THE ALACTIC OXYGEN DEBT: ITS POWER, CAPACITY AND EFFICIENCY

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The immediate energy source for muscular contraction is generally assumed to be the splitting of ATP, which is immediately resynthesized by creatinephosphate (CP) splitting. These two reactions can be considered in series and, by calling phosphagen (PG) the sum of ATP + CP, the overall reaction can be simplified (5):

\[ \text{PG} \xrightarrow{\text{Pi} + \text{G}} \]

During steady state exercise the rate of PG splitting must be equal to the rate of its resynthesis, which in turn depends on energy yielding processes such as oxidations and/or glycolysis. However, since both lactic acid (LA) production and \( O_2 \) consumption are delayed processes in respect to the mechanical events of muscular contraction (8, 11), during the initial phase of the exercise the rate of PG splitting is higher than its rate of resynthesis. It follows that during work at steady state the concentration of PG in muscle is lower than at rest (3, 13). The net alactic \( O_2 \) debt (\( V_{O_2}^\text{al} \)) represents the oxidative energy necessary to resynthesize the amount of phosphagen split at the onset of work: this has been found to increase linearly with the \( O_2 \) uptake both in man and in isolated muscle (10, 13).

During short term exercise the rate of PG splitting may be higher than its rate of resynthesis, so that a steady state can not be attained. Moreover, in very heavy exercise, exhaustion may be reached within 5 to 10 seconds, a time too short to build an appreciable amount of LA, or to increase the \( O_2 \) uptake signifi-

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cantly above the resting value (8, 11). It may then be assumed, without appreciable error, that in these conditions the work is performed entirely at the expense of PG splitting. Oxidations and/or LA production enter into the picture only later, when the exercise is over, to restore the PG level in muscle at its resting value.

For a full understanding of the PG splitting mechanism the following characteristics should be known: a) the rate of energy output (power), b) the total energy available (capacity) and c) the efficiency.

a) **Power.**

It has been shown by Margaria et al. (8) that in the first few seconds of muscular activity energy is drawn only from PG breakdown and no LA is formed, even during very strenuous exercise (Fig. 1). By plotting the intensity of exercise (in oxidative energy requirement) as a function of the duration of the work without the intervention of LA (Fig. 2, line "alact."), a straight line is obtained. This can be extrapolated at \( t = 0 \),

\[
\Delta LA \text{ mg \%}
\]

\[
\text{sec}
\]

**Fig. 1.** Increase in lactic acid concentration in blood above resting value (\( \Delta LA \text{ mg \%} \)), as a function of the duration of the exercise (sec), in four non athletic subjects running on the treadmill at 18 km/h, at the incline indicated. The time during which the exercise can be carried on without LA production is given, for each work load, by the intercept on the abscissa. (After 8).