Drafting, pacing, winning – why the fastest 1,500-meter runner did not become the Paris 2024 Olympic champion

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Abstract

Introduction: Considering the season bests before the Olympics as well as individual critical velocities, the question arose, why the obviously fastest runner of the 2024 season, Ingebrigtsen, did not became Olympic champion over the 1,500 m despite being in a top form in Paris. Beside the fact that the winner of the race improved his personal best by 2.9 s in the, the answer may lie in the tactical decision making during the race. Methods: To answer this question a race and performance analysis of Hocker (winner), Kerr (2nd place) and Ingebrigtsen (4th place, world lead 2024) as well as a literature search was carried out to narratively review potential factors of middle-distance race performance in elite athletes that may be modulated by tactical decisions. Results: Based on the data of Kyle (1979) and assuming a distance of 2 m to the front runner at a running velocity of 7.2 $m*s^{-1}$ an approximately 3% higher energy consumption can be assumed for the front runner Ingebrigtsen compared to the drafting runners. This corresponds to a theoretical time loss of 1.0 to 1.7 s per 400 m for the front runner. Further, empirical data and models of fatigue support the view of a negative effect of a very fast start, as realized by Ingebrigtsen, on middle-distance performance. Conclusion: On the home straight Hocker outpaced Ingebrigtsen (13.84 s) by almost a second in the last 100 m with 13.05 s, probably because of his well-preserved anaerobic capacity through drafting and running the curves on the inner bend.

Keypoints

- **Tactical Decisions**: The outcome of the race was influenced by the tactical decisions made during the race, with Ingebrigtsen's strategy of leading the pack potentially contributing to his "loss", despite being in top form.

- **Energy Consumption**: Being in the front position caused Ingebrigtsen to expend approximately 3% more energy than the runners behind him, leading to a theoretical time loss of up to 1.0 to 1.7 seconds per 400 meters.

- **Fatigue Impact**: Starting the race too quickly, as Ingebrigtsen did, likely also led to early fatigue, while Hocker's ability to conserve energy through drafting and running on the inner bend allowed him to maintain his anaerobic capacity until the end.

1 Introduction

The middle distances can be regarded as complex disciplines of track running given that they combine the requirements of sprinting (high force/power and anaerobic capacity to maximize running velocity) and long distance running (high maximal oxygen uptake (VO_2), faster VO_2-kinetics, better running economy, and higher anaerobic threshold) (Brandon, 1995). For instance, the 1,500 m performance is mainly determined by the rate of the aerobic substrate metabolism (around ¾) but also by anaerobic capacities (Busso & Chatagnon, 2006; Duffield et al., 2005; Ferri et al., 2012; Hill, 1999). Given the minor margins between the top performances in Olympic or World Championship finals, superior race tactics might compensate for the small differences in the physiological feats of elite distance runners, making the difference between a gold and a silver medal or between a medal or non-medal position.

At the 2024 Olympic Games in Paris, a duel was expected between the 2021 Olympic champion, Jakob Ingebrigtsen (Norway), and the 2023 world champion, Josh Kerr (Great Britain). In the end, however, Cole Hocker (USA) won the race ahead of Kerr in a high-class race with an Olympic record. Ingebrigtsen, who´s personal best was 2.3 s and 3.9 s faster than Kerr's and Hocker's, respectively, and who led the field from the start up to 1,400 m, finished fourth. Considering the season bests before the Olympics, the question arises, why the obviously fastest runner, Ingebrigtsen, did not became Olympic champion despite being in a top form. Beside the fact that Hocker improved his best time by 2.9 s and relegated Kerr to second place with an individual improvement of 1.3 s in the fastest Olympic 1,500 m final ever, the answer may lie in tactical decisions during the race. To answer this question a 1) race and performance analysis of the runners Cole Hocker (winner of the final), Josh Kerr (2nd place) and Jakob Ingebrigtsen (4th place, 2024 world lead) as well as a literature search was carried out to narratively review potential factors of middle-distance race performance in elite athletes that may be modulated by tactical decisions.

2 Methods

The 1,500 m and 5,000 m split times were retrieved from the official times of the Olympic broadcasting and were visualized using a special custom-made video software (Institute of Applied Training Science, IAT Leipzig, Germany). The personal and season bests of the runners were retrieved from the World Athletics Website (https://worldathletics.org/athletes/).

The literature was screened for articles addressing potentially positive or detrimental effects of tactical decisions on middle-distance running performance. Therefore, a two-armed research strategy was applied. First, a keyword search of English-language articles in the Scopus database up to and including the November 01, 2024, index date was performed with the search strings:

1. running AND air resistance OR wind resistance OR aerodynamic drag OR drafting OR aerodynamic: 1130 hits, the exclusion of articles including the keywords “Railroads”, “Railroad Cars”, “Railroad Transportation”, “High-speed Train”, “High Speed Trains”, “Vehicles”, “High Speed Train HST”, “Vehicle Performance” resulted in 865 hits, of them 54 were found to be relevant to the topic after screening title and abstract.

2. middle distance OR 1500 OR 3000 OR 800 AND running AND pacing: 91 hits, 38 found to be relevant after screening title and abstract.

3. priming OR warm up OR pacing OR tactic AND oxygen uptake: 517 hits, the exclusion of articles including the keywords “Cardiac Pacing, Artificial”, “Heart Pacing”, “Heart failure”, “Heart”, “Myocardium”, “Artificial Heart Pacemaker” resulted in 330 hits, with 19 valuated as relevant to the topic after screening title and abstract.

4. running AND championships OR race AND extra distance OR position OR covered distance: 289 hits, 14 selected as relevant to the topic after screening title and abstract.

Second, a keyword search was undertaken using the AI research platform ResearchRabbit to search for additional papers relevant to the topic.

The full text was screened, if no clear decision could be made after abstract and title screening. After merging and deletion of duplicates content from 114 journal articles (reference list in the supplemental material) were considered in this narrative review to address the potential effects of pacing, drafting and covered distance on 1,500 m performance and positioning in the 2024 Olympic men final.

3 Results

In the following the race and physiological performances using the individual bests and the model of critical velocity, a detailed race exploration based on video data analysis and assumptions from the literature review regarding the factors *drafting, pacing* and *covered distance* will be presented.

3. 1 Performance and race analysis

A look at the best times over 800 m up to 5,000 m of the three runners before the Olympic Games (Tab.1) indicate, firstly, that all of them had high level performances over all distances.

Table 1 Personal bests and corresponding average velocity

	800 m		**1,500 m**		**3,000 m**		**5,000** m	
	Velocity [m/s]	Time [s]	Velocity [m/s]	Time [s]	Velocity [m/s]	Time [s]	Velocity [m/s]	Time [s]
Ingebrigtsen	7.516	106.44	7.256	206.73	6.762	443.63	6.507	768.45
Kerr	7.594	105.35	7.175	209.05	6.665	450.14	6.221	803.78
Hocker	7.574	105.63	7.123	210.59	6.588	455.35	6.420	778.82

Secondly, data imply that, out of the three runners, Ingebrigtsen had not only the best 1,500 m performance, but the highest aerobic performance potential indicated by the higher velocity over 3,000 and 5,000 m (Fig. 1).

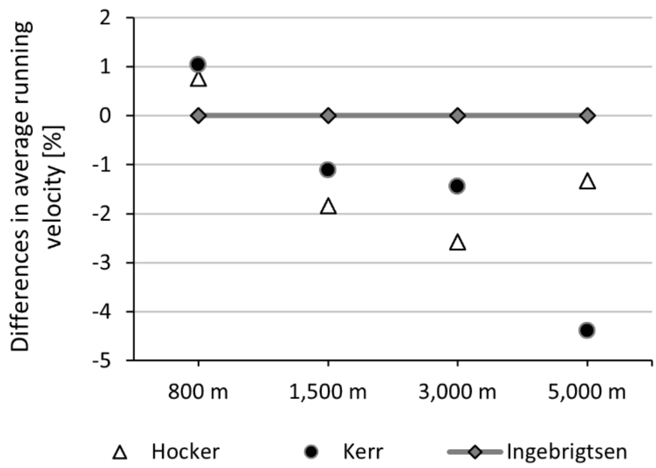

Fig. 1 Percentage differences in average running velocity of Hocker and Kerr in relation to Ingebrigtsen based on the runners` personal bests across 800 – 5,000m before the Paris Olympic 1,500 m final

Further, critical velocity, reflecting the aerobic potential as the maximal metabolic steady state performance, can be calculated from the individual personal bests. Using a distance-time model, critical velocity corresponds to the slope of the regression lines (Jones et al., 2019), while the anaerobic capacity in terms of the distance (D´) is represented by the intercepts of the regression lines (Fig. 2). The higher the actual running velocity above the critical velocity, the more rapidly D′ will be utilized, with the limit of tolerance coinciding with the exhaustion of D′ (Jones et al., 2019). The relative difference in critical velocity, compared to Ingebrigtsen, is -1.6% for Hocker and -5.1% for Kerr, respectively, and the values correspond to the relative differences in 5,000 m velocity. A somewhat stronger anaerobic capacity was expected to exist for Kerr and Hocker if comparing the 800 m personal bests of the three runners. In contrast, the calculation of D´ results in no difference between Ingebrigtsen (166.6 m) and Hocker (166.6 m), while Kerr (226.3 m) seems to have a higher anaerobic potential (Fig. 2). Since the calculation of critical velocity and D` assumes that the personal bests reflect optimal races showing the full physiological potential of a runner at the same time, temporal changes cannot be considered (e. g. due to training periodization or changes of the preferred competition distance over an athlete´s career with respective changes of training volume, distribution, and intensity). Thus, the calculation of critical velocity and D´ are only an approximation of the actual physiological potential of an athlete at a time.

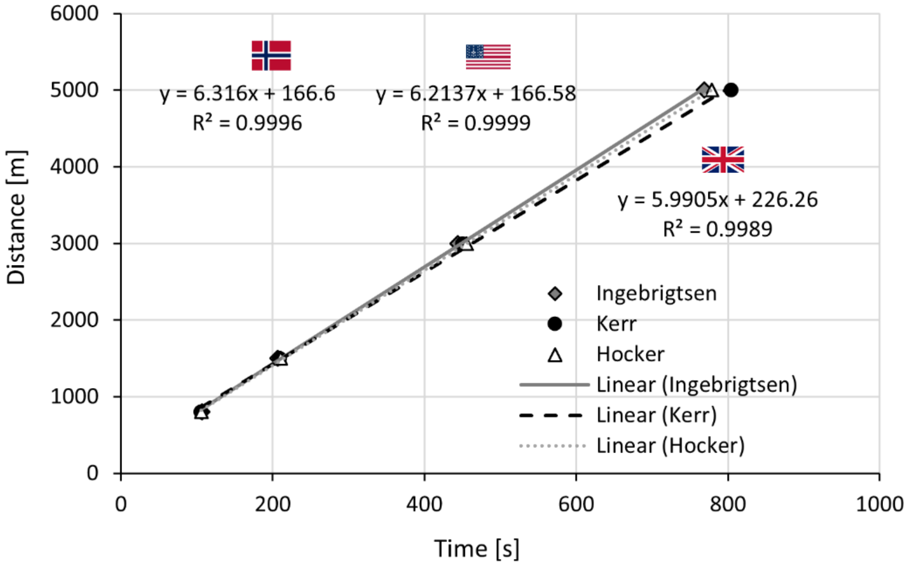

Fig. 2 Distance-time plot for the personal bests across 800 – 5,000 m and regression lines. The slopes correspond to critical velocity (m/s) and intercepts to D` (m)

Before focusing on the tactical decisions and their potential effects, it has to be stated that Ingebrigtsen`s Olympic final performance was within the margins of typical individual seasonal variability of top athletes reported in the literature (mean: 1.1%, 90% confidence interval: 1.0 – 1.1%, (Malcata & Hopkins, 2014)), if compared to his season best before the Olympics. Kerr and Hocker performed slightly better (Ingebrigtsen: 0.7% slower, Kerr 1.48% (based on 1,500 m split time from mile race) and Hocker 1.40 % faster than the individual season best before the Paris 2024 Olympic games). Hocker's and Kerr's finishing times exceeded the margins of the reported 90% confidence interval for seasonal variability if referred to their pre-Olympic season best.

Figure 3 shows the individual 100-m split times during the 1,500-m final. Ingebrigtsen took the lead after just 100 m and ran the entire race at the front. Kerr was in third position throughout, while Hocker, on the other hand, started the first 300 m at the ninth position, then ran to the seventh and fifth position up to 1,200 m and gradually moved forward over the last 300 m, only taking the lead on the home straight.

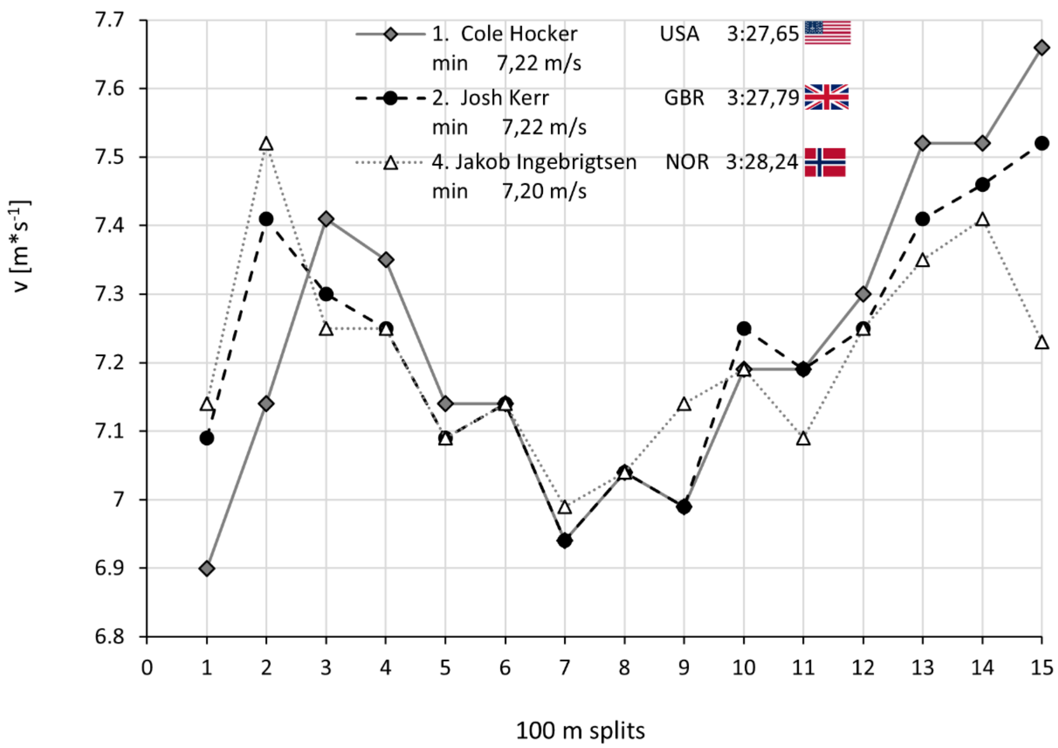

Fig. 3 Average velocity (v) for each 100 m split for Ingebrigtsen, Kerr and Hocker

3.2 Drafting

Hill (1928) was probably the first who assumed the fractional energy consumption required to overcome air-resistance being around 3% of the total energy costs of distance running. In the 1970s and 80s Pugh (1971), (1984) and Davies (1980) published results, which showed that highly trained runners use around 4-8% and 8-16% of their total energy costs to overcome air resistance on a calm, windless day at a running velocity of 6 m/s and 10 m/s, respectively. Based on Pugh’s (1970) equation, the additional energy required to overcome air resistance of a runner with a body weight of 70 kg at a velocity of 7.2 m*s^{-1} results in an additional oxygen uptake of 10.7 ml*min^{-1}*kg^{-1}. Such values correspond to the difference between VO_2peak at sea level and VO_2peak at an altitude of ca. 3,000 m (Pugh, 1967; Wehrlin & Hallén, 2006) and has been theoretically translated to slowing down a 1,500 m-performance from 3:29 min to ≥ 3:40 min (Peronnet et al., 1991). Comparable or even higher requirements have been measured or modeled by other authors for energy consumption, power or drag forces as well as respective savings by drafting (e. g., Jones and Doust (1996), Kipp et al. (2019), Marro et al. (2023), Mesquita et al. (2024), Pecchiari et al. (2023), Pritchard (1993), Schickhofer and Hanson (2021), Shanebrook and Jaszczak (1976), Valsecchi et al. (2022), Ward-Smith (1984)) . Therefore, substantially reducing these energy requirements by drafting should translate into a significant increase in performance. In a single case study Pugh (1971) proved the energy requirement for overcoming air resistance to be reduced by up to 80% and the total energy consumption by 6.5% if a runner benefits from drafting at a running velocity of 6.0 m/s around one meter behind a front runner. This theoretically results in a reduction of approximately -4 s per 400 m, although the author already assumed that in competition situations only approximately -1 s per 400 m would be a more reliable estimate due to non-optimal distances to the front runner (Pugh, 1971). Kyle (1979) analyzed the influence of drafting during cycling in a standing position and extrapolated these results to calculate the energy consumption of drafting runners in relation to their distance to the front runner. For a velocity of 6 m*s^{-1} and a distance of 2 m to the front runner (reduction of the energy required to overcome the air resistance by 40%), the author determined a reduction of the total energy requirement of approximately -2% or -1.42 s per 400 m. The studies of Beaumont et al. (2019), Beaumont et al. (2022), Davies (1980) , Valsecchi et al. (2022) and others prove that drafting has a meaningful effect on physiological costs of middle- and long-distance running. To our knowledge, there is only one study, addressing drafting during middle-distance running under ecological conditions in ten male elite runners (Zouhal et al., 2015). Comparing a drafting and a non-drafting 3,000 m race, the authors found significantly faster running times and lower blood lactate concentrations for the drafting race, while the cardiorespiratory responses were not different between the conditions. Based on the data of Kyle (1979) and assuming a distance of 2 m to the front runner at a running velocity of 7.2 $m*s^{-1}$ an approximately 3% higher energy consumption can be assumed for the front runner Ingebrigtsen compared to the drafting runners Kerr and Hocker. This corresponds to a theoretical time loss of 1.7 s per 400 m for the front runner. This figure must be considered as an estimate, since constitution of the runners and the actual reduction in air resistance due to varying distance to the front runner may significantly differ. Taking into account the stature of Ingebrigtsen (body height circa 1.87m) and findings of even greater reduction in metabolic costs for drafting at middle-distance velocities and smaller distances between the runners (Kyle, 1979; Trenchard et al., 2017), this figure seems to be not too high. Wind in the stadium would increase the disadvantage, since a headwind would exponentially increase air resistance and no benefit from a tailwind can be assumed for the front runner. Translating the metabolic savings into time gains for the drafting runners more conservatively by considering a curvilinear relationship between metabolic rate and running speed (Batliner et al., 2018) and using the formulas provided by Kipp et al. (2019) results in a theoretical time win of 1.0 s per 400 m.

On the home straight Hocker and Kerr outpaced Ingebrigtsen (13.84 s) by more than half a second in the last 100 m with 13.05 s and 13.29 s, speaking for their well-preserved anaerobic capacity through drafting until the end of the race. Interestingly, during the 5,000 m final, which took place a few days later and which was not as fast as the 1,500 m final, Ingebrigtsen achieved 1:19.96 min over the final 600 m corresponding to an astonishing average time of 13.33 s per 100 m or an average velocity of 7.50 $m*s^{-1}$. During the 1,500 m final this velocity was only exceeded during the final 300 m by Hocker, for final 100 m of Kerr and during the

100 to 200 m-split of Ingebrigtsen. These observations stress the importance of saving the anaerobic capacity (D´) as long as possible for a medal success in the 1,500 m similar to long-distance races (Casado et al., 2024).

The concept of fatigue provides an explanation for the positive effects of drafting. In order to overcome air resistance at the same running velocity, the front runner has to generate consistently higher muscle forces per unit of time. This accelerates neural and muscular impairments. The neural impairments include aspects related to muscle activation that include a reduction in voluntary activation of individual muscles associated with modulations in cortical motoneurons and/or spinal α-motoneurons (Behrens et al., 2023). The main factors involved in the decrease in contractile function are reductions in sarcolemmal excitability, Ca^{2+} release from the sarcoplasmic reticulum, myofibrillar Ca^{2+} sensitivity and the force-generating capacity of the cross-bridges (Behrens et al., 2023). On a psychophysiological level, the perception of fatigue increases, influenced by perceptual and affective responses to exercise. For instance, the perception of effort increases due to the decline in contractile function of muscles and a compensatory increase in muscle activation to maintain the required force output (Behrens et al., 2023; Pageaux, 2016). The inhibitory afferent feedback from group III and IV muscle afferents shapes the intensity of perceptions like exercise-induced muscle pain, resulting in a negative affective valence and decreases in performance and exercise tolerance (Behrens et al., 2023; Hartman et al., 2019; Smith et al., 2020).

It can be assumed that due to drafting Hocker and Kerr could delay the mechanism of performance fatigue and perceived fatigue. Besides it can be accepted that Hocker, who always had four to eight runners in front of him up to the final 300 m, benefited more from drafting compared to Kerr. In view of the lower critical velocity, Kerr might has depleted his "anaerobic" capacity (D') earlier and to a greater extent than Hocker. In the sub-2 marathon project, several front runners moved in a V-formation in front of Eliud Kipchoge to reduce air resistance. Modelling reveals time savings of up to more than 4 minutes during the marathon for optimal drafting strategies and formation of elite marathoners at speeds around 5.75 $m*s^{-1}$ (Beaumont et al., 2021; Hoogkamer et al., 2018, 2019; Marro et al., 2023; Polidori et al., 2020). Unfortunately, to our knowledge, no such data are available for middle-distance running under competitive conditions on a stadium track and with regard to more than one front runner.

3.3 Covered distance

Another aspect that can potentially influence the outcome of track races is the distance actually covered. With a given curve radius of 36.5 m and a lane width of 1.22 m, a runner on the second lane runs more than seven meters further per lap if compared to running on the first lane. Jones and Whipp (2002) have impressively shown the difference between official split distances and the actual distance a runner covers as well as the potential effect of these differences on the times and rankings in the 2000 Olympic 800 m and 5,000 m finals. González-Mohíno et al. (2021) found that even slight differences in the covered distance can impact the end position in World Championship and Olympic Games 800 m finals.

A quantification of the distance actually covered in international competitions is not easy, but a study by Yang et al. (2023) revealed a real distance of 1,510 m for a runner using object tracking with Open CV. For the 1,500 m final in Paris 2024, however, this aspect appears less relevant, as all three runners ran almost the entire race on the inside lane.

3.4 Pacing and VO_2 kinetics

The course of the race revealed that Hocker, at 28.5 s, had a much smoother start than Ingebrigtsen (27.3 s) and Kerr (27.6 s) over the first 200 m. In the first curve, Ingebrigtsen's velocity was approximately 5% faster than Hocker's, at a time when a levelling-off of VO_2

peak cannot yet be assumed and anaerobic processes make a significant contribution to the energy supply.

1,500 m races primarily tax the severe intensity domain and, thus, VO_2 kinetics show a pronounced slow component. Depending on the athletic level, training status and exercise intensity, VO_2 takes around 30-120 s to reach the intensity-dependent steady state (Poole & Jones, 2012). Hanon et al. (2008) demonstrated a peaking of VO_2 at a level similar to incremental-tests based VO_{2max} after a duration of 75.9 ± 7.5 s in a 1,500 m test in trained runners (exercise time: 245.4 ± 6.04 s). Others found that VO_2 during a simulated run peaks at around 90% of VO_2max (Leger and Ferguson, Ariyoshi et al). Because of their higher (aerobic) performance level significantly faster VO_2 kinetics (< 60 s) can be assumed for Olympic finalists. Nevertheless, non-mitochondrial ATP resynthesis (phosphocreatine degradation and anaerobic glycolysis) makes a significant contribution to energy supply at the beginning of a 1,500 m race. Especially at high starting velocities, the larger recruitment of fast fatiguing motor units would lead to an early increase in inorganic phosphate and lactate as well as a drop in pH. Consequently, fast starts should increase performance fatigue and thus, limiting the end spurt capabilities of a runner (Azevedo et al., 2019). On the other hand, pacing strategies including a fast start may exert a priming effect on VO_2-kinetics (Goulding et al., 2023; Sandals et al., 2006). Some studies – predominantly in cyclists – seem to support aggressive pacing as a kind of priming to improve oxygen-uptake kinetics (Brock et al., 2018; Burnley et al., 2002; do Nascimento et al., 2015; Heubert et al., 2005; Turnes et al., 2014; Wittekind & Beneke, 2009; Wood et al., 2014), while others do not (Bailey et al., 2016; Corrêa Caritá et al., 2014; Jones et al., 2008). For instance, Wood et al. (2014) were able to demonstrate the positive effect of aggressive pacing (15 s all-out sprint at the beginning) on VO_2 kinetics and performance in sub-elite cyclists. Similar results were found in 600 to 800 m middle-distance running (Sandals et al., 2006; Turnes et al., 2014). However, Abbiss and

Laursen (2008) and Wood et al. (2014) restrict their recommendations for endurance disciplines with exercise durations of less than 120 – 180 s, which is significantly shorter than the duration of 1,500 m run. Further, priming for 90 s had no longer a positive effect on performance (Wood et al., 2014). It is also questionable whether these results can be easily transferred from cycling and sub-elite running to highly trained middle-distance runners that already possess a fast VO_2 response (Billat et al., 1998; Caputo & Denadai, 2006; Carter et al., 2000; Hill et al., 2003; Jones & McConnell, 1999). Moreover, the pacing pattern of the Olympic 1,500 m final, where severe intensities and high running speeds were realized throughout the whole race might be different from the pattern and setup during the experimental studies. A real benefit of a fast start leading to faster VO_2 kinetics and thereby affecting the relative contribution of aerobic and anaerobic processes to overall energy utilization during longer middle-distance running was called into question as early as 1974 by experimental findings of Léger and Ferguson (1974). The authors did not find any differences for VO_2, post-exercise VO_2 or peak blood lactate concentration between a fast or a slow start pacing strategy. In contrast, Hanon et al. (2008) measured faster VO_2-kinetics if a fast start was applied. In that regard is must be critically considered, that the negative correlation ($r = -0.69$, $p < 0.05$) between starting velocity and the time to reach VO_2peak in these runners, may have been strongly biased by the data of the participant with the significantly slowest individual starting velocity. Further, the authors found a negative correlation between the starting velocity (quantified as the percentage of the individual velocity at VO_2max at 250m after onset of the 1,500m test) and 1,500 m race performance in trained runners and concluded – similar to Léger and Ferguson (1974) – that a fast start does not necessarily lead to a good performance. Similar associations were reported by Zouhal et al. (2015) for a 3,000 m race, where the fastest starts produced the worst performances, while even pacing resulted in the fastest times. Accordingly, Foster et al. (1993) found slow starts and even pacing producing the best performances and fast, very fast and very slow starts the worst performances in middle-distance cycling (2 km). Further, based on their analysis and models Le Hyaric et al. (2024) assumed Ingebrigtsen's VO_2-kinetics to be faster than that of his opponents, which makes a very fast start to accelerate VO_2-uptake appear even less sensible. Experimental findings do further support the notion, that priming may only be effective in subjects exhibiting slow VO_2-uptake kinetics (Jones et al., 2008; Nederveen et al., 2017). Further, Bellinger et al. (2021) tried to elucidate the physiological determinants of successful tempo-oriented vs. tactical 1,500 m races, especially the characteristics that underpin last lap speed in tactical 1,500-m competitions. In fast pace races (sustained pace from the start) velocity at VO_2peak and running economy (both considered as superior for Ingebrigtsen in comparison to his opponents) were the key determinants of overall 1,500-m running performance as well as last lap speed.

Even if Ingebrigtsen's pacing was similar to the typical tempo-oriented and world record races (Kelemen et al., 2023), the first 200 m in particular could have led to the fact that he ended up 1.5 s slower than his European record from the Diamond League meeting in Monaco in July 2024. There, he ran at a much more consistent pace over the course of the race and ran the first 400 m around 0.5 s slower. However, the fact that he was able to run behind pacemakers up to 1,100 m in Monaco and, thus, saved his anaerobic capacity is probably even more decisive.

Based on the above findings from the literature it is very likely that Ingebrigtsen's fast race start significantly accelerated performance fatigue and thus increased his race time, rather than significantly accelerating the VO_2-kinetics.

4 Discussion

In summary, Hocker might have benefited from a very smart race tactic, which allowed him to make the best possible use of his metabolic resources by drafting and running on the inner lane and, thereby, delaying performance fatigue associated with high-intensity efforts. In addition to these race tactical decisions, it can also be assumed, based on the best times, that Hocker was able to draw on a higher aerobic performance than Kerr, helping to save his anaerobic capacity until the home straight. In the narrative review presented here, other aspects (e. g. mental aspects, performance fatigue caused by the preliminary and semi-final races or the use of regeneration strategies or priming exercises before the race) could not be considered or ruled out as influencing factors. However, the findings from the literature and assumptions presented here provide a sufficient explanation for the outcome of the men Paris Olympic 1,500 m final, where seemingly not the fastest but the smartest competitor won the race.

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