A pre-exercise cycling protocol alters pacing behavior in competitive time-trials

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Abstract

Purpose: The behavior of an opponent has been shown to alter pacing and performance. To advance our understanding of the impact of perceptual stimuli such as an opponent on pacing and performance, this study examined the effect of a pre-exercise cycling protocol on exercise regulation with and without an opponent. *Methods:* Twelve trained cyclists performed four experimental, self-paced 4-km time trial conditions on an advanced cycle ergometer in a randomized, counterbalanced order. Participants started the time trial in Rested State (RS) or performed a 10-min Cycling Protocol at 67% peak power output (CP) before the time trial. During the time trials, participants had to ride alone (NO) or against a virtual opponent (OP). As such the experimental conditions were: 1) RS-NO, 2) RS-OP, 3) CP-NO and 4) CP-OP. Repeated-measures ANOVAs ($p < 0.05$) were used to examine differences in pacing and performance in terms of power output. *Results:* A faster pace was adopted in the first kilometer during RS-OP (318 ± 72 W) compared with RS-NO (291 ± 81 W; $p = 0.026$), leading to an improved finishing time during RS-OP compared with RS-NO ($p = 0.046$). No differences in either pacing or performance were found between CP-NO and CP-OP. *Conclusions:* the evoked response by the opponent to adopt a faster initial pace in their 4-km time trial disappeared when cyclists had to perform a preceding cycling protocol. The outcomes of this study highlight that perceived exertion alters the responsiveness to perceptual stimuli of cyclists during competition.

Key words: Pacing strategy; Competition; Sport; Decision-making; Perception

INTRODUCTION

Athletes are required to continuously make decisions during their competition about how and when to invest their available energy resources¹. This goal-directed regulation of their exercise intensity is also known as pacing². However, the underlying mechanisms behind this decision-making process involved in pacing are still strongly debated. Nevertheless, despite the variety of proposed pacing theories, what they all seem to agree on is the importance of sensations of fatigue and a willingness to tolerate discomfort, in anticipation of future rewards³.

In terms of the studies performed related to pacing, the focus up until quite recently has been mainly onto how exercisers are able to pre-plan pacing strategies, and concepts such as teleoanticipation⁴ and template formation⁵. In this sense, afferent feedback via group III/IV muscle afferents has been suggested as an important variable in the decision-making process regarding exercise regulation and performance^{1,6,7}. Indeed, impairing lower limb muscle afferent feedback via group III/IV muscle afferents led to a faster initial pace⁸. In addition, exercise-induced fatigue before the start of a race has been shown to evoke a more conservative starting pace, likely due to an increased perceived exertion⁹⁻¹¹. In this respect, previous research has reported a 10-min pre-exercise protocol at 67% of PPO results into a decreased performance and decline in muscle and potentiated twitch force^{9,12}. As it is well known that most neuromuscular changes induced by exercise typically dissipate within two to three minutes^{13,14}, one may assess the effect of perceived exertion due to a pre-exercise protocol on pacing and performance without the possibly confounding effect of muscle fatigue, by using this pre-exercise protocol of moderate intensity in combination with a rest period of more than 3 minutes after protocol completion and before the time trial.

Although feedback regarding the internal bodily state is crucial in exercise regulation, the importance of whatever is happening in the external world around the exerciser has been highlighted recently as crucial in the context of pacing^{1,15,16}. In this respect, previous research demonstrated that an external stimulus, for example an opponent, could also impact upon pacing behavior and performance while internal stimuli remain unchanged. The presence of a (virtual) opponent has been shown to invite exercisers to alter their pacing behavior¹⁷, and improve time trial performance¹⁷⁻²³. This performance improvement was found to be related to cyclists being able to handle higher levels of muscle fatigue in the presence of an opponent, without a change in perceived exertion²⁰. This supports the idea that perceptual affordances provided by the environment and perceived exertion impact the decision-making process involved in pacing.

To advance our understanding of the impact of perceptual stimuli such as an opponent on pacing and performance, this study examined the effect of a pre-exercise cycling protocol on exercise regulation with and without an opponent. Whereas perceived exertion is seen as one of the key regulators of pacing behavior, an increase in this variable before the time trial will likely affect the impact of a perceptual stimulus on pacing and performance. Therefore, it is hypothesized that the faster initial pace and enhanced performance evoked by the opponent's presence will disappear when a moderate increase in perceived exertion is induced to the participant via a cycling protocol in advance of the time trial.

MATERIALS AND METHODS

Participants

Twelve moderate physically active participants with at least two years of experience of cycling at a moderate to high intensity (age: 36.8 ± 10.0 years; body mass: 82.1 ± 13.9 kg; height: 1.80 ± 0.10 m) participated in this study. Before participating, all participants gave written informed consent and completed a health screening questionnaire (Physical Active

Readiness Questionnaire²⁴). The study was approved by the ethical committee of the University of Essex in accordance with the Declaration of Helsinki.

<<Please insert Figure 1 about here>>

Experimental design

A schematic overview of the study design can be found in Figure 1. Participants visited the laboratory on six separate occasions. During their first visit, participants performed a maximal incremental test. In their second to sixth visit, participants were asked to perform a self-paced 4-km time-trial at maximal effort. Participants completed an incremental test in their first visit to determine peak power output (PPO). A 5-minute warm-up at 100 W was followed by a 3-minute rest period before starting the test. The incremental test had an initial workload of 100 W and a workload increase of 25 W every minute until volitional exhaustion. Rating of Perceived Exertion (RPE) was recorded 10 seconds before each stage completion and directly after the point of volitional exhaustion. Participants were instructed to maintain a cadence within 80-100 rpm and given strong verbal encouragement in the later stages. The highest mean power output achieved during any 60 second period was recorded as the participant's PPO.

During their second visit, participants performed a self-paced familiarization 4-km time trial (FAM). During their third to sixth visits, participants completed one of the four experimental 4-km time trials in a randomized and counterbalanced order. In the experimental time trial conditions, the internal (perceived exertion) and/or external (opponent presence) status of the athlete-environment relationship were manipulated (see Figure 1). This will be done by manipulating both the (perceived) exertion before the exercise as well as the presence or absence of a virtual opponent (external stimulus). The (perceived) exertion before the start of the time trial will be altered via a pre-exercise cycling protocol of moderate intensity. As such, participants started the time trial in a rested state (RS) or performed a 10-minute cycling protocol at 67% peak power output⁹ (CP) before the time trial. During the time trials, participants had to ride alone (NO) or against a virtual opponent (OP). As a result, the experimental conditions were: 1) RS-NO, 2) RS-OP, 3) CP-NO and 4) CP-OP. In the trials involving the 10-min at 67% PPO pre-exercise cycling protocol, the 4-km time trials started 4 minutes after completion of the pre-exercise protocol. Before the trials with a virtual opponent, participants were told that their opponent would be of similar level of performance in order to make sure a participant would perceive his opponent as competitive. Although participants were unaware of this, the opponent was in fact their own previous performance during FAM.

Experimental procedures

Before each time trial, participants were instructed to complete the time trial as quickly as possible. No verbal coaching or motivation was given to the participants during any of the time trials. To minimize circadian variation, time trials were completed at the same time of the day (± 2 hours). Participants were asked to maintain normal activity and sleep pattern throughout the testing period. In addition, participants were asked to refrain from any alcohol consumption and strenuous exercise in the preceding 24 hours, 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 premeditated 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.

Time trials were performed on an advanced cycle ergometer (Velotron Dynafit, Racermate, Seattle, USA). 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. Only relative

distance feedback was provided during the time trials. All participants started each time trial in the exact same gear, being 52/19. Participants were allowed to change the gearing according to their own preferences throughout the time trial. In the opponent conditions, a virtual opponent was projected as well. Power output, velocity, distance, cadence, and gearing were monitored continuously during each trial (sample frequency = 4 Hz). In addition, heart rate was monitored every second (Polar M400, Polar Inc.). Rate of perceived exertion (RPE) was asked after the pre-exercise protocol, at 100 seconds, 200 seconds and 300 seconds after starting the time trial, and directly after passing the finish line on a Borg-scale of 6-20.

Statistical analyses

Mean power output, heart rate, cadence, and finish time were calculated to examine 4-km time trial performance. Data were assessed for normality using the Shapiro-Wilk test. Differences in performance between conditions were assessed using a repeated-measures ANOVA. To assess differences in pacing behavior between the conditions, mean power output, heart rate, cadence, and split times for each kilometer segment were calculated, and differences were tested using a two-way repeated-measures ANOVA (conditions x segment). In addition, RPE was evaluated using a two-way repeated-measures ANOVA (conditions x asking point). A Greenhouse-Geisser correction was used when sphericity could not be assumed. Post-hoc tests were performed when significant main or interaction effect were found for performance and/or pacing behavior. All analyses were performed using SPSS 19.0, and significance was accepted at $p < 0.05$. Data are presented as means $\pm$ SD.

RESULTS

The participants achieved a mean PPO of 351 ± 35 W in the maximal incremental test, and can be classified as trained cyclists based on the guidelines of De Pauw et al.²⁵

Performance analysis

Mean ($\pm$ SD) finishing time, power output, heart rate, and cadence for the four experimental time trial conditions are shown in Table 1. A main effect was found for finishing times ($F = 3.523$; $p = 0.026$), power output ($F = 4.127$; $p = 0.014$), heart rate ($F = 9.204$; $p < 0.001$), and cadence ($F = 3.911$; $p = 0.017$). Post hoc analysis revealed only a difference in finishing time between RS-NO and RS-OP ($p = 0.046$). Participants showed lower mean power outputs in RS-NO compared with RS-OP ($p = 0.020$) and CP-NO ($p = 0.024$), respectively. No differences in mean power output were found between CP-NO and CP-OP ($p = 0.486$), or between RS-OP and CP-OP ($p = 0.370$). Mean heart rate over the time trials was lower during RS-NO compared with RS-OP ($p = 0.026$), CP-NO ($p = 0.004$), and CP-OP ($p = 0.006$). In addition, mean heart rate was higher during both CP-NO ($p = 0.031$) as well as CP-OP ($p = 0.036$) compared with RS-OP. No differences in mean heart rate were found between CP-NO and CP-OP ($p = 0.800$). Finally, post hoc analysis showed that the participants adopted a lower cadence during CP-NO compared with RS-NO ($p = 0.044$) and RS-OP ($p = 0.023$), and during CP-OP compared with RS-NO ($p = 0.048$). No differences in cadence were found between RS-NO and RS-OP ($p = 0.669$), or between CP-NO and CP-OP ($p = 0.287$).

<<Please insert Table 1 about here>>

<<Please insert Figure 2 about here>>

Pacing analysis

Mean power outputs per kilometer are shown in Figure 2. Main effects for condition ($F = 4.127$, $p = 0.014$), and segment ($F = 5.821$, $p = 0.026$), and an interaction effect for condition

x segment ($F = 2.643$, $p = 0.017$) were found, indicating differences in pacing profile between conditions. Post hoc analysis revealed a faster initial pace during RS-OP compared with RS-NO, with higher power outputs between 0-1 km ($p = 0.026$). In addition, a faster end spurt (3-4 km) was noticed in RS-OP compared with RS-NO ($p = 0.031$). No differences in pacing were reported between RS-NO and CP-NO, RS-OP and CP-OP, or between CP-NO and CP-OP.

A main effect for heart rate was found for condition ($F = 8.681$, $p < 0.001$) and segment ($F = 132.3$, $p < 0.001$). An interaction effect was reported for condition x segment ($F = 6.365$, $p = 0.001$). Post hoc tests showed heart rate values were higher in the time trials in which a pre-exercise cycling protocol had to be completed during the first (all $p < 0.01$) and second kilometer. In addition, heart rate was higher in RS-OP compared with RS-NO in the first kilometer. A main effect for condition ($F = 3.911$, $p = 0.017$), and segment ($F = 20.99$, $p < 0.001$), but no interaction effect for condition x segment ($F = 1.027$, $p = 0.427$) was found for cadence.

Mean RPE scores per point of asking for each experimental condition are shown in Table 2. Main effects for condition ($F = 3.622$, $p = 0.024$), and point of asking ($F = 137.2$, $p < 0.001$), and an interaction effect for condition x point of asking ($F = 2.967$, $p = 0.028$) were found. Post-hoc analysis revealed higher RPE scores after 100 seconds into the time trial in both CP-NO and CP-OP compared with RS-NO ($p = 0.001$ and $p = 0.001$, respectively) and RS-OP ($p = 0.009$ and $p = 0.042$, respectively). In addition, RPE was higher 200 seconds into the time trial in both CP-NO and CP-OP compared with RS-NO ($p = 0.020$ and $p = 0.001$, respectively).

<<Please insert Table 2 about here>>

DISCUSSION

The present study examined the interaction between (perceived) exertion and the response to external stimuli in the context of pacing regulation. This has been done by manipulating the pre-exercise state and the presence/absence of an opponent (external stimulus). It has been shown that the faster initial pace and enhanced performance evoked by the opponent's behavior in the rested starting conditions disappeared after the induction of a moderate perceived exertion by a pre-exercise cycling protocol before the 4-km time trial. Thereby, our findings illustrate the importance of the interaction between external stimuli and (perceived) exertion on the regulation of the exercise intensity. Additionally, the present study adds onto the existing knowledge by taking the novel approach to not only manipulate the external stimulus (i.e. the virtual opponent) as previously done, but to also manipulate the internal exercise status of the athlete before the time trial with and without opponent.

When participants had to complete a pre-exercise cycling protocol before their 4-km time trial, the presence of an opponent did not lead to an improvement in performance. In addition, the evoked response by the opponent to adopt a faster initial pace disappeared. A crucial factor for this lack of an effect could be related to the increased perceived exertion in the initial stages of the time trial after the pre-exercise cycling protocol compared with the rested time trials. The importance of perceived exertion as a key regulator in pacing has been highlighted frequently²⁶⁻²⁸. Similarly, perception of exertion has often been related to performance^{27,29}. Indeed, exercising in conditions such as hypoxia³⁰, hyperoxia³¹ or hot temperatures³⁰ altered power output, but not rate of perceived exertion over the race compared with control conditions.

In this perspective, our findings support the assumption that an exerciser's perceived action capabilities in terms of exercise regulation appear to be strongly related to the exerciser's perceived exertion. Therefore it is crucial to gain insight into how perceived exertion is derived, in order to understand the underpinning mechanisms influencing the selection of

pace. A higher RPE is typically associated with increased physiological stress and fatigue²⁸. However, the factors that influence one's perceived exertion during exercise are extremely complicated as perceived exertion is believed to be influenced by numerous factors, including effort, strain, pain, discomfort and/or fatigue^{27,28}. In this respect, a reciprocal interaction appears to exist between perceptual stimuli and perceived exertion. That is, where Konings et al.²⁰ has shown an effect of a perceptual stimulus on perceived exertion, the present study demonstrates that when an increased perceived exertion was induced before the exercise task the effect of the perceptual stimulus on pacing and performance disappears. This means that during demanding exercise tasks, internal and external stimuli cannot be seen as separate entities when related to the decision-making process involved in exercise regulation, but rather interact and continuously impact on each other throughout the exercise task. In this respect, it is also important to gain more insight into individual differences that may exist in how one responds to a perceptual stimuli, possibly related to specific personality traits as competitiveness or risk perception. Moreover, to further explore the generalizability of the effects of motivating incentives on pacing and performance to other groups and settings, it is advised for future research to use real-life competitors or monetary rewards, and to use different target population such as for example elite athletes, inexperienced children, or individuals with an intellectual disability.

Previous studies showed that the induction of moderate to high levels of muscle fatigue and/or muscle damage before the start of a race, caused by either a pre-exercise protocol⁹⁻¹¹ or intensive training periods³², evoked a more conservative starting pace. Interestingly, the pre-exercise cycling protocol in advance of the time-trials in this study, did not negatively affect time trial performance. However, where previous studies aimed specifically to enhance (muscle) fatigue, the aim of the pre-exercise cycling protocol in this study was to enhance perceived exertion before starting the time trial. In fact, to minimize the effect of muscle fatigue we chose a pre-exercise protocol of moderate intensity and a 4-min rest period after protocol completion before the time trial, whereas it is well known that most neuromuscular changes induced by exercise typically dissipate within two to three minutes^{13,14}. There are several indications that the 10-min pre-exercise cycling protocol did succeed in enhancing perceived exertion in our participants. First of all, reported RPE scores before starting the time trial were higher after completion of the pre-exercise cycling protocol in comparison to the control conditions. In addition, relatively higher RPE scores and higher heart rate values were found in the initial phase of the time-trial in the pre-exercise cycling protocol time trial conditions.

Nevertheless, previous research has still reported a 10-min pre-exercise protocol at 67% of PPO could result into a decreased performance¹². Again, the 4-min rest period after protocol completion before the time trial could have reduced the detrimental effect on performance in relation to this previous study. In fact, one could argue that the performance in the pre-exercise protocol conditions might have benefitted from a faster VO₂ response associated with a relatively more intense warm-up³³. However, in this respect it seems reasonable to expect that the pacing differences due to the presence of a virtual competitor should still exist as in the resting conditions, whereas the same pre-exercise protocol was performed before both conditions. However, such an effect has not been found in the present study.

Practical Applications

The controlled situation of a laboratory cycling time trial experiment has proven to be an effective method to explore the environmental influence of a competitor on pacing behavior and performance¹⁷⁻²³. The presence of a virtual competitor has been shown to improve time trial performance in cycling^{17-20,22,23} as well as in 5-km running²¹. This performance improvement has been related to a decreased internal focus of attention¹⁹, higher anaerobic contribution¹⁸, improved heat tolerance²³, and the ability to handle higher levels of muscle

fatigue without changing perceived exertion²⁰. Our findings support this existing literature that trained cyclists are able to improve their performance when an opponent is present in rested conditions. In addition, our findings confirm that in rested conditions the initial behavior of a virtual opponent could invite a cyclist to adopt a faster initial pace¹⁷. However, when participants had to complete a pre-exercise cycling protocol before their 4-km time trial, the presence of an opponent did not lead to an improvement in performance. In addition, the evoked response by the opponent to adopt a faster initial pace disappeared. These outcomes highlight that cyclists respond differently to a competitive situation based on their perceived exertion, potentially leading to impaired tactical decision-making during competitions.

Conclusions

The present study has shown once again that providing an external stimulus (i.e. presence of an opponent) impacts upon exercise regulation^{3,17–20,22,23}. However, a novel finding was that the evoked response by the opponent to adopt a faster initial pace appeared to diminish when the internal status of the participants was altered due to engagement in a pre-exercise cycling protocol of moderate intensity before the start of the time trial. This lack of behavioral response to the opponent after pre-exertion is likely related to the increase in perceived exertion before the time trial exercise caused by the pre-exercise protocol, as the pacing response to the behavior of an opponent in the same participants is still apparent in rested state. In this respect, our findings highlight that perceived exertion alters the responsiveness to perceptual stimuli of cyclists during competition.

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FIGURE CAPTIONS

Figure 1. Schematic overview of experimental set-up. Visit 3-6 were performed in randomized counterbalanced order and each visit was separated by at least 48 hours.

Figure 2. Average power output per kilometer segment for each experimental condition. In addition, the average power output per kilometer of the virtual opponent in the experimental conditions RS-OP and CP-OP is displayed.

*Difference between RS-NO and RS-OP ($p < 0.05$)