Breaking Boards

Scientists say it's not a trick—it just takes blinding speed and a couple thousand newtons

BY CURTIS RIST

ADVANCED DEGREES IN PHYSICS come in different varieties. At the Massachusetts Institute of Technology, students earn them by writing a dissertation. At the Karate Institute in midtown Manhattan, they earn them by breaking one-inch-thick pine boards. Lots of them.

Ben Paris, a fourth-degree black belt in tae kwon do, is happy to demonstrate his grasp of the scientific principles. First, he adjusts his belt. Then he lets out a short, sharp yell, snaps his left leg forward, and smashes his foot through three boards, showering the mat with splinters. "Five boards is about the most I can break," Paris says. "But I'm not really limited by strength; I'm more or less limited by the size of the hands holding the boards."

Few things offer more visceral proof of the power of physics than a karate chop. Punch a brick with your bare hand, untutored in the martial arts, and you may break a finger. Punch it with the proper force, momentum, and positioning, and you'll break the brick instead. "Amazingly, there are no tricks involved at all," says Michael Feld, a physicist at MIT. "What you have here is one of the most efficient human movements ever conceived. We've found nothing in our studies to improve upon the art."

In the late 1970s, when Feld was earning a brown belt in karate, his instructor, Ronald McNair, also happened to be his physics student. (McNair later died tragically while working as a scientist-astronaut aboard Space Shuttle *Challenger*.) The secret to karate, both men agreed, lies in the speed and exceptional focus of the strike. But just how fast does a karate punch move? To find out, they joined with undergraduate Stephen Wilk and set up a strobe light that flashed either 60 or 120 times per second. Then they photographed McNair and others throwing various kicks and punches. Once the film was developed, they could calculate the speed of a punch by counting how many times the strobe flashed until the fist hit its target.

Feld and McNair found that beginning students can throw a karate chop at about 20 feet per second—just enough to break a one-inch board. But a black belt like McNair could chop at 46 feet per second. At that speed, a 1½-pound hand can deliver a wallop of up to 2,800 newtons (one newton is roughly equal to the force exerted by the weight of an apple). Splitting a typical concrete slab 1½ inches thick takes on average only 1,900 newtons.

Of course, the best boxers can punch as quickly and powerfully as any black belt. Why can't they break concrete blocks too? The answer lies in the nature of their punches. When a boxer throws his fist, he usually ends the move-

Ben Paris, a fourth-degree black belt in tae kwon do, breaks three boards with a flying kick. Using a stroboscope, researchers have measured kicks that travel up to 47 feet per second and generate a force more than 400 times greater than that of gravity.

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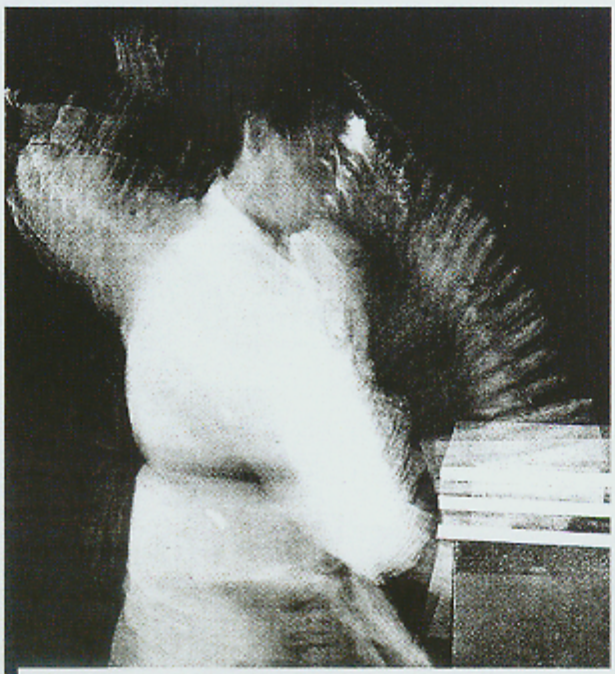
ment with follow-through. This gives the punch maximum momentum (golf and tennis players follow through for the same reason), and it can help knock an opponent down. But the impact itself is diffuse: It's meant to jar an opponent's brain, not crack his skull.

A karate chop, on the other hand, has no follow-through at all: It lashes out like a cobra and then withdraws instantly. When a black belt hits a slab of concrete, for instance, his fist touches the block for fewer than five milliseconds, and yet the block breaks with a resounding crack.

To understand how this works, Jearl Walker, a former tae kwon do student who now teaches physics at Cleveland State University, set up a study much like Feld's and McNair's. A well-thrown fist, he found, reaches its maximum velocity when the arm is about 80 percent extended. "That's exactly what my tae kwon do master had taught me," Walker says. "You learn to focus your punch in your imagination so that it terminates inside your opponent's body, rather than on the surface. To deliver the maximum power, you want to make contact before the slowdown begins."

The purpose of all that focused power is brutally obvious: to break bones and rupture tissue. But success also depends on more subtle forces. Solid as they seem, all materials are at least slightly elastic. Whack them in the right spot and they will start to oscillate. A punch with a follow-through would dampen such oscillations, but a karate chop, by pulling away at the last moment, lets them move freely. "If you tweak a rubber band it goes up and down, and the same is true if you tweak a board or a brick with a much greater force," Feld says. "When they reach their elastic limits, they start to yield. In other words, they break."

Fortunately for most of us, reaching that limit in bones is no easy matter. Feld says bone can withstand 40 times more force than concrete, and a cylinder of bone less than an inch in diameter and 2½ inches long can withstand a force of more than 25,000 newtons. Hands and feet can withstand even more than that, because their skin, muscles, ligaments, tendons, and cartilage absorb a great deal of impact. As a result, a well-kicked foot can absorb about 2,000 times as much force as concrete before breaking.



Grand master Sihak Henry Cho is in his sixties, but his karate chop can still deliver about 100 joules of energy—more than enough to split five pine boards in half.

Feld himself has never broken a finger in karate, even though he once broke eight one-inch-thick boards at a time. Still, good bones and a Ph.D. in physics alone couldn't earn him a black belt. "Tiger Woods didn't just wake up one morning and start hitting a ball 320 yards, and we don't just walk in and shatter a cinderblock," says Sihak Henry Cho, grand master at the Karate Institute. "Everybody has to work at it."

Students not only have to increase their speed and improve their aim, they have to toughen up their hands and feet by striking them against a post wrapped in foam and canvas. "In the beginning, your skin is so soft you may end up cutting it. And then comes the blood," Cho says. "This is not recommended." Over time, the *shuto,* or knife-edge of the hand, develops a callus that acts exactly like a car bumper, absorbing and diffusing the force of the collision. "You practice every day hitting harder and harder and harder, and then you can hit as hard as you can without really getting hurt," Cho says.

Martial arts experts take care to break only those things that can actually be broken. When whacking a pine board, for instance, they align it with the grain running parallel to the strike, so that it cleaves easily. If they're looking for something more challenging, they'll choose patio blocks made of concrete rather than bricks, which are much less brittle.

As students advance, they spend more of their time focusing on form and finesse than on trying to break ever-thicker materials. "Rather than seeing students break a dozen boards, I'd like to see them jump over my shoulder and break one board while flying through the air," Cho says. As a young man in Korea, he learned to prop a brick on top of a post and shear it in two with the side of his hand—leaving one half of the brick still perched on the post. In 1967, at a martial arts championship in Madison Square Garden (where Cho says he introduced his friend Bruce Lee to that year's champion, Chuck Norris), Cho performed an even neater trick. Leaping into the air with a roundhouse kick, he split a single inch-thick board that his partner was dangling by a string.

"Being good at karate is a lot like being good at telling a joke," Cho says. "It's not what you break; it's how you break it." ⓓ