Effects of Priming and Pacing Strategy on Oxygen-Uptake Kinetics and Cycling Performance

Stephen J. Bailey, Anni Vanhatalo, Matthew I. Black, Fred J. DiMenna, and Andrew M. Jones

Purpose: To assess whether combining prior “priming” exercise with an all-out pacing strategy is more effective at improving oxygen-uptake (VO₂) kinetics and cycling performance than either intervention administered independently. Methods: Nine men completed target-work cycling performance trials using a self-paced or all-out pacing strategy with or without prior severe-intensity (70%Δ) priming exercise. Breath-by-breath pulmonary VO₂ and cycling power output were measured during all trials. Results: Compared with the self-paced unprimed control trial (22 ± 5 s), the VO₂ mean response time (MRT) was shorter (VO₂ kinetics were faster) with all-out pacing (17 ± 4 s) and priming (17 ± 3 s), with the lowest VO₂ MRT observed when all-out pacing and priming were combined (15 ± 4 s) (P < .05). However, total O₂ consumed and end-exercise VO₂ were only higher than the control condition in the primed trials (P < .05). Similarly, cycling performance was improved compared with control (98 ± 11 s) in the self-paced primed (93 ± 8 s) and all-out primed (92 ± 8 s) trials (P < .05) but not the all-out unprimed trial (97 ± 5 s; P > .05). Conclusions: These findings suggest that combining an all-out start with severe-intensity priming exercise additively improves VO₂ MRT but not total O₂ consumption and cycling performance since these were improved by a similar magnitude in both primed trials relative to the self-paced unprimed control condition. Therefore, these results support the use of priming exercise as a precompetition intervention to improve oxidative metabolism and performance during short-duration high-intensity cycling exercise, independent of the pacing strategy adopted.

Keywords: pulmonary VO₂, warm-up exercise, fast start, all-out start, near-infrared spectroscopy, exercise performance

Cycling performance is a function of the power required to overcome resistive forces (eg, air and rolling resistance) and power generation from the contracting skeletal muscles.1,2 The potential of the skeletal muscles to maintain a high power output is influenced by the energy contribution from aerobic and anaerobic metabolism.3,4 While oxidative ATP turnover increases exponentially after the onset of exercise, muscle ATP demand increases immediately, which mandates an important energy contribution from anaerobic metabolism in the initial stages of exercise.5 At a given rate of ATP turnover, speeding the rate at which pulmonary oxygen uptake (VO₂) increases over the initial stages of exercise would be expected to attenuate the reliance on the finite anaerobic energy reserves and blunt the accumulation of metabolites linked to the process of muscle fatigue.5 Therefore, interventions that enhance pulmonary VO₂ kinetics would be hypothesized to increase mean skeletal-muscle power output during short-duration high-intensity exercise, permitting a higher cycling speed and a faster race-completion time.6

Pulmonary VO₂ rises with more-rapid overall response kinetics after prior “priming” exercise compared with control7–9 and also when exercise is initiated with a fast-start or all-out strategy compared with even-start and slow-start strategies.10–12 Moreover, performing priming exercise before9 or adopting fast-start or all-out pacing strategies during11,15 exercise at very high work rates, where fatigue ensues before the peak VO₂ (VO₂peak) can be attained (ie, extreme-intensity exercise),16 increases the percentage of VO₂peak that can be achieved. In addition to improving aspects of VO₂ kinetics, priming exercise and fast-start or all-out pacing strategies have been shown to improve exercise tolerance7,9,14 and performance,8,10–12,15,17–22 Since prior warm-up exercise and fast-start strategies are recommended as interventions to enhance VO₂ kinetics and athletic performance,23 understanding if and how priming exercise and different pacing strategies interact might help inform best practice for optimizing exercise performance.

The purpose of this study was to investigate whether combining prior severe-intensity priming exercise with an all-out pacing strategy would have an additive effect on the improvements in performance and VO₂ kinetics that have been reported when either of these interventions is applied independently. We hypothesized that, compared with a self-paced unprimed control condition, time-trial performance, VO₂ kinetics, total O₂ consumption, and the percentage of VO₂peak attained would be improved by a similar extent in a self-paced primed trial and an all-out unprimed trial, but the greatest improvement in these parameters would occur when severe-intensity priming exercise and an all-out pacing strategy were combined.

Methods

Subjects
Nine competitive male athletes (mean ± SD age 20 ± 1 y, stature 1.82 ± 0.06 m, body mass 77 ± 8 kg) volunteered to participate.
in this study. The study was approved by the University of Exeter research ethics committee, and all subjects were required to give their written informed consent before the commencement of the study. Subjects were instructed to arrive at the laboratory in a rested and fully hydrated state, at least 3 hours postprandial, and to avoid strenuous exercise in the 24 hours preceding each testing session.

Experimental Overview

The subjects were required to report to the laboratory on 7 occasions over a 4- to 5-week period, with the 7 visits being separated by at least 48 hours. After the completion of preliminary exercise tests, all subjects completed 4 exercise performance trials (visits 4–7) during which pulmonary VO$_2$, blood [lactate], muscle (de) oxygenation, and exercise performance were assessed. To determine a potential interaction between pacing strategy and priming exercise on performance and the physiological responses during exercise, we employed a paradigm comprising 2 different pacing strategies (self-paced and all-out) that were completed with and without priming exercise.

Incremental Test

On the first laboratory visit, subjects completed a ramp-incremental cycling test for determination of VO$_{2peak}$, gas-exchange threshold (GET), and the work rate that would require 70%Δ of the difference between the work rate at the GET and VO$_{2peak}$ as described previously. Subjects were provided with a 5-second countdown before the commencement of all cycling trials. In addition to a warm-up, the first trial was used to familiarize subjects with the fixed resistance that would be imposed in all subsequent trials. In this first trial, subjects were instructed to complete the 40-kJ warm-up by cycling at a submaximal cadence of 70 to 90 rpm. After a 10-minute passive recovery period, subjects repeated the 40-kJ trial, but, on this occasion, they were instructed to complete the 40 kJ in the fastest time possible using a self-selected pacing strategy. After a further 25- to 30-minute passive recovery, subjects completed a third 40 kJ trial using an all-out pacing strategy. The power output was continuously recorded at 5 Hz during these trials and averaged into 1-second bins for subsequent analysis. To estimate the work required for a completion time of 100 seconds for each individual subject, the mean power output during the self-paced trial was multiplied by 100. This individualized work target was set during all subsequent experimental trials in an attempt to yield a completion time reflective of a 1000-m track cycling performance.

Familiarization Trials

During the first familiarization trial (visit 2), subjects were familiarized with the standing start and were required to complete three 40-kJ trials lasting approximately 100 seconds. The resistance on the pedals during the trials was set for each individual using the linear mode of the Lode ergometer so that the subject would attain the power output associated with 70%Δ on reaching his preferred cadence (linear factor = power/preferred cadence$^2$). Subjects were provided with a 5-second countdown before the commencement of all cycling trials. In addition to a warm-up, the first trial was used to familiarize subjects with the fixed resistance that would be imposed in all subsequent trials. In this first trial, subjects were instructed to complete the 40-kJ warm-up by cycling at a submaximal cadence of 70 to 90 rpm. After a 10-minute passive recovery period, subjects repeated the 40-kJ trial, but, on this occasion, they were instructed to complete the 40 kJ in the fastest time possible using a self-selected pacing strategy. After a further 25- to 30-minute passive recovery, subjects completed a third 40 kJ trial using an all-out pacing strategy. The power output was continuously recorded at 5 Hz during these trials and averaged into 1-second bins for subsequent analysis. To estimate the work required for a completion time of 100 seconds for each individual subject, the mean power output during the self-paced trial was multiplied by 100. This individualized work target was set during all subsequent experimental trials in an attempt to yield a completion time reflective of a 1000-m track cycling performance for a trained but subelite cyclist.

During the second familiarization trial, subjects were familiarized with the priming-exercise protocol and completed 2 additional trials at their individualized work target. The priming-exercise protocol comprised 4 minutes of baseline cycling at 20 W before an abrupt transition to the severe-intensity target work rate (70%Δ). The severe-intensity priming bout was 5 minutes in duration. After a 17-minute passive recovery, subjects remounted the cycle ergometer and rested for an additional 3 minutes. This priming regimen was selected since it has been shown to be particularly effective at improving performance during subsequent high-intensity cycling exercise. Subjects then completed their individualized work target as quickly as possible using a self-paced pacing strategy. After 25- to 30-minute passive recovery, they completed a third performance trial using an all-out pacing strategy. Therefore, all subjects completed 5 repetitions of the performance trial and 1 repetition to the priming bout before the experimental testing.

Experimental Trials

In a randomized order, subjects completed self-paced and all-out trials with and without severe-intensity priming exercise over 4 separate experimental trials. They were instructed to complete each trial as quickly as possible. Each trial was preceded by 3 minutes of resting on the cycle ergometer. Ten seconds before the commencement of each trial, subjects were instructed to adjust the crank angle to their preferred starting position, which was established in the familiarization trials and replicated in all experimental trials, and to assume a standing position on the cycle ergometer. They were then provided with a 5-second countdown to indicate when the trial would commence. For the initial 10 seconds of the trial, subjects were required to cycle in the upright position before being instructed to assume a seated position for the remainder of the trial. They were made aware of their work target before each trial, and the work target and accrued work during the trial were displayed on a computer screen placed directly in front of them. Strong verbal encouragement was provided during all trials, but subjects were not aware of the elapsed time during the trials.

Measurements

All cycle tests were performed on an electronically braked cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands). During all tests, pulmonary-gas exchange and ventilation were measured breath by breath using an online gas analyzer (Jaeger Oxycon Pro, Hoechberg, Germany). Muscle-oxygenation variables (deoxygenated hemoglobin concentration [HHb], oxygenated hemoglobin concentration [O$_2$Hb], total hemoglobin concentration [Hb$_{tot}$], and tissue oxygenation index [TOI]) were measured using near-infrared spectroscopy (model NIRO 300, Hamamatsu Photonics KK, Higashi-ku, Japan), and a blood sample was collected from a fingertip into a capillary tube 30 seconds before the commencement of the trial and immediately after the trial for blood [lactate] determination (YSI 1500, Yellow Springs Instruments, Yellow Springs, OH, USA), as described previously.

Data-Analysis Procedures

Before analysis, the breath-by-breath VO$_2$ data from each test were treated as described previously. A single-exponential model without time delay, with the fitting window commencing at $t = 0$ second (equivalent to the mean response time, MRT) was used to characterize the kinetics of the overall VO$_2$ response during the trials as described in the equation $\text{VO}_2(t) = \text{VO}_2\text{baseline} + A(1-e^{-t/\text{MRT}})$, where $\text{VO}_2(t)$ represents the absolute VO$_2$ at a given time $t$, $\text{VO}_2\text{baseline}$ represents the mean VO$_2$ measured over the final 90 seconds of baseline, and $A$ and MRT represent the amplitude and MRT, respectively, describing the overall increase in VO$_2$ above baseline. An iterative process was used to minimize the sum of the squared errors between the fitted function and the observed values.
We quantified the \( \dot{V}O_2 \) MRT with the fitting window constrained to both completion time (end exercise) and at the minimum completion time for each subject across the 4 experimental trials (\( T_{\text{min}} \)). The absolute \( \dot{V}O_2 \) at, and the total \( O_2 \) consumed up to, 60 seconds (\( \pm 5 \) s), end exercise (average over the final 10 s), and \( T_{\text{min}} \) (average over the final 10 s) were also calculated. We also divided the total \( O_2 \) consumed up to 60 seconds by the work accumulated over the corresponding time frame to provide an indication of the oxidative energy provision relative to external power output.

The \([HHb]\), \([O2Hb]\), \([Hb_{tot}]\), and TOI values at baseline (average over the 90 s preceding the onset of the trial), 20 seconds (\( \pm 5 \) s), 60 seconds (\( \pm 5 \) s), and end exercise (average over the final 10 s) were also calculated.

Performance during the fixed-work trial was determined by the time required to complete the designated work target. Peak power output during the trials was taken as the highest 1-second power output during the trial, and end-exercise power output was taken as the average power output over the final 10 seconds of the trial.

### Statistical Analysis

A 2-way (pacing \( \times \) priming) repeated-measures ANOVA was employed to determine the effects of pacing strategy and priming exercise on the relevant physiological and performance variables. Where the analysis revealed a significant difference, individual paired \( t \) tests were employed with a Fisher least-significant difference to determine the origin of such effects. All data are presented as mean \( \pm \) SD. Statistical significance was accepted when \( P < .05 \).

### Results

During the ramp-incremental test, subjects attained a peak work rate of 370 \( \pm \) 45 W and a \( \dot{V}O_2 \)peak of 4.18 \( \pm \) 0.56 L/min. The work target for the performance trials was 41.3 \( \pm \) 4.8 kJ and the work rate applied during the severe-intensity priming bout was 273 \( \pm \) 37 W.

### Blood [Lactate]

Baseline blood [lactate] was greater in the primed trials (\( P < .001 \); Table 1). End-exercise blood [lactate] was higher in the self-paced primed and all-out primed trials than in the self-paced unprimed control trial (\( P < .05 \)) but not the all-out unprimed trial (\( P > .05 \); Table 1).

### Near-Infrared Spectroscopy

Baseline muscle \([O_2Hb]\), \([Hb_{oxo}]\), and TOI values were higher in the primed trials (\( P < .05 \); Table 2). Muscle \([O_2Hb]\) and \([Hb_{oxo}]\) were greater during exercise in the primed trials, whereas TOI was higher 20 seconds into exercise in the primed trials than in the all-out unprimed condition (\( P < .05 \); Table 2). Muscle \([HHb]\) \( \tau + TD \) was shorter in both primed trials than in the self-paced unprimed control (\( P < .05 \); Figure 1; Table 2).

### VO2 Kinetics

Compared with the self-paced unprimed control, the \( \dot{V}O_2 \) MRT was shorter in all other experimental conditions (\( P < .05 \)). Moreover, the \( \dot{V}O_2 \) MRT was shorter in the all-out primed than in the all-out unprimed and self-paced primed conditions (\( P < .05 \); Table 3, Figure 2). The total \( O_2 \) consumed and the total \( O_2 \) consumed divided by work done over the first 60 seconds of exercise were greater in the self-paced primed and all-out primed trials than in their respective unprimed conditions (\( P < .01 \); Table 3). In the unprimed trials the end-exercise \( \dot{V}O_2 \) was lower than the ramp test \( \dot{V}O_2 \)peak and the end-exercise \( \dot{V}O_2 \) during the primed trials (\( P < .05 \)), whereas the end-exercise \( \dot{V}O_2 \) during the primed trials was not different from the \( \dot{V}O_2 \)peak (\( P > .05 \); Table 3).

### Cycling Performance

The peak power output and total work done over the first 60 seconds were higher in the all-out trials (\( P < .05 \)), whereas end-exercise power output was higher with priming (\( P < .05 \); Figure 3). Trial-completion time was faster than control (98 \( \pm \) 11 s) in the self-paced (93 \( \pm \) 8 s) and all-out (92 \( \pm \) 8 s) primed trials (both \( P < .05 \)) but not with all-out pacing alone (97 \( \pm \) 5 s; \( P > .05 \); Figure 4). Completion time was also shorter in the all-out trial after priming than in the all-out trial without priming (\( P < .05 \)).

### Discussion

The principal original findings from this study are that muscle (de)oxygennation, pulmonary \( VO_2 \), and performance were similar during short-duration high-intensity cycling exercise initiated with a self-paced or all-out pacing strategy in the unprimed state, but these variables were enhanced by a similar magnitude when either of these pacing strategies was preceded by a bout of priming exercise. These findings might have important implications for performance enhancement in short-duration high-intensity events such as 1000-m track cycling and suggest that priming exercise is similarly effective at improving muscle (de)oxygennation, pulmonary \( VO_2 \), and cycling performance irrespective of whether an all-out or self-paced pacing strategy is applied.

When all-out pacing and priming were combined, the \( \dot{V}O_2 \) MRT (when modeled to \( T_{\text{min}} \)) was 12% shorter than in either intervention administered independently, or 32% shorter than the control trial. The \( \dot{V}O_2 \) MRT was 23% shorter than in the control trial with priming or all-out pacing alone. Faster overall \( VO_2 \) kinetics have been reported in previous studies after priming exercise and
when fast-start strategies are employed. In contrast to the findings of this study, a recent study observed no additive effect of combining heavy-intensity priming and a fast-start strategy on the \( V\dot{O}_2 \) MRT. These conflicting findings might be linked to between-studies differences in priming intensity and pacing strategies and the potential for more-rapid \( V\dot{O}_2 \) kinetics with the severe-intensity priming and all-out pacing strategy used in the current study relative to the heavy-intensity priming and fast-start strategy imposed by Caritá et al. Nonetheless, despite an additive improvement in the \( V\dot{O}_2 \) MRT, the total \( O_2 \) consumed up to Tmin and the \( V\dot{O}_2 \) attained at end exercise were higher in both primed trials but were not different between the 2 primed trials or between the 2 unprimed trials. Indeed, subjects were able to attain their \( V\dot{O}_2\text{peak} \) (ie, as measured on the initial ramp test) during the short-duration cycling bouts after priming regardless of pacing strategy employed, whereas without priming, they were not. This is consistent with reports that priming exercise permits the attainment of \( V\dot{O}_2\text{peak} \) during extreme-intensity exercise where \( V\dot{O}_2\text{peak} \) is not attained in the unprimed condition. Therefore, the attainment of \( V\dot{O}_2\text{peak} \) with priming permitted a greater total \( O_2 \) consumption, whereas the faster \( V\dot{O}_2 \) kinetics with an all-out start were not sufficient to increase total \( O_2 \) consumption, as the percentage of \( V\dot{O}_2\text{peak} \) attained was not significantly altered.

Muscle blood flow at rest and during the initial stages of exercise have been shown to increase after intense priming exercise. Our findings of a greater muscle \([Hbtot]\), \([O2Hb]\), and TOI with priming are compatible with previous reports of improved muscle perfusion and \( O_2 \) availability after priming. However, in addition to greater muscle \( O_2 \) delivery, enhanced muscle \( O_2 \) extraction and faster muscle \([HHb]\) kinetics have also been previously reported after priming exercise. In line with these findings, muscle \([HHb]\) \( \tau + TD \) was shorter with priming in this study, suggestive of enhanced fractional \( O_2 \) extraction contributing to faster \( V\dot{O}_2 \) kinetics after priming.

### Table 2 Muscle-Oxygenation Responses During the SP-UP, AO-UP, SP-P, and AO-P Conditions, Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>SP-UP</th>
<th>AO-UP</th>
<th>SP-P</th>
<th>AO-P</th>
</tr>
</thead>
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<td><strong>Muscle deoxyhemoglobin</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>baseline (A.U.)</td>
<td>–3 ± 5</td>
<td>–4 ± 3</td>
<td>–6 ± 4*</td>
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<td>20 s (A.U.)</td>
<td>27 ± 11</td>
<td>28 ± 9</td>
<td>25 ± 11</td>
<td>28 ± 11</td>
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<tr>
<td>60 s (A.U.)</td>
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<td>25 ± 9</td>
<td>25 ± 11</td>
<td>27 ± 11</td>
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<td>end exercise (A.U.)</td>
<td>24 ± 11</td>
<td>23 ± 8</td>
<td>24 ± 10</td>
<td>26 ± 11</td>
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<td>( \tau + ) time delay peak fit (s)</td>
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<td>8 ± 2</td>
<td>6 ± 2*</td>
<td>6 ± 2*</td>
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<td>7 ± 2</td>
<td>5 ± 2*</td>
<td>5 ± 2*</td>
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<td><strong>Muscle oxyhemoglobin</strong></td>
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<td><strong>Muscle total hemoglobin</strong></td>
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<td><strong>Tissue-oxygenation index</strong></td>
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<td>end exercise (%)</td>
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<td>38 ± 10</td>
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<td>38 ± 11</td>
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</table>

Abbreviations: SP, self-paced; UP, unprimed; AO, all-out; P, primed; A.U., arbitrary units; Tmin, minimum completion time across the 4 trials for each subject.

*Significantly different from SP-UP (\( P < .05 \)). ¥Significantly different from AO-UP (\( P < .05 \)).
Table 3  Pulmonary-Oxygen-Uptake Responses During the SP-UP, AO-UP, SP-P, and AO-P Conditions, Mean ± SD

<table>
<thead>
<tr>
<th></th>
<th>SP-UP</th>
<th>AO-UP</th>
<th>SP-P</th>
<th>AO-P</th>
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</thead>
<tbody>
<tr>
<td>Baseline (L/min)</td>
<td>0.59 ± 0.10</td>
<td>0.58 ± 0.08</td>
<td>0.68 ± 0.13*</td>
<td>0.63 ± 0.15</td>
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<td>60 s (L/min)</td>
<td>3.81 ± 0.38</td>
<td>3.73 ± 0.40</td>
<td>4.07 ± 0.52¥</td>
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<td>End exercise (L/min)</td>
<td>3.80 ± 0.36‡</td>
<td>3.77 ± 0.39‡</td>
<td>3.97 ± 0.47¥</td>
<td>3.92 ± 0.42¥</td>
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<td>Mean response time T_min (s)</td>
<td>22 ± 5</td>
<td>17 ± 3*</td>
<td>17 ± 3*</td>
<td>15 ± 4¥†</td>
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<tr>
<td>Mean response time end exercise (s)</td>
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<td>17 ± 3*</td>
<td>17 ± 3*</td>
<td>15 ± 4¥†</td>
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<tr>
<td>Total O₂ consumed to 60 s (L)</td>
<td>2.95 ± 0.34</td>
<td>3.03 ± 0.31</td>
<td>3.26 ± 0.25¥</td>
<td>3.28 ± 0.32¥</td>
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<td>Total O₂ consumed/work to 60 s (mL/kJ)</td>
<td>103 ± 11</td>
<td>99 ± 7</td>
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<td>Total O₂ consumed to T_min (L)</td>
<td>4.82 ± 0.34</td>
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<td>Total O₂ consumed to end exercise (L)</td>
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<td>5.30 ± 0.57</td>
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</table>

Abbreviations: SP, self-paced; UP, unprimed; AO, all-out; P, primed; T_min, minimum completion time across the 4 trials for each subject.

*Significantly different from SP-UP (P < .05). ¥Significantly different from AO-UP (P < .05). †Significantly different from SP-P (P < .05). ‡Significantly different from the pulmonary oxygen uptake determined in the ramp test (P < .05).
and greater O2 consumption after priming exercise in this study are likely to have arisen as a result of a positive interaction between improvements in muscle O2 supply and O2 extraction.

Although total O2 consumption over the initial 60 seconds of exercise was greater with priming, changes in total O2 consumption between the experimental conditions were not proportional to alterations in power output in all conditions. Commencing exercise at a higher power output, as observed when all-out pacing strategies are employed, would be expected to promote more-rapid increases in aerobic, anaerobic, and total ATP turnover rates. Therefore, while VO2 increased more rapidly in the all-out trials than in the self-paced unprimed trial, this potential for an increased aerobic energy yield in the all-out conditions was accompanied by a greater total work done over the initial stages of exercise. However, since priming exercise does not increase the total ATP turnover rate in a subsequent bout of exercise at the same absolute work rate and since the pattern of work-rate distribution over the first 60 seconds was similar for primed and unprimed conditions when the same pacing strategy was employed, the total ATP turnover rate and its temporal fluctuation might be expected to be similar between the 2 self-paced trials and the 2 all-out trials. The O2 consumed per unit work over the first 60 seconds was higher after priming (−9% and −7% for self-paced primed compared with self-paced unprimed and all-out primed compared with all-out unprimed, respectively). This is suggestive of a greater proportional aerobic energy contribution in the self-paced primed and all-out primed trials relative to their respective unprimed conditions. Consistent with this interpretation, intense priming exercise has been shown to increase aerobic ATP turnover and decrease anaerobic ATP turnover, without altering the total ATP turnover, during the initial stages of a subsequent bout of intense constant-work-rate exercise.

Cycling performance was not significantly affected by the pacing strategy employed in this study in either the primed or unprimed trials. While the VO2 MRT was shorter in the all-out unprimed trial than in the self-paced unprimed trial, VO2peak was not attained in either of these trials, and O2 consumed relative to work done over the first 60 seconds were similar between trials. We have previously shown that fast-start and all-out pacing strategies are ergogenic during short-duration high-intensity exercise when VO2 kinetics are faster and the percentage of VO2peak attained is greater, but not necessarily when VO2 kinetics are faster without changes in the percentage of VO2peak attained or total O2 consumed. On the other hand, the total O2 consumed and O2 consumption relative to work done over the first 60 seconds

Figure 2 — Pulmonary oxygen-uptake (VO2) responses in (A) the self-paced (SP) unprimed (UP) trial compared with the all-out (AO) UP trial, (B) the SP primed (P) trial compared with the AO-P trial, (C) SP-UP compared with SP-P, and (D) AO-UP compared with AO-P. Data are presented as group mean responses with the end-exercise pulmonary VO2 presented with y-axis ± SEM error bars and x-axis ± SEM error bars for completion time in the performance test. The dashed vertical lines represent the start of the cycling performance trials. *Significantly longer completion time relative to the respective comparison condition (P < .05). #Significantly higher pulmonary VO2 relative to the respective comparison condition (P < .05).
were higher, the percentage of VO$_2$peak attained was increased, and exercise performance was improved with priming when the same pacing strategy was employed. This finding is consistent with previous reports that priming exercise is ergogenic, particularly when baseline blood [lactate] is elevated to 3 to 4 mM, and suggests that priming might improve short-duration high-intensity exercise performance by increasing the absolute aerobic energy contribution to total energy turnover. However, since the exercise performance trials in this study were conducted in competitive, but not highly trained, athletes in an exercise physiology laboratory, further research is required to assess the effects of pacing and prior-exercise strategies on cycling performance in well-trained cyclists in the velodrome.

In conclusion, while VO$_2$ kinetics were faster when an all-out pacing strategy was employed, there were no changes in muscle (de)oxygenation, total O$_2$ consumption, the percentage of VO$_2$peak attained, and cycling performance between the all-out and self-paced conditions. However, pulmonary VO$_2$ and muscle (de)oxygenation kinetics were speeded, total O$_2$ consumption and the percentage of VO$_2$peak attained were increased, and cycling performance was improved in the self-paced primed and all-out primed trials compared with their respective unprimed conditions. Therefore, while combining priming with an all-out start evoked additive

Figure 3 — Cycle-ergometry power-output responses in (A) the self-paced (SP) unprimed (UP) trial compared with the all-out (AO) UP trial, (B) the SP primed (P) trial compared with the AO-P trial, (C) SP-UP compared with SP-P, and (D) AO-UP compared with AO-P. Data are presented as group mean responses with the end-exercise power output presented with y-axis ± SEM error bars and x-axis ± SEM error bars for completion time in the performance tests. The dashed vertical lines represent the start of the cycling performance trial. *Significantly longer completion time relative to the respective comparison condition (P < .05). #Significantly higher power output relative to the respective comparison condition (P < .05).

Figure 4 — Completion times during the target-work cycling trials in the self-paced (SP) unprimed (UP), all-out (AO) UP, SP primed (P) and AO-P conditions. Data are presented as group mean responses with ± SEM error bars. *Significantly faster completion time compared with SP-UP (P < .05). ¥Significantly faster completion time compared with SP-UP and AO-UP (P < .05).
improvements in VO\textsubscript{2} kinetics, a similar magnitude of improvement in muscle (de)oxygenation variables, total O\textsubscript{2} consumption, and short-duration high-intensity cycling performance was observed with priming regardless of the pacing strategy adopted. These findings support the use of prior high-intensity priming exercise as a precompetition intervention to increase oxidative energy contribution and improve performance in short-duration high-intensity events such as 1000-m track cycling.

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