Lucky Bounce

An incredibly accurate new formula for predicting lead changes shows just how random basketball truly is.

By Marcus Woo

Chaos wins! The Golden State Warriors celebrate after defeating the Cleveland Cavaliers in Game 6 to win the 2015 NBA Finals on June 16, 2015, at the Quicken Loans Arena in Cleveland.

Photo by Timothy A. Clary/AFP/Getty Images

As a Bay Area native, I've been following the Golden State Warriors since the end of the **Run TMC era** of Tim Hardaway, Mitch Richmond, and Chris Mullin in the late 1980s and early 1990s. Over most of the last two decades, the Warriors have been plain lousy—and it seemed they always would be. Even as they became a playoff team in the past couple of seasons, not many imagined they would be a bona fide championship contender.

So when J.R. Smith knocked down a three to cut the Warriors' lead to 4 points with 33 seconds left in Game 6 of the NBA Finals, I, along with Warriors fans everywhere, got anxious. The Warriors had built what seemed like an insurmountable cushion—up 15 points with about five minutes to go and 11 with one minute left—to clinch the championship. But a flurry of Smith three-pointers brought the Cleveland Cavaliers back.

Fortunately, Stephen Curry would get fouled and sink two free throws, the Cavs wouldn't score again, and the Warriors would close out a **well-deserved title**. But did Warriors fans really have a reason to sweat during that last minute? As Kevin Garnett would say, **anything is possible**, but is anything really *that possible*?

Not quite.

Even after Smith's three-pointer, the Warriors still had a nearly 99 percent chance of holding on to their lead. That's according to a new formula a team of researchers derived to calculate whether a team's lead is safe. The formula is part of a **new analysis**, to be published soon in the physics journal ***Physical Review E***, of how leads ebb and flow over the course of a basketball game and other team sports. Its findings would surprise the most informed sports fans: Over the course of a game, leads go up and down in pretty much a random fashion.

Sports stat geeks have previously come up with **ways to calculate** the likelihood that a team will win. To be clear, though, the new formula doesn't predict win probability, but the chances a winning team will not relinquish its lead at any remaining point in the game—a subtle but important distinction. This new work also differs because it provides a prediction based on a deeper understanding of how leads change. Other win probability calculators are based on historical statistics, but this new formula is based on a basic principle in physics, and its predictions are astonishingly accurate.

The researchers compared their formula's results with data from almost 12,000 NBA games from 2002 to 2010. When they plotted the predictions, the curve aligned almost perfectly with the data. The researchers also compared their formula with one devised by sports analytics guru **Bill James**. They found that his formula, as **discussed in *Slate* in 2008**, was too conservative, requiring a larger lead and less time remaining for a safe margin. (James' formula was relatively simple. You subtract three from the lead, add one-half if the leading team has the ball—subtract one-half if they don't—and then square the total. The lead is safe if that number is more than the number of seconds remaining.)

The new formula doesn't just work better than James' version, though. It aligns with a fundamental concept in math and physics: the **random walk**. That principle is exactly what it sounds like: a meandering, aimless path. One of its first applications was to describe the apparent jittering of a pollen grain floating in water. The grain, getting knocked around by water molecules, moves around randomly. (This phenomenon, called **Brownian motion**, was first explained using the idea of a random walk by Albert Einstein in 1905.) It turns out that a random walk describes everything from how the smell of sizzling bacon wafts through the kitchen to the ups and downs of stock market prices. Now you can include basketball lead changes to the list.

The equation itself is a bit more complicated than James' version, involving a well-known mathematical function called the **error function**. But it can be expressed as a rule of thumb for determining what the lead and remaining time have to be for a team to have a 90 percent chance at maintaining that lead: $L = .4602\sqrt{t}$, where L is the lead and t is the number of seconds remaining.* Using the formula, you can calculate that if a team has a 10-point lead with just under eight minutes left (like the Warriors did in Game 6), then 90 percent of the time, they'll keep that lead for the rest of the game.

But none of this is to say that basketball is a random game. What it means is that at the sport's highest levels—the NBA, and especially the Finals—the players and coaches are just so good that in the end, they cancel each other out. What ultimately determines the scores are random events. **"**You have highly trained athletes, highly trained teams, highly developed strategies—you have all that going on to gain some kind of systematic advantage," says Sidney Redner, a physicist at the Santa Fe Institute who was part of the new study. "But all that remains under all that competition is underlying random fluctuations."

Which, if you think about it, makes sense. How many times have you blamed a loss on a referee's lousy call or a fluke injury? (Sorry, **Kevin and Kyrie**.) Coaches talk about how every loose ball matters, and indeed, it does. A random bounce here or there often determines the final outcome. Desire, hard work, and talent make a champion. But you need luck, too—and the Warriors enjoyed lots of it this year, avoiding major injuries, facing depleted teams in the playoffs, and not having to play the Clippers or the Spurs—two of the few teams that could have given Warriors big problems.

Still, the extent to which chance plays a role in basketball games astonished even the experts. "It knocked my socks off," says Steven Strogatz, an applied mathematician at Cornell University. "The basketball fans among us were surprised that the random-walk model could explain so much of the data."

Crunching through the math reveals something else. Most of the important scoring action happens during the beginning and end of the game. A team is most likely to hold a lead for the longest time during the first and last few minutes. The last lead change of a game also tends to happen at these moments.* So does the period when a team grows its largest lead. That means if you're short on time, you might get away with watching only a game's beginning and end. Everything in between is a tossup. "If you're a cynic like me," Redner says, "that should justify why you should never watch basketball."

The results reveal the inherent randomness in sports—a randomness that Redner says is akin to a series of coin flips. Even when the researchers accounted for the quality of teams, randomness still played the dominant role.

Redner, as you may have guessed, isn't a sports fan. But for the rest of us, we generally don't watch only for the score. It's the randomness we love, and even Redner sees that. "If you make a game completely predictable," he says, "then there's no reason to watch." We watch for the unexpected and the improbable, for **Reggie Miller's eight points in nine seconds**, for **Tracy McGrady's 13 points in 33 seconds**, and in this year's playoffs, for **Curry's corner trey forcing overtime against New Orleans**.

Statistically, taken over thousands of games, all those heated discussions about player matchups, defensive strategy and tactics, and whether a team has momentum amounts to hogwash, says Redner. If that's true, I say so be it. Sure, we force overblown narratives—stories of underdogs and redemption, of heroes and villains—onto what may simply be a series of random events. But that's part of the fun. So if you'll excuse me, I've got a championship to celebrate.

***Correction, June 19, 2015:** Due to a production error, this article originally misstated the formula by which the safety of a lead is calculated. It also misstated that the last lead change tends to happen in the final moments of a game. It happens in the final moments or in the first moments.*