The Secret to Human Speed

By Dina Fine Maron

On a Friday morning this past February champion sprinter Mike Rodgers got strapped into a safety harness suspended from the ceiling above a custom-built treadmill. “No one’s ever fallen, but you can be the first,” he was told. Rodgers smirked and steeled himself to run. He was training for the Olympic trials. But that day he was not completing one of his standard, punishing drills on the track or in the weight room at his gym. Instead he had showed up at a small, white building in Dallas with “Locomotor Performance Laboratory” embossed on the door.

From the outside, the structure looks uninteresting, a converted printing shop across from a doggy day care and a yoga studio. But in recent years dozens of sprinters like Rodgers have been coming by this Southern Methodist University facility to get advice on their running technique from sports scientist Peter G. Weyand or to help him with his studies. Weyand has conducted what many researchers consider to be some of the best science to date on the biomechanics of sprinting and how these elite athletes achieve their record-breaking speeds. Ahead of the 2016 Summer Olympics in Rio de Janeiro, his findings have even been incorporated into training for top U.S. sprinters.

The heart of the operation is Weyand’s treadmill, a roughly $250,000 contraption outfitted with specialized plates measuring the force that the runner exerts on the ground during locomotion. Three cameras positioned around the machine capture high-speed, 3-D images of the user’s stride. Rodgers is hoping all these data will reveal insights that could help him make adjustments that would shave off crucial fractions of a second in the 100-meter dash.

Clad in the same type of shoes, spandex top and shorts, and reflective stickers Weyand asks all his subjects to wear, Rodgers starts to run, loping along at a little more than 6.5 miles an hour to warm up. Soon, however, he reaches more than 23 miles per hour.

At this pace, the tattoo on his right calf—the cartoon Road Runner with the phrase "Catch me" inscribed below it—is a blur to the naked eye. The equipment feeds measurements into a specialized computer program that graphs his movements.

Weyand has studied more than 120 runners, including 12 other world-class sprinters—observations that have helped fill in a long-standing gap in scientists' understanding of the biomechanics of running at high speed. Before his investigations, the prevailing wisdom about great sprinters was that they are particularly adept at quickly repositioning their limbs for their next step while their feet are in the air. This claim stemmed largely from intuition rather than a theory based on evidence, however. Weyand was the first to test this idea scientifically—and his findings indicate that it is wrong. Instead the key to speed seems to be something else altogether, a factor that Weyand says he can teach sprinters to improve.

On Your Mark

Although running as a sport dates back to at least 776 B.C., when a footrace was the only event in the earliest Olympic Games, the science underpinning it has long lagged far behind. Perhaps the earliest attempt to obtain rigorous data on runners came from British Nobelist Archibald Hill, who in 1927 conducted an experiment in which runners wearing magnets sprinted past large coils of wire that detected the magnets. Knowing the distance between wire coils, he could calculate the velocity and acceleration of the passing runners.

The invention of modern force plates in the 1950s provided the means to study another aspect of running. These devices, which resemble scales, record the amount of weight applied to them and measure it over the course of a stride. With such tools, scientists can examine the changing force exerted by a runner at different speeds during a race or compare the forces from different types of footfalls—those of runners who strike with their heel first versus those who strike toe first, for instance. Italian scientist Giovanni Cavagna gathered force data on runners in the 1970s by having them run over plates set up on a track. But because the plates are so expensive, he had just a few of them—enough to capture data from just a small fraction of a race. To obtain a complete run, Cavagna had to hold multiple races and manually move the plates forward after each one, recording only a few of the runners' steps at a time, which he then cobbled together into a composite picture.

Based on those and other early studies, sprinting science focused primarily on what slows runners down—air resistance, says animal locomotion expert Jim Usherwood of the University of London—as opposed to what speeds them up. On the whole, the work shed little light on what sprinters could do to boost their performance.

Weyand's research has helped shift that focus and generated insights that athletes can act on. But he is not the first to envision such advances. Because speed is the product of stride length times stride frequency, runners presumed that cutting down the amount of time each foot spends on the ground would net greater speed. In 2000 Weyand and his colleagues published a landmark paper showing how it is actually done. They enlisted 33 runners of varying abilities to run on an earlier iteration of their force-plate-equipped treadmill. The results proved surprising. Weyand expected that the feet of faster runners would spend less time on the ground and hence more time in the air than the feet of their slower counterparts. But he did not foresee that regardless of the runners' abilities, they would all take the same amount of time between when a foot lifted off the ground and when that same foot made contact for its next step.

What actually set the great sprinters apart from the rest, Weyand's team discovered, was the force with which the runners hit the ground. In subsequent work, Weyand further determined that at top speeds the best runners landed with a peak force up to five times their body weight, compared with 3.5 times among the average runners. That difference is significant because like a superball that bounces higher the harder it is thrown, a runner who hits the ground with greater force stores up more energy at impact and will travel forward farther and faster as a result, with longer strides. Forceful hits also allow runners to rebound more quickly, reducing the time that feet are touching the ground and thus increasing stride frequency. The best runners have longer, more frequent strides.

Get Set

Recently Weyand's team additionally figured out how the best sprinters are able to generate those higher forces—and in so doing forced a revision of another central tenet of the running world. According to the popular so-called spring-mass model of running mechanics put forward in the late 1980s, the legs of runners move relatively passively, working like pogo sticks to catch the body on hitting the ground and then pushing the body back into the air on rebounding. Graphical representations of the force of their footfall resemble a gentle, symmetrical curve.

But the model is based on observations of runners moving at slower speeds. When Weyand, Southern Methodist physicist Laurence Ryan and biomechanics expert Ken Clark, now at West Chester University, analyzed their video footage and force data, they noticed that the model did not seem to hold for the fastest runners. Instead of contracting and expanding smoothly like pogo stick springs, their legs operated more like pistons, delivering abrupt, intense hits. Force data from their footfall made a tight, tall peak.

Careful study of the lower limbs of these fast runners revealed subtle factors that contribute to the elevated forces they generate: they stiffen the ankle right before they hit the ground, which serves to decelerate the foot and ankle fractions of a second after impact. This deceleration helps to maximize the force exerted on the body by the ground in response to impact and to prevent the loss of that force. Elite sprinters also keep their knees high, maximizing their distance from the ground, which gives them time and space to accelerate their footfall and ultimately land with greater force. The findings, published in 2014, make sense logically, Weyand says: if you hit someone with a limp wrist, it will not have as much force.

Yet if you keep your wrist stiff, then you will pack a better punch, he observes.

Those insights are now informing what the team says to runners and coaches who seek their advice on how to boost sprinting performance. "It's about simple cues. We don't say, decelerate yourself—we say, stay stiff into the ground, and then deceleration will happen because of that," Weyand says. A runner who heeds this advice will feel a harder hit to the ground with each footfall, he adds. The comportment of the rest of the body is also important, including the ankles, knees, hips, torso and head, which should also be kept stiff.

Weyand's findings have not surprised everyone. Biomechanist Ralph Mann, a former Olympic hurdler who now works with runners and coaches at USA Track & Field, had already been giving that type of feedback to runners, says USA Track & Field coach Darryl Woodson, who coaches eight sprinters, including Rodgers. Woodson says having concrete data supporting Mann's advice, however, made coaches "feel more confident in what they told runners."

Go!

Elite athletes who have taken Weyand's tutelage to heart report improvement. Olympic hurdler David Oliver wanted to enhance his performance after he took home the bronze in his event in 2008, so his strengthening coach brought him to Weyand in 2012. Weyand pinpointed Oliver's two weak areas: his feet hit too far from his center of mass, and his knees were too far back—instead of parallel with or ahead of the alternate knee—which limited the force of his hits. Oliver says he focused on those problems in his training and strengthening exercises and saw a consistent improvement after several months. He went on to win the gold medal at a world championship event held in Moscow the following year in the 110-meter hurdles, and he is still fourth on the all-time-greatest list for that event.

But anecdotal reports notwithstanding, no scientific studies on these runners after they have attempted to follow Weyand's advice have been published to date. One analysis currently under way suggests that his recommendations can bring significant benefits, however. Matt Bundle of the University of Montana has been analyzing how the pointers affect volunteer sprinters and has found improvements "on the order of the bump we think people get from performance-enhancing drugs," he says. "It's a pretty dramatic augmentation."

Still, Weyand acknowledges that biomechanics are not the whole story. There are still many areas left to study and things outside of a runner's control, he says. Genetics, for example, are clearly very important. "If you don't have a decent build and muscle properties that will allow you to be forceful, you won't get [great sprinting] done," Weyand explains. And sometimes an athlete can compensate for biomechanical shortcomings: the fastest person ever timed, Usain Bolt of Jamaica, does not execute all his mechanics flawlessly, according to Weyand. That not quite perfect form suggests that other factors must help Bolt's game—especially his height and strength.

Sports scientists observe that Weyand's discoveries apply not just to elite athletes but also to recreational sprinters. Maintaining a stiff ankle, getting knees higher and trying to hit the ground with great force will not make most people Olympians but could help get them to a personal best, they say. Of course, hitting the ground so hard could be problematic for a recreational runner. If a person has poor form, for example, such blows could boost chances of potential injuries, including knee pain, arch pain, shin splints or a condition known as metatarsalgia, in which the ball of the foot becomes inflamed. French researcher JB Morin of the University of Nice Sophia Antipolis recommends running downhill as part of a training regimen designed to keep ankles straight. He also suggests jumping rope to help with quick rebounding. (Weyand's findings apply exclusively to sprinters. Endurance runners cannot hit the ground with as much force, because they instead need to preserve their energy over a longer time.)

For his part, Rodgers is getting good news from Weyand. In general, the best sprinters "attack the ground," according to the sports scientist. Rodgers's force data demonstrated that he already does exactly that. Although he weighs only about 165 pounds, he hit the treadmill with more than 700 pounds of force—and that was when his muscles were tired from a prior workout. There are no guarantees at the Olympics, but if Rodgers qualifies to compete, his assessment bodes well for race day.

About the Author

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