therefore no longer simply "Can humans break two hours?" but "Why did it happen now, and what does the race profile reveal about the mechanisms that allowed it to occur?"

The answer is unlikely to lie in a single factor. Human physiology did not suddenly change, nor did training principles transform overnight. However, the race profile suggests that the decisive issue was not simply the presence of exceptional physiological capacity, but the ability to preserve and express that capacity after more than 30 km of marathon-specific stress (Maunder et al. 2021; Jones 2024). Throughout this Perspective, collective pacing, high-rate fueling, gastrointestinal training, advanced footwear technology, and performance support systems are therefore not treated as independent explanations, but as potential supports for late-race capacity expression (Jeukendrup 2014; Costa et al. 2017; Hoogkamer et al. 2018; Grivas 2025; Grivas et al. 2026).

Sawe's race profile: late-race acceleration rather than survival

The most striking feature of Sawe's 1:59:30 performance was not only the final time, but the way the race unfolded. According to official and race-specific reports, he reached halfway in 60:29 and completed the second half in 59:01, producing a negative split of 1 min 28 s. Even more remarkable was the reported 27:36 segment between 30 and 40 km (Johnson and Gault 2026; World Athletics 2026). Race-specific reports further indicate that the decisive acceleration occurred after the final pacer stepped off shortly after 25 km. Sawe reportedly covered 30–35 km in 13:54 and 35–40 km in 13:42, before completing the final 2.2 km in approximately 5:51 (Chavez 2026; Johnson and Gault 2026). These segmental splits suggest progressive late-race acceleration rather than simple pace maintenance.

This is precisely the phase of the marathon where many runners begin to slow because of increasing metabolic strain, neuromuscular fatigue, rising perceived exertion, and reduced ability to maintain mechanical efficiency (Tucker 2009; Renfree et al. 2014; Smyth 2021). Thus, the key race signal was not simply that Sawe ran the second half faster than the first, but that he continued to increase speed during the phase of the race most commonly associated with performance deterioration.

This matters scientifically because the marathon is often decided not by the ability to produce high speed in a fresh state, but by the ability to preserve speed when fatigue begins to disrupt the relationship between physiological capacity and running velocity (March et al. 2011; Hanley 2015; Smyth 2021; Maunder et al. 2021; Jones 2024). In this sense, the first official sub-2-hour marathon appears to have been less about expanding the theoretical ceiling of human physiology and more about expressing elite physiological capacity under extreme fatigue. This race profile therefore provides the empirical anchor for the central argument of this Perspective: the decisive feature of the breakthrough was fatigue-resistant expression of capacity, not simply superior fresh-state physiological capacity.

From individual breakthrough to collective negative splitting

The significance of Sawe's pacing profile becomes clearer when the wider front group is considered. According to official race timing data, the leading men reached halfway together in 60:29. Kejelcha finished second in 1:59:41 in his marathon debut, while Kiplimo finished third in 2:00:28. Based on these split and finishing times, Kejelcha and Kiplimo completed the second half in approximately 59:12 and 59:59, respectively. Thus, together with Sawe's 59:01 second half, the race produced three sub-60-minute second halves among the top three finishers (TCS London Marathon 2026; World Athletics 2026) (Table 1).

This pattern suggests that the performance was not only an individual breakthrough, but also a front-group phenomenon. The presence of multiple athletes capable of sustaining historic pace may have helped normalize the risk of maintaining record-level speed deep into the race. From this perspective, the collective negative-split pattern can be interpreted as a real-world expression of pacing principles

Table 1 Comparative pacing and late-race profile of the leading men in the first official sub-2-hour marathon

Athlete	Final time (h:m:s)	First half (m:s)	Second half (m:s)	Half difference (m:s)	30 km split (h:m:s)	40 km split (h:m:s)	30–40 km (m:s)	40 km–finish (m:s)	Key interpretation
Sabastian Sawe	1:59:30	60:29	59:01	−1:28	1:26:03	1:53:39	27:36	5:51	Fastest final segment and strongest evidence of fatigue-resistant capacity expression
Yomif Kejelcha	1:59:41	60:29	59:12	−1:17	1:26:03	1:53:39	27:36	6:02	Sub-2 debut with exceptional late-race speed preservation and competitive proximity
Jacob Kiplimo	2:00:28	60:29	59:59	−0:30	1:26:05	1:54:00	27:55	6:28	Near-sub-2 performance showing front-group late-race speed preservation

Negative values for half difference indicate a negative split. Final time, 30 km split, and 40 km split are cumulative race times, whereas first half, second half, 30–40 km, and 40 km–finish are segment durations calculated from the available split and finishing times

h:m:s hours:minutes:seconds, *m:s* minutes:seconds

previously discussed in relation to endurance performance and marathon race execution (Grivas 2025; Grivas et al. 2026).

Such collective performance is important because endurance racing is not only an individual physiological test. It is also a dynamic competitive system in which pacing behavior emerges from the interaction between physiology, perception, decision-making, environmental constraints, and opponent behavior (Renfree et al. 2014; Renfree and Casado 2018; Konings and Hettinga 2018). In this context, the sub-2-hour barrier did not fall in isolation. It fell within a race environment in which several athletes were able to operate at or near the previous boundary of human marathon performance. Accordingly, the front-group pattern should be interpreted as part of the race context that supported late-race capacity expression, rather than as a separate explanation for the breakthrough.

Because this Perspective integrates official timing data, calculated race metrics, race-specific reports, and physiological interpretation, the level of evidential certainty differs across claims. Finishing times and available split data are treated as higher-confidence race evidence, whereas reported fueling strategy, bicarbonate use, shoe model, injury history, and training volume are interpreted cautiously as race-report evidence rather than independently verified physiological measurements.

Fatigue resistance as the decisive race trait

The race profile suggests that fatigue resistance is the central physiological lens through which the first official sub-2-hour marathon should be interpreted. The traditional determinants of marathon performance remain essential: such a performance requires exceptional aerobic capacity, outstanding RE, and the ability to sustain a very high fraction of VO_{2max} (Joyner 1991; Jones et al. 2021). However, determinants measured under rested or controlled conditions alone do not explain how record-level speed was preserved and expressed during the final phase of the race.

Fatigue resistance, or physiological durability, refers to the ability to preserve key performance characteristics despite prolonged exercise-induced stress (Maunder et al. 2021; Jones 2024). In the marathon, this means maintaining RE, neuromuscular coordination, substrate availability, thermoregulatory stability, perceived exertion control, and tactical decision-making after substantial metabolic, mechanical, and perceptual fatigue has already accumulated.

Sawe's late-race acceleration suggests that the key determinant was not merely the ability to run fast, but the ability to remain efficient and aggressive when the marathon usually begins to degrade performance. This is the critical distinction between capacity and expression of capacity. Laboratory measures help define what may be possible under controlled conditions; fatigue resistance determines how much of that capacity can still be expressed after 30 km. This also supports the argument that successful negative-split execution should be viewed as a marker of preserved physiological and perceptual control rather than merely a retrospective pacing label (Grivas 2025; Grivas et al. 2026).

Future models of elite marathon performance should therefore not only ask how high an athlete's VO_{2max} is, how economical the athlete is, or what percentage of VO_{2max} can be sustained in rested conditions. They should also ask how these variables change after prolonged running and whether the athlete can preserve speed when the cost of maintaining pace begins to rise. Thus, fatigue resistance is not presented here as one determinant among many, but as the organizing mechanism through which the race profile can be understood.

Fueling beyond previous models

Nutrition appears to have played a central role in race execution. Previous sub-2-hour discussions commonly emphasized CHO intake ranges of approximately 60–90 $g \cdot h^{-1}$, or up to about 100 g·h^{-1}, especially when multiple transportable CHO are used (Jeukendrup 2010, 2014; Burke et al. 2011; Thomas et al. 2016; Grivas 2026). Post-race reports citing Maurten's nutritional scientist Joshua Rowe indicated that Sawe followed a highly structured race-day fueling strategy and averaged approximately 115 g·h^{-1} of CHO from start to finish (Chavez 2026; Johnson and Gault 2026). This value should be interpreted cautiously because it derives from post-race reporting rather than peer-reviewed measurement. Nevertheless, if accurate, it suggests that elite marathon fueling may be moving toward individualized high-rate CHO delivery strategies that exceed traditional intake models and require extensive gastrointestinal preparation.

The reported strategy also suggests that fueling was not merely improvised on race day. Race-specific reports indicated that the nutrition team worked with Sawe's group in Kenya across multiple visits and repeatedly rehearsed the race-day protocol in training to improve gastrointestinal tolerance and CHO delivery (Chavez 2026). This is consistent with evidence that high-rate CHO intake requires gastrointestinal tolerance, repeated practice, product familiarity, and precise timing. Gastrointestinal training may allow athletes to tolerate and absorb large amounts of CHO with reduced gastrointestinal distress, supporting high rates of exogenous CHO oxidation during prolonged exercise (Costa et al. 2017; Miall et al. 2018).

The relationship between high-rate fueling and late-race acceleration is especially relevant. A 27:36 segment from 30 to 40 km requires not only mechanical efficiency and aerobic power, but also sufficient CHO availability at the point where glycogen depletion and metabolic fatigue would normally threaten pace maintenance. Thus, if the reported intake is accurate, high-rate CHO delivery may have helped preserve metabolic control and enabled the athlete to express speed late in the race.

In this interpretation, high-rate CHO delivery is not presented as an independent explanation for the sub-2-hour performance. Rather, it represents a potential metabolic support for preserving substrate availability, maintaining physiological control, and expressing speed during the late-race fatigue phase. The conceptual shift is therefore from "fueling to avoid collapse" toward "fueling to support late-race capacity expression."

Buffering as an adjunct, not an explanation

Race-specific reports also indicated the use of sodium bicarbonate before the race. Its contribution cannot be isolated from the broader performance system, particularly in a primarily aerobic event such as the marathon. Nevertheless, bicarbonate may have acted as an adjunct by supporting tolerance to transient increases in glycolytic contribution during surges or late-race accelerations (Peart et al. 2012; Hadzic et al. 2019; Grgic et al. 2021). It should therefore be interpreted as a marginal support for late-race capacity expression, not as an independent explanation for the sub-2-hour performance.

Footwear, technology, and the meaning of the barrier

The first official sub-2-hour marathon has intensified the debate about whether the performance should be interpreted primarily as a human physiological achievement or as the outcome of a technology-mediated performance system (Muniz-Pardos et al. 2021, 2024). This is not a trivial question. It is unlikely that the basic physiological determinants of elite marathon performance changed fundamentally within a decade. However, the technological environment of elite marathon running has changed substantially, particularly through advanced footwear technology, which can reduce the energetic cost of running and influence marathon performance trajectories (Hoogkamer et al. 2018; Kipp et al. 2019; Muniz-Pardos et al. 2021).

Technological and scientific advances have always been embedded in sport, including running surfaces, footwear, nutrition science, recovery methods, timing systems, and race logistics. Therefore, the issue is not whether technology belongs in elite marathon running; it clearly does. The more important question is whether the scale, accessibility, inter-individual variability, and cumulative impact of modern technologies are beginning to alter how record progression and human limits should be interpreted (Muniz-Pardos et al. 2021, 2024). Recognizing the role of technology should not diminish the athlete's achievement: no shoe can replace years of training, resilience, pain tolerance, tactical intelligence, psychological strength, and race execution. At the same time, the athlete's achievement should not prevent critical examination of how technological assistance shapes performance.

Modern racing shoes that combine compliant and resilient foams, curved plates or rods, low mass, and optimized geometry can reduce the energetic cost of running (Hoogkamer et al. 2018; Kipp et al. 2019). Evidence also suggests that recent improvements in marathon times are likely strongly influenced by technology rather than by sudden changes in human physiology (Muniz-Pardos et al. 2021). Importantly, responses to advanced footwear technology vary substantially between athletes, meaning that shoes may not only improve performance on average but may also influence competitive outcomes differently across individuals (Knopp et al. 2023).

Race-specific reports indicated that several leading men wore the Adidas Adizero Adios Pro Evo 3, a model reported to weigh approximately 97 g in a men's size 9, with a 39-mm stack height and substantially reduced mass compared with its predecessor (Chavez 2026; Johnson and Gault 2026). Because these model-specific details derive from race-specific and manufacturer-related reporting rather than independent laboratory testing, they should be interpreted cautiously. These characteristics are relevant because shoe mass, foam properties, longitudinal bending stiffness, and geometry can influence running economy and mechanical energy return. However, independent peer-reviewed metabolic data on this exact model are currently limited. Therefore, its precise contribution to Sawe's performance relative to previous footwear remains uncertain.

The relevant question is not whether the athlete or the shoe broke the two-hour barrier. The more scientifically useful question is whether advanced footwear helped reduce the energetic and mechanical cost of sustaining speed during the late-race fatigue phase. In this sense, footwear should be interpreted as a potential amplifier of capacity expression under fatigue, not as a stand-alone explanation for the sub-2-hour marathon (Muniz-Pardos et al. 2024).

The performance ecosystem

The performance ecosystem should be understood as the context through which physiological capacity is converted into race execution. In elite marathon running, this context includes altitude exposure, training continuity, group-based pacing demands, individualized fueling rehearsal, footwear access, recovery support, favorable environmental conditions, and race-specific preparation (Saunders et al. 2004; Jones et al. 2021; Périard et al. 2021; Grivas 2026).

Race-specific reports suggest that Sawe's preparation was not perfectly linear, with injury-related disruption during December and January before a return to full training in February and a reported peak of approximately 240 km (150 miles) in a single week (Chavez 2026). These details should be interpreted cautiously because they derive from post-race reporting rather than independently verified training data. Their relevance is not that they independently explain the sub-2-hour performance, but that they illustrate how support systems may help convert elite physiological potential into race execution (Jones et al. 2021; Grivas 2026).

Altitude exposure, group training, recovery support, rehearsed fueling, footwear access, and favorable environmental conditions should therefore be viewed as components of the same coordinated performance environment rather than isolated determinants (Saunders et al. 2004; Renfree and Casado 2018; Mujika et al. 2019; Périard et al. 2021; Grivas 2026). This does not reduce individual achievement. Rather, it clarifies how exceptional individual physiology can remain available and be expressed when the marathon reaches its most demanding phase. In this framing, the performance ecosystem is best interpreted as a background condition supporting late-race capacity expression, not as a separate explanation for the breakthrough.

Psychological proximity and the collapse of the symbolic barrier

The sub-2-hour marathon was not only a physiological barrier; it was also a symbolic barrier. Once such a barrier is broken under official race conditions, its psychological meaning changes. This does not imply that belief alone produces performance. However, belief may influence how athletes interpret possibility, tolerate discomfort, and commit to extreme pace when racing near historical limits.

Bandura's self-efficacy theory suggests that confidence is strengthened by mastery experiences and by observing similar others achieve difficult goals (Bandura 1977). In elite marathon running, this effect is likely strongest among athletes already close to the barrier. Kejelcha's reported 1:59:41 in the same race is therefore relevant because the barrier did not fall with one athlete far ahead of the field; it fell with another athlete only seconds behind. This may reduce the psychological distance between the elite field and the sub-2 standard.

For future contenders, the first official sub-2-hour marathon may shift the question from "Is this possible?" to "Can I be the next athlete to do it?" Such psychological proximity may influence pacing commitment, willingness to remain attached to aggressive race speeds, and tolerance of discomfort during decisive late-race phases (Stone et al. 2012; Renfree et al. 2014). Again, this is not blind belief. It is evidence-based confidence emerging from proximity, preparation, and direct competitive comparison. Psychological proximity is therefore interpreted here as a possible contributor to pacing commitment and risk tolerance under fatigue, not as an independent cause of the performance.

Why now? An integrated explanation

The answer to "why now?" is not that one determinant changed abruptly, but that several supports may have enabled the same central outcome: the preservation and expression of capacity after 30 km. Physiology remained the foundation, but the decisive issue was not fresh-state capacity alone. The race profile suggests that the winner and the front group were able to maintain and increase speed during

Table 2 Interacting supports for late-race capacity expression in the first official sub-2-hour marathon

Factor	Role in the breakthrough	Key interpretation
Exceptional physiology	Provides the aerobic and metabolic foundation	Necessary but not sufficient
Fatigue resistance	Preserves speed, economy, and regulation after 30 km	Central race trait
Collective pacing	Sustains historic pace within the front group	Creates shared performance environment
High-rate fueling	Supports carbohydrate availability late in the race	From anti-collapse fueling to acceleration support
Gastrointestinal training	Enables tolerance of high carbohydrate intake	Nutrition becomes trainable
Sodium bicarbonate	May support tolerance of surges	Adjunct, not explanation
Advanced footwear	Reduces energetic cost and modifies mechanics	Performance amplifier
Favorable environmental conditions	May reduce thermoregulatory strain during late-race running	Contextual support for capacity expression
Performance ecosystem	Integrates altitude, group training, recovery, and expertise	Converts potential into race execution
Psychological proximity	Makes the barrier more attainable for similar athletes	Evidence-based confidence

the phase in which marathon performance usually deteriorates (Smyth 2021; Maunder et al. 2021; Jones 2024).

High-rate CHO delivery may have supported substrate availability, gastrointestinal training may have allowed this strategy to be tolerated, advanced footwear may have reduced energetic and mechanical cost, and favorable environmental conditions may have reduced thermoregulatory strain (Jeukendrup 2014; Costa et al. 2017; Renfree and Casado 2018; Hoogkamer et al. 2018; Périard et al. 2021; Knopp et al. 2023; Grivas 2026; Johnson and Gault 2026). In parallel, the competitive front-group context may have supported pacing commitment and risk tolerance (Renfree and Casado 2018). These factors should therefore be interpreted as interacting supports for late-race capacity expression rather than as independent explanations. Thus, the first official sub-2-hour marathon may be best interpreted as a case of fatigue-resistant capacity expression within an optimized athlete–technology–performance system (Table 2).

Research agenda and testable hypotheses

This Perspective generates five testable hypotheses for future research.

1. Durability hypothesis. Late-marathon performance may be better predicted by the deterioration in RE, oxygen cost, biomechanics, perceived exertion, substrate use, and neuromuscular control after 25–30 km than by fresh-state RE or VO_{2max} alone.
2. Fueling hypothesis. Individualized CHO intakes exceeding 100 $g \cdot h^{-1}$ may improve late-race speed preservation only in athletes with trained gastrointestinal tolerance. Future studies should compare standard CHO intake with individualized high-rate CHO strategies under race-relevant conditions, while assessing gastrointestinal symptoms, exogenous CHO oxidation, perceived exertion, and segment-specific speed preservation.
3. Footwear-under-fatigue hypothesis. Shoe-related metabolic savings may differ between fresh and fatigued states. Therefore, advanced footwear should be tested at elite-relevant speeds after prolonged marathon-specific running, not only under fresh laboratory conditions. These studies should evaluate not only RE, but also stability, neuromuscular fatigue, comfort, and late-race biomechanics.
4. Collective-pacing hypothesis. Front-group density, drafting context, time gaps, and opponent proximity may reduce pacing variability and support late-race acceleration in major marathons. Future race analyses should therefore quantify not only individual split patterns, but also the competitive configuration in which those splits occur.
5. Psychological-proximity hypothesis. Once a symbolic barrier is broken under official race conditions, elite athletes' willingness to tolerate risk and discomfort at record-level pace may increase, particularly when the model athlete is perceived as competitively proximal.

Testing these hypotheses will require integration of laboratory physiology, race split analysis, wearable data, fueling records, footwear testing, environmental and thermoregulatory measures, biomechanics, and psychological measures in race-relevant contexts.

Conclusion

The first official sub-2-hour marathon should not be interpreted as a sudden expansion of human physiological limits, nor as a purely technology-driven outcome. Its race profile suggests that the decisive feature was fatigue resistance: the preservation and expression of physiological capacity after more than 30 km of marathon-specific stress. The collective front-group pattern reinforces this interpretation, indicating that the barrier fell within a race environment that supported late-race speed preservation rather than through isolated individual survival at record pace. The post-sub-2 era should therefore be studied through fatigue resistance, race execution, and integrated athlete–technology–performance systems, rather than through fresh-state physiological ceilings alone. The central question is no longer simply whether humans can break two hours, but how physiological capacity can be preserved, supported, and expressed under the extreme fatigue of elite marathon racing.

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