Headfirst Running

New thinking on training the mind/muscle connection

By Matt Fitzgerald

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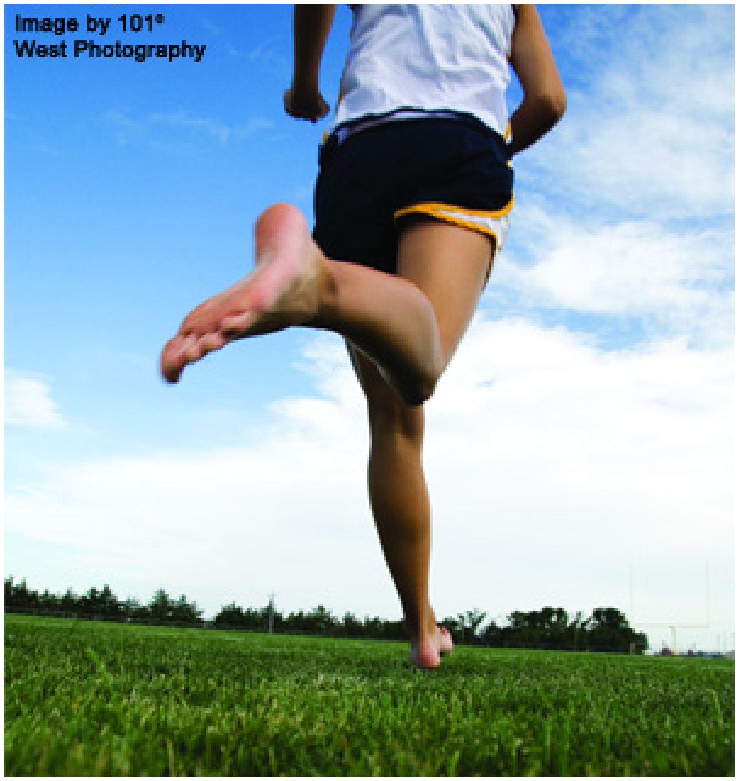

Every competitive runner is familiar with the “sticky road” phenomenon. In the latter stages of a race or tough workout you begin to feel as though the pavement beneath you has been replaced with some type of flypaper or resurfaced with gluey, wet tar. Whereas in the early miles your feet bounced lightly off the ground, you now have to actively yank them away from the gummy surface. With each stride the effort required to do so increases, and as a result your feet seem to spend twice as much time in contact with the earth as they did in the beginning.

Studies have shown that this feeling is no illusion. Our feet really do remain “stuck” to the ground longer as we begin to fatigue. Exercise scientists do not yet fully understand what causes the running stride to deteriorate in this manner during prolonged hard running, but they do know that it’s fundamentally a neuromuscular phenomenon — that is, a phenomenon based on brain-muscle communications. In response to chemical “warning” signals sent from the working muscles to the brain — signals such as rising muscle acidity and various indicators of muscle damage — the brain protectively reduces electrical output to the muscles, thereby preserving the body’s homeostasis but at the price of causing the stride to lose its former bounciness.

A New Model of Running Performance and Fatigue

Such discoveries are part of a quiet revolution that has occurred within the past decade in the scientific understanding of running performance and fatigue. Exercise physiologists used to understand running performance and fatigue primarily in terms of energy. Runners improved their performance by increasing their ability to consume oxygen, so they could pour more aerobic energy into running faster, and by increasing their capacity to store and conserve carbohydrate fuel, so they could run farther before running out of energy.

Scientists are now increasingly thinking of running performance and fatigue in terms of the stride and its neuromuscular basis. Runners improve by increasing their stride power and economy, as well as the capacity to sustain stride power and economy at race intensity, and all of these improvements are made possible by changes in the way the brain and muscles communicate. Fatigue is simply an involuntary deterioration of the stride caused by a reduction of motor output to the muscles from the brain that serves to protect the runner from running to the point of permanent tissue or organ damage.
Seen from this new perspective, the training process takes on a slightly different meaning. Each workout is an opportunity to practice brain-muscle communications and thereby alter them in ways that improve the stride. This newfangled neuromuscular model of running performance and fatigue certainly does not demand a wholesale transformation of training practices, but it may encourage a reshuffling of your current training priorities.

Our very latest knowledge about the several roles of brain-muscle communications in running performance and the nature of neuromuscular adaptations to training suggests that every runner's top five training priorities should be as follows: **1) repetition, 2) variation, 3) exposure to fatigue, 4) conscious control, and 5) maximal effort.**

Repetition

Form drills, like high knees, help your brain find your most efficient stride

Most children develop some sort of running ability by age three. They do so by practicing the movement patterns that make up the stride and gradually developing the ability to perform them efficiently. Those of us who choose to build on this rudimentary running ability and eventually become able to sustain relatively fast speeds over long distances seldom appreciate the degree to which our continued improvement is due to the very same process of repeatedly practicing movements and thereby gaining efficiency.

Frequent repetition of any motor skill causes physical changes in the brain that scientists are now able to observe. For example, it has recently been discovered that consistent practice of a sports movement causes a sheath of fatty tissue, called myelin, which insulates the wire-like connections between brain cells, to thicken around those connections that are most often used in the performance of that particular motor skill. Thanks to the improved insulation afforded by this myelin growth, nerve impulses travel faster along the nerves and can be more precisely timed, resulting in more powerful and efficient movement.

This process actually causes the brain regions involved in activating certain muscles to grow. Thus, as a runner, you probably have a greater than normal volume of tissue in the area of your brain's motor center that is responsible for activating the muscles of your legs.

Another observable change associated with motor skill mastery is that the amount of brain activity that occurs during the performance of a motor skill decreases. This process indicates a progressive trimming of waste from the muscle movements involved. In the case of running, training reduces the amount of wasteful muscular "co-contraction" that occurs during running. Co-contraction refers to the tensing of muscles opposing the working muscles at various points in the stride action.

For example, during the swing phase of the stride, when the thigh is moving forward, the hip flexors (the muscles that connect the thigh to the torso on the front of the body) are the primary working muscles. The gluteal muscles of the buttocks are directly opposed to the hip flexors. Their job at this point of the stride is to relax and stretch. Any tension in the gluteal muscles will create resistance, requiring the hip flexors to work harder to pull the thigh forward. A certain amount of co-contraction is necessary at most times to stabilize joints and guide the direction of movements, but less experienced and less fit runners exhibit excessive co-contraction that does nothing but waste energy.

These and other neuromuscular adaptations that underlie the mastery of the running skill represent the true foundation for improvement in the sport. The cause of these changes is practicing the skill over and over. So the single most effective way to improve as a runner is to consistently run a lot. How much is a lot? Ideally, you will do close to the maximum amount of running your body can handle without becoming injured or hampering your ability to perform your most important workouts (high-intensity runs and long runs) at a high level. When pursued sensibly, this high-volume approach to training will gradually increase the maximum running volume you can effectively handle — an increased capacity you should then take advantage of by running even more.

Most of us choose to run less than this ideal amount because we are unwilling or unable to make a greater time commitment to training. That's OK. In this case you'll want to make every effort to get the most out of every mile you run by focusing on the next four training priorities, starting with variation.

Variation

Some people have "natural coordination" and therefore tend to master new motor skills faster than others. Studies involving tasks such as throwing Frisbees at targets have shown that such individuals have an innate tendency to vary their technique more than slower learners do. As a result, they discover more effective movement patterns and discard less effective movement patterns faster.

Because running is as complex a motor skill as throwing a Frisbee, there is every reason to believe that the same phenomenon is manifest in runners. The brains of individual runners probably have widely varying propensities to try out subtly different ways of coordinating the muscles during running. Those with the most "play" in their muscle recruitment patterns probably learn new efficiencies the fastest.

Regardless of how much natural coordination you have, you can increase your rate of stride improvement by continually forcing yourself to vary your stride in training. Throwing disparate types of running challenges at your neuromuscular system forces it to get creative — to try out different patterns of muscle recruitment, some of which will be more efficient, others of which will help you resist fatigue better.

The most fundamental form of variation is pace, as different running speeds entail different stride rates, lengths, and power output levels. Each week of training should include efforts at a variety of intensity levels ranging from a slow jog to maximal effort (see below). There are many other ways to vary your training, however. Your training should involve a mix of level, uphill, and downhill running and a variety of running surfaces. Also try to mix in some barefoot running with your normal shod running each week. (When weather or lack of access to an appropriate surface makes barefoot running impossible, you can simulate it in minimalist running "shoes" such as Nike Frees or Vibram FiveFingers.) Running technique drills such as single-leg running and "high knees" constitute helpful forms of stride variation, as well.

Exposure to Fatigue

One of the most important factors that stimulate neuromuscular adaptations resulting in greater fatigue resistance is exposure to running fatigue. Scientists are rapidly learning more about the mechanisms of these adaptations. They've learned that a key player in some of them is an immune system signaling compound called interleukin-6 (IL-6). Two factors associated with running fatigue — muscle glycogen depletion and muscle damage — cause circulating levels of IL-6 to increase dramatically. In the short term, high concentrations of IL-6 in the brain cause exhaustion to occur. In the longer term, IL-6 coordinates many of the body's fitness adaptations, ranging from increased fat burning to greater resistance to muscle damage.
Another endurance-boosting neuromuscular adaptation that occurs in response to exposure to running fatigue is improvement in motor unit cycling. A motor unit is a bundle of muscle fibers that is fed by a single motor nerve. During running, only 20 to 30 percent of the motor units in your working muscles are active simultaneously. But it's not the same 20 to 30 percent of motor units that are active throughout a run. On the contrary, most of the motor units in the working muscles contribute to the running effort at various times over the course of a run, but none are active all the time. Instead, they take turns. While some are active, others rest, awaiting their next turn. This cycling of motor units allows you to run much farther than you could if any of the motor units in your working muscles were forced to remain constantly active.

Your training program should optimize your exposure to fatigue in order to maximize such neuromuscular adaptations. There are three main ways to achieve this objective. First, your training program should include three workouts per week that result in a high level of fatigue — typically a tempo run, a session of high-intensity intervals, and a long endurance run. Doing fewer fatigue-inducing workouts will not produce

sufficient fatigue exposure to maximize the neuromuscular adaptations you're seeking. However, attempting to do more than three hard workouts per week will cause you to carry too much residual fatigue between workouts, hampering your performance in them.
Instead of trying to do more than three hard workouts per week, you can increase your exposure to fatigue in a more productive way by adding short, easy recovery workouts to your schedule. Such workouts are gentle enough so that they will not hinder your recovery from previous hard training, but because you start these runs in a pre-fatigued state (within 24 hours after completing a hard run), they provide extra exposure to fatigue despite their brevity and slow pace.

A third means of increasing your exposure to fatigue is interval workouts. The recovery periods that occur between high-intensity running intervals enable you to spend more total time running at high-intensity than would be possible with a single, sustained high-intensity effort to exhaustion. Any time you train above anaerobic threshold intensity, your workout should have an interval format.

Conscious Control

Conventional wisdom holds that stride technique is more or less untrainable. Your natural stride is, for better or worse, the stride you're stuck with. This assumption is patently false. If you work hard enough at it, you can train to run in any way you please — on one leg, with both arms extended overhead, or however.

Conscious control is necessary to achieve a perfect stride

There are certain stride characteristics that nearly all of the best runners share, and which average runners have in lesser degree or lack entirely. To the best of our ability, we average runners should try to reproduce these features of effective stride technique in our own strides.

In many sports, systematic technique development through conscious emulation of effective technique — whether it's hitting a backhand in tennis, carving a turn on skis, or fielding a ground ball in baseball — are routine. This approach is essentially a two-step process of neuromuscular retraining. Step one is experimentation, in which the athlete consciously fiddles with the technique of a particular sports movement in order to break out of the motor patterns stored in the brain and eventually execute a modified movement that is more like that of the best athletes. Step two is to repeat this new movement over and over until it replaces the old technique as the automatic, second-nature motor pattern ingrained in the brain's motor center.

Runners can do the same thing. In every stride of every run you do, you should make a conscious effort to control at least one element of your stride in a way that makes it more like the stride technique of the best runners. The most effective tools for this purpose are proprioceptive cues. Proprioceptive cues are used to improve technique in a number of sports, including swimming and golf. They are particular thoughts and sensations that athletes focus on while performing a sports movement to help them control that movement in a desired way. There are many proprioceptive cues that you can use to run more like an elite.

It is beyond the scope of this article to address all of the key characteristics of elite running form or to present proprioceptive cues designed to cultivate each of them, so let me focus on the most widespread and costly stride error among non-elite runners: overstriding, or striking the ground heel first with the leg extended in front of the body instead of flat-footed with the foot underneath the hips. Overstriding is a unique stride error in that it is not caused by poor coordination, per se, but by the wearing of running shoes. Nobody overstrides while running barefoot, because you would immediately bruise your heel if you did. The cushioning of running shoes seems to confuse the body's proprioceptive system in a way that causes overstriding in roughly 80 percent of runners. (Fewer than 10 percent of elite runners overstride.) Fortunately, you can train yourself not to overstride even while wearing running shoes. These two proprioceptive cues will help:

Falling Forward: Tilt your whole body slightly forward as you run. Don't bend at the waist! Tilt your entire body from the ankles. When you're first getting a feel for this proprioceptive cue, feel free to exaggerate your lean to the point where you feel you're about to fall on your face. Then ease back to a point where you feel comfortable and in control, but gravity still seems to be pulling you forward. A slight, whole-body forward tilt forces the foot to land more in line with the hips.

Pulling the Road: Imagine that your running route is like a giant non-motorized treadmill. On a non-motorized treadmill, you are able to run in place by pulling the treadmill belt backward with your feet. Envision yourself doing the same thing with the road as you run outdoors. You're not actually moving forward — you're simulating forward movement by pulling the road behind you with each foot. This proprioceptive cue will encourage you to begin retracting your leg before your foot lands, so that your foot lands underneath your body rather than ahead of it.

Including some barefoot running in your weekly training regimen will give you some automatic practice in flat-footed running that the above-described proprioceptive cues will help transfer over to your shod running. Switching over to minimalist running shoes such as the Nike Frees or racing flats for some of your runs will aid this process by making the heel pay a higher price for heel-first landings.

Maximal Effort

Photo by 101° West Photography

Barefoot running uses variation to stimualte stride-improving changes in brain-muscle communication

Distance running is not often thought of as a power sport, but it really is. Power is defined as the rapid application of force. Runners apply force to the ground with the foot. The more force your foot applies to the ground, and the faster it does so, the farther forward you will travel with each stride.
Distance runners do not race anywhere close to their maximal power output level. However, it is beneficial to include maximal power efforts as a regular feature of your training. Doing so may slightly increase your maximal stride power, but more importantly, it will increase your power output level (hence your speed) at race effort.

There are several specific neuromuscular adaptations that increase stride power. The most important one is an increase in the number of muscle fibers within the working muscles that your brain can activate simultaneously. When you contract a muscle with all of your strength — for example, when showing off your biceps muscle — you may assume that all of the fibers in that muscle are active. But they are not. The average person is only able to activate roughly half of the fibers in a given muscle when contracting it with maximal effort. Maximal power training increases the number of muscle fibers within a given muscle that you can activate simultaneously, resulting in greater maximal power output.

Another power-boosting neuromuscular adaptation is an increase in motor unit firing rate. Motor unit firing rate refers to the time that elapses between the instant your brain generates a command for a muscle to contract and the time that contraction begins. Proper training shortens this span, allowing the muscles to apply force more rapidly.

The safest and most efficient way to incorporate maximal power efforts into your training is to perform short (10-second), steep hill sprints once or twice a week. Start with a single sprint up a steep hill following an easy run. This will cause a small amount of tissue strain that will in turn trigger neuromuscular changes to better protect your muscles against strain in your next steep hill sprint, which you should do three days later, again following an easy run.
Continue doing hill sprints twice a week, increasing the number of sprints you do by one sprint per week. Build up to at least six sprints and as many as 10. Once you reach the maximum number of sprints you're comfortable with, eliminate one weekly hill sprint session and continue doing one session per week until your goal race.

Matt Fitzgerald's most recent book is Brain Training for Runners.