Chasing Pheidippides

Training to Combat Marathon Fatigue

BY JASON R. KARP, PH.D.

From a physiologist's perspective, fatigue is the inability to maintain or repeat a given level of muscle force production, resulting in an acute impairment of performance. Fatigue is not something specific to slow or average runners. Even world record holders become fatigued; they just do it at a much faster pace than the rest of us. Indeed, fatigue is necessary to protect our bodies from damage.

However, the only way to get faster is to cause some damage so the fatigue occurs at a faster pace. To do that, you must repeatedly threaten the body's survival with training stimuli so that your body adapts and physiologically overcompensates. When the same stress is encountered again, it does not cause the same degree of physiological disruption. In other words, your body adapts to handle the threat. Below are the main factors involved in marathon fatigue.

LIMITATIONS IN AEROBIC METABOLISM

To provide energy for muscle contraction, a high-energy chemical compound called adenosine triphosphate (ATP) is broken down into its constituents—adenosine diphosphate (ADP) and inorganic phosphate (P_i). Since our muscles don't store much ATP, we must constantly regenerate it.

The formation and regeneration of ATP is thus a circular process—ATP is broken down into ADP and P_i, and then ADP and P_i combine to regenerate ATP. Since the marathon is almost purely aerobic, limitations in the aerobic regeneration of ATP (due to inadequate blood flow to and oxygen use by the muscles) contribute to fatigue.

GLYCOGEN DEPLETION

It has been known since the 1960s that endurance performance is strongly influenced by the amount of carbohydrates stored in skeletal muscles (glycogen), with fatigue coinciding with glycogen depletion. You have enough stored glycogen to last slightly more than two hours of sustained running at a moderate intensity.

So, unless you plan on running the marathon as fast as Meb Keflezighi, you're going to run out of fuel. Glycogen depletion and the accompanying low blood sugar (hypoglycemia) coincide with hitting the infamous Wall.

OTHER CAUSES OF MARATHON FATIGUE

The length of the marathon opens up doors for other fatigue-inducing problems. For example, running for so long can cause psychological or neural fatigue, the latter of which is due to changes in the levels of the brain neurotransmitters serotonin and dopamine, which increase the perception of effort, cause you to feel tired, and inhibit the central nervous system command to the muscles.

When you sweat a lot, you become dehydrated, which decreases the plasma volume of the blood, decreasing the heart's stroke volume and cardiac output. When these key characteristics of the heart decrease, oxygen flow to your muscles is compromised, and the pace slows. The relentless pounding on the pavement causes muscle-fiber damage, which decreases muscle force production.

Finally, since your muscles produce heat when they contract, running for long periods of time is a threat to your body temperature; the resulting hyperthermia decreases blood flow to the active muscles (since more blood is directed to the skin to increase convective cooling), reducing the ability to regenerate ATP via aerobic metabolism. Here's how to combat marathon fatigue and chase Pheidippides.

HIGH MILEAGE

A high training volume improves many aspects of aerobic metabolism, including the number of red blood cells, hemoglobin concentration, muscle capillary and mitochondrial volumes, and aerobic enzymes, together resulting in greater oxygen-carrying capability and greater ability to use the available oxygen.

High mileage also seems to improve running economy, the oxygen cost of maintaining a given pace. Research has shown that runners who perform high volumes of endurance training tend to be more economical, which has led to the suggestion among scientists that running high mileage (greater than 70 miles per week) improves running economy. Economy is improved largely from increases to capillary and mitochondrial density, the former facilitating oxygen diffusion into your muscles and the latter increasing aerobic metabolic capacity.

It is also possible that the countless repetitions of the running movements result in optimized biomechanics and muscle-fiber recruitment patterns. Additionally, economy may be improved by the weight loss that often accompanies high mileage, which leads to lower oxygen cost; the hypertrophy of slow-twitch skeletal muscle fibers, which are more suited for aerobic metabolism; and a greater ability for tendons to store and utilize elastic energy. Because it's hard to prove cause and effect, 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 without getting injured.

TEMPO RUNS

Tempo runs improve your lactate threshold (LT), the fastest speed you can sustain aerobically—above which acidosis occurs—and the best physiological predictor of distance running performance.

Increasing your LT pace allows you to run faster before you fatigue because it allows you to run faster before oxygen-independent (anaerobic) metabolism begins to play a significant role. The benefit to being able to run aerobically at 6:30 pace compared with 7:00 pace is obvious. Since optimal marathon pace is only about 15 to 20 seconds per mile slower than LT pace (with the difference in paces getting larger as performance level declines), the goal of marathon training is to increase the pace at which your LT occurs and to increase your ability to sustain as high of a percentage of your LT as possible.

I typically use four types of LT workouts with my marathoners: (1) continuous runs (from three or four miles to six or seven miles, or from 20 to 25 minutes to about 45 minutes) at LT pace; (2) intervals run at LT pace with short rest periods, such as 4 x 1 mile or 6 x 1,200 meters at LT pace with one-minute rest; (3) shorter intervals run at slightly faster than LT pace with very short rest periods, such as two sets of 4 x 1,000 meters at five to 10 seconds per mile faster than LT pace with 45 seconds rest and two minutes rest between sets; and (4) LT/LSD combo runs, medium-long continuous runs with segments run at LT pace, such as 12 to 16 miles easy with the last two to four miles at LT pace, five miles easy plus three miles at LT pace plus five miles easy plus three miles at LT pace, or 10 miles easy plus four miles at LT pace.

LT pace is about 10 to 15 seconds per mile slower than 5K race pace (or about 10K race pace) for runners slower than about 40 minutes for 10K. For highly trained and elite runners, the 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). The pace should feel "comfortably hard."

As your LT training progresses, increase the training load by spending more time at LT pace rather than by running faster. You can do this by increasing the volume of a single workout or by adding a second LT workout each week. Increase the pace of the workouts only once your shorter races leading up to the marathon have shown that you are indeed faster. After you've done a few of the LT/LSD combo runs, try running the last one to two miles faster than LT pace.

RUN LONG

Repeatedly running for long periods of time (longer than two hours) helps you combat the psychological and neural causes of fatigue by practicing to tolerate prolonged exertion. It also presents a threat to the muscles' survival by depleting their storage of fuel. Given adequate ingested carbohydrates following the long run, the skeletal muscles respond rather elegantly to the "empty tank" by synthesizing and storing more glycogen, thus increasing endurance for future efforts.

To maximize the rate at which glycogen is stored, ingest 0.7 gram of simple carbohydrates (such as glucose) per pound of body weight within 30 minutes after long runs and continue to consume 0.7 gram per pound every two hours for four to six hours afterward. My research published in *International Journal of Sport Nutrition and Exercise Metabolism* in 2006 has shown that chocolate milk, with its high carbohydrate and protein contents, is a great postworkout recovery drink.

INGEST CARBS DURING THE RACE

That muscles prefer carbohydrates as a fuel is so fundamental to exercise metabolism that even research examining supplementation with carbohydrate *during* prolonged exercise has shown that fatigue can be delayed. Begin ingesting glucose about 30 minutes before you hit The Wall so the glucose has time to be absorbed into your blood where it can be used for energy.

DRINK FLUIDS WITH SODIUM

Since your sweat rate exceeds your ability to ingest fluid while running, dehydration is difficult to prevent. However, since endurance performance declines with only a 2 to 3 percent loss of body weight due to fluid loss, it's important to minimize its effects. During the marathon, drink fluids with sodium. Since water goes wherever sodium goes, more water is conserved by the kidneys when you ingest sodium with the water.

RUN LONG ON PAVEMENT

Unless you're planning on running a trail marathon, do all of your long runs on pavement to prepare for the muscle-fiber damage you'll sustain in the race. To preserve your legs, do other runs during the week on softer surfaces.

ACCLIMATIZE TO THE HEAT

Climate has a greater effect on the marathon (or ultramarathon) than it does on any other race. If your marathon is going to be in hot, humid weather, prepare yourself by acclimatizing to those conditions beforehand. While cardiovascular

adaptations to running in the heat are nearly complete within one week, the sweating response takes about two weeks, so give yourself at least two weeks of slowly introducing yourself to the heat.

The next time you train for a marathon, follow these fatigue-combating guidelines. And if you train smart enough, not only will you increase your fitness, you may even be able to chase Pheidippides.