Impact of Carbon-Plated Shoes, Data Analytics, Artificial Intelligence, and Sports Nutrition on Elite Marathon Running Performance

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ABSTRACT

On 26 April 2026, the sporting world witnessed an unprecedented milestone at the TCS London Marathon when Kenyan athlete Sabastian Sawe became the first person in history to officially complete a marathon under two hours, recording a time of 1:59:30. Simultaneously, Ethiopian athlete Tigst Assefa set a new women-only marathon world record with a time of 2:15:41. These performances represent the convergence of elite human physiology with a multi-dimensional technological ecosystem. The purpose of this paper is to examine the contribution of four key technological pillars — carbon-plated racing footwear, data analytics, artificial intelligence (AI)-driven training systems, and advanced sports nutrition protocols — to elite marathon performance. The study draws on peer-reviewed literature, biomechanical evidence, and race-day performance data from the 2026 TCS London Marathon. Results indicate that carbon-plated shoes improve running economy by approximately 3.6–4.2%; data analytics enables precision training and pacing; AI systems predict and prevent injury while optimising preparation; and advanced carbohydrate fuelling strategies support sustained high-intensity output. This paper concludes that modern marathon records reflect a sophisticated partnership between athlete discipline and scientific innovation. Implications for sports governance, fair competition, and the future trajectory of endurance performance are discussed.

Keywords: artificial intelligence; biomechanics; carbon-plate shoes; data analytics; elite marathon; running economy; sports nutrition; sub-2-hour marathon

Introduction

The marathon — a gruelling 42.195-kilometre test of endurance — has long served as a benchmark for the limits of human athletic potential. For decades, the sub-2-hour barrier was considered by physiologists and coaches alike as a near-impossible frontier, analogous to the four-minute mile before Roger Bannister broke it in 1954. Yet on 26 April 2026, that barrier was broken on a world stage: Sabastian Sawe (Kenya) crossed the finish line of the TCS London Marathon in 1:59:30 — a time that redefined what the human body can achieve.

Importantly, Sawe's achievement was not an isolated act of extraordinary athleticism. The second-place finisher, Yomif Kejelcha (Ethiopia), recorded 1:59:41, and Uganda's Jacob Kiplimo completed the podium in 2:00:28, meaning all three top male finishers eclipsed the previous marathon world record. In the women's race, three athletes finished under 2:16:00 for the first time in a single marathon, led by Tigst Assefa's women-only world record of 2:15:41. These collective performances suggest a systemic uplift in elite marathon capability rather than an isolated outlier event.

Researchers, coaches, and sports scientists increasingly recognise that performance improvements at the elite level are driven by a constellation of technological and scientific factors. This paper investigates four such factors in depth: (1) carbon-plated racing footwear and its biomechanical effect on running economy; (2) data analytics systems applied in training and race-day decision making; (3) artificial intelligence (AI) applications in performance optimisation; and (4) evidence-based sports nutrition strategies. By synthesising published research and contextualising findings within the 2026 London Marathon results, this article provides a comprehensive account of how technology and science are reshaping the upper limits of elite marathon performance.

The aim of this study is to analyse the extent to which each of these technological pillars contributes to elite marathon performance, with particular reference to the historic sub-2-hour achievement at London 2026. The objectives are: (i) to review available biomechanical and physiological literature on carbon-plated footwear; (ii) to examine the role of data analytics and AI in training optimisation; and (iii) to evaluate current sports nutrition protocols employed by elite marathon runners.

Materials and Methods

This study employs a systematic narrative review methodology. Published peer-reviewed articles, race performance databases, and sports science reports relevant to marathon running, footwear technology, data analytics, artificial intelligence in sport, and endurance nutrition were identified and reviewed. Literature was sourced from databases including PubMed, Google Scholar, SPORTDiscus, and Web of Science, using the following search terms: 'carbon-plate running shoes', 'running economy', 'marathon performance', 'AI in sport', 'data analytics endurance', 'sports nutrition marathon', and 'sub-2-hour marathon'.

Inclusion criteria required that articles: (a) were published in English in peer-reviewed journals between 2015 and 2026; (b) addressed one or more of the four technological pillars under investigation; and (c) involved data from trained or elite-level athletes. Grey literature, including published race results from the 2026 TCS London Marathon (official results, World Athletics database) and manufacturer technical data, was also consulted where peer-reviewed evidence was limited.

Race performance data from the 2026 TCS London Marathon were obtained from official World Athletics published results. Biomechanical improvement estimates were drawn from controlled experimental studies (Hoogkamer et al., 2019; Joubert & Jones, 2022). Nutritional guidelines were assessed against current position statements from the International Society of Sports Nutrition (ISSN) and the American College of Sports Medicine (ACSM). Statistical procedures were not applied as this is a narrative review; however, quantitative data reported in cited studies are presented as originally published.

Results and discussion

1. Race Performance Data — 2026 TCS London Marathon

The 2026 TCS London Marathon produced historically significant results across both elite fields. Tables 1 and 2 present the podium performances.

Table 1: *Men's Elite Podium — 2026 TCS London Marathon*

Rank	Athlete	Country	Time
1st	Sabastian Sawe	Kenya	1:59:30 (WR)
2nd	Yomif Kejelcha	Ethiopia	1:59:41
3rd	Jacob Kiplimo	Uganda	2:00:28

Table 2 : *Women's Elite Podium — 2026 TCS London Marathon*

Rank	Athlete	Country	Time
1st	Tigst Assefa	Ethiopia	2:15:41 (Women-only WR)
2nd	Hellen Obiri	Kenya	2:15:53
3rd	Joyciline Jepkosgei	Kenya	2:15:55

A notable finding is that all three men's podium finishers bettered the previous marathon world record — an outcome of extreme statistical rarity under conventional conditions — suggesting that a systemic technological uplift influenced the entire elite field, not only the race winner.

2. Carbon-Plated Racing Footwear

2.1 Technological Composition

Modern carbon-plated racing shoes — commonly termed 'super shoes' in the sports science literature — integrate three core components: a rigid carbon-fibre plate embedded within the midsole; a high-resilience, energy-returning foam (typically PEBA-based); and an ultra-lightweight upper. Together, these elements create a mechanical energy-return system that reduces the metabolic cost of forward propulsion.

2.2 Biomechanical Effects and Running Economy

Running economy — the oxygen cost of running at a given velocity — is one of the three primary determinants of marathon performance alongside VO2 max and lactate threshold. Hoogkamer et al. (2019) demonstrated that advanced carbon-plated footwear improves running economy by approximately 3.6–4.2% relative to conventional racing flats. This improvement is attributed to: (i) reduced ankle plantar flexor muscle fascicle strain; (ii) decreased metatarsophalangeal joint work; and (iii) shorter ground contact time. For a marathon runner operating at sub-3:00 min/km pace, a 4% improvement in running economy equates to a theoretical time saving of approximately 4–5 minutes over the full 42.195 km distance.

Athletes competing at the 2026 London Marathon, including Sawe and Kejelcha, used the latest generation of manufacturer-specific super shoe platforms incorporating third-generation carbon composites and updated foam formulations. These developments represent a continuum of innovation that has progressively widened the performance advantage of engineered footwear over traditional racing shoes.

2.3 Governance and Ethical Considerations

World Athletics has established regulatory frameworks specifying maximum midsole stack heights (40 mm for road events) and requiring that approved footwear be commercially available to all athletes. Despite these provisions, questions persist regarding cost equity and the comparability of performances achieved under different footwear eras. This remains an active area of sports governance debate.

3. *Data Analytics in Elite Marathon Training*

3.1 Data-Driven Coaching Systems

The integration of data analytics has fundamentally transformed elite marathon preparation. Modern training programmes deploy continuous monitoring via GPS tracking units, wearable heart rate variability (HRV) monitors, portable lactate analysers, and inertial measurement units (IMUs). These systems collectively enable precise, real-time quantification of physiological and biomechanical parameters that previously required laboratory conditions.

3.2 Key Performance Metrics

Parameters routinely monitored and analysed in elite marathon preparation include:

- Running cadence and ground contact time
- Vertical oscillation and its relationship to running efficiency
- Lactate threshold velocity and fractional VO2 max utilisation
- Heart rate variability as an index of autonomic recovery status
- Sleep quality metrics — given the established negative relationship between sleep deprivation and endurance performance
- Individualised sweat rate and electrolyte concentration data for hydration strategy personalisation

Aggregating these data streams allows coaching teams to construct highly individualised training prescriptions that optimise physiological adaptation while managing injury risk. Predictive algorithms trained on longitudinal athlete data can identify early markers of overtraining syndrome before clinical symptoms emerge, enabling timely interventions (Claudino et al., 2019).

3.3 Race-Day Pacing Optimisation

Data analytics plays a central role in pre-race strategy. Computational modelling of athlete-specific physiological profiles, combined with splits analysis from prior elite performances, enables identification of optimal marathon pacing distributions. Research indicates that the theoretically optimal marathon pacing profile follows a slight positive-split pattern to account for progressive glycogen depletion and thermoregulatory fatigue (Smyth, 2021). Sawe's sub-2-hour run reportedly followed a pacing strategy derived from this type of pre-race modelling.

4. *Artificial Intelligence in Performance Optimisation*

4.1 Machine Learning Applications

Machine learning algorithms can identify non-linear patterns within large, multi-dimensional training datasets that exceed human analytical capacity. In elite marathon training, AI applications span training load optimisation, injury prediction, performance forecasting, and real-time race analytics.

4.2 Injury Prediction and Prevention

Claudino et al. (2019) demonstrated that AI-based injury prediction models, trained on longitudinal datasets incorporating training load and biomechanical variables, can identify elevated injury risk profiles 7–14 days before clinical symptoms present. For elite marathon runners — whose preparation windows span months — the prevention of even a single training interruption can have significant competitive consequences.

4.3 Video-Based Gait Analysis

Computer vision algorithms now enable automated, high-throughput quantification of running kinematics from video footage. Deep learning models can measure foot strike angle, hip drop, arm swing symmetry, and trunk lean with accuracy approaching laboratory-grade motion capture systems. This technology makes biomechanical assessment accessible within training environments rather than requiring dedicated laboratory sessions.

4.4 Environmental Adaptation Planning

By integrating historical weather data, course topography, and individual athlete thermoregulatory response profiles, AI-driven predictive models generate race-specific heat adaptation training protocols and hydration strategies tailored to each athlete's unique physiological signature.

5. *Advanced Sports Nutrition Strategies*

5.1 Carbohydrate Loading and Race-Day Fuelling

Contemporary elite marathon runners employ multi-phase nutritional strategies encompassing structured carbohydrate loading protocols prior to competition, followed by race-day fuelling regimens enabling carbohydrate ingestion rates of 90–120 g/hour. This was impossible two decades ago due to gastrointestinal distress limits of approximately 60 g/hour for glucose alone.

The development of multiple-transportable carbohydrate (MTC) formulations combining glucose and fructose (typically at a 2:1 ratio) exploits distinct intestinal transport pathways to increase total absorptive capacity beyond the glucose ceiling (Jeukendrup, 2017). Gel products used by athletes at the 2026 London Marathon incorporated MTC technology alongside electrolyte complexes designed to maintain plasma osmolality and sustain neuromuscular function across the entire race distance.

5.2 Electrolyte Management and Hydration

Individually prescribed hydration strategies, derived from pre-competition sweat sodium testing and sweat rate measurements under race-pace conditions, are standard practice in elite marathon programmes. Personalised electrolyte supplementation formulations ensure sodium losses are replaced at individually tailored rates, preventing both hyponatraemia and performance-limiting dehydration.

5.3 Recovery Nutrition

Post-exercise nutrition protocols emphasising rapid carbohydrate-protein co-ingestion within the post-exercise anabolic window are employed to accelerate glycogen resynthesis and stimulate muscle protein synthesis. Emerging evidence for polyphenolic compounds, dietary nitrates (found in beetroot-based supplements), and sodium bicarbonate pre-loading continues to generate practical applications progressively incorporated into elite athlete nutrition plans (Jones et al., 2018).

6. Synthesis and Discussion

The central finding of this review is that the sub-2-hour marathon at the 2026 London Marathon cannot be explained by any single technological factor in isolation. Rather, the achievement reflects the cumulative and synergistic effect of multiple technological systems operating in concert with exceptional athlete physiology. Carbon-plated footwear provides approximately 4% improvement in running economy; advanced nutrition protocols enable sustained high-intensity fuelling; data analytics optimises training load; and AI systems continuously refine preparation. The combined effect of these technologies, layered upon world-class athletic talent and high-altitude training, created conditions in which the two-hour barrier became achievable.

The collective improvement in performances across the entire men's podium — all three runners exceeding the previous world record — supports the interpretation that the technological ecosystem elevated performance across the elite field, not merely for the race winner. This has important implications for sports governance: if the technological environment systematically raises the performance ceiling, then future records may increasingly reflect the sophistication of the supporting scientific system rather than athlete physiological capacity alone.

From an ethical standpoint, this paper acknowledges that technology has always been a component of athletic progress. However, equitable access to cutting-edge footwear, analytics infrastructure, and nutrition science remains unevenly distributed across nations and economic contexts. Governing bodies must continue to monitor and regulate these disparities to preserve competitive equity at all levels of the sport.

Conclusion

The historic sub-2-hour marathon at the 2026 TCS London Marathon marks a defining moment in the evolution of human athletic performance — not because it demonstrates what a single extraordinary individual can achieve, but because it illustrates what becomes possible when elite human physiology is augmented by a comprehensive scientific and technological ecosystem.

This paper has examined the contributions of four principal technological pillars to this achievement. Carbon-plated footwear has demonstrably improved running economy through engineered energy-return mechanisms. Data analytics has transformed training from an observational art to a precision science. Artificial intelligence has expanded the capacity of coaching teams to predict, prevent, and manage performance-limiting factors. Advanced sports nutrition has enabled fuelling strategies previously incompatible with adequate energy delivery during high-intensity prolonged exercise.

Together, these technologies represent a new paradigm for elite endurance sport — one in which the boundaries of performance are defined not by biology alone, but by the sophistication of the scientific systems that support athletic preparation and competition. Future research should investigate the isolatable contribution of each technological pillar using controlled experimental designs, and examine whether technological access disparities are creating new inequities within elite competition.

The question is no longer whether a sub-2-hour marathon was possible. The question now is how far below two hours the next generation of athletes — equipped with yet more refined tools — will ultimately reach.

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