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The Behavior of an Opponent Alters Pacing Decisions in 4-km Cycling Time Trials

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Abstract

Introduction: The present study aimed to explore how athletes respond to different behaviors of their opponents. ***Methods:*** Twelve moderately to highly physically active participants with at least two years of cycling experience completed four 4-km time trials on a Velotron cycle ergometer. After a familiarization time trial (FAM), participants performed three experimental time trials in randomized order with no opponent (NO), a virtual opponent who started slower and finished faster compared to FAM (OP-SLOWFAST), or a virtual opponent who started faster and finished slower compared to FAM (OP-FASTSLOW). Repeated-measures ANOVAs ($p<0.05$) were used to examine differences in pacing and performance related to power output, velocity, and RPE. ***Results:*** OP-SLOWFAST and OP-FASTSLOW were completed faster compared to NO (385.5±27.5, 385.0±28.6, and 390.6±29.3 s, respectively). An interaction effect for condition x distance ($F=3.944$, $P<0.001$) indicated differences in pacing profiles between conditions. Post-hoc analysis revealed that a less aggressive starting strategy was adopted in NO compared to OP-FASTSLOW and OP-SLOWFAST during the initial 1000m. Finally, a faster starting opponent evokes higher power outputs by the participants in the initial 750m compared to a slower starting opponent. ***Conclusion:*** The present study is the first to show that the behavior of an opponent affects pacing-related decisions in laboratory-controlled conditions. Our findings support the recently proposed interdependence of perception and action, and emphasize the interaction with the environment as an important determinant for an athlete's pacing decisions, especially during the initial stages of a race.

Highlights

- The pacing behavior of an opponent alters pacing decisions of an athlete in lab-controlled conditions
- A faster starting opponent evokes a faster start compared to a slower starting one.
- The behavior of an opponent is an important determinant for an athlete's pacing decisions, which is thus far often overlooked in investigating pacing behavior.

Keywords: Decision-making, Pacing strategy, Interpersonal competition, Motivation, Exercise

1. Introduction

Pacing has been defined as the goal-directed regulation of exercise intensity over an exercise bout [1], in which athletes need to decide how and when to invest their energy [2]. Recent theoretical frameworks from both heuristic [3] and ecological [2] perspectives emphasized that pacing is a decision-making process in which interaction with the environment is a crucial determinant for the regulation of the exercise intensity. That is, in addition to internal characteristics such as perceived fatigue, athletes may decide to alter their pacing behavior based on environmental characteristics [2] such as drafting possibilities or expectations or actions of the opponents behaviors affecting winning chances.

Even though some form of interpersonal competition is indispensable in every (elite) sport, research about the exact influence of different opponents on pacing behavior, tactics, decision-making and performance of athletes is still limited. A better understanding of how athletes respond to their opponents could assist coaches and athletes to optimally prepare themselves for the tactical decision-making involved in athletic competitions [2,3]. The relatively controlled and simplified situation of cycling a time trial against a competing opponent while monitoring pacing behavior can provide new insights in how exercisers regulate their exercise intensity, supporting the suggestion that not only internal, but also external information is incorporated in the decision at what intensity to exercise [2]. A better understanding of the decision-making process involved in pacing behavior could even contribute to our general understanding of the way people pace their activities in daily life or how exercise intensity is regulated when achieving demanding goals in a rehabilitation context [4].

Previous research has explored the effect of an opponent on pacing and performance, and reported a positive effect of the presence of a direct opponent on performance [5–11]. In addition, the performance enhancement when an opponent is present appeared to be independent of the performance of the opponent [11]. On the other hand, it is still unclear if every competitor evokes a similar behavioral response or whether different behavior of the opponents might alter the decisions of the competing athlete. By manipulating the pacing strategy of a virtual opponent, the present study explored how exercisers responded to different opponents in a well-controlled, experimental setting. It is hypothesized that exercisers adapt their pacing behavior and decision-making regarding the regulation of exercise intensity over the race based on the strategy employed by the opponent. We expect that a faster or slower starting opponent will invite exercisers to adopt a respectively faster or slower starting pacing strategy, mirroring the behavior of the opponent. This will provide support for the notion that there is an interdependence of perception and action when regulating exercise intensities in competitive situations, which will emphasize the interaction with the environment as a crucial, but often overlooked determinant for an athlete's decisions regarding the regulation of exercise intensity.

2. Materials and methods

2.1 Participants

Twelve participants with at least two years of cycling experience (age: 25.8±9.5 years; body mass: 74.2±10.8 kg; height: 176.2±6.4 cm) participated in this study. All participants were moderate to highly physically active (two or more moderate to high-intensity training sessions per week), familiar to pacing their exercise, and were able to complete a 4-km cycling time-trial within seven minutes. Before participating all participants gave written informed consent and completed a health screening questionnaire (Physical Activity Readiness Questionnaire; [12]. The study was approved by the university's local ethical committee in accordance to the Declaration of Helsinki.

2.2 Experimental procedures

Participants completed four 4-km cycling time trials. They were allowed to perform a 5-min self-paced warm-up of low to moderate intensity, followed by a 5-min inactive recovery period before starting the time trials. To control for warm-up intensity, participants were asked to exercise at an intensity similar to previous visits. The first time trial was always a familiarization trial (FAM). Hereafter, participants completed one time trial without opponent (NO) and two time trials with an opponent (OP-FASTSLOW and OP-SLOWFAST) in a random order.

Two opponents (OP-SLOWFAST and OP-FASTSLOW, respectively) were constructed for each participant using different pacing profiles compared to the participant in his FAM in order to explore how athletes respond to different opponents. OP-FASTSLOW adopted a faster pace (+3% compared to FAM) between 250m-2000m, followed by a slower pace (-1% compared to FAM) between 2000m-3750m. In contrast, OP-SLOWFAST adopted a slower pace (-1% compared to FAM) between 250m-2000m, followed by a faster pace (+3% compared to FAM) between 2000m-3750m. Both opponents adopted a velocity in the first and last 250m that was 1% faster compared to the participants' FAM in order to match the start and end spurt of the participants. This was done to increase the participant's perception of the opponent as a realistic competitor of a level of performance within reach of the participant. Based on an expected performance improvement of 1% after FAM [8,13], the pacing profiles of the both opponents were constructed to a finishing time 1% faster compared to FAM. Although the pacing strategies differed between the opponent conditions, the finishing time of the opponent was for both opponent conditions exactly the same. Accuracy of the "constructed opponents" compared to the "calculated opponent" has been determined. If an error of more than 1sec was found, the trial was repeated until an acceptable error was achieved. The mean error was 0.39±0.18 sec, with a maximal error of 0.76 sec.

Before every time trial, participants were instructed to perform optimally and give maximal effort. No verbal coaching or motivation was given to the participants during any of the trials. In order to simulate real competitive situations, participants were shown a leader board before the start of the virtual opponent trials on which they could compare their ranked previous performances to other (anonymous) participants. A "ghost" rider was added to the first and last positions on the chart, so that also the fastest and slowest rider believed that there was respectively a rider ranked closely ahead or behind them, who would be competitive for him as opponent [14]. In addition, participants were told that their opponent would be of similar level of performance in order to stimulate the participant to perceive the virtual opponent as a realistic and competitive one.

Time-trials were completed at the same time of the day (±2 h), and the same day of the week to minimize circadian variation [15,16]. Participants were asked to maintain normal activity and sleep pattern throughout the testing period. In addition, participants were asked to refrain from any strenuous exercise and alcohol consumption in the preceding 24-h, and from caffeine and food consumption respectively, four and two hours before the start of the test. Participants were informed that the study was examining the influence of external factors on performance during cycling time trials. To prevent any pre-meditated influence on preparation or pre-exercise state, the specific feedback presented for each trial was only revealed immediately before the start of the time trial. All trials were conducted in ambient temperatures between 18-21°C.

2.3 Apparatus

Time trials were performed on acycle ergometer (Velotron Dynafit, Racermate, Seattle, USA) that has been shown to be a reliable and valid tool to measure cycling performance and pacing behavior [17–19]. Using the Velotron 3D software, a straight and flat

4-km time trial course with no wind was programmed and projected onto a screen for all trials. During the time trials only relative distance feedback was provided. In the opponent conditions, a virtual opponent was projected. Participant started every trial in the same gear, but were free to change their gear ratio throughout the time trial. Power output, velocity, distance, cadence, and gearing were monitored continuously during each trial (sample frequency = 4 Hz). Rate of perceived exertion (RPE) on a Borg-scale of 6-20 [20] was asked after the warm-up, before the start of the time trial, at three random points during the time trial, and directly after passing the finish line.

2.4 Data analysis

Mean power output, velocity, cadence, and finish time were calculated in order to examine performance. Differences in performance between conditions were assessed using a repeated-measures ANOVA. During each time trial, RPE was asked at three random moments. Before statistical analyses on RPE were performed, we calculated whether these moments were, on average, asked at similar points during the race for every condition using a One-Way ANOVA. To assess differences in pacing behavior between the conditions, average power output, cadence, and split times for each 250m segment were calculated, and differences were tested using a two-way repeated-measures ANOVA (conditions x distance). Post-hoc tests with Bonferroni correction were performed when significant results were found. All analyses were performed using SPSS 19.0, and significance was accepted at $P<0.05$. Data are presented as means ± SD.

3. Results

3.1 Performance analysis

Mean (±SD) performance times, power outputs, velocities, and final RPE scores for the four time trial conditions are shown in Table 1. Mean finishing times of the virtual opponents were respectively 389.20±29.22 sec (OP-SLOWFAST) and 389.36±29.53 sec (OP-FASTSLOW). A difference in performance times was found between conditions ($p=0.036$). Post-hoc analysis showed that participants were faster during both OP-SLOWFAST ($F=3.095$, $p=0.010$) and OP-FASTSLOW ($F=4.182$, $p=0.002$) compared to NO. No difference was found between OP-SLOWFAST and OP-FASTSLOW in performance time ($F=0.417$, $p=0.685$). Mean power output (PO) and velocity (V) were higher during both OP-SLOWFAST (PO: $F=3.274$, $p=0.007$; V: $F=3.090$, $p=0.010$) and OP-FASTSLOW (PO: $F=3.388$, $p=0.006$; V: $F=3.837$, $p=0.003$) compared to NO, while no difference was found between OP-SLOWFAST and OP-FASTSLOW (PO: $F=1.047$, $p=0.317$; V: $F=0.710$, $p=0.493$). Finally, participants adopted a higher mean cadence during NO compared to OP-SLOWFAST ($F=2.433$, $p=0.033$), but not compared to OP-FASTSLOW ($F=0.849$, $p=0.414$). No differences in mean cadence were found between OP-SLOWFAST and OP-FASTSLOW ($F=0.317$, $p=0.757$).

Table 1. Mean ± SD of the Completion times, Power outputs, Velocities and Cadence for each experimental condition.

Condition	Completion Time (sec)^{B,C}	Power output (W)^{B,C}	Velocity (km/h)^{B,C}	Cadence (rpm)^{A,B}
FAM	393.08 ± 31.5	279.0 ± 56.3	37.10 ± 2.88	97.1 ± 8.4
NO	390.57 ± 29.3	279.2 ± 51.5	37.30 ± 2.70	101.0 ± 10.8
OP-SLOWFAST	385.53 ± 27.5	288.4 ± 52.2	37.74 ± 2.63	97.6 ± 12.0
OP-FASTSLOW	384.98 ± 28.6	291.6 ± 57.2	37.84 ± 2.84	98.3 ± 13.1

^{A} Difference between FAM and NO (P<0.05), ^{B} Difference between NO and OP-SLOWFAST (P<0.05), ^{C} Difference between NO and OP-FASTSLOW (P<0.05), ^{D} Difference between OP-SLOWFAST and OP-FASTSLOW (P<0.05).

3.2 Pacing analysis

Mean power outputs per 250m section are shown in Figure 1. Main effects for condition (F=3.193, P=0.036), and distance (F=13.750, P<0.001), and an interaction effect for condition x distance (F=3.944, P<0.001) were found, indicating differences in pacing profile between conditions. Post-hoc analysis revealed that in the initial 1000m, a less aggressive starting strategy was adopted in NO compared to FAM, OP-SLOWFAST, and OP-FASTSLOW (see Figure 1 and Figure 2). Subsequently, higher power outputs in NO were found during the middle part compared to FAM. However, in the OP-SLOWFAST, and OP-FASTSLOW conditions, participants continued at a similar power output compared to NO after respectively 750m and 1000m. In addition, power output in the OP-FASTSLOW was higher compared to the OP-SLOWFAST condition during the 250-500m section, but lower during the 2250-2500m section. Mean times (in seconds) the participants were in front or behind their opponent during OP-SLOWFAST and OP-FASTSLOW are shown in Figure 3.

A significant main effect for distance (F=10.270, P<0.001), and an interaction effect for condition x distance (F=3.120, P<0.001) were found for cadence, while the main effect for condition was indifferent (F=1.092, P=0.332). Post-hoc analysis indicated no differences in cadence during OP-FASTSLOW compared to NO (F=1.092, P=0.332) or OP-SLOWFAST (F=1.092, P=0.332). In contrast, NO showed a higher cadence compared to OP-SLOWFAST after 1750m until 3750m.

No difference was found between conditions for % of TT completion for the second (F=0.370, P=0.695) and third (F=1.886, P=0.175) moment when RPE was asked. A difference between conditions for % of TT completion was found for the first moment when RPE was asked (F=2.346, P=0.022). Post-hoc analysis revealed only a significant difference between FAM and NO (F=2.984, P=0.003). Mean RPE scores after the warming-up, and before, during and after the time trial per condition were shown in Table 2. A main effect for distance (F=211.195, P<0.001), and condition (F=1.980, P=0.021) were found for RPE, while no condition x distance interaction effect (F=1.299, P=0.293) was found. However, post-hoc analysis revealed no differences between conditions for the RPE score before or during the time trials (see Table 2). RPE scores at the finish were higher in OP-FASTSLOW compared to NO (F=2.462, p=0.032) but not statistically significant in OP-SLOWFAST (F=2.206, p=0.052) compared to NO.

Table 2. RPE scores (6-20) before, during and after the 4-km time trial (TT). In addition, the average % completion time (Compl time %) at the moment of asking RPE is given.

	FAM		**NO**		**OP-SLOWFAST**		**OP-FASTSLOW**	
	RPE	Compl time %	RPE	Compl time %	RPE	Compl time %	RPE	Compl time %
Warm-up	10.2±2.6	N/A	9.3±2.0	N/A	8.8±2.3	N/A	9.6±3.0	N/A
TT start	6.7±1.1	0±0	6.4±1.0	0±0	6.5±1.2	0±0	6.6±1.4	0±0
TT 1	14.1±2.2	33±5[A]	12.9±2.7	23±4	13.5±2.3	23±5	13.6±2.2	27±6
TT 2	15.6±1.6	56±7	15.1±2.3	50±4	15.6±1.7	51±3	15.8±2.2	52±8
TT 3	17.2±1.7	78±7	17.0±1.7	79±6	16.9±1.4	76±7	17.5±1.6	80±8
TT finish	18.8±1.1	100±0	18.5±1.0	100±0	19.1±0.7[B]	100±0	19.3±0.8	100±0

[A] Difference between FAM and NO (P<0.05), [B] Difference between NO and OP-FASTSLOW (P<0.05).

4. Discussion

The present study explored whether different pacing strategies of a competing opponent would influence the pacing behavior of an athlete. Our main findings indicated that pacing behavior differed depending on the pacing profile of the virtual opponent. That is, a faster starting opponent evoked a faster start strategy in the competing participant compared to a slower starting opponent. In this respect, the present study adds a crucial determinant for the regulation of exercise intensity onto previous literature that suggested that the exercise intensity was regulated by a predetermined exercise template set in advance of the race, matching the expected physical sensations of effort with the actual physical sensations of effort [21,22]. The present study expanded on this idea and has shown that this suggested predetermined exercise template can be altered by the behavior of an opponent during the race. The behavior of an opponent seems to evoke an intuitive behavioral response in the beginning stages of race that could alter the deliberate decision to adopt a specific pacing profile. This supports the theoretical framework of Smits et al. [2] in which the decision-making processes involved in pacing depend on one's perception of action possibilities in the environment [2]. In this respect, the present study demonstrated that the behavior of an opponent appeared to invite athletes to change their behavior, thereby emphasizing the interaction with the environment as an important determinant for the regulation of the exercise intensity. The different actions of the opponents evoked different action responses in the participating subjects.

The construction of the virtual opponents was a crucial aspect for this study. In order to simulate real competitive situations, the opponents were constructed to be realistic and competitive for the participant. Previous research and pilot measurements indicated a performance improvement of 1% could be expected after the familiarization trial [13]. Therefore, the virtual opponents were constructed in such a way that their finishing time would be 1% faster compared to FAM. Indeed, finishing times in NO were on average 0.7% faster compared to FAM. As a result, the finishing times of the virtual opponents were not different compared to the finishing times of the participants in NO, supporting our aim to construct competitive opponents. With this experimental set-up, we have constructed an ideal situation to investigate how circumstantial factors can affect the regulation of exercise intensity in a sport-specific, well-controlled laboratory condition.

Another crucial element in the construction of the virtual opponents was that to evoke a behavioral response of the athlete, the opponents needed to perform clearly different pacing profiles compared to the self-paced performance of the participant, similar to as occurs in actual competition. Also in this respect, the present study succeeded in constructing realistic and competitive opponents. The pacing profiles of the virtual opponents as used in both opponent conditions were clearly different compared to each other and compared to the pacing strategy of the participants during NO (see Figure 2). However, due to the modification in pacing strategy towards a less aggressive start in NO compared to FAM, the relatively slow starting opponent compared to the participant in FAM had on average still a faster initial pace compared to the participant in NO (See Figure 2). Similar modifications in pacing strategy in consecutive trials have been found in previous studies, stressing the importance of the inclusion of a familiarization trial as done in the present study [7,13]. Those studies also indicated that the adopted pacing strategies became relatively stable after the first trial [7,13]. Nevertheless, adding a second familiarization session might have been useful as it could have produced a more consistent profile between FAM and NO.

Moderately trained participants were able to improve 4-km time trial performance against both opponents compared to their individual time trial performance (see Table 1). Previous research has shown that deceptive feedback had no additional acute or residual effect on performance [10]. Moreover, the performance enhancement when an opponent is present, appeared to be independent of the performance of the opponent, despite different psychological responses [11]. This study adds onto this knowledge by showing that the performance improvement when an opponent is present, is also independent of the pacing profile of the opponent.

The presence of a competitive opponent, independent of its pacing behavior, seems to enable the participants to use a greater degree of their physiologic capacity that cannot be fully accessed when competing alone [23]. In fact, previous literature showed a greater anaerobic energy capacity could be achieved during time trials when an opponent was present [6]. In addition, the presence of an opponent has been related to a greater external distraction, deterring perceived exertion when an opponent was present [8]. Indeed, differences in RPE were found between the experimental conditions after, but not during the race (see Table 2). One could argue that the improved performance in the opponent conditions compared to NO might be related to the faster VO_2 response associated with a faster start [24,25]. However, in this respect it seems reasonable to expect that the faster starting strategy as used in FAM would also lead to a better performance in FAM compared to NO. However, such an effect has not been found in the present study. Finally, visual perception of the opponent seems crucial for finding performance improvements such as those in the present study. Indeed, participants in previous research involving a non-visible opponent were not able to improve performance, even if a monetary reward was offered [7]. Again, this would suggest that perceptual affordances provided by the environment could influence the maximal effort an athlete is willing to exert, and alter pacing behavior and performance.

When racing against an opponent, the cyclists seemed to adapt their initial pace in order to keep up with the pace of their virtual opponent (see Figure 1 and 2). Interestingly, a change in pace of the opponent halfway the time-trial did not have a major effect onto the pacing behavior of the participants (Figure 2). The tendency to adjust the initial pace to other competitors seems to correspond to pacing strategies as demonstrated during actual athletic competitions. Elite middle- and long-distance runners tended to adopt a fast starting pace in order to keep up with the leaders [26–30]. In contrast, athletes adopted a slower initial pace during sports as track cycling and short-track speed skating [31–33], most likely due to the aerodynamic benefits of drafting behind your opponents [34]. The present study has shown that even without the presence of any aerodynamic benefit or disadvantages, athletes still are triggered to change their pacing based on the behavior the opponent. Nevertheless, the role of the specific demands of a sport, such as aerodynamic constraints, needs to be taken into account for optimal decision-making regarding pacing during actual competitions.

5. Conclusion

In conclusion, the present study is the first to show that not only presence, but also the behavior of an opponent affected decisions regarding the regulation of exercise intensity in laboratory-controlled conditions. These findings emphasize the interaction with the environment as an important determinant of pacing, supporting the suggestion that not only internal, but also external information is incorporated in the regulation of exercise intensity.

Acknowledgements and Conflict of Interest

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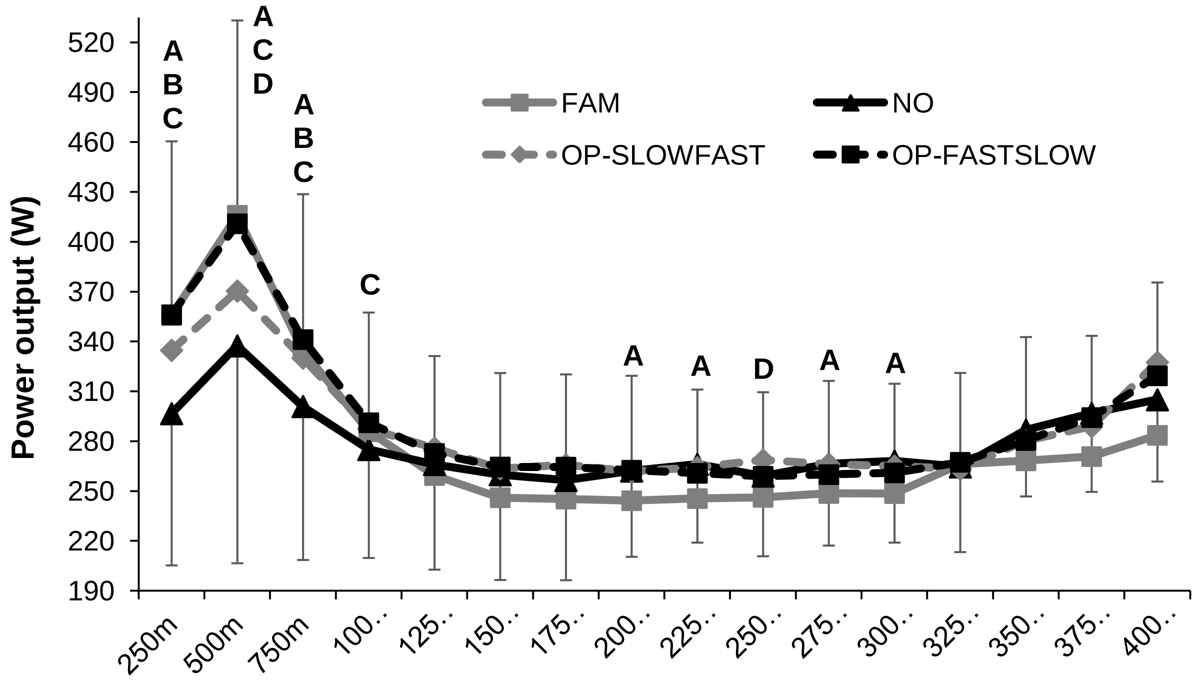

Figure 1: Average power output per 250m section for FAM, NO, OP-SLOWFAST, OP-FASTSLOW.

[A] Difference in power output between FAM and NO (P<0.05), [B] Difference in power output between NO and OP-SLOWFAST (P<0.05), [C] Difference in power output between NO and OP-FASTSLOW (P<0.05), [D] Difference in power output between OP-SLOWFAST and OP-FASTSLOW (P<0.05).

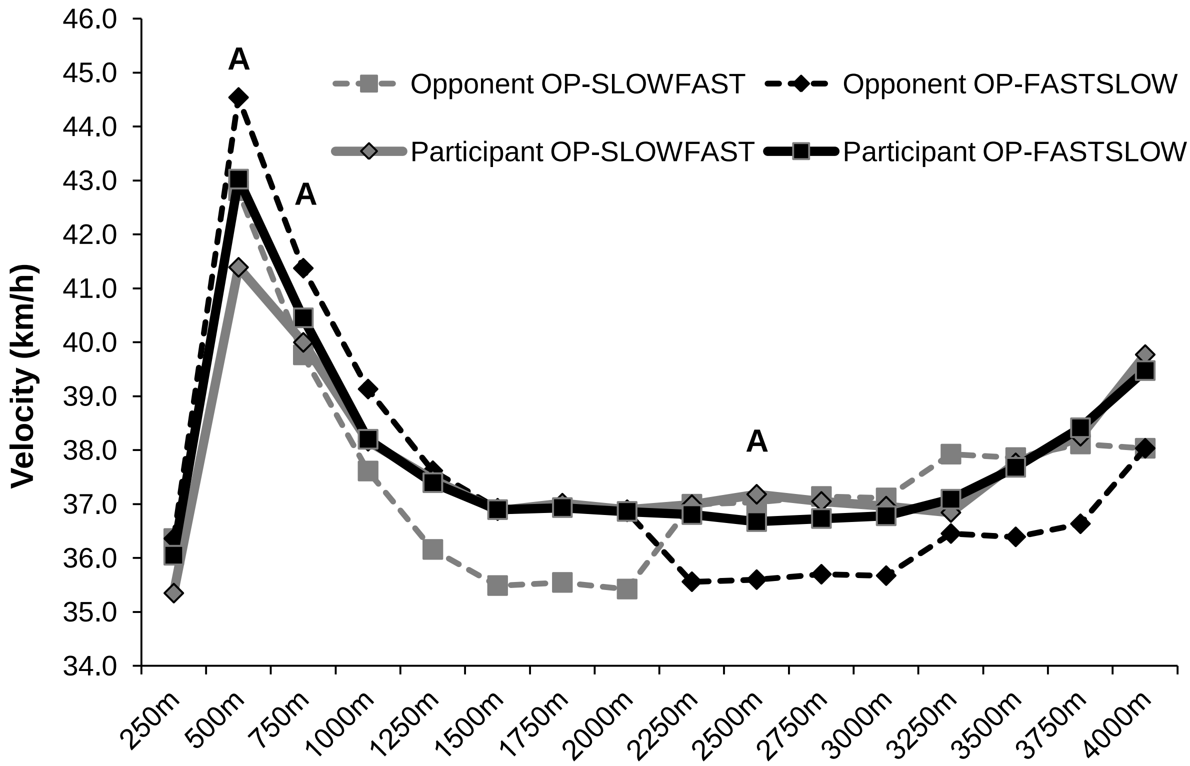

Figure 2: Average velocity per 250m section for NO, OP-SLOWFAST and OP-FASTSLOW and their respective opponents.
[A] Difference in velocity for participant between OP-SLOWFAST and OP-FASTSLOW (P<0.05)

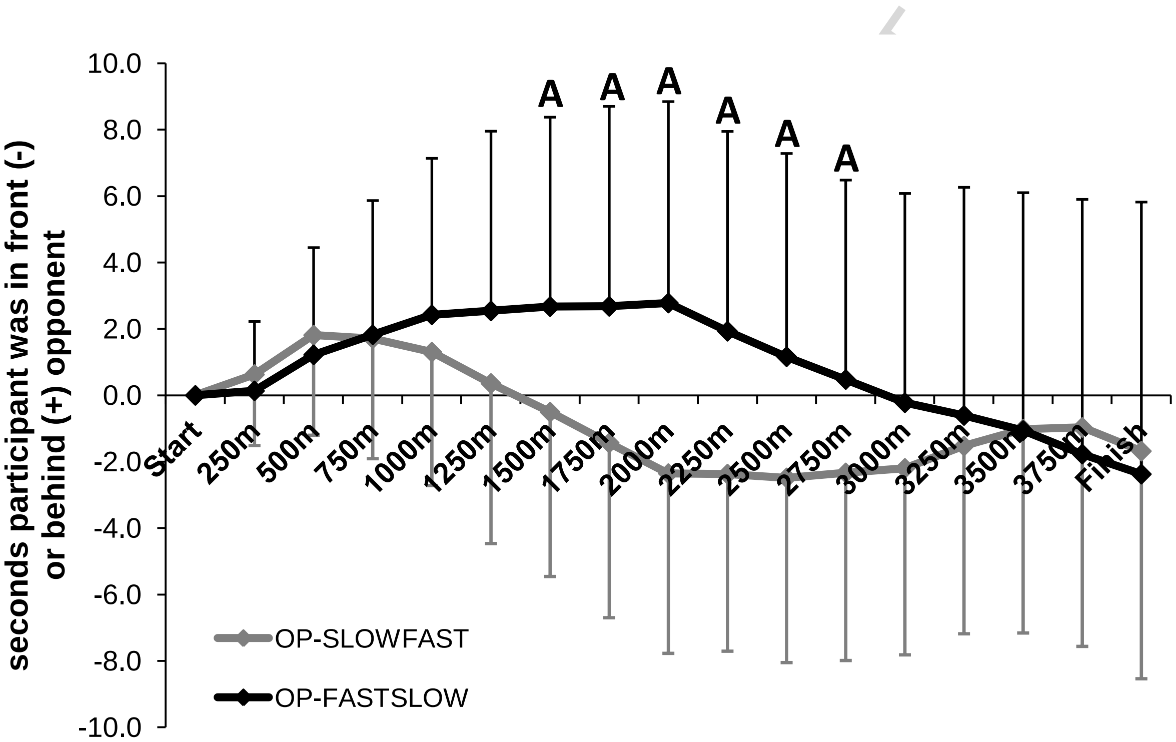

Figure 3: Average time in seconds the participant was in front (-) or behind (+) his opponent during OP-SLOWFAST and OP-FASTSLOW
[A] Difference between OP-SLOWFAST and OP-FASTSLOW in the time difference between opponent and participant (P<0.05).

Highlights

- The pacing behavior of an opponent alters pacing decisions of an athlete in lab-controlled conditions
- A faster starting opponent evokes a faster start compared to a slower starting one.
- The behavior of an opponent is an important determinant for an athlete's pacing decisions, which is thus far often overlooked in investigating pacing behavior.