Combined prior exercise and fast-start improves VO_2 kinetics and cycling performance

Original Investigation

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ABSTRACT

Purpose: To investigate whether oxygen uptake ($\dot{V}_{O_2}$) kinetics and simulated 4-km cycling performance are synergistically improved by prior 'priming' exercise and an all-out starting strategy. **Methods:** Nine males completed four target work trials (114 ± 17 kJ) to assess $\dot{V}_{O_2}$ kinetics and cycling performance in a repeated-measures, cross-over experimental design. Trials were initiated with either a 12-s all-out start or a self-selected start and preceded by prior severe-intensity (70%Δ) priming exercise or no priming exercise. **Results:** The $\dot{V}_{O_2}$ MRT was lower (indicative of faster $\dot{V}_{O_2}$ kinetics) in the all-out primed condition (20 ± 6 s) compared to the all-out unprimed (23 ± 6 s), self-paced-unprimed (42 ± 13 s) and self-paced-primed (42 ± 11 s) trials (P<0.05), with the $\dot{V}_{O_2}$ MRT also lower in the all-out unprimed compared to self-paced-unprimed and self-paced-primed trials (P<0.05). Trial completion time was shorter (performance was enhanced) in the all-out primed trial (402 ± 14 s) compared to the all-out unprimed (408 ± 14 s), self-paced-unprimed (411 ± 16 s) and self-paced-primed (411 ± 19 s) trials (P<0.05) with no differences between the latter three trials. **Conclusions:** The findings from this study suggest that combining severe-intensity priming exercise with a short-duration all-out starting strategy can expedite the adjustment of $\dot{V}_{O_2}$ and lower completion time during a cycling performance trial to a greater extent than either intervention administered independently. These results might have implications for optimising performance in short-duration high-intensity competitive events such as a 4-km cycling time trial.

Key Words: Pulmonary $\dot{V}_{O_2}$, warm-up exercise, fast/all-out start, near-infrared spectroscopy, exercise performance

INTRODUCTION

The transition from rest to exercise mandates an immediate increase in skeletal muscle contractile activity and ATP turnover. In contrast, the rate of pulmonary oxygen uptake ($\dot{V}_{O_2}$) increases with exponential response kinetics,[1] which closely reflects the kinetics of muscle $\dot{V}_{O_2}$,[2] following the onset of exercise. Consequently, a compensatory increase in anaerobic energy liberation is obligatory. Increased dependence on ATP supply through anaerobic metabolism accelerates the depletion of the finite energy reserves, phosphocreatine (PCr) and glycogen, and the accumulation of metabolites such as H^+, inorganic phosphate, adenosine diphosphate and ammonia, factors which contribute to the development of skeletal muscle fatigue.[3] At a given rate of skeletal muscle work and ATP turnover, a more rapid adjustment of $\dot{V}_{O_2}$ following the onset of exercise would be expected to increase the proportional energy yield from oxidative phosphorylation, lower the energy contribution from anaerobic metabolism and blunt the perturbation to muscle metabolic homeostasis.[4] Therefore, increasing the oxidative energy yield in the initial stages of exercise has the potential to increase the mean skeletal muscle power output during a short-duration high-intensity endurance event resulting in a faster race completion time.[5]

Completing high-intensity exercise prior to (priming exercise), or adopting a fast-start/all-out starting strategy during, high-intensity exercise has been shown to speed $\dot{V}_{O_2}$ kinetics and improve exercise performance.[6-19] We have recently shown that, compared to an unprimed, self-paced control trial, an all-out pacing strategy does not improve 1-km cycling performance more than priming alone[20] despite the fact that this pacing strategy is considered optimal for this type of event.[12,19] Hence, for a 1-km cycling time trial, the ergogenic effects of priming and all-out pacing do not appear to be synergistic. However, it has been suggested that 1.5-km cycling time trial performance can be improved with a short-duration (15-s), but not long-duration (90-s), all-out start compared to a self-selected pacing strategy.[21] Therefore, the all-out pacing strategy administered in our previous study (~90-100-s)[20] might have been too long to amplify the priming-induced improvement in performance during the simulated 1-km cycling time trial. It has been suggested that completing priming exercise[18] and adopting a short-duration all-out start can independently enhance 4-km cycling performance.[12,19] However, it has yet to be determined whether combining priming exercise with a short-duration faster starting strategy has a synergistic effect on performance during a simulated 4-km cycling time trial and whether this effect is linked to improved muscle (de)oxygenation responses or $\dot{V}_{O_2}$ kinetics ~~and performance during a simulated 4-km cycling time trial~~. This information might help coaches and athletes optimise performance in such events.

The purpose of this study was to compare the individual and combined effects of priming exercise and a 12-s all-out start on $\dot{V}_{O_2}$ kinetics and completion time during simulated 4-km cycling time trials. Near-infrared spectroscopy was utilised to assess muscle (de)oxygenation responses[22] and provide insight into the mechanism that might underlie changes in $\dot{V}_{O_2}$ kinetics between the different pacing-priming permutations investigated in the current study. We chose severe-intensity priming with 20 minutes of recovery in conjunction with a 12-s all-out start-strategy because each of these has proven effective in similar events. For example, the former improves exercise tolerance during continuous cycling of similar duration to a 4-km trial,[9] while the latter optimises 4-km cycling performance.[12] We hypothesised that the pacing and priming interventions would both independently speed muscle (de)oxygenation and $\dot{V}_{O_2}$ kinetics and improve cycling performance, but that the

effects would be greater with combined pacing and priming than either intervention administered independently.

METHODS

Subjects

Nine competitive male athletes (mean ± SD: age 21 ± 3 yr, stature 1.80 ± 0.04 m, body mass 77 ± 8 kg) volunteered to participate in this study which was approved by the University of Exeter Research Ethics Committee. All subjects were required to give their written informed consent prior to commencement of the study. Subjects were instructed to arrive at the laboratory in a rested and fully hydrated state, at least 3-h postprandial, and to avoid strenuous exercise in the 24-h preceding each testing session.

Experimental Overview

The subjects were required to report to the laboratory on eight occasions over a 4-5-week period with the eight visits separated by at least 48-h. Following the completion of preliminary exercise tests (see below), pulmonary $\dot{V}_{O2}$, blood [lactate], muscle (de)oxygenation and exercise performance were assessed in four experimental conditions (visits 5-8). These conditions consisted of two 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 the $\dot{V}_{O2peak}$, gas exchange threshold (GET) and the work rates that would require 65% and 70%Δ (GET work rate plus 65 or 70% of the difference between the work rate at the GET and $\dot{V}_{O2peak}$) as described previously.[9]

Familiarisation Trials

During the first familiarisation trial (visit 2), subjects were familiarised to the 'standing' start and were required to complete three target work trials. 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 65%Δ on reaching a cadence of 90 rpm (linear factor = power/preferred cadence^2). Subjects were provided with a 5-s countdown prior to the commencement of all cycling trials. The first trial was used to familiarise subjects to the fixed resistance that would be imposed in all subsequent trials, in addition to serving as a warm up. The target accumulation of work for the first trial was 40-kJ and subjects were instructed to complete this trial at a submaximal cadence of 70-90 rpm. Following a 10-min passive recovery period, subjects completed a self-paced 93-kJ trial where they were instructed to complete the trial in the fastest time possible. Following a further 25-30-min passive recovery, subjects completed a 40-kJ trial using an 'all-out' pacing strategy. This pacing strategy consisted of a 12-s all-out start followed by a self-selected pacing strategy until the 40-kJ work target had been achieved. The power output was continuously recorded at 5-Hz during these trials and averaged into 1-s bins for subsequent analysis. In order to estimate the work required for a completion time of 420-s for each individual subject, the mean power output during the 93-kJ self-paced trial was multiplied by 420. This individualised work target was set during all subsequent experimental trials in an attempt to yield a completion time reflective of a 4-km track cycling performance for a trained but sub-elite cyclist.[23]

During the second familiarisation trial (visit 3), subjects were familiarised to the priming exercise protocol and completed two additional trials at their individualised work target. The

priming exercise protocol comprised 4-min 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 3-min in duration. Following a 17-min passive recovery, subjects remounted the cycle ergometer and rested for an additional 3-min. Subjects then completed their individualised work target as quickly as possible using a self-paced pacing strategy. Following 25-30-min passive recovery, subjects completed a third performance trial to 40 kJ using the 'all-out' pacing strategy.

In the final familiarisation trial (visit 4), subjects completed their individualised work target as quickly as possible using the all-out pacing strategy. Therefore, all subjects completed six repetitions of the performance trial and one repetition of the priming bout prior to the experimental testing.

Experimental Trials

In a randomised order, subjects completed a self-paced trial with and without severe-intensity priming exercise and an all-out trial with and without severe-intensity priming exercise over four separate experimental trials. Subjects were instructed to complete each trial as quickly as possible. Each trial was preceded by 3-min of resting baseline on the cycle ergometer. Ten seconds prior to the commencement of each trial, subjects were instructed to adjust the crank angle to their preferred starting position, which was established in the familiarisation trials and replicated in all experimental trials, and to assume a standing position on the cycle ergometer. Subjects were then provided with a 5-s countdown to indicate when the trial would commence. For the initial 12-s 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. Subjects were made aware of their work target prior to each trial and the work target and accrued work during the trial was displayed on a computer screen placed directly in front of the subject. Strong verbal encouragement was provided throughout, but subjects were not aware of the elapsed time during the trials. A power output profile for a representative individual completing the self-paced unprimed control trial is presented in Figure 1.

Measurements

All cycle tests were performed on an electrically-braked cycle ergometer (Lode Excalibur Sport, Groningen, the 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_2Hb] and total hemoglobin concentration [Hb_{tot}] were measured using near-infrared spectroscopy (model NIRO 200, Hamamatsu Photonics KK, Hiugashi-ku, Japan). A blood sample was collected from a fingertip into a capillary tube 30-s prior to the commencement of the trial and immediately following the trial for blood [lactate] determination (YSI 1500, Yellow Springs Instruments, Yellow Springs, OH, United States), as described previously.[8]

Data Analysis Procedures

The breath-by-breath $\dot{V}_{O2}$ data from each test were initially examined to exclude errant breaths caused by coughing, swallowing, sighing, etc., and those values lying more than four standard deviations from the local mean were removed. Subsequently, a custom-designed curve-fitting program using non-linear least-squares regression analysis was employed to 'fit' the data from each test. ~~Prior to analysis, the breath-by-breath $\dot{V}_{O2}$ data from each test were treated as described previously.[8]~~ Specifically, a single-exponential model without time delay, with the fitting window commencing at t = 0 s (equivalent to the mean response time, MRT)

was used to characterise the kinetics of the overall $\dot{V}_{O2}$ response during the trials as described in the following equation:

$$\dot{V}_{O2}(t) = \dot{V}_{O2\ baseline} + A\,(1-e^{-(t/MRT)}) \qquad \text{(Eqn. 1)}$$

where $\dot{V}_{O2}(t)$ represents the absolute $\dot{V}_{O2}$ at a given time *t*; $\dot{V}_{O2baseline}$ represents the mean $\dot{V}_{O2}$ measured over the final 90 s of baseline; and A and MRT represent the amplitude and MRT, respectively, describing the overall increase in $\dot{V}_{O2}$ above baseline. An iterative process was used to minimise the sum of the squared errors between the fitted function and the observed values. We quantified the $\dot{V}_{O2}$ MRT with the fitting window constrained to both 120 s and end-exercise (see Figure 1 for an example of the model fit for a representative individual). The absolute $\dot{V}_{O2}$ at, and the total O_2 consumed up to 60 s (± 5 s) and 120 s (± 5 s) ~~and the minimum completion time for each subject across the four experimental trials (T_{min}) (mean of the final 30 s)~~ were also calculated. We also divided the total O_2 consumed up to 60 s and 120 s ~~and T_{min}~~ by the work accumulated over the corresponding time frame to provide an indication of the oxidative energy provision relative to external work production.

To fit the [HHb] data, we used a modified version of Equation 1 with a time constant (τ; time to achieve 63% of mono-exponential response amplitude) instead of MRT and time-delay (TD) because the [HHb] response does not increase at t=0. The fitting window was constrained from the first data point ≥1 SD above the baseline mean to the point at which mono-exponentiality became distorted (as determined by visual inspection of residual plots). The [HHb] TD and τ values were summed to provide information on overall [HHb] kinetics. The [HHb], [O_2Hb] and [Hb_{tot}] values at baseline (average over the 90 s preceding the onset of the trial), 60 s (± 5 s), 120 s (± 5 s), and end-exercise (average over the final 30 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-s power output during the trial and end-exercise power output was taken as the mean power output over the final 10 s of the trial.

Statistical Analysis

A two-way (pacing x priming) repeated-measures ANOVA was employed to determine the effects of priming exercise and pacing strategy on the relevant physiological and performance variables. Where the analysis revealed a significant difference, individual paired *t*-tests were employed with a Fisher's LSD to determine the origin of such effects. All data are presented as mean ± SD. Statistical significance was accepted when $P<0.05$.

RESULTS

The work target for the performance trials was 114 ± 17 kJ and the work rate applied during the severe-intensity priming bout was 247 ± 30 W.

Cycling Performance

The total work done over the first 120 s was significantly greater in the all-out trials ($P<0.05$; Figure 2). Trial completion time was significantly shorter in the all-out primed trial (402 ± 14 s $P<0.05$; Figure 2) compared to the self-paced-unprimed control (411 ± 16 s), the self-paced-primed (411 ± 19 s) and the all-out unprimed (408 ± 14 s) trials ($P<0.05$), with no difference between the latter three trials ($P>0.05$).

$\dot{V}_{O2}$ Kinetics

Regardless of whether the fitting window was constrained to 120 s or end exercise, the $\dot{V}_{O2}$ MRT was significantly shorter in the all-out primed condition compared to all other experimental conditions and in the all-out unprimed condition compared to both self-paced trials (P<0.05; Table 1). Similarly, the total O_2 consumed up to 120 s was significantly greater in the all-out primed condition compared to all other experimental conditions and in the all-out unprimed condition compared to both self-paced trials (P<0.05; Table 1; Figure 3). When normalized to the total work done up to various time points, the total O_2 consumed was higher in the all-out compared to the self-paced trials (P<0.05; Table 1) up to 120 s and tended to be higher in the all-out primed compared to all-out unprimed trial (P=0.08) up to 60 s. The end-exercise $\dot{V}_{O2}$ was higher in the all-out primed (P<0.05; Table 1) compared to unprimed trials, but not different compared to the self-paced primed trial (P>0.05).

Near-infrared Spectroscopy

Muscle [HHb] and [Hb_{tot}] were higher at baseline and throughout exercise in the primed trials (P<0.05; Table 2). Muscle [HHb] τ + TD was shorter in the all-out primed trial compared to all other experimental conditions and in the all-out unprimed compared to the self-paced-unprimed control trial (P<0.05; Table 2; Figure 4).

Blood [lactate]

Baseline blood [lactate] was significantly greater in the self-paced primed (2.6 ± 0.4 mM) and all-out primed (2.7 ± 0.5 mM) trials compared to the self-paced unprimed (1.1 ± 0.3 mM) and all-out unprimed (1.2 ± 0.4 mM) trials (P<0.001). End-exercise blood [lactate] was higher in the self-paced-primed trial (10.5 ± 1.9 mM) compared to the self-paced-unprimed control trial (8.8 ± 2.0 mM; P<0.05), but not the all-out-unprimed (9.8 ± 2.7 mM) or all-out-primed (8.9 ± 2.8 mM) trials (P>0.05). There were no differences in the change in blood [lactate] from the start to the end of exercise between any of the experimental conditions (P<0.05).

DISCUSSION

The main original finding from this study is that combining severe-intensity priming exercise with a brief (12-s) all-out start improved simulated 4-km cycling time trial performance. The improved exercise performance exhibited when priming exercise and a faster starting strategy were combined was accompanied by faster muscle HHb kinetics, suggestive of a faster rate of muscle O_2 extraction,[22] and faster pulmonary $\dot{V}_{O2}$ kinetics, suggestive of faster muscle $\dot{V}_{O2}$ kinetics,[2] following the onset of the performance trial. These findings suggest that combining priming exercise with a faster starting strategy can improve muscle HHb kinetics, $\dot{V}_{O2}$ kinetics and performance during a simulated 4-km cycling time trial to a greater extent compared to either of these interventions administered independently. These results might have important implications for optimising performance in endurance events such as 4-km track cycling.

Commencing a cycling trial with a faster starting strategy resulted in faster overall $\dot{V}_{O2}$ kinetics and increased total O_2 consumption compared to a self-paced trial, consistent with previous reports.[6-8,10,14,17,21] Conversely, and in contrast to previous findings,[9,11,13,15,16,18] the priming regime employed in this study did not alter $\dot{V}_{O2}$ kinetics during a subsequent self-paced trial. However, combining severe-intensity priming with a faster starting strategy resulted in faster overall $\dot{V}_{O2}$ kinetics and increased total O_2 consumption compared to either intervention administered independently. An additive effect of priming exercise and a faster starting strategy on $\dot{V}_{O2}$ kinetics has been observed in some,[20] but not all,[24] previous studies.

Taken together, our findings suggest that adopting a short-duration all-out starting strategy can increase $\dot{V}_{O2}$ over the initial stages of exercise and that $\dot{V}_{O2}$ is increased further if this is preceded by a bout of severe-intensity priming exercise. Moreover, there was a higher O_2 consumed per unit work done over the first 120 s of exercise, suggestive of a greater proportional energy contribution from oxidative metabolism, in the trials completed with a faster starting strategy compared to the trials completed with a self-paced strategy. There was also a trend (P=0.08) for a greater O_2 consumed per unit work done over the first 60 s of exercise with the short-duration all-out starting strategy completed with priming exercise compared to the short-duration all-out starting strategy completed without priming exercise. Therefore our results suggest that, while starting exercise with a short-duration all-out pacing strategy can positively impact $\dot{V}_{O2}$ kinetics, this effect is augmented when preceded by prior severe-intensity exercise.

At baseline and throughout exercise, muscle [Hb_{tot}] was higher in the trials completed following priming exercise compared to the trials completed without priming exercise. Muscle [O_2Hb] was also higher at baseline in the trials completed following priming exercise. These results are consistent with previous findings of higher muscle [O_2Hb] and [Hb_{tot}] after priming exercise[9,20] which suggests a priming exercise-induced increase in skeletal muscle perfusion and O_2 delivery.[25,26] Therefore, the absence of an effect on $\dot{V}_{O2}$ kinetics in the trials completed after priming exercise in this study cannot be ascribed to a failure to increase muscle O_2 supply. Although muscle [O_2Hb] and [Hb_{tot}] were not impacted by adopting a short-duration all-out start strategy, muscle [HHb] increased more rapidly in the trials with the faster starting strategy compared to the self-paced trials. Since muscle [HHb] kinetics provides a non-invasive proxy for muscle O_2 extraction kinetics,[22] and since $\dot{V}_{O2}$ kinetics was only expedited during the trials initiated with a faster starting strategy, when muscle [HHb] kinetics was also speeded, our results suggest that the faster starting strategy used in this study improved $\dot{V}_{O2}$ kinetics, principally, by increasing muscle O_2 extraction. This interpretation is further supported by our observation that $\dot{V}_{O2}$ kinetics was speeded in the faster starting trial preceded by priming exercise, compared to the faster starting trial completed without priming exercise, concomitant with faster muscle [HHb] kinetics. Collectively, these findings suggest that combining severe-intensity priming exercise with a short-duration fast-starting strategy can synergistically speed both $\dot{V}_{O2}$ and [HHb] kinetics.

The time required to complete the simulated 4-km cycling time trial (~ 410 s) was shorter (i.e., performance was improved) when priming and the all-out start strategy were combined compared to the self-paced unprimed control trial (2.3%), the self-paced primed trial (2.1%) and the short-duration all-out start trial completed without priming exercise (1.6%). Importantly, performance was similar during these latter three trials, which suggests that when applied exclusively, neither severe-intensity priming exercise nor a short-duration all-out starting strategy improves performance compared to the self-paced unprimed control condition. Previous studies have reported that combining priming exercise with a faster starting strategy does not additively improve exercise performance ~~with performance improved following priming exercise with no further improvements when adopting a faster-starting strategy~~.[20,24] For example, performance was enhanced after priming exercise independent of the pacing strategy adopted, but performance was not enhanced when adopting an all-out start without prior priming exercise, during a simulated 1-km cycling time trial (~90-100 s completion time) in our previous study.[20] Our findings might conflict with those presented in previous studies due to inter-study differences in the priming exercise and pacing strategies administered, and the duration/distance of the exercise performance test.

The improved performance in the combined priming exercise and faster start trial was accompanied by faster [HHb] and $\dot{V}_{O2}$ kinetics, and increased total O_2 consumption and O_2 consumed per unit work done over the initial stages of exercise compared to the other experimental conditions. Although these physiological responses were improved in the all-out unprimed trial compared to the self-paced unprimed control trial, these responses were improved further and exercise performance was only enhanced compared to the self-paced unprimed control trial when severe-intensity priming exercise and an all-out start were combined. The higher initial power output in the all-out trials would be expected to increase ATP turnover and the associated perturbation to the phosphorylation potential[27] providing a greater stimulus for mitochondrial respiration and muscle O_2 extraction.[28] These factors are likely to underpin the faster $\dot{V}_{O2}$ kinetics in the all-out unprimed trial compared to the self-paced unprimed control trial. In addition, combining the all-out start with severe-intensity priming exercise enhanced muscle O_2 availability, as suggested by the higher muscle [Hb_{tot}] in the current study and evidenced by increased muscle oxygenation and blood flow previously reported after priming exercise.[9,20,25,26] This might have permitted further improvements in muscle [HHb] and $\dot{V}_{O2}$ kinetics leading to enhanced performance in the all-out primed trial compared to the all-out unprimed trial.

The observations in the current study are consistent with our recent findings that performance is optimised during a simulated 1-km time trial when $\dot{V}_{O2}$ kinetics is speeded concomitant with faster muscle [HHb] kinetics, and increased total O_2 consumption and O_2 consumed per unit work done over the initial stages of exercise.[20] In that study, these physiological responses were evoked and performance was optimised with severe-intensity priming exercise independent of the pacing strategy adopted. Conversely, these physiological responses were only evoked, and exercise performance was only enhanced, when severe-intensity priming exercise was combined with a short-duration all-out starting strategy during the simulated 4-km cycling time trial employed in the current study. Together, these findings are important as they suggest that the optimal pacing-priming permutation is likely to differ depending on the race distance and might be discriminated using non-invasive procedures (muscle [HHb] kinetics, total O_2 consumption and O_2 consumed per unit work done over the initial stages of exercise) that can be readily assessed in a laboratory or field setting. These observations might have important implications for coaches and athletes aiming to optimise performance in short-duration track cycling events.

In conclusion, completing severe-intensity priming exercise prior to, or adopting a short-duration faster starting strategy during, a simulated 4-km cycling time trial in the laboratory did not independently improve trial completion time compared to a self-paced unprimed control trial. However, combining severe-intensity priming exercise and a short-duration faster starting strategy improved simulated 4-km cycling time trial performance. Importantly, performance was optimised when muscle [HHb] and pulmonary $\dot{V}_{O2}$ kinetics were speeded, and total O_2 consumption and O_2 consumed per unit work done over the initial stages of exercise were increased, suggesting that the ergogenic potential of different pacing-priming permutations might be linked to their ability to improve aspects of pulmonary $\dot{V}_{O2}$ and muscle deoxygenation kinetics. These findings support the use of combined severe-intensity priming exercise and a short-duration all-out strategy to optimise performance during short-duration high-intensity cycling events such as 4-km track cycling races.

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Figure Legends

Figure 1. Pulmonary oxygen uptake ($\dot{V}_{O_2}$) (upper panel) and power output (lower panel) profiles for a representative individual completing the self-paced unprimed controlled trial. The $\dot{V}_{O_2}$ and power output data are presented as 5-s averages. The mono-exponential model fit to the $\dot{V}_{O_2}$ data is indicated by the solid back line with the fitting window commencing at 0 s and constrained to 120 s. The solid grey line represents the residuals between the fitted and observed $\dot{V}_{O_2}$ data.

Figure 2. Total work done up to 60 s (panel A), total work done up to 120 s (panel B), mean power output (panel C) and completion time (panel D) during the target-work cycling trials in the self-paced unprimed (SP-UP), self-paced primed (SP-P), all-out unprimed (AO-UP) and all-out primed (AO-P) conditions. Data are presented as group mean responses with ± SEM error bars. * indicates higher compared to SP-UP and SP-P (P<0.01). # indicates different from SP-UP, SP-P and AO-UP (P<0.01).

Figure 3. Pulmonary oxygen uptake ($\dot{V}_{O_2}$) over the first 120 s of the self-paced unprimed (SP-UP) trial compared to the self-paced primed (SP-P) trial (upper panel), the all-out unprimed (AO-UP) trial (middle panel) and the all-out primed (AO-P) trial (lower panel). Data are presented as group mean responses with SEM error bars every 15 s. The dashed vertical lines represent the start of the cycling performance trials.

Figure 4. Near-infrared spectroscopy-derived muscle deoxyhemoglobin concentration ([HHb]) responses over the first 60 s of the self-paced unprimed (SP-UP) trial compared to the self-paced primed (SP-P) trial (upper panel), the all-out unprimed (AO-UP) trial (middle panel) and the all-out primed (AO-P) trial (lower panel). Data are presented as group mean responses with SEM error bars every 15 s. The data are normalised to end-exercise and expressed as the change (Δ) from baseline. The dashed vertical lines represent the start of the cycling performance trial.