What Limits How Fast You Can Run?

During the 2008, 2012, and 2016 Olympics, the world marveled at Usain Bolt's lightning-fast sprints. At the Rio 2016 games, he completed the 200-meter dash in 19.78-seconds. When he crossed the finish line, he was a full three meters ahead of the second place runner. His speed in that race of 10.1 meters per second (about 36.4 kilometers per hour or 22.6 miles per hour) is astonishingly fast.The pace of elite runners like Bolt is impossible for most of us—but why? What sets apart elite sprinters from average joggers?

Figure 1. Fastest Man Alive. Usain Bolt during a practice run for the 100-meter sprint, a race he eventually wins, at the Rio 2016 Olympics.
Source: Fernando Frazo/Agncia Brasil Wikimedia Commons.

Understanding what sets Usain Bolt apart could help scientists understand more about how humans run, which could then lead to better training routines for aspiring athletes, and help us avoid and treat injuries. In search of answers, a team of scientists asked a group of runners—some champions, some average joggers, some women, some men—to visit their lab at the Concord Field Station, an off-campus research facility run by Harvard University. In the lab, the scientists had a special treadmill with a floor (the area underneath the belt you run on) made of force plates which could measure the force generated by the runner's feet. The force plates would also keep track of force over time, so the scientists would know exactly how long contact and aerial phases were (how long the feet were on the ground and in the air, respectively), how many strides a runner took in a given amount of time, and how much force was applied with each footstep.

When the scientists plotted their measurements for stride frequency, contact time, aerial time, and maximum force over running speeds, they found that stride frequency increased with running speed. Since their legs were swinging faster, the runners' aerial time and contact times both decreased. But, surprisingly, aerial and contact time did not shrink the same amount. In fact, aerial time did not change much at all, whereas contact time shrunk a lot! To make up for the shorter contact time, the amount of force applied by the runner's feet also increased.

The scientists experienced their biggest shock when they compared what happened at top speed between elite and average runners. Even though the elite runners could run twice as fast as the average runners, all of the stride frequencies, aerial times, and contact times were about the same. One characteristic of the strides was quite different, however: the force a fast runner (someone with a top speed of about 11.1 m/s) used to push off the ground was 1.26 times greater than that of an average runner (someone with a top speed of 6.2 m/s). This means that the only difference between most of us and the champions, when we both are running at top speed, is the amount of force we use to push off the ground!

Reference

Weyand, Peter G., Deborah B. Sternlight, Matthew J. Bellizzi, and Seth Wright. 2000. "Faster top running speeds are achieved with greater ground forces not more rapid leg movements." *Journal of Applied Physiology* 89(5): 1991–1999.

BiteScientist Profiles

Kelsey Lucas is fascinated by how the amazing behaviors animals do arise from the inner workings of their bodies and the physical laws that govern them. By understanding animal behavior holistically, she strives to better understand how nature works around us and how we can better care for, connect to, and learn from it.

Charles Fidler has a wide variety of interests related to STEM education. As an informal educator and teacher in Billerica and Acton-Boxborough, he helped students make connections between their real life experiences and the physics they were learning in the classroom. Now as a STEM education consultant, Charles works on developing high-quality science materials (like this lesson!).