THE GO FAST FIVE

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Five physiological lessons you must learn and how they can make you a faster runner

One of the things I love most about the sport of distance running is that, in its simplicity of putting one foot in front of the other, it is also extremely complex. When done correctly, it is a scientific endeavor to maximize one's speed and endurance. Unfortunately, nearly all scientists spend their careers in academia without venturing out into the arena that got many of them interested in physiology in the first place—competitive sport. As a result, few scientists are coaches. The opposite is also true—few coaches are scientists. Being both, I have learned that each can learn from the other, as my experience has given me a unique view of the sport and of the training process. Here are five lessons I have learned from physiology and how they can make you a faster runner.

Lactate threshold and running economy are more important than VO2max

While VO2max (the maximum volume of oxygen your muscles can consume per minute) has received most of the attention among runners and coaches, a high VO2max alone is not enough to attain elite-level performances; it simply gains one access into the club, since a runner cannot attain a high level of performance without a high VO2max. But, while you can improve your VO2max, it is largely genetically determined. The other two major physiological players of distance running performance—lactate threshold (LT) and running economy (RE)—exert a greater influence on your performance and are more responsive to training. I have tested many athletes in the laboratory with an elite-level VO2max, but few of them were capable of running at the elite or even sub-elite level because they did not have a high LT or were not very economical.

From the time of the classic study published in Medicine and Science in Sports and Exercise in 1979, research has shown that the LT is the best physiological predictor of distance running performance. It is an important physiological variable that demarcates the transition between running that is almost purely aerobic and running that includes significant oxygen-independent (anaerobic) metabolism. It represents the fastest speed you can sustain aerobically. (All running speeds have an anaerobic contribution, although at speeds slower than the LT, that contribution is negligible.) Since the LT represents your fastest sustainable pace, the longer the race, the more important your LT.

Running Economy (RE) is the volume of oxygen consumed at submaximal speeds. In 1930, David Dill and his colleagues were among the first physiologists to suggest that there are marked differences in the amount of oxygen different athletes use when running at the same speeds, and that these differences in "economy" of oxygen use is a major factor explaining differences in running performance in athletes with similar VO2max values. For example, research has shown that, while Kenyan runners have similar VO2max and LT values as their American/European counterparts, the Kenyans are more economical, possibly due to their light, non-muscular legs that interestingly resemble those of thoroughbred race horses. The heavier your legs, the more oxygen it costs to move them.

RE is probably even more important than the LT in determining distance running performance because it indicates how hard you're working in relation to your maximum ability to use oxygen. For example, if two runners have a VO2max of 70 milliliters of oxygen per kilogram of body weight per minute and an LT pace of 7 minutes per mile, but Jack uses 50 and Martin uses 60 milliliters of oxygen while running at 7:30 pace, the pace feels easier for Jack because he is more economical. Therefore, Jack can run faster before using the same amount of oxygen and feeling the same amount of fatigue as Martin. I have yet to see a runner who has superior RE who does not also have a high VO2max and LT.

Despite its importance, RE seems to be the most difficult of the three physiological players to train. While many runners and coaches think that RE is a reflection of running form, it is more influenced by those microscopic structures that influence oxygen delivery to and use by the muscles—capillaries and mitochondria, the densities of which are both enhanced with high mileage. Research has shown that runners who run high mileage (more than 70 miles per week) tend to be more economical, which leads one to believe that running high mileage improves RE. In addition to increasing mitochondrial and capillary density, the greater repetition of running movements may result in better biomechanics and muscle fiber recruitment patterns and a synchronization of breathing and stride rate, which may reduce the oxygen cost of breathing. RE may also be improved by the weight loss that often accompanies high mileage, which lowers the oxygen cost. Since VO2max plateaus with about 70 to 75 miles per week, improved RE may be the most significant attribute gained from running high mileage. However, it's hard to prove cause and effect, since it is not entirely clear whether high mileage runners become more economical by running more miles or are innately more economical and can therefore handle higher mileage.

Research has shown that the lactate threshold (LT) is the best physiological predictor of distance running performance

Other forms of training, like intervals and tempo runs, can also improve RE since, as VO2max and LT improve, the oxygen cost of any submaximal speed is also likely to improve. However, it is possible to become more economical without improving VO2max or LT, as research on power training with very heavy weights and plyometrics has shown. Power training focuses on the neural, rather than metabolic, component of muscle force development to improve RE.

There are different muscle fiber types

There are two types of runners—those who have superior speed, whose performance gets better as the race gets shorter, and those who have superior endurance, whose performance gets better as the race gets longer. Most runners, unless they are individually coached, follow some generic training program. However, those programs don't acknowledge differences in runners' muscle fiber types and their associated metabolic profiles. The types of fibers that make up individual muscles greatly influence your performance.

Humans have three different types of muscle fibers, with gradations between them (see Characteristics of the 3 Muscle Fiber Types). Slow-twitch (ST) fibers are recruited for all of your aerobic runs, while fast-twitch B (FT-B) fibers are only recruited for short anaerobic, high-force production activities, such as sprinting, hurdling, and jumping. Fast-twitch A (FT-A) fibers, which represent a transition between the two extremes of ST and FT-B fibers, are recruited for prolonged anaerobic activities with a relatively high-force output, such as racing 400 meters. It's a given that you have more ST fibers than FT fibers, otherwise you would be a sprinter rather than a distance runner.

However, even within a group of distance runners, there is still a disparity in the amount of ST fibers. Some runners may have 90 percent ST and 10 percent FT fibers (marathoners), while others may have 60 percent ST and 40 percent FT fibers (milers). In lieu of a muscle biopsy to determine your exact muscle fiber type composition, ask yourself the following questions:

1 When you race, a) are you able to hang with your competitors during the middle stages, but get out-kicked in the last quarter to half-mile or b) do you have a hard time maintaining the pace during the middle stages, but can finish fast and out-kick others?

If you answered a, you probably have more ST fibers. If you answered b, you have more FT fibers.

2 Which type of workouts feel easier and more natural—a) long intervals (800-meter to mile repeats), long runs, and tempo runs, or b) short, fast intervals (200s and 400s)?

If you answered a, you have more ST fibers. If you answered b, you have more FT fibers.

3 Which workouts do you look forward to more—a) long intervals and tempo runs or b) short, fast intervals?

If you answered a, you have more ST fibers. If you answered b, you have more FT fibers. (People tend to get excited about tasks at which they excel, while being more anxious about tasks that are difficult.)

Understanding your fiber type can help you train smarter. While most runners do the same workouts to focus on a specific race, your training and racing should reflect your physiology. For example, if you have 90 percent ST and 10 percent FT fibers, your best race will likely be the marathon and your training should focus on mileage and tempo runs. If you have 60 percent ST and 40 percent FT fibers, your best race will likely be the 800 meters or mile, and your training should focus less on mileage and more on interval training. If both runners want to race a 5K or 10K, the former runner should initially do longer intervals, trying to get faster with training, such as 1,200-meter repeats at 5K race pace, increasing speed to 3K race pace or decreasing the recovery as training progresses. The latter runner should do shorter intervals, trying to hold the pace for longer with training, such as 800-meter repeats at 3K race pace, increasing distance to 1,200 meters or increasing the number of repeats as training progresses. Thus, there can be two paths to meet at the same point.

A larger, stronger heart can pump more blood and oxygen to your muscles

The amount of blood the heart pumps with each contraction of its left ventricle (the heart's largest chamber that is responsible for sending blood to every part of your body except the lungs) is called the stroke volume. Multiply the stroke volume by your heart rate, and you get the amount of blood pumped by your heart each minute, called the cardiac output. The larger your left ventricle, the more blood it can hold; the more blood it can hold, the more blood it can pump. So characteristic is a large heart of genetically gifted and highly trained runners that it is considered a physiological condition by the scientific and medical communities called Athlete's Heart. While you and I may never attain the heart size and associated cardiac output of an Olympic champion, specific training can make your heart larger and increase your stroke volume and cardiac output.

Long intervals provide the heaviest load on the cardiovascular system because of the repeated attainment of the heart's maximum stroke volume and cardiac output (and, by definition, your VO2max). In response to the imposed threat of running at your heart's maximum ability to pump blood, your heart responds by increasing its contractility (pumping strength) and by enlarging its most important chamber so that more blood and oxygen can be sent to the working skeletal muscles.

In lieu of a laboratory test to tell you the velocity at which VO2max is achieved (vVO2max), you can use current race performances or heart rate. vVO2max is close to 1-mile race pace for recreational runners and close to 2-mile race pace (10 to 15 seconds per mile faster than 5K race pace) for highly trained runners. You should be within a few beats of your maximum heart rate by the end of each interval. Examples of workouts are: 1) 3 x 1,200 meters (or 4-5 minutes) @ vVO2max with 3 to 4 minutes recovery; 2) 4 x 1,000 meters (or 3-4 minutes) @ vVO2max with 2½ to 3 minutes recovery; and 3) 6 x 800 meters (or 3 minutes) @ vVO2max with 2½ to 3 minutes recovery.

Metabolism is tightly regulated by enzymes and oxygen

Enzymes function as biological catalysts that speed up chemical reactions. In the absence of enzymes, chemical reactions would not occur quickly enough to generate the energy needed to run. The amount of an enzyme also controls which metabolic pathway is used. For example, having more aerobic enzymes will steer metabolism toward a greater reliance on aerobic metabolism (Krebs cycle and electron transport chain) at a given submaximal speed. Enzymes are also activated or inhibited (i.e., their effectiveness in speeding up chemical reactions can be either increased or decreased), determining which metabolic pathways are functional during certain cellular conditions. Thus, enzymes essentially control metabolism and therefore control the pace at which you fatigue.

Having more aerobic enzymes will steer metabolism toward a greater reliance on aerobic metabolism at a given submaximal speed

A number of studies have documented an increase in enzyme activity in response to training. One of the first among these was published in 1967 in Journal of Biological Chemistry, in which aerobically trained rats increased mitochondrial enzyme activity, increasing the mitochondria's capacity to consume oxygen. More recently, a study published in Journal of Applied Physiology in 2006 found that citrate synthase (a key aerobic enzyme) activity significantly increased by 37 percent in novice runners after 13 weeks of training during which weekly mileage increased from 15 to 36. Similarly, sprint training induces changes in the anaerobic enzyme profile of muscles and also increases aerobic enzyme activity, particularly when long sprints or short recovery between short sprints are used. For example, a study published in Journal of Applied Physiology in 1998 found that sprint cycle training three times per week for seven weeks using 30-second maximum-effort intervals significantly increased both anaerobic and aerobic enzyme activity. Research on changes in enzyme activity with sprint running is currently lacking.

Metabolism is also regulated by its patriarch—oxygen. The availability of oxygen determines which metabolic pathway predominates. For example, at the end of the metabolic pathway that breaks down carbohydrates (glycolysis), there is a fork in the road. When there is adequate oxygen to meet the muscle's needs, the final product of glycolysis—pyruvate—is converted into an important metabolic intermediate that enters the Krebs cycle for oxidation. This irreversible conversion of pyruvate inside your muscles' mitochondria is a decisive reaction in metabolism since it commits the carbohydrates broken down through glycolysis to be oxidized by the Krebs cycle. However, when there is not adequate oxygen to meet the muscle's needs, pyruvate is converted into lactate. An associated consequence of this latter fate is the accumulation of metabolites and the development of acidosis, causing your muscles to fatigue and you to slow down.

The more aerobically developed you are, by focusing on increasing your mileage and doing LT runs, the more you'll steer pyruvate toward the Krebs cycle and away from lactate production at a given pace. That's a good thing, because the amount of energy you get from pyruvate entering the Krebs cycle is 19 times greater than what you get from pyruvate being converted into lactate. While pyruvate will always be converted into lactate given a fast enough speed, the goal of training is to increase the speed at which that occurs.

Carbohydrates are extremely important

The many proponents of diets like Atkins and South Beach would have the public believe that carbohydrates are some kind of poison. Don't listen to them. Carbohydrates are a runner's best friend. Carbohydrates are stored in our skeletal muscles and liver as glycogen, and are also found as sugar (glucose) in the blood. When we run, our bodies use a combination of blood glucose and glycogen as fuel to regenerate the high-energy chemical compound ATP through a process called glycolysis. Endurance performance is strongly influenced by the amount of pre-exercise muscle glycogen, with intense endurance exercise decreasing muscle glycogen content. Carbohydrates are so important that ingesting them during prolonged exercise can even delay fatigue. With the well-documented decrease in muscle glycogen content that accompanies endurance exercise, an empty-refill cycle becomes evident. Since your muscles prefer carbohydrates as fuel, a metabolic priority of recovering muscle is to replenish muscle glycogen stores. And the more your glycogen tank is emptied, the greater it's refilled. Empty a full glass, and you get a refilled larger glass in its place. Much like your neighborhood pub.

Glycogen synthesis is controlled by the hormone insulin and the availability and uptake of glucose from the circulation. Insulin, which is secreted from the pancreas, is the primary signal for glycogen synthesis. Through its effect on proteins that transport glucose, insulin draws glucose from the blood into muscle cells. Glucose is then used to make new glycogen, which is simply a branched chain of glucose molecules. The higher the blood insulin concentration and the greater the availability of glucose, the faster glycogen is synthesized and stored. So, how do you increase insulin concentration and make glucose available? Consume carbohydrates.

Research has shown that the synthesis of glycogen between training sessions occurs most rapidly if carbohydrates are consumed immediately after exercise. Indeed, delaying carbohydrate ingestion for just two hours after a workout significantly reduces the rate at which muscle glycogen is resynthesized and stored. To maximize the rate of glycogen synthesis, consume 0.7 gram of simple carbohydrates (preferably glucose) per pound of body weight within 30 minutes after you run and every two hours for four to six hours. It would be even better if you can eat or drink more often, since research has shown that a more frequent ingestion of smaller amounts of carbohydrates has an even greater effect on glycogen synthesis, as it better maintains blood glucose and insulin levels. Despite the many highly advertised commercial sports drinks, any drink that contains a large amount of glucose is great for recovery. For example, my research published in International Journal of Sport Nutrition and Exercise Metabolism in 2006 showed that chocolate milk is just as or better than other recovery drinks after exhausting exercise. While some studies have found that consuming carbohydrates and protein together also speeds muscle glycogen storage, others have not found this to be the case. The total amount of calories consumed seems to be more important for recovery than the carbohydrate-protein mix.

If you want to get the most from your training and racing, learn these lessons. Not only will you be rewarded with higher levels of fitness and new personal records, you'll make a complex sport a little simpler. **UF**

Next issue's Peak Fitness column will discuss the three ways your body produces energy to exercise.

Try This: Training Lactate Threshold (LT)

LT Pace

LT pace is about 10 to 15 seconds per mile slower than 5K race pace (or about 10K race pace) for slower runners (slower than about 40 minutes for 10K). If using a heart rate (HR) monitor, the pace is about 75 to 80% max HR. For highly trained and elite runners, LT pace is about 25 to 30 seconds per mile slower than 5K race pace (or about 15 to 20 seconds per mile slower than 10K race pace) and corresponds to about 85 to 90% max HR.
The pace should feel "comfortably hard."

LT Workouts

- continuous runs at LT pace, starting at about 3 miles and increasing up to 7 to 8 miles (or about 45 minutes) for marathoners
- intervals @ LT pace with short rest periods, such as 4 to 6 x 1 mile @ LT pace with 1 minute rest
- shorter intervals at slightly faster than LT pace with very short rest periods, such as 2 sets of 4 x 1,000 meters @ 5 to 10 seconds per mile faster than LT pace with 45 seconds rest and two minutes rest between sets
- long, slow distance runs with segments run at LT pace (for marathoners), such as 12 to 16 miles with last 2 to 4 miles @ LT pace or 2 miles + 3 miles @ LT pace + 6 miles + 3 miles @ LT pace

Characteristics of the 3 Muscle Fiber Types

	Slow-Twitch (ST)	Fast-Twitch A (FT-A)	Fast-Twitch B (FT-B)
Contraction time	Slow	Fast	Very Fast
Size of motor neuron	Small	Large	Very Large
Resistance to fatigue	High	Intermediate	Low
Activity	Aerobic	Long-term Anaerobic	Short-term Anaerobic
Force production	Low	High	Very High
Mitochondrial density	High	High	Low
Capillary density	High	Intermediate	Low
Oxidative capacity	High	High	Low
Glycolytic capacity	Low	High	High

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