Instability of the "Steady State" during Exercise*

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With 2 Figures in the Text

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Oxygen consumption during exercise is usually represented by a smooth curve that rises at the beginning of the exercise and then becomes a horizontal line during the "steady state". A study concerned with oxygen debt in exercise (Luke and Ralston 1962) provided a large number of individual values of the rate of oxygen consumption during exercise. When these values were plotted against time, it was evident that the "steady state" was only relatively steady; marked fluctuations in the rate of oxygen consumption were present throughout the exercise (Fig. 1). It also appeared that the fluctuations varied with the intensity of exercise. Ralston (1958) showed that the speed of walking that is the most economical with respect to energy expended per distance covered is also the most comfortable. This speed is about 4.5 km/hr, with some variation according to the size of the individual subject. This finding suggested the possibility of a correlation between ease in performing work and degree of instability of the "steady state". Therefore, standard deviations were calculated for the fluctuations in the rate of oxygen consumption from the average rate for each test.

Method

The open circuit method was employed. Pulmonary ventilation was measured with a Max Planck type of respirometer, and oxygen concentration in successive samples of expired air was determined with the Beckman-Pauling oxygen analyzer. The rate of oxygen consumption ($\dot{V}_O_2$), although expressed as ml/min, was in the majority of cases obtained from measurements made at 3-min-intervals. The minute-to-minute fluctuations were thus reduced to an average of a longer time interval. Only in the intense exercise did the equipment permit measurement of

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the $\dot{V}_O_2$ separately for every minute; these data were used to calculate the fluctuations over 3-min as well as 1-min intervals.

112 tests were made on 12 normal male human subjects. The exercise consisted of walking or running on the treadmill with four different work loads: (a) very mild exercise: 2.2 km/hr on 0% upgrade, mean $\dot{V}_O_2$, 536 ml/min; (b) mild exercise:

- 4.5 km/hr on 0% upgrade, mean $\dot{V}_O_2$, 746 ml/min;
- 6.0 km/hr on 5% upgrade, mean $\dot{V}_O_2$, 1,878 ml/min;
- 11.2 km/hr on 7% upgrade, mean $\dot{V}_O_2$, 2,610 ml/min.

Results

The results are given in Fig. 2. The average standard deviation (S.D.) expressed in milliliters of $O_2$ increases with increasing intensity of exercise. However, when the S.D. is expressed as per cent of the average $\dot{V}_O_2$ in "steady state", a different trend becomes apparent.

In very mild exercise the average per cent S.D. was 5.2. In mild exercise the average per cent S.D. was 4.0, and the entire range of individual deviations was shifted to lower values than those for the very mild exercise. In moderate exercise the average per cent S.D. was still smaller (2.5), and again the entire range was shifted to lower values. In intense exercise the average per cent S.D. became larger (5.0), and