

SPECIAL FITNESS ISSUE: THE FOOT

Such power, such grace

Overlooking the feet can be an athlete's greatest mistake. To treat them well, you must first understand them.

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ORTHOPEDIC surgeons and podiatrists who study it, operate on it and care for it are as enamored of the often sweaty, sometimes stinky, foot as are cardiologists of the heart, or neurologists of the brain. "It's ingenious," says Edward Glaser, a Tennessee podiatrist who switched professions from mechanical engineering to podiatry because of his admiration for the foot's function. "As a machine, it's an engineering marvel."

The foot is built to walk on everything natural — grassy knoll, pine needle forest floor, volcanic rock — uphill and down. It is constantly balancing, changing direction and absorbing a pounding equal to 3.5 times the body's weight, only to spring back in time for the next step.

With its 26 bones and 33 joints, the foot is a biomechanical masterpiece. "There's something wonderful about it," says Dr. Nancy Kadel, professor of orthopedics and sports medicine at the University of Washington. "It's a flexible shock absorber, then it's a rigid platform that propels you forward. It adapts to sand when you walk on the beach. Then you climb onto rocks to look at the tide pools, and it drapes over the rocks."

But as close as it is to perfection for locomotion, two modern environmental necessities stand in the way of allowing it to maintain its full nature-given glory: hard surfaces and the shoe. For a walker, and more so for a runner, a steady diet of concrete asks a lot of that magnificently springy arch. By forcing it flatter, it shifts balance unnaturally, the effects being felt all the way through the foot, ankle, leg, hips and back. Add a pair of shoes for the toes to bump against, the heel to blister against, and you've got the potential to adversely affect almost every bone, muscle and ligament in the body.

It took millions of years for the foot to assume its present shape, a shape it's held for millions more years. The rest of the body has adapted, finding its center of gravity over the spaced left, right footprints of walking, the straighter, in-line footprints of running. But the foot and its attached body parts have had mere thousands of years to adjust to a steady diet of cobblestone, wood surfaces and sandals — not to mention the relatively recent introduction of concrete, asphalt, loafers and stilettos.

To see what's happened in the evolution of the foot over several million years, try the old trick used to teach kids their left from their right hand. Stick the thumbs out as the back of the hand faces you. The one that forms the "L" is the left hand.

Now try it with your feet. Humans, who have an opposable thumb but a big toe that lines up with the other four, can't do it, haven't been able to do it for maybe 4 million to 6

million years.

The big toe, once sticking out to the side to help our hominine ancestors climb trees and grasp branches, eventually took its place in the lineup of toes, stabilizing the foot and allowing us to walk upright.

Not that the other toes don't matter. The baby to the middle piggy stand in a rigid line from heel to the toe tips, giving people support when standing still. The other two toes are loose, aiding in balance. Daniel Altchuler, a Santa Monica podiatrist, is in the habit of watching how people stand when they're waiting in line. "People standing in line always stand on the outside of the foot."

The foot's ability to provide rigid stability for standing still, then spring into action to absorb shock and muster the flexibility to push off and move allows for the beauty of ballet and the power behind a football kick. It also gives the marathoner endurance, the sprinter speed and the high jumper lift.

Ancestral links

The earliest evidence that this pair of bony appendages were ready to support us on their own, without help from the front paws, are the Laetoli footprints, a trail left by three human ancestors taking a stroll on two feet almost 4 million years ago. They walked together on soft ground, intermittently covered by volcanic ash and rain, leaving behind a bipedal record that hardened like a plaster of Paris science project. The footprints were discovered in Tanzania in 1976 by a team led by paleoanthropologist Mary Leakey.

Another clue to how long humans have been upright are the fossilized remains of Lucy, discovered in Ethiopia in 1974. Her remains are from about the same time as the Laetoli footprints, give or take half a million years. But the bones in Lucy's wrists, according to research by scientists Brian Richmond and David Strait of George Washington University, suggest that, while she herself didn't walk on all fours, she retained some of the bone structure that allowed for knuckle walking. Bones from her wrists, the researchers found, remained rigid enough to help support her body on all fours.

Gaps in the fossil record don't allow for pinning down exactly when hominids stood up and walked on two feet. "Estimates vary, but most experts would put this transition at about 6 million years ago," says Thomas Greiner, professor of anatomy and physical anthropology at the University of Wisconsin at LaCrosse.

That's about when our human ancestors made the biological commitment to give up the advantages of an opposable toe for the alternative advantages of having two hands free to hunt and gather. "I think the human foot is essentially an organ that was designed first for grasping, but that has been modified for support and propulsion of the human body," says Greiner.

The modifications have resulted in a functional work of art, one foot sharing with the other the weight of daily living. "It's a linkage system," says Dr. Carol Frey, director of West Coast Sports Medicine Foundation in Manhattan Beach and assistant clinical professor of orthopedics at UCLA. "One joint moves, and the others move. It allows you

to balance on uneven terrain. It can adapt to jumping, landing and things as intricate as dancing."

Those adaptations spin off the basic, but complicated, process of walking. With each of the 10,000 steps required to cover a mile (about 9,000 for men, 11,000 for women), when the heel first hits the ground, the mid-foot collapses slightly, the arch helping to absorb the shock of the impact. As the walker rolls to the middle of the foot, ideally from the outside toward the ball, the foot flattens more. The toes bend to push off. Off the ground again, the arch springs back, aided by the non-rigid, unlocked big and second toe, providing more energy to the forward propulsion and getting the foot ready for the shock of the next landing. "The design of the human foot allows for more energy rebound than any shoe can," says Frey.

When people start to pick up the pace, say faster than an eight-minute mile, they land more toward the middle of the foot. Sprinters often run entirely on the balls of their feet. "When your heel hits the ground walking, your foot needs to be supple to absorb the shock — even more so when running," says Dr. Nelson SooHoo, professor of orthopedic surgery at UCLA. "Then it transforms into something very rigid to get you off the ground."

Success from head to toe

Not all feet are created equal, what with high, normal or flat arches, wide or narrow widths, and differences in flexibility. But most experts now believe that an athlete, a dancer or a soldier can excel with their natural-born feet, no matter what their shape. What gives great athletes and performers an advantage probably has more to do with muscles throughout their bodies — not to mention passion and discipline.

Some people have high arches, and with them, the benefit of going on point, or up on their toes, in ballet. But dancers can pay a price for the artful beauty of a high arch if it's rigid. The whole foot is less supple, less able to absorb the shocks of use and overuse. "Over time, if you're not adjusting to the shock and overusing the stiffness of your foot, you can get arthritis in the feet and ankles," says SooHoo.

The perfect ballet foot, says Kadel, is defined more by its flexibility than its arch. Before medical school, she studied dance at the Martha Graham School of Contemporary Dance in New York City. For the 200th anniversary of the Brooklyn Bridge, she was part of a troupe that danced across the structure. "Some people with flat feet have very flexible feet and can go on point. With any sport, or dance, there's a beautiful combination of factors: a genetic predisposition, a passion for the sport, and a drive to work really hard," she says. "I never want someone to think, 'I can't dance because I don't have the right kind of foot.' If you love to dance, you'll find a way."

The flat foot, once all that was required for a 4F deferment from the draft, has been given the go-ahead for military duty, thanks in part to studies showing it is no more prone to injury than other types of feet. A 1985 study in the journal *Orthopedic Review* looked at the feet of 287 men and women who were Israeli Defense Force trainees. Those with high arches were almost four times more likely to suffer stress fractures. A 1999 study in the *American Journal of Sports Medicine* followed 449 trainees, equally divided into groups with high, normal and low arch height, at the U.S. Naval Special Warfare Training

Center, and found no differences in injury rates.

Flat, normal or high arch, a flexible foot is a healthy foot. Any foot can increase flexibility with simple stretching exercises. They include walking on the beach and picking up sand with the toes, using bare feet to pick up one marble at a time, or scrunching a towel with bare toes. "Your feet have the potential to get stronger," says Frey.

Even more than the flexibility of the foot, athletic or dance prowess depends on conditioning the whole body — allowing the foot to take full advantage of disciplined muscles and tendons in the legs, hips and back. Savion Glover, for example, probably has a lot of fast-twitch muscle fibers, enabling his superbly trained foot to tap at breakneck speed, says Santa Monica podiatrist Altchuler. Eyelids, for example, have fast-twitch muscle fibers, and sprinters are likely to be genetically endowed with an abundance of such fibers throughout their bodies. It's the fast-twitch muscles throughout the body that enable a tap dancer to hoof it, or a sprinter to push off and run fast. But though they work quickly, fast-twitch muscles can tire easily. Marathoners probably have more slow-twitch muscle fibers throughout their body, like those found along the spine. Those muscles give the entire body, including the feet, the endurance needed to keep going for 26.2 miles.

In constant development

The foot was one of the last things added to the human body in evolution, and it's still evolving, says Frey. Though the normal foot has 26 bones, some people might have an extra one or two, most commonly near the heel. "I can't tell you if they're more evolved, or less evolved," she says. Maybe the extra one isn't necessary, and the owner's multigenerational offspring will lose it. Or maybe it's a new bone evolving, perhaps some day to give future people extra speed or bounce.

Any non-required bone is as likely to get in the way as it is to help, like an extra navicular bone, near the heel. If it sticks out, it can make getting into a ski boot or an ice skate difficult, says Altchuler, who has seen athletes with the problem. "So they'll just punch out a part of the boot," he says.

Even as the foot evolved out of its ability to grasp tree branches, some of that grabbing ability remains. Think of Christy Brown, the painter and author of "My Left Foot." Born with cerebral palsy, he learned to pick up a paintbrush and to type with his toes. "People who have lost arms learn to eat with their feet. People who live on houseboats in Hong Kong can fold fishing nets with their feet," says Frey.

Despite the foot's brilliant design, it evolved while walking on soft earth, sand and occasional forays over rock. Today, humans walk on unforgiving surfaces, sometimes covered with broken glass, metal bits, chewed gum, cigarette butts and other debris tossed about by a litterbug-prone, advanced society.

In defense, we need shoes.

It is the shoes, says Greiner, that are responsible for the slight difference seen in the footprints of modern human beings when compared with the 4-million-year-old footprints

of our ancestors in Tanzania. "The Laetoli footprints are very similar to the footprints of humans today," he says. With one exception: Modern humans from industrialized countries have less space between the big toe and the other four toes. That difference is not seen when the ancient footprints are compared with the footprints of people today who live in parts of the world where shoes are not required — evidence that it's shoes, not evolution, responsible for the change.

"You and I and people who grow up wearing shoes have deformed feet," says Greiner. "Any parent will tell you that kids outgrow their shoes faster than they can buy them." And every time a child wears a shoe that's just a bit too small, they're undergoing what amounts to a minor foot binding, pushing that big toe closer to the others.

If that constant, minor binding continues, the foot begins to take on the shape of the shoe, leading to the many woes of the foot: corns, bunions, hammertoes.

"The vast majority of those problems are environmental," says SooHoo. "People with foot problems develop them from shoe wear."

Cement, tile, wood and other unforgiving surfaces compound the problems by urging the foot to flatten, probably more than nature intended. That throws the walker off balance and forces the foot and entire body to accept more force than it is ready for. In an attempt to hang onto the center of gravity, the foot adjusts, turning either in or out and the body responds by flexing more at the mid-foot, ankle, knee and hip. Years of adapting to the increased stress adds to a multitude of aches and pains up and down the entire body.

As the African American spiritual "Dem Dry Bones," says: "Your toe bone connected to your foot bone, your foot bone connected to your ankle bone, your ankle bone connected to your leg bone ... " and on up, through the knee, the thigh, the hip, the back, the shoulders, the neck and the head bone. "When you have bad foot mechanics, the body will compensate for it," says Altchuler. "Other things will start to break down." When the foot isn't happy, it can make the rest of the body miserable.

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