TACTICAL MODELS OF WINNING PERFORMANCE IN ROWING, CANOE SPRINT, AND SHORT TRACK SPEED SKATING AT THE OLYMPICS

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ABSTRACT
The study aimed to identify the tactical models used by Olympic champions in rowing, canoe sprint, and short-track speed skating, and to determine which characteristics of race times, tactical positioning, and pacing behavior defined their winning performances. This retrospective, descriptive study analyzed the performances of 12 Olympic champions from the 2014-2024 Games across three men's individual events: single sculls (2000 m), kayak single (1000 m), and 1000 m in short track. A total of 31 performances were examined. The variables included race times, split times, starting positions, intermediate positions, and final rankings. Descriptive statistics, frequency analysis, and Repeated Measures ANOVA were applied to evaluate performance dynamics. Mauchly's test, Greenhouse-Geisser correction, and Wilks' Lambda were used to test sphericity and within-subject effects. Analyses were performed using the statistical program SPSS. The results showed low variability in race times across all disciplines, confirming the high stability of Olympic-level performance. In rowing, champions adopted a front-leading strategy with consistent control throughout the race. In canoe sprint, a positive pacing pattern was found, characterized by a fast start and gradual deceleration. In short track, pacing was non-linear, with sharp acceleration between the first and third laps and the fastest mean time recorded in Lap 7. Despite different energy demands and competition environments, all champions demonstrated optimized effort distribution and stable performance. The findings highlight the role of tactical control and pacing strategies in achieving Olympic success, providing practical implications for race modeling and training optimization.

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INTRODUCTION

Tactical preparation in modern sports plays a decisive role in achieving high results, as sporting success depends not only on the athletes' physical and technical skills, but also on their ability to make quick and effective decisions in a dynamic competitive environment (Lobanov & Sirakovskaya, 2019; Chai et al., 2010). The importance of tactics varies across different sports and disciplines. Its specific characteristics are determined by the nature of the interactions between competitors, as well as the characteristics and intensity of the competitive exercise. Tactics are directly linked to competitive activity. In most cyclic sports, such as rowing, canoe sprint, and short track speed skating, tactical execution primarily involves the rational distribution of effort throughout the race distance and the adaptation to temporary situational factors (Mihaylov & Andonov, 2016; Zhelyazkov & Dasheva, 2011, 2017; Zhelyazkov et al., 2020). In their pursuit of optimal performance, athletes constantly decide when and how to allocate their energy resources – a determining factor for success in both time-trial events (Foster et al., 2003) and "head-to-head" formats (Edwards, Polman, 2013; Edwards et al., 2016; Hettinga et al., 2017; Konings, Hettinga, 2018a).

In the scientific literature, pacing, or the purposeful regulation of effort intensity (Abbiss & Laursen, 2008), is viewed as a behavioral expression of the continuous decision-making process, which depends on the athletes' perception of action opportunities within the competitive environment (Renfree et al., 2014). During the race, athletes continuously choose among multiple action options (Withagen et al., 2012) – whether to maintain the current pace, slow down, or accelerate. Competitors decide "*what to do*" (action selection) and "*how to do it*" (action specification) (Cisek & Kalaska, 2010), constantly evaluating the potential benefits and drawbacks of each alternative (Konings et al., 2016a; Renfree et al., 2014).

One of the modern approaches to improving competitive efficiency is the development of effective performance models, based on the specific characteristics of the respective sport and the generalization of knowledge about the competitive activity of elite athletes (Holodova, 2013). A number of authors have examined the characteristics of competitive performance in rowing (Chu et al., 2025; Garland, 2005; Martins et al., 2022; Muehlbauer, Melges, 2011), canoe sprint (Goreham et al., 2021; Estreich et al., 2025; Borges et al., 2013), and short track speed skating (Konings et al., 2016b; Menting et al., 2019; Noorbergen et al., 2016). However, existing research has not yet focused on the tactical models that have led Olympic champions to win. The study of these models may contribute to a deeper understanding of the strategies through which elite athletes achieve optimal pacing and tactical positioning across different competitive environments.

The aim of the study was to identify the tactical models used by Olympic champions in rowing, canoe sprint, and short-track speed skating, and to answer the question of which characteristics of race times, tactical positioning, and pacing behavior determined their winning performance.

METHODOLOGY

Sample

This retrospective, descriptive study examined the performance of 12 Olympic champions from the Games in Sochi 2014, Rio de Janeiro 2016, PyeongChang 2018, Tokyo 2020, Beijing 2022, and Paris 2024 in the following men's individual events: 2000 m single sculls (M1x) in rowing, 1000 m single kayak (K1 men) in canoe sprint, and 1000 m in short track speed skating. A total of 31 races were included (12 in rowing, 9 in canoe sprint, and 10 in short track), from all qualifying rounds – heats, quarterfinals, semifinals, and final A. The results of competitors in short track who fell or were classified by referee decision were excluded from the analysis. Informed consent from the competitors was not required, as all data were publicly available on the official websites of World Rowing (https://worldrowing.com), the International Canoe Federation (ICF, https://www.canoeicf.com), and the International Skating Union (ISU, https://www.isu.org).

Variables

The following variables were analyzed:

- ✓ final race times on the distances for each round
- ✓ tactical positioning, including starting position, intermediate positions along the distance, and final ranking at the race
- ✓ split times recorded as follows: in rowing – at every 500 m (4 segments), in canoe sprint – at every 250 m (4 segments), in short track – at each lap on the distance (9 laps).

Procedures

All data were systematized into a database for statistical analysis. For each race, the variables were structured and coded. Starting positions were coded from 1 (inner) to the outer lane. Intermediate positions and final rankings were coded from 1 (leading competitor) to the last place in the heat (usually 6 rowers, 8 kayakers, and 4-5 skaters participate).

Statistical analyses

For the purposes of the study, various statistical methods were employed to evaluate race times, tactical positioning, and pacing behavior over the different distances. Final race times were analyzed using descriptive statistics, including minimum and maximum values, mean (*M*), standard deviation (*SD*), standard error of mean (SE), coefficient of variation (V%), skewness, and kurtosis. Tactical positioning was evaluated through frequency analysis of the positions occupied in each race segment/lap. Pacing behavior was analyzed using Repeated Measures ANOVA, with race segment/lap as the within-subject factor and split times as the dependent variable. The assumption of sphericity was tested with Mauchly's test. When violations were detected, two complementary approaches were applied: (1) a multivariate test (*Wilks' Lambda*), which does not rely on sphericity and assesses the overall segment effect, and (2) an univariate ANOVA with Greenhouse-Geisser correction for detailed analysis. Effect sizes were estimated using partial eta squared (η^2), and *Bonferroni*-adjusted post-hoc tests were performed to determine significant pairwise differences between segments/laps. All analyses were conducted using the statistical program SPSS at a significance level of $p < .005$. Results are presented in tables and figures illustrating the tactical winning models applied by Olympic champions in the sports under consideration.

RESULTS

Time analysis

The variation analysis of the race times of Olympic champions shows clearly defined performance ranges and low variability within each examined sport (Table 1).

The mean race times ranged from 85.09 s in the short track to 410.31 s in rowing, reflecting the specific characteristics of the distances in the respective sports. The time range (R) was largest in rowing (37.00 s), moderate in canoe sprint (18,44 s), and minimal in short track (3.00 s). The coefficient of variation (V) was between 1.29% and 3.17%, indicating relative stability of the results, with the most consistent in the short track. The Skewness values were close to zero, showing that the distribution of times was nearly symmetrical, with a slight elongation toward slower results in rowing and toward faster results in canoe sprint. The negative Kurtosis values indicated a more even and "flatter" distribution of times, meaning that the results were more evenly spread around the mean value.

Table 1. *Descriptive statistics and variation analysis of the race times of Olympic champions in rowing, canoe sprint, and short track*

Race time	*n*	*R* (s)	x_{min} (s)	x_{max} (s)	*M* (s)	SE *M* (s)	*SD* (s)	V (%)	As	Ex
Rowing M1x 2000 m	12	37.00	395.77	432.77	410,31	3.54	12.26	2.99	0.578	-1.052
Canoe sprint MK1 1000 m	9	18.44	200.64	219.08	211.58	2.32	6.95	3.17	-0.468	-1.378
Short Track Men 1000 m	10	3.00	83.77	86.77	85.09	0.35	1.10	1.29	0.325	-1.428

Tactical positioning

The frequency analysis of the tactical positioning of Olympic champions revealed the dynamics of their tactical behaviour during the race (Table 2).

Table 2. *Tactical positioning of Olympic champions during the race (%)*

Rowing M1x 2000 m		Start position	0-500 m	500-1000 m	1000-1500 m	1500-2000 m
Position	1		66.7%	83.3%	91.7%	91.7%
	2	16.7%	16.7%	8.3%	8.3%	8.3%
	3	25%	8.3%	8.3%		
	4	58.3%	8.3%			
	5					
	6					
Total 12		100%	100%	100%	100%	100%

Canoe Sprint MK1 1000 m		Start position	0-250 m	250-500 m	500-750 m	750-1000 m
Position	1		11.1%	33.3%	44.4%	55.6%
	2	22.2%	55.6%	33.3%	22.2%	11.1%
	3	22.2%	11.1%		11.1%	33.3%
	4					
	5	44.4%	11.1%	22.2%	11.1%	
	6		11.1%	11.1%		
	7	11.1%			11.1%	
	8					
Total 9		100%	100%	100%	100%	100%

Short track 1000 m men		Start pos.	Lap 1	Lap 2	Lap 3	Lap 4	Lap 5	Lap 6	Lap 7	Lap 8	Lap 9
Position	1	40%	70%	50%	70%	80%	70%	70%	70%	70%	100%
	2	10%		30%	20%	10%	20%	20%	20%	30%	
	3	20%									
	4	30%	30%	20%	10%	10%	10%	10%	10%		
	5										
Total 10		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

In rowing (M1x 2000 m), champions most often started from position 4 (58.3%) and took the lead after the first 500 m in 66.7% of the races. This trend intensified in the last 1000 m, where champions occupied the first position in 91.7%, reflecting stable dominance in the second half of the distance. In canoe sprint (MK1 1000 m), the most frequent starting position was lane 5 (44.4%). Champions rarely led at the beginning – only 11.1% of the performances in the first 250 m – but progressively moved forward, reaching the leading position in 55.6% of the races in the final 250 m. This suggests a more tactical start and finishing sprint at the end of the distance.

In short track (men 1000 m), champions started from the first position in 40% of the races. Tactical positioning was characterized by a certain dynamic: in the first lap, 70% of the champions occupied the leading position; in the second lap, this percentage temporarily decreased to 50%, before increasing again to 80% in the fourth lap. In the following laps, a slight decline was observed (70%), while in the final lap, all champions (100%) were in first position, confirming the decisive role of the finishing sprint in this sport.

Pacing behavior

The analysis of the pacing behavior of Olympic champions revealed statistically significant differences in the times of each segment/lap, indicating clear changes in speed distribution throughout the distance (Table 3).

Table 3. *Main statistical indicators from Repeated Measures ANOVA for pacing behavior in rowing, canoe sprint, and short track Olympic events*

Statistical Test / Indicator	Value Rowing	Value Canoe Sprint	Value Short Track
Mauchly's Test of Sphericity (W)	0.132	0.023	0.000
Chi-Square	(χ^2, df =5) 19.651	(χ^2, df =5) 25.216	(χ^2, df =35) 91.556
p-value (Sphericity assumption)	.002	< .001	< .001
Greenhouse-Geisser epsilon (ε)	0.533	0.383	0.328
Multivariate ANOVA (Wilks' Lambda)	0.179	0.066	0.000
F	(3, 9) 13.722	(3, 6) 28.493	(8, 2) 540.438
p-value (Wilks' Lambda)	0.001	0.001	0.002
Partial Eta Squared (η^2) – Multivariate	0.821	0.934	1.000
Univariate ANOVA (Greenhouse-Geisser corrected)	F(1.599; 17.593) = 10.535	F(1.149; 9.189) = 7.163	F(2.625; 23.622) = 226.900
p-value (Segment/Lap effect)	.002	.022	< .001
Partial Eta Squared (η^2) – Univariate	0.489	0.472	0.962
Largest pairwise difference	(Seg1 – Seg4) 4.698 s (p = .021)	(Seg1 – Seg4) 4.858 s (p = .069)	(Lap1 – Lap7) 3.449 s (p < .001)
Smallest non-significant difference	(Seg2 – Seg3) 0.257 s (p = 1.000)	(Seg2 – Seg3) 0.760 s (p = 1.000)	(Lap4 – Lap5) 0.010 s (p = 1.000)

In rowing (n = 12), champions demonstrated a faster start, with the largest difference observed between the first and last 500 m (4.698 s; p = .021). In the middle of the race (Seg2-Seg3), however, no significant differences were found, suggesting a temporary stabilization of pace (0.257 s; p = 1.000).

In canoe sprint (n = 9), a similar pattern with gradual slowing down was observed: the largest difference occurred between the first and last 250 m (4.858 s; p = .069). However, in the middle segments (Seg2-Seg3), a non-significant but larger difference (0.760 s; p = 1.000) was found compared to rowing and short track.

In short track (n = 10), a non-linear pacing pattern was identified: champions accelerated sharply after the first lap, with the largest statistically significant difference observed between Lap 1 and Lap 7 (3.449 s; p < .001). During the middle part of the race, the pace stabilized, with no significant differences between some laps (e.g., Lap 4 and Lap 5, 0.010 s; p = 1.000). In the final laps, a slight deceleration was recorded.

As shown in Figure 1, in rowing, the pacing profile is almost linear but not entirely even. The fastest mean split time was recorded in the first segment (0-500 m) of the distance. Between the first and second segments (500-1000 m), a clear increase in time was observed, while the second and third segments (1000-1500 m) showed nearly identical mean values. The difference between the third and fourth segments (1500-2000 m) indicates a slight deceleration towards the end of the distance. This pattern demonstrates a controlled and evenly distributed effort throughout the race.

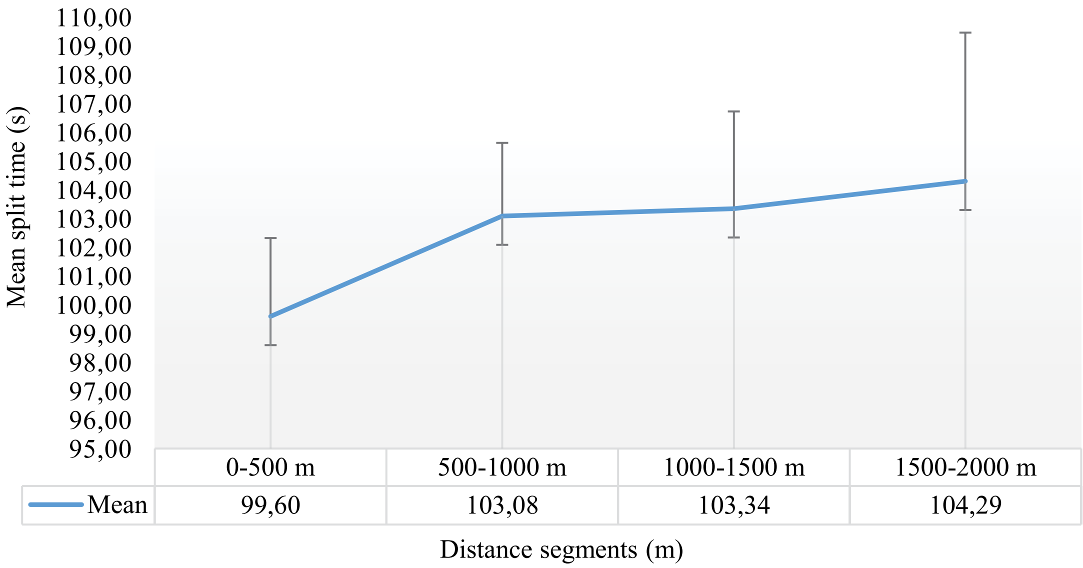

Figure 1. *Mean (±SD) pacing profile of Olympic champions in men's single sculls (2000 m) across 500 m segments at the last three Olympic Games*

As shown in Figure 2, the pacing profile in canoe sprint exhibits an almost linear pattern, with a gradual increase in split times over the course of the distance. The fastest mean time was recorded in the first segment (0-250 m), reflecting a fast start. In the following segments (250-500 m, 500-750 m, and 750-1000 m), a smooth and progressive deceleration was observed, characteristic of controlled and evenly distributed effort in this discipline.

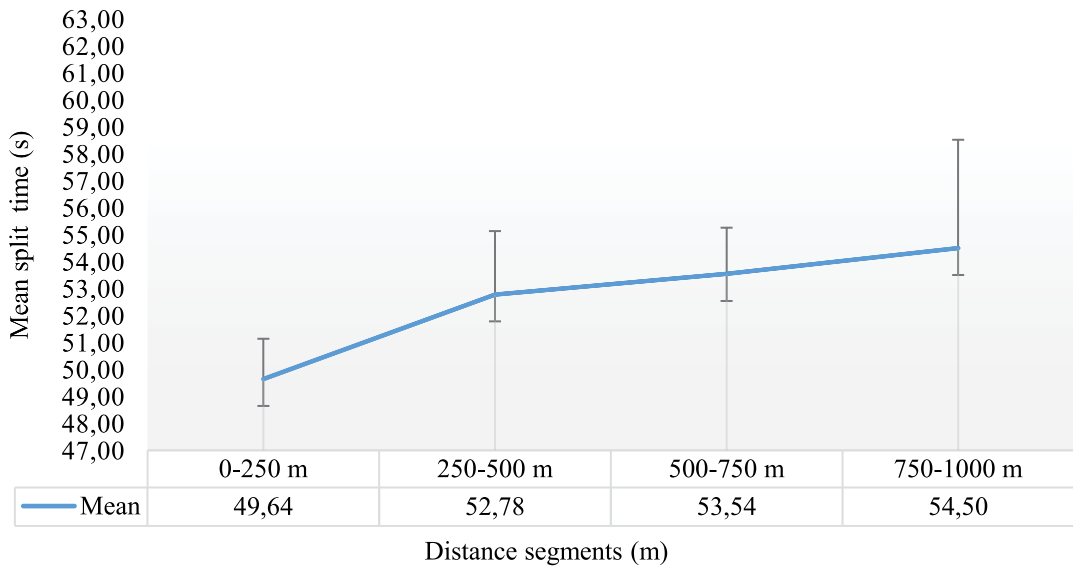

Figure 2. *Mean (±SD) pacing profile of Olympic champions in men's kayak single (1000 m) across 250 m segments at the last three Olympic Games*

As shown in Figure 3, the pacing profile in men's 1000 m short track speed skating is characterized by distinct variations in lap times during the first half of the distance. The most substantial decrease in lap times occurred between the first and second laps, and between the second and third laps. Thereafter, lap times gradually decreased until Lap 7, which represented the fastest segment of the distance. In Lap 8 and 9, a slight increase in lap times was observed, indicating controlled pacing and consistent performance towards the finish.

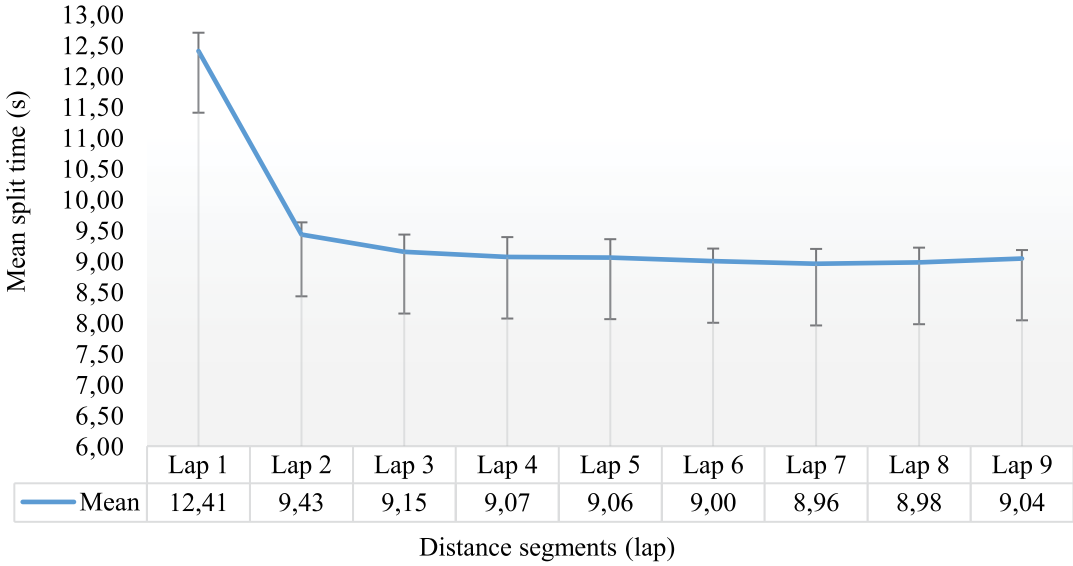

Figure 3. *Mean (±SD) pacing profile of Olympic champions in men's 1000 m short track across laps segments at the last three Winter Olympic Games*

DISCUSSION

The analysis of the performance of Olympic champions in rowing, canoe sprint, and short track revealed both general patterns and specific characteristics related to the tactical demands of each sport. The variation analysis of race times confirmed low variability across all three sports, which is expected for elite athletes competing at the Olympic Games. The largest time range was observed in rowing (R = 37.00 s), which can be explained by the longer distance and the greater influence of meteorological and hydrodynamic factors, such as wind, water current, and temperature. The canoe sprint demonstrated moderate variability (V = 3.17%), while the short track showed the lowest variability (V = 1.29%), reflecting the controlled indoor conditions, shorter distance, and higher speeds reached by competitors. The near-zero skewness and negative kurtosis (Ex < 0) values indicate relatively homogeneous results and the absence of extreme outliers in all three sports.

The comparison of tactical positioning revealed distinct differences between sports. In rowing, champions relied on early leadership, taking the lead after the first 500 m in 66.7% of the races, with dominance increasing to 91.7% in the second half of the distance. This pattern confirms the importance of a controlled but fast start, followed by the maintenance of a high and steady pace throughout the distance. In canoe sprint, a more progressive and tactical distribution of effort was observed. The proportion of champions leading the race increased gradually – from 11.1% in the first 250 m to 55.6% in the final 250 m. This pattern suggests a strategy based on energy conservation for a powerful finishing sprint. Champions in short track demonstrated the most dynamic tactical positioning, characteristic of contact sports. The leaders' positions fluctuated in the early and middle laps, while the decisive moment occurred in the final lap, when all champions (100%) were in first position. This underlines the strategic importance of group positioning, energy conserving, and timing the finishing sprint to perfection.

The pacing analysis using Repeated Measures ANOVA confirmed significant differences between segments/laps in all three sports. In rowing and canoe sprint, the pacing pattern was nearly linear, characterized by a fast start, a stabilized mid-phase, and a slight increase in segment times towards the end of the race. This model is characteristic of disciplines with a predominantly aerobic profile, where effective energy management is key to achieving optimal performance. Short track, however, displayed a non-linear pacing profile, characterized by a sharp decrease in lap times during the second and third laps, followed by a relatively stable speed in the middle part of the distance. The shortest mean lap time was recorded in the 7^{th} lap, after which a slight increase in times was observed during the 8^{th} and 9^{th} laps. This model reflects the tactical specificity of short track speed skating – combining positional strategy in the group at the start, controlled pacing in the middle, and the ability to accelerate at the end of the distance, where the overtaking plays a decisive role in success.

CONCLUSION

The analysis of pacing behavior, tactical positioning, and race time variability of Olympic champions in rowing, canoe sprint, and short-track speed skating revealed specific performance models for each sport. The results showed that, despite differences in energy demands, race duration, and competition environment, champions in all three sports demonstrated high performance stability and clearly defined pacing strategies. In rowing, champions typically adopted a front-leading strategy, characterized by an early lead and consistent control throughout the middle and final stages of the distance. This approach reflects the aerobic endurance demands of the sport and the importance of maintaining a steady rhythm under variable environmental conditions. In canoe sprint, the champions displayed a positive pacing pattern, starting fast and showing a gradual increase in segment times towards the end of the distance. This indicates a controlled distribution of effort, where athletes aim to reach optimal speed early and maintain it efficiently until the finish. In short track, a non-linear and highly dynamic pacing profile was observed, where winning was determined by a waiting strategy, based on precise tactical positioning within the group and an explosive finishing attack.

A common feature across all three sports is the low variability of race times and the strategic control of positioning and pacing, highlighting the role of optimized tactical behavior in achieving Olympic-level success. These findings contribute to a deeper understanding of the mechanisms underlying elite performance and can assist coaches and athletes in refining race strategies and designing effective training models.

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