The VO₂ response profile in severe intensity upper body and lower body exercise

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Introduction

The focus of the present study was on the effect of exercise mode on the VO₂ response profile during severe intensity exercise. Based on the results of previous studies that have compared characteristics of the fast and slow components during severe intensity exercise performed using different exercise modes, it would appear that the overall response is greater, meaning a higher VO₂max is achieved, and the overall response is faster, meaning the VO₂max is achieved faster, in running compared to cycling. Specifically, the time constant of the exponential primary response has been reported to be faster (time constant, τ₁ (defined below) = 14 s versus 25 s, p < 0.01) (Hill et al. 2003) or to appear to be faster (16 s versus 23 s, n.s.) (Carter et al. 2000) in running than in cycling. In both these studies, the absolute magnitude of the primary component was greater in running than cycling; however, when expressed as a percentage of the overall increase in VO₂, the contribution of the primary component was only slightly higher in running (90% versus 83%, p < 0.05, in the Carter study and 86% versus 82%, n.s., in the Hill study). While it may seem intuitive that the response would be faster, as well as greater, in exercise that involves a larger muscle mass, Koga and colleagues (2001) have noted that, if the VO₂ response is limited by the cardiovascular response, and if we assume that the cardiovascular response is not directly a function of the muscle mass that is activated, then the VO₂ response might be expected to be faster in exercise using a smaller muscle mass.

In the previous studies, which used running and cycling, the difference in absolute metabolic demand (and muscle mass activated and VO₂max attained) was ~10%. The purpose of the present study was to describe the VO₂ response profile during severe intensity constant-power lower body cycle ergometer exercise and upper body arm cranking exercise, where the difference in muscle mass activated would be much greater than 10%. To compare responses in a meaningful way, intensities were were equated based on metabolic responses to incremental exercise tests performed using legs or arms. The hypothesis was that the primary phase of the VO₂ response would be faster in leg exercise than in arm exercise.

Methods

Participants were eight women (mean ± SD age 24 ± 4 yr, height 167 ± 7 cm, and weight 61 ± 11 kg) and seven men (26 ± 3 yr, 180 ± 8 cm, and 85 ± 16 kg). All were undergraduate kinesiology majors. Prior to performing the constant-power tests, each participant performed one incremental maximal arm cranking test and one incremental maximal cycle ergometer test.

Intensity for the constant power tests was individually calculated to fall halfway between the work rate at the gas exchange threshold and the peak work rate achieved in the incremental test. Tests were performed following a 3-min period of breathing through the mouthpiece while resting in the exercise posture. Cadence was increased and the resistance applied within 2-3 s at the onset of exercise. Cadence was constant at 80 revolutions per minute. VO₂ were obtained on a breath-by-breath basis using a MedGraphics system. Tests were terminated after 6 min.

After the first 20-s of data were discarded, smoothed VO₂ data were fit to a two-phase model, which ignores the cardiodynamic response:

\[ VO₂(t) = A₀ + (A₁ · (1 – e^{–(t – TD₁)/τ₁})) + (A₂ · (1 – e^{–(t – TD₂)/τ₂})) \]

where VO₂(t) is the value for VO₂ at time = t, A₀ is the baseline VO₂, A₁ and A₂ are the asymptotic amplitudes for the primary and slow components; τ₁ and τ₂ are the time constants; and TD₁ and TD₂ are the time delays. Amplitudes were truncated to reflect the actual increase in each phase; truncated values were A'₁ and A'₂.

Results

The primary response appeared to be slower in leg exercise versus arm exercise (τ₁ = 57 s versus 45 s, p= 0.29). While the amplitude of the primary component was clearly higher in leg exercise when expressed in absolute terms (892 ml/min versus 442 ml/min, p < 0.01), the primary response contributed the same percentage of the overall response in leg and arm exercise (75% versus 74%, p = 0.91).

Discussion/Conclusion

The primary response was not faster in leg exercise compared to arm exercise, and our hypothesis was rejected. Using a larger muscle mass appears to speed the VO₂ response when relatively large muscle masses are involved, as in leg cycling and running (Carter et al. 2000, Hill et al. 2003). However, arm exercise may represent an activity that is so different, in terms of cardiovascular adjustments relative to metabolic demand, that the role of muscle mass itself is reduced, lost completely, or reversed, as has been suggested (Koga et al. 2001). Nevertheless, at equivalent exercise intensities, the magnitude of the increase in VO₂ in absolute terms is greater in leg exercise than in arm exercise. However, the VO₂ response profile, as quantified by either the time constant of the primary response or the percentage of the overall increase in VO₂ that can be attributed to the various components, is virtually identical in leg and arm exercise.

References