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Sprinting and endurance for cyclists and runners

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ELITE SPRINTERS RUN 100-m races at 10 m/s, but the (different) elite runners who race over 10 km can manage only about 6 m/s over the longer distance. Elite cyclists reach 20 m/s in short sprints but only about 14 m/s over 10 km. It is well known that long races are slower than sprints because they have to be supported almost entirely by aerobic metabolism. Anaerobic metabolism makes higher power outputs possible in sprints, but these higher powers can be sustained only briefly because only a limited amount of energy can be liberated anaerobically if there is no time for rest and recovery. In a paper in this issue of the *American Journal of Physiology–Regulatory, Integrative and Comparative Physiology*, Weyand and colleagues (4) throw new light on these issues by comparing cycling with running.

Bundle, Hoyt, and Weyand (1) had previously shown that a runner's maximum speed (maximum velocity; V_{max}), for a run of duration (t), was well predicted by the empirical equation

$$V_{max\ t} = V_{max\ aer} + (V_{max\ an} - V_{max\ aer})e^{-kt} \qquad (1)$$

In this equation, $V_{max\ aer}$ is the maximum speed that could be sustained by aerobic metabolism alone, $V_{max\ an}$ is the maximum that could be achieved briefly using anaerobic metabolism, and k is a constant. By fitting this equation to a subject's speeds in trials of a range of durations, from 3 to 240 s, they were able to determine $V_{max\ aer}$, $V_{max\ an}$, and k. $V_{max\ aer}$ and $V_{max\ an}$ have different values for different runners; middle-distance runners have higher $V_{max\ aer}$ and lower $V_{max\ an}$ than sprinters. The constant k, however, has about the same value (0.013 s) for everyone.

In their new study, Weyand et al. (4) have measured the mechanical power (P) that cyclists could maintain for different times, on a bicycle ergometer. They obtained the equation

$$P_{max\ t} = P_{max\ aer} + (P_{max\ an} - P_{max\ aer})e^{-kt} \qquad (2)$$

This equation has the same form as *Eq. 1*, but intriguingly, the constant (k) is different (0.026 s).

For fair comparison between *Eqs. 1* (for running) and *2* (for cycling), we need to express them in the same currency. Both have been rewritten in terms of metabolic power ($\dot{E}$), which was estimated for sprint performance by extrapolation from the oxygen consumption in less intense, aerobic exercise (3, 4). The resulting equation, both for running and for cycling, was

$$\dot{E}_{max\ t} = \dot{E}_{max\ aer} + (\dot{E}_{max\ an} - \dot{E}_{max\ aer})e^{-kt} \qquad (3)$$

The constant (k) has the same values as in *Eqs. 1* and *2*; it is 0.013 s for running and 0.026 s for cycling. At first sight, this seems very surprising. Why should the anaerobic contribution diminish faster with time for cycling than for running?

There is another difference between running and cycling, which affects *Eq. 3*. In comparisons between similar subjects, $\dot{E}_{max\ an}$ is found to be twice as high for cycling as for running, whereas $\dot{E}_{max\ aer}$ has the same value for both modes of exercise.

Weyand et al. (4) point out that, in cycling, each foot exerts large forces only during its downstroke for 50% of the cycle duration. In running at any speed, each foot is on the ground and exerts large forces only for about 24% of the stride duration. They suggest that $\dot{E}_{max\ an}$ is twice as large for cycling as for running because the energy is expended for twice as large a fraction of the time. For the same reason, the limited anaerobic capacity is exhausted twice as fast in cycling, so k is twice as large. $\dot{E}_{max\ aer}$ depends on the rate at which aerobically generated ATP can be supplied to the muscle, not on the rate at which the myosin can use it. ATP can be generated throughout the cycle of movement, whether the muscle is active or not, so $\dot{E}_{max,\ aer}$ is the same for running as for cycling.

The finding that ($\dot{E}_{max\ an}/\dot{E}_{max\ aer}$) is twice as high for cycling as for running may seem paradoxical in the context of the information noted in my first paragraph that (sprint speed/aerobic speed) is higher for running than for cycling. The explanation is that the power required for running is roughly proportional to speed, whereas the power needed for cycling approaches proportionality to (speed)^3 because it is dominated, at high speeds, by the power needed to overcome air resistance (2).

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