Kinetics of Oxygen Uptake and Recovery for Supramaximal Work of Short Duration

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Abstract. In order to follow the time pattern of oxygen uptake and recovery for supramaximal work of short duration, 35 male subjects (mean age 21.4 years, mean body weight 71.9 kg) pedalled a bicycle ergometer at maximal speed for 1 min. A constant frictional resistance of 5.5 kg was used, resulting in a total work output of 2890 kpm (85 revolutions, SD = 7.5). The total percent decrement in work output from the initial rate on this test was 59.7%. The total oxygen uptake during the work averaged 2.35 l, the net oxygen recovery was 4.89 l, while the net work efficiency was 19.3%. One and two component exponential curves fit the observed oxygen uptake and recovery measures with a high degree of accuracy. Comparison of the curve parameters with published data showed large differences for the post exercise oxygen recovery and the slow component of the recovery curve. The magnitude of the fast component of recovery was similar to other data. The total oxygen uptake during the test was found to be 10% lower than the maximal oxygen uptake determined on a separate progressive step-increment test. It was shown, by curve analysis, that the maximal oxygen uptake would have been reached in approximately 2 min.

Key words: \( O_2 \) Uptake — \( O_2 \) Debt — Supramaximal Work.

The kinetics of oxygen uptake during exercise and recovery have been studied for light [2, 9, 13, 15, 28, 34], moderate [7, 8, 14, 16, 21, 24, 26], and moderately heavy work [16, 19, 23, 25] of various durations. Depending on the intensity of the exercise, either a single or double component exponential equation has been found to describe the time pattern of oxygen uptake during the exercise and subsequent recovery. The derivation and explanation of the exponential formula can be found in several reports [9, 15, 16, 20, 26, 34]. Briefly, the equation states that the rate of oxygen uptake \( (Y) \) at any time \( t \) of exercise is given by the equation:

\[
Y = C - a_1 e^{-k_1 t} + a_2 e^{-k_2 t},
\]

where, \( C \) is the resting oxygen uptake + \((a_1 + a_2)\), \( a_1 + a_2 \) represent the steady-level oxygen uptake above rest, and the exponentials equal the
amount of oxygen uptake. During recovery, the negative term changes to positive, C equals resting oxygen uptake, $a_1 + a_2$ represents the amount of oxygen uptake at $t = 0$ (end of exercise and beginning of recovery), and the exponentials represent the fast and slow pay-off components first described by Hill et al. [16] and Margaria et al. [26].

In the 1920's interpretation of the exponential uptake and recovery curves were based on the assumed time course of lactate accumulation and disappearance [16]. In 1933, Margaria et al. demonstrated that the fast component of the recovery curve was not responsible for this lactate disappearance but was related to the oxidation of substances furnishing the energy for the resynthesis of phosphagens split during muscular contraction.

The fast component ($a_1 e^{-k_1 t}$), which has been shown to be approximately a linear function of the oxygen uptake in exercise [14, 26], as well as the slower 'lactacid' component ($a_2 e^{-k_2 t}$) have been studied by numerous investigators for light to moderate work [1, 3, 8, 20, 21, 24, 27, 29, 33]. There are, however, very little data on the magnitude of these two exponential components, as well as the time pattern of oxygen uptake during exercise and recovery for extremely heavy work (supramaximal work) of short duration where only a very small portion of the energy requirement is met by aerobic metabolism. It has been pointed out by Margaria [24] that during such work (as for example cycling against a very heavy resistance at maximal speed for 40 to 60 sec) an individual will reach his anaerobic capacity. Thus, it is possible that the kinetics of oxygen uptake for this exercise and recovery will be quite different than it is for light or moderately heavy exercise conditions, possibly due to such factors as increased lactate production [23], extra oxygen cost of ventilation [32], or increased temperature during recovery [3].

Therefore, the aim of the present study is to examine the kinetics (time pattern) of oxygen uptake during exercise and recovery for supramaximal work of short duration.

Methods

Subjects. Thirty-five male college students served as subjects. The mean age was 21.4 years (SD = 2.4) and mean weight 71.9 kg (SD = 7.5). These were all volunteer subjects from the general physical activities program of the University. Students involved in intercollegiate athletics, or who were participating in a conditioning program were omitted from the sample.

Supramaximal Work of Short Duration. Each subject rode a Monarch bicycle ergometer (Sweden) for 1 min as fast as possible with a constant frictional resistance of 5.5 kg/revolution. The choice of this workload was based on the observation that subjects are able to accomplish more work per unit time with this particular rate-profile (resistance × pedal frequency) than one involving a greater or lesser