Linear Determination of the $\dot{V}O_2$ Half Time Response During Exercise*

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Summary. The oxygen consumption ($\dot{V}O_2$) half time response was determined on eight female subjects during exercise using a nonlinear equation of the form $\dot{V}O_2t = \dot{V}O_2ss (1 - e^{-kt})$, where $\dot{V}O_2t = \dot{V}O_2$ at time t of exercise, $\dot{V}O_2ss = \dot{V}O_2$ at steady state, e = natural log, and k = constant of the curve, and a simple, linear equation of the form $t = b(\dot{V}O_2t/\dot{V}O_2ss) + a$. The slope (b) and intercept (a) of the line, respectively, were determined for each work load and each subject using the $\dot{V}O_2$ measurements within the initial linear portion of the individual $\dot{V}O_2$ uptake curves. Two treadmill walks were used ($X = 38$ and $65\% \dot{V}O_2 max$). For the lower work load, the $X \pm SD$ for the nonlinear and linear half time responses were $21.6 \pm 4.8$ s and $21.6 \pm 4.9$ S, respectively, and for the higher load $32.8 \pm 5.6$ s and $32.6 \pm 3.6$ s, respectively. No significant differences between linear and nonlinear means were found. The linear correlation between determinations was 0.88 ($p < 0.001$). The standard error of estimate was $\pm 3.4$ s with 95% confidence limits of $\pm 7.2$ s ($\pm 25.7\%$ of the nonlinear half time mean). The $\dot{V}O_2$ half time response for the higher work load was significantly greater ($p < 0.01$) than for the lower load. Linear correlations of 0.84 and 0.76 ($p < 0.01$) between % $\dot{V}O_2$ max and linear and nonlinear determinations of the half time responses, respectively, were also found. We conclude that (1) the $\dot{V}O_2$ half time response at the onset of steady state exercise can be accurately determined on a group basis but not an individual basis from simple linear equations, and (2) the $\dot{V}O_2$ half time response is slower with increasing work loads.

Key words: $\dot{V}O_2$ half time response — $O_2$ kinetics — $\dot{V}O_2$ kinetics — Exercise — Females

* Supported by a grant from the Central Ohio Heart Chapter
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0301-5548/80/0044/0077/$ 01.00
The speed of the increase in oxygen consumption (\(\dot{V}O_2\)) at the onset of exercise is commonly determined by the \(\dot{V}O_2\) half time response, i.e., the length of time required to increase the \(\dot{V}O_2\) to one-half of the steady-state \(\dot{V}O_2\) value (Bason et al. 1973; Cerretelli et al. 1966; Hagberg et al. 1978; Henry 1951; Hickson et al. 1978; Weltman and Katch 1976; Whipp and Wasserman 1972). Since the time course of the \(\dot{V}O_2\) response at the onset of exercise is exponential (Henry 1951; Henry and DeMoor 1956; Margaria et al. 1965), the \(\dot{V}O_2\) half time has until now been determined using complex nonlinear equations. However, most of the \(\dot{V}O_2\) half time values for various exercise loads have been shown on the average to be between 10 and 40 s (Bason et al. 1973; Cerretelli et al. 1966; Hagberg et al. 1978; Henry 1951; Hickson et al. 1978; Weltman and Katch 1976; Whipp and Wasserman 1972), times which are well within the linear portion of the exponential \(\dot{V}O_2\) uptake curve. This prompted us to investigate the possibility of determining the \(\dot{V}O_2\) half time response using a simple linear equation. The results of this investigation are the subject of this report.

**Material and Methods**

Eight female students at The Ohio State University were used as subjects. Each was given a thorough medical examination and each signed an informed consent prior to the initiation of the study. The subjects were moderately active but none was engaged in a systematic exercise training program prior to the study. Their maximal aerobic power (\(\dot{V}O_2\) max) as determined on an inclined treadmill, average 41.7 ml \(\cdot\) kg\(^{-1}\) \(\cdot\) min\(^{-1}\) and ranged between 34.6 and 46.9 ml \(\cdot\) kg\(^{-1}\) \(\cdot\) min\(^{-1}\).

Two submaximal treadmill walks of 6 min duration were used: (a) 4.8 km \(\cdot\) h\(^{-1}\) up a 2% grade, and (b) 4.8 km \(\cdot\) h\(^{-1}\) up a 10% grade. The 2% load averaged 38% \(\dot{V}O_2\) max (range 32–46%) whereas the 10% load averaged 65% \(\dot{V}O_2\) max (range 55–77%). Six subjects performed the 2% load and eight subjects the 10% load.

Oxygen consumption (\(\dot{V}O_2\)) was measured every 20 s during the first 3 min of exercise and every 1 min thereafter. An open-circuit system was used in which expired air was collected into metrological balloons and immediately analyzed on electronic analyzers for \(O_2\) and \(CO_2\) concentrations. The analyzers were previously calibrated with gases analyzed by the Haldane technique. Inspired ventilation was measured with a Cowan CD-4 gas meter especially equipped with a digital display and printer, programmed to readout and print every 20 s. The gas meter was previously calibrated against a Tissot spirometer.

The nonlinear determination of the \(\dot{V}O_2\) half time response was calculated as described by Hagberg et al. (1978) using the equation first proposed by Henry (1951):

\[
\dot{V}O_2,t = \dot{V}O_2,ss \left(1 - e^{-kt}\right)
\]

where:

- \(\dot{V}O_2,t\) = exercise oxygen consumption at time \(t\),
- \(\dot{V}O_2,ss\) = steady state oxygen consumption for the exercise,
- \(e\) = natural logarithm of numbers,
- \(t\) = time in s,
- \(k\) = constant of the curve.

The \(\dot{V}O_2,ss\) for each subject was determined by averaging the last several \(\dot{V}O_2\) measurements of each exercise load. This usually involved 3–6 measurements (the last 3–4 min of the exercise). Time \(t\) was taken as the midpoint of the period in which a given \(\dot{V}O_2\) measurement was determined. From equation (1) the \(\dot{V}O_2\) half time response, in seconds, is mathematically equal to 0.693/\(k\). For each subject, between six and ten measured \(\dot{V}O_2\) responses were used in the determination of \(k\).

The linear determination of the \(\dot{V}O_2\) half time response was calculated by the least-squares equation as follows:

\[
t = b(\dot{V}O_2,t/\dot{V}O_2,ss) + a
\]