When scientists use the phrase "running economy," they aren't talking about shoe sales or road race entry fees. Instead, they are referring to something similar to the so-called fuel economy of one's car. As you know, a car's fuel economy is the distance it can travel on a certain amount of gasoline; a compact sedan that gets 40 miles per gallon (mpg) is said to be very economical, whereas a gas-guzzling SUV getting 10 mpg is considered uneconomical.

Runners, like cars, can vary considerably in their fuel economy; it's just that runners burn carbohydrates and fat rather than gasoline. In this article, I'll discuss some of the factors that affect running economy in hopes of helping you get as much mileage as possible out of your fuel.

**The importance of economy**

Measuring someone's running economy is equivalent to asking the question, "How far can this person run using a given amount of energy?" Energy use is usually reported in terms of oxygen consumption; the farther the person can run per unit of oxygen consumed -- or, stated another way, the less oxygen he/she consumes in running a given distance -- the more economical he/she is.

Economy is an important determinant of performance, as seen in the following example. Imagine two runners, Audrey and Blythe, of equal height and weight. Both can consume a maximum of 4 liters of oxygen per minute while running, but Audrey uses 12 liters of oxygen to run one kilometer, whereas Blythe consumes 16 liters per kilometer. Based on these numbers, Audrey, the more economical runner, would be able to cover one kilometer in 3 minutes, while Blythe would take 4 minutes to complete the same distance. In other words, although both Audrey and Blythe have highly aerobic bodies that can guzzle lots of oxygen, Audrey's body is much better at converting that oxygen into forward motion, allowing her to clobber Blythe in a head-to-head race.

As discussed below, factors such as stride length, shoe weight, and air resistance can affect an individual's running economy and thus his/her running performance as well. Interestingly, though, one thing that doesn't affect economy much is running speed. It takes about the same amount of oxygen (and, likewise, about the same number of calories) to run a mile regardless of whether you are running quickly or slowly (Daniels, Medicine and Science in Sports and Exercise 17: 332-8, 1985). Therefore, if one of your exercise goals is to burn calories, it's important to understand that running your 5-mile loop faster than usual won't help you unload more calories than usual (Ballor et al., American Journal of Clinical Nutrition 51: 142-6, 1990). However, running fast for 45 minutes will consume more calories than running slowly for 45 minutes, since you'll go...
farther during that 45 minutes if you're running fast. Thus, in terms of burning calories, the advantage of fast-paced running is that it allows you to cram more miles into a given amount of time.

**Economy and stride length**

Given that running form varies so much from person to person, you may wonder: is there a single "right" way to run, or does each person naturally adopt a stride most economical for him/her? The scarcity of peer-reviewed research on form prevents us from fully addressing this question; however, some data on economy and stride length do provide a partial answer. In the experiments of Cavanagh & Williams (Medicine and Science in Sports and Exercise 14: 30-35, 1982), ten male runners completed several bouts of treadmill exercise at the same speed but using a different stride length for each bout; furthermore, each runner's oxygen consumption was measured during each bout. Cavanagh & Williams found that each subject ran most economically (i.e., consumed the least oxygen) when taking strides close to his natural stride length (the stride length used when running without any supervision or feedback). Large deviations from this natural stride length resulted in a less favorable running economy.

An interesting follow-up study on stride length was conducted by Morgan et al. (Journal of Applied Physiology 77: 245-51, 1994). They examined 45 recreational runners and, like Cavanagh & Williams, found that most demonstrated a near-optimal stride length for the speed at which they were tested. However, nine of the runners were diagnosed as overstriders and were subsequently trained to reduce their strides to a more optimal length. After three weeks of training, these nine showed significant improvements in running economy relative to a control group. Thus, although most people naturally settle into a stride that is right for them, those who do not can benefit from the expertise of a biomechanics lab.

**Economy and weight**

Common sense suggests that carrying around extra weight is bad for your running economy; if you wear a heavy backpack, for example, you have to work harder (i.e., consume more oxygen) to maintain a given speed or traverse a given distance (Cureton et al., Medicine and Science in Sports 10: 194-9, 1978; Keren et al., European Journal of Applied Physiology 46: 317-24, 1981). While no runner would make the mistake of wearing a loaded backpack during a race, there are some who spend lots of time developing their upper bodies, thus adding on muscle that is not particularly useful for running but nevertheless has to be carried around -- kind of like a backpack.

It is noteworthy that adding weight to your torso does not have the same effect as adding the same weight to your feet; loads placed toward the ends of the limbs hurt your economy more (i.e., increase your oxygen consumption more) because, with each stride, they must be accelerated and decelerated back and forth (Myers & Steudel, Journal of Experimental Biology 116: 363-73, 1985; Martin, Medicine and Science in Sports and Exercise 17: 427-33, 1985). Thus, although an extra 200 grams around your trunk (in the
form of, say, a shirt) will have a negligible affect on economy and performance, adding 200 grams to your feet (by wearing training shoes instead of racing flats) can increase oxygen consumption by 1-2% (Burkett et al., Medicine and Science in Sports and Exercise 17: 158-63, 1985; Jones et al., Ergonomics 29: 439-43, 1986; Hamill et al., Medicine and Science in Sports and Exercise 20: 515-21, 1988). However, in selecting a shoe to use in competition, cushioning must also be considered; a light shoe with no cushioning is not necessarily superior to a heavy but supportive shoe.

**Economy and air resistance**

A final factor that affects running economy is the air resistance one encounters in overground running, as opposed to stationary treadmill running. Pugh (Journal of Physiology 207: 823-35, 1970; Journal of Physiology 213: 255-76, 1971) and Davies (Journal of Applied Physiology 48: 702-9, 1980) have shown that the energy used to overcome air resistance is approximately proportional to the square of the effective wind velocity (e.g., someone running at a speed of 10 kilometers per hour into a 5 km/hr headwind is effectively facing a wind of 15 km/hr). Because of this velocity-squared relationship, the effect of air resistance on economy increases dramatically at high wind and/or racing speeds. For example, according to Davies, 2% of the energy used by a top marathoner running at a speed of 5 meters per second is devoted to overcoming air resistance; for an elite sprinter covering 10 meters per second, the figure rises to about 8%. However, Pugh (Journal of Physiology 213: 255-76, 1971) and Kyle (Ergonomics 22: 387-97, 1979) have confirmed that running behind other runners can reduce these energy costs substantially. In short, drafting is not just for cyclists; runners can and should benefit from it as well.

As pointed out by Kyle & Caiozzo (Medicine and Science in Sports and Exercise 18: 509-15, 1986), the air resistance one encounters while running can also be minimized by grooming oneself to be as aerodynamic as possible. Kyle's careful wind-tunnel experiments showed that, among other things, loose, wrinkled clothing, long, thick cotton socks, and long hair are significant sources of wind drag. Since these items are unlikely to affect marathon performance by more than 5 to 15 seconds (Kyle & Caiozzo, 1986), recreational athletes need not worry about them. Nevertheless, in a tightly bunched pack of elite runners, those who insist on looking fashionable may arrive "fashionably late" at the finish line.

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