The New Physics of Tennis

Unlocking the mysteries of Rafael Nadal's killer topspin

In the French Open final this June, many thought that 6-foot-4-inch Robin Soderling would overpower Rafael Nadal, just as he had Roger Federer in the quarterfinals. On serve at 2–1 in the second set, he hit a sharp, low slice crosscourt to Nadal's service line—the type of shot that has been unattackable, too low and close to the net to return aggressively: hit it just a bit too hard, and it floats long.

But Nadal took three strides into the court and ripped a short-hopped forehand cross-court from the service line. The speed of his racket put the ball on a trajectory to the back fence, but his high-tech copolyester strings bent it down inside Soderling's own service line for an untouchable winner. Soderling dropped his head in disbelief as commentator John McEnroe prefaced the television replay: "Take a look at this ball right here!"

Video: Joshua Speckman demonstrates how new technology is warping the tennis world.

"Yep, that's impossible," Nate Ferguson, the stringer and racket technician of Federer, Novak Djokovic, Andy Murray, and Soderling, told me later. "The ball's 18 inches off the ground and hit for a winner [from there]—that's bullshit."

Copoly strings help generate so much spin that today's players—dubbed the "new-string generation" by Federer— can hit once-inconceivable drives, angled winners, and passing shots. But despite the widespread belief of players that copoly strings have changed the game, scientists until recently could find no evidence that a string's material, thickness, tension, or texture made a real difference in spin generation.

Enter the Japanese engineer Yoshihiko Kawazoe. In 2004, he decided to test a string lubricant that its inventor, Kenji Okimoto, thought would "revive" old, worn strings. Kawazoe realized that, despite much research, scientists had only a shadowy idea of what happens during the 4 or 5 milliseconds when the ball is on the strings, simply because they couldn't see it. But with an ultra-high-speed, 10,000-frame-per-second

camera, Kawazoe solved the mystery of strings and spin.

In capturing 40 to 50 frames of each ball-string impact, he saw that lubricated strings slid with the ball and snapped back as it left. As they snapped back into line, they transferred more energy to the ball in the tangential (parallel to the racket face) direction and gave it more spin—which was easily calculated from the super-slow-motion rotation of the ball as it left the strings. In technical studies published in 2006 and 2007, International Tennis Federation researchers reported that the same movement that Kawazoe observed with lubricated strings occurs with copoly as well.

Copoly strings—slippery and stiff—generate more spin not because of more friction, but because of less. "The old argument was that the better the grip between the strings and the ball, the more spin you would get. But that's not true," said Rod Cross, an Australian physicist and co-author of *Technical Tennis*.

Last April, Cross and his co-author, Crawford Lindsey, published their study showing that copoly strings generate 20 percent more spin than nylon strings, and 11 percent more than natural gut. Such differences help explain how a contemporary powerhouse like Rafael Nadal can hit with twice as much spin as Andre Agassi did.

Looking back, Lindsey and Kawazoe told me they are befuddled by how long people took to realize that polyester strings generated extra spin through sideways sliding and snapback. They should have known this, because 30 years ago, a radical innovation —"spaghetti strings"—used the same mechanism to generate more spin than even the best copolys.

"In spaghetti strings, the [horizontal and vertical] strings weren't woven," said Cross. "And because they weren't woven, there was lots of freedom of movement within the string plane, and that produced almost a factor-of-two increase in the amount of spin. And that's why the ITF banned them."

Remarkably, the ITF's 1978 ruling that all strings must be interwoven was the first rule constraining the design of either rackets or strings. Stuart Miller, the head of science and technology for the ITF, said that it tries to test each string that hits the market, "looking for anything that would, in our opinion, fundamentally change the nature of the game," or introduce a "step change" in spin generation.

But two step-changing technologies have so far evaded regulation: the large-headed racket, which reached its spin potential only after three generations of technique refinements; and copoly strings, whose spin-boosting nature eluded proof for 15 years. Together, they can generate as much spin, or more, in the hands of today's players as could a spaghetti racket wielded by a '70s-era player.

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