Attenuation of VO_2 Slow Component during Heavy-Intensity Interval Exercise

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Abstract

The VO_2 slow component (VO_{SC}) is a slow, exponential increase in VO_2 that takes place during constant load exercise above ventilatory threshold (VT). **Purpose:** The purpose of this study was to examine the amplitude of the VO_{2SC} during various heavy intensity interval exercise when controlling the VO_2 on-kinetics. **Methods:** Six males (24 ± 5 yrs.) participated in a total of 7 visits. The first visit consisted of a graded exercise test (20 W/min) until volitional fatigue. VO_{2peak} was determined as the highest VO_2 averaged over a 15-second interval, and was used to determine the subject's work rates for each experimental condition that corresponded with 50% of the difference between VO_{2peak} and VT (Δ50%). The three experimental conditions were: continuous (CON), intermittent (INT), and extended intermittent (EXT), two trials were completed for each condition. Pulmonary gas exchange (VO_2, VCO_2) and minute ventilation (V_E) were measured through breath-by-breath analysis. Each experimental condition consisted of a 4-minute warm-up (20W), followed by heavy intensity exercise. To control on-transition kinetics, the work rate during the initial 3 min for each condition was kept the same. During CON, work rate was unchanged for 3 additional min. During INT, the remaining 3 min consisted of 3 s rest intervals interspersed every 10 s. For the EXT condition, 3 s recovery intervals were inserted every 10 s until the total work performed matched the total work performed for the CON condition. Phase II VO_2 responses (time constant, τVO_2) were analyzed using either a 2- or 3-component exponential model after interpolating to 1 s and ensemble averaging each trial. One-way ANOVAs were computed to assess the difference in means for each condition. Significance was established if $p < 0.05$. **Results:** τVO_2 was similar (CON: 32.5 ± 1.7 s; INT: 36.6 ± 1.8 s; EXT: 36.1 ± 2.6 s, p=0.50) as expected. The amplitude of VO_{2SC}, as measured by $\Delta VO_{2(6\text{-}3)}$, was decreased in both INT and EXT compared to the CON condition (-8 ± 35 mL/min; -39 ± 43 mL/min; 367 ± 50 mL/min, $p < 0.001$). $\Delta HR_{(6\text{-}3)}$ was lower in INT and EXT (3 ± 2 bpm; 3 ± 1 bpm, respectively) compared to CON (15 ± 2 bpm, $p < 0.001$). **Conclusion:** These findings suggest that the VO_{2SC} was abolished with the addition of 3 s recovery intervals (INT and EXT). This is possibly due to myocardial work, as evidence by $\Delta HR_{(6\text{-}3)}$, being lower in INT and EXT compared to CON.

Background

- The onset of constant-intensity exercise, performed above ventilatory threshold (VT), initially results in an exponential increase in pulmonary VO_2, followed by a more slow and progressive increase of VO_2 referred to as the VO_2 slow component (VO_{2sc})
- The magnitude of VO_{2sc} increases with greater workloads of exercise
- This additional O_2 cost reflects a decreasing metabolic efficiency resulting in muscle fatigue, reduced exercise tolerance, and/or impaired sport performance (1)
- Previous investigations have demonstrated that the acute responses of VO_{2sc} are different between continuous and intermittent (brief rest intervals, 3 sec) exercise. This may be due to the reduction in workload in intermittent compared to continuous, due to 3 sec rest intervals (2)
- Preliminary results from our laboratory have observed that different VO_{2sc} responses may also take place when workloads are equal between continuous and intermittent (Unpublished observations)

Experimental Conditions

- Each experimental condition consisted of a 4-minute warm-up at 20 W followed by 6 minutes of the experimental condition followed by 4 minutes of recovery at 20W

Condition	Exercise Protocol
Continuous (CON)	Performed at a constant work rate throughout
Interval (INT)	Performed at constant work rate for 3 minutes followed by 3 minutes with 3 second rest intervals every 10 seconds at 20W
Interval Extended (EXT)	Performed at constant work rate for 3 minutes followed by 3 minutes and 52 seconds with 3 second rest intervals every 10 seconds at 20W

Purpose

The purpose of this study was to examine the magnitude of the VO_{2SC} during various heavy-intensity interval exercise when controlling the VO_2 on-kinetics.

Methods

Experimental Design

- 7 male subjects participated in this study (25 ± 6.4 yrs.)
- This study consisted of a total of 7 visits. Visit 1 consisted of a graded maximal exercise test. Visits 2-7 consisted of 2 visits for each experimental condition
- The graded maximal exercise test followed a 20 W/min progressive watt protocol and was continued to volitional fatigue to determine VO_{2peak}
- Work rates for the experimental trials were set at 50% of the difference between VO_{2peak} and VT (Δ50%) based on the results of a previously performed max test
  - $\Delta 50\% = VT + [(VO_{2peak} - VT) \times 0.50]$

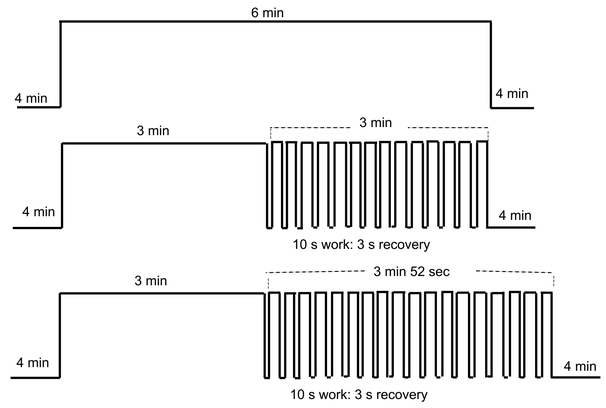


Figure 1. Overview of protocol for CON condition (top panel), INT condition (middle panel), and interval extended (EXT) (bottom panel).

Measurements

- Pulmonary gas exchange (VO_2, VCO_2) and minute ventilation were measured via breath-by-breath analysis through a metabolic measurement system that collected expired gas flows through a turbine and optoelectronic reader that was calibrated prior to each visit. Heart rate was monitored by a chest strap monitor
- One-way ANOVAs were used to compare differences among conditions for VO_2, V_E, and HR.
  - Significant was set a priori at $p < 0.05$.

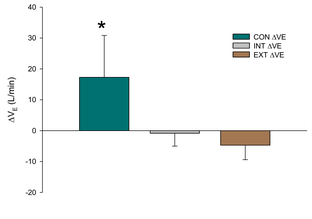


Figure 2. Mean $\Delta V_{E(EE\text{-}3\ min)}$ for CON, INT, and EXT conditions

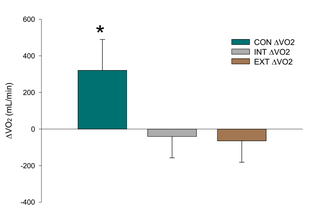


Figure 3. Mean $\Delta VO_{2(EE\text{-}3\ min)}$ for CON, INT, and EXT conditions

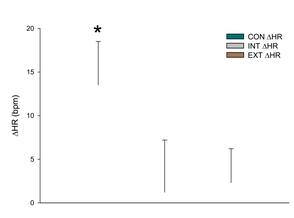


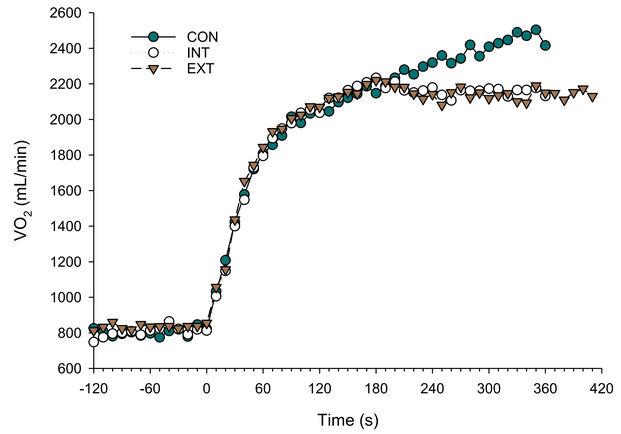
Figure 4. Mean $\Delta HR_{(EE\text{-}3\ min)}$ for CON, INT, and EXT conditions

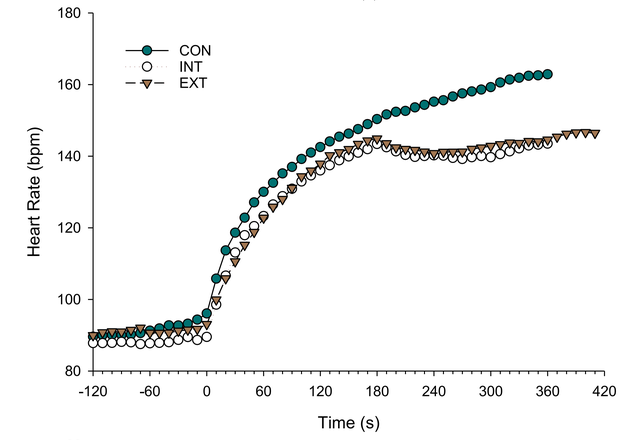
* - significant difference between CON and INT, EXT

Conclusion

These results suggest that VO_{2SC} was attenuated with the addition of 3 sec recovery intervals during both INT and EXT. This may be due to the higher levels of myocardial work during CON compared to INT and EXT, as shown by measurements of HR.

RESULTS





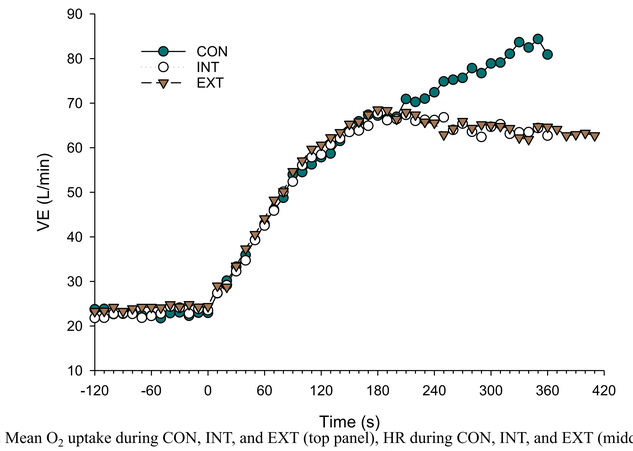


Figure 5. Mean O_2 uptake during CON, INT, and EXT (top panel), HR during CON, INT, and EXT (middle panel), and minute ventilation during CON, INT, and EXT (bottom panel). Breath-by-breath analysis data was interpolated to 1-s intervals and averaged into 10-s bins.

References

1. Burnley, M. & Jones, A.M. Oxygen uptake kinetics as a determinant of sports performance. *Eur J Sport Sci,* 2007; 7: 63-79.
2. McCrudden, M.C., Keir, D.A., & Belfry, G.R. The effects of short work vs. longer work periods within intermittent exercise on VO_{2p} kinetics, muscle deoxygenation, and energy system contribution. *J Appl Physiol,* 2017; 122: 1435-1444.