Baseball and Mathematics

by Marvin L. Bittinger

It [baseball] breaks your heart. It is designed to break your heart. The game begins in the spring when everything else begins again, and it blossoms in the summer, filling the afternoons and evenings, and then as soon as the chill rains come, it stops and leaves you to face the fall alone.

—A. BARTLETT GIAMATTI, - former commissioner of Major League Baseball

INTRODUCTION

There are number of things in life that I love dearly, but I'd say the top five are:

1. My wife and family
2. Mathematics
3. Baseball (Cincinnati Reds)
4. Hiking in Moab, Utah
5. Softball (Arizona State University Women's Team)

My wife agrees with the list, but not necessarily the order, wondering if baseball is really number 1. In truth, I can walk out onto a baseball/softball field amid the red dirt, the white chalk lines, and the freshly mown grass, and just feel the goodness of life. The thought quickly comes to mind, "Where are the guys? Let's have a game!" I am not a great, not even a good, player but my passion for the game is great!

Dusty Baker, as Manager of the Cincinnati Reds

Photo Courtesy, Joe Robbins/Brian Spurlock Photography

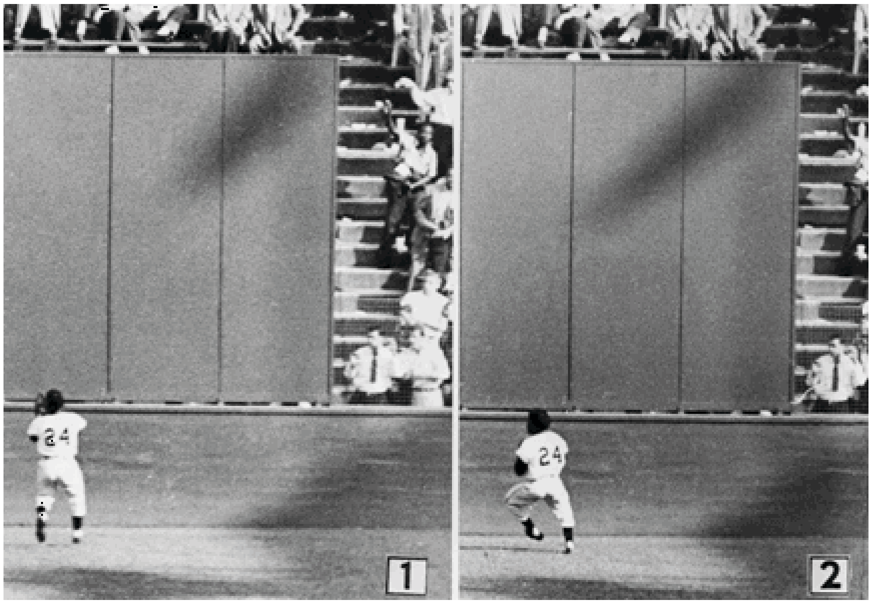
Upon seeing his picture, you are probably asking how does this math textbook author connect with Dusty Baker, the former manager of the San Francisco Giants, Chicago Cubs, and present manager of the Cincinnati Reds? And what does his picture have to do with mathematics? The answer to these questions is a fantasy come true for your author. It is a bizarre story that springs from my love of both baseball and mathematics.

I grew up in a neighborhood with numerous empty lots. We spent most of our summer days on those lots playing basebball from morning to night. We used any kind of ball we could find—new, taped, hardball, or softball; and any kind of bat, mostly filled with glue and nails and covered with tape. It saddens me now when I drive by a school yard near my house and see two beautiful ballfields and backstops that are rarely used. How my baseball buddies and I would have loved to play on those fields! As most of my friends and family will tell you, I love to eat. But, when my grandmother, a tremendous cook, would call me to come home for dinner and we were playing baseball, I never wanted to go.

I love to ask the following question, “Can you name two people who were ever cut from a Little League baseball team?” Ironically, I know two such guys. One is my dear friend and present manager of the Cincinnati Reds, Dusty Baker, cut by his father three times because he had a bad attitude. The other was yours truly at the age of 12 for lack of playing ability. Little League was organized late in my hometown, Akron, Ohio. Compared to other cities, there were only a few teams with too many kids to fill them. So, they held tryouts. I went to a tryout with great expectations, only to be cut—a devastating experience to a 12-year-old boy who just loved to play ball. In my mind, my baseball days were over. For the next 20 years, my baseball involvement was limited to attending Cleveland Indians games and listening to Jimmy Dudley broadcast the games on WAKR.

My early memories of TV were rooting for the Brooklyn Dodgers to beat the hated New York Yankees in the World Series. I detested the Yankees because, other than in 1954, my Indians placed second to them every year. I remember all too well watching the Indians play the Giants in the 1954 World Series. I know right where I was sitting when my heart was torn out as Willie Mays made that incredible catch in centerfield off the bat of Vic Wertz. What 13-year-old kid sitting in front of the TV set would have dreamed that someday he would write a book with the manager of those same Giants, and actually shake the hand of Willie Mays? Not me, not me, NOT ME!!

Each of us goes through the process of discerning our strengths and weaknesses. I realized very early in life that poor vision and limited athletic ability was going to prevent being a professional baseball player. I moved on to academic pursuits, where I seemed to have more God-given talents. But at the age of 32, when I had my education completed and my profession as a math educator well under way, I started playing and coaching some slow-pitch softball teams.



Willie Mays making that catch in the 1954 World Series.

Some years later I came to know Barton (Bart) L. Kaufman. Bart was an outstanding athlete, playing outfield for Indiana University. In 1961 he finished second in the Big Ten batting title race, first place going to Bill Freehan, who later caught for the Detroit Tigers. Bart could hit, and he still can. He calls me “Right-hander” from our days playing softball together.

Bart was recommended to me as a financial advisor around 1975. I was drawn to him because of his tremendous intelligence, outstanding character, and knowledge of life insurance and estate planning. But I must admit the crowning part of my decision to work with him was his passion for sports and especially the Cincinnati Reds. Our relationship through the years has evolved from business acquaintances to very close friends. It would take another chapter in this book to relate all the contributions Bart has made to my life; suffice it to say they approach infinity as a limit.

Bart’s father, wanting to give him every advantage, sent his teenage son to summer instructional camp at the Dodgers spring training complex in Vero Beach, Florida. At that same complex, in the mid-eighties, the Dodgers started their Adult Baseball Fantasy Camps, offered to anyone at least 30 years old who is willing to pay the admission. Campers went to the Vero Beach spring training site, Dodgertown, took instruction and played a 9-

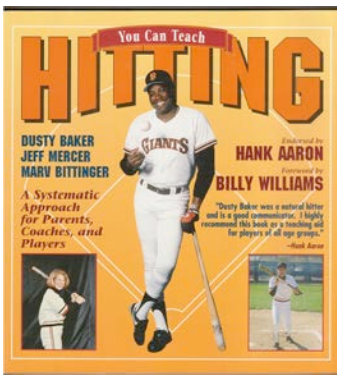
inning baseball game every day for a week. They slept in the same beds as the Dodger players and ate the same food. The camps were coached by former Dodger stars such as Carl Erskine, Reggie Smith, Steve Garvey, Jerry Ruess, Jeff Torborg, and Tommy Davis.

Bart attended these camps and, knowing my love of the game, urged, if not begged, me to attend with him. But I continually refused, explaining that I had only one good eye (the other is what used to be called a "lazy eye" so I have no depth perception) and that I was so lacking in talent that I got cut in Little League. However, after he told me Jane Fonda attended one year and that he needed a roommate, I finally went in 1989. I loved it so much that I have ended up going to 25 adult baseball fantasy camps with the Dodgers, Giants, and most recently the Reds.

Dodger Camp at Dodgertown in Vero Beach, FL, was truly baseball heaven. We usually had instruction in the mornings and played a nine-inning baseball game in the afternoons. In the evenings we met together for dinner and awards, and were regaled with war stories from the former players. At the end of the week, the campers played a game against the former players—they slaughtered us, but that makes for more good stories. I will always remember getting base hits off Jerry Reuss and Ron Perranoski. I also faced the great Hall-of-Famer, Bob Gibson, who struck me out. With each pitch I was scared to death that I might get hit and die! He actually just lobbed up the pitches, but that did not relieve my fears.

It was my first time at camp in the fall of 1989 when I met Dusty Baker, a former Dodgers star, who was then batting coach for the San Francisco Giants. Dusty gave me two 45-minute hitting lessons. What a thrill for a poor-vision guy who got cut from Little League!

I had a great time and became obsessed with these camps, looking forward to them each year with a goal of improving my hitting skills. When I was looking for batting lessons one year I met Jeff Mercer, former assistant coach at Indiana University, who was running an indoor baseball facility here in Indianapolis. Jeff was an exceptional instructor and was willing to help an old guy with one eye and poor athletic ability. When he learned that I was an author, Jeff told me he had always wanted to write a book on hitting and asked how he might go about it. Believe me, I have had many discussions with people who want to write; I usually suggest they write an outline, a proposal, and maybe a sample chapter and show them to me. Most of the time, the idea blows into the wind. But that wasn't true in Jeff's case; he came back to me two weeks later with an outline and a sample chapter—and it was good!



You Can Teach Hitting

I was determined to get this book published but felt we needed someone with a national baseball reputation as a co-author. So I contacted Dusty Baker and met him for lunch in Cincinnati when the Giants were in town playing the Reds. He liked the idea of writing a book and producing a set of instructional videos, and later a CD-ROM. These led most recently to an enhanced ebook on the skill of hitting a baseball, by Dusty Baker, Marv Bittinger, & Jeff Mercer:

> *Dusty Baker's Hitting Handbook.* For more information visit the *iTunes bookstore* or www.hitthandbook.com.

A college baseball coach, Jeff Mercer, a professional baseball manager, Dusty Baker, and a math textbook author, Marv Bittinger, ready to play ball! No matter the job, they possess the same love of the game.

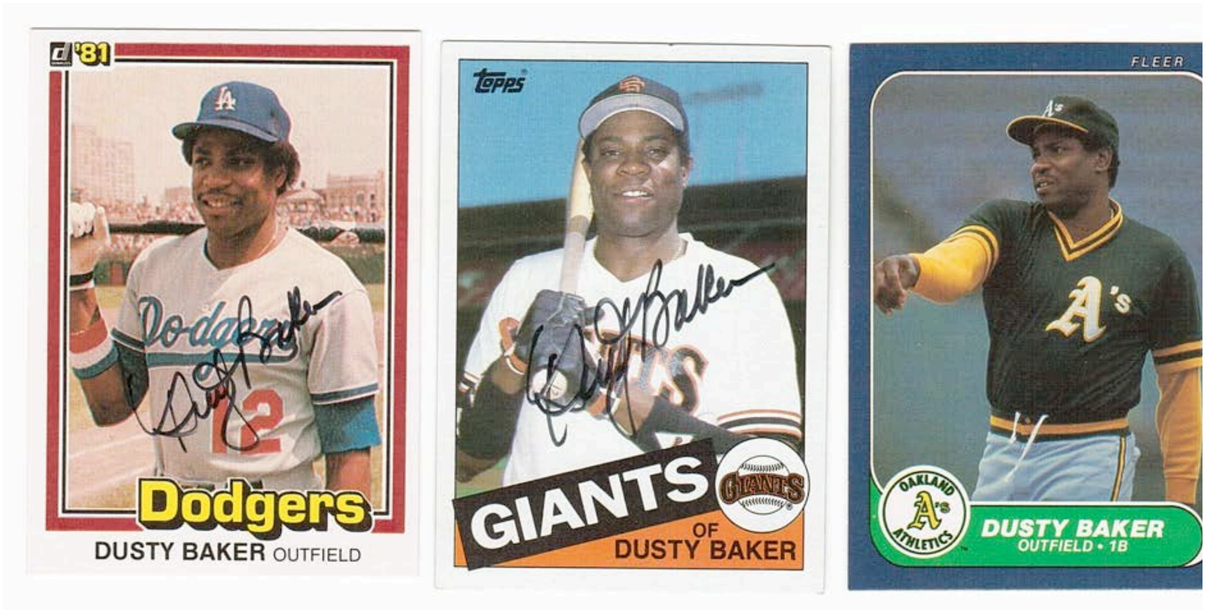
By now you are probably wondering how all the preceding leads to math and baseball. At the end of our lunch, when it was time for Dusty to go to the ballpark, he mentioned that since we were going to write a book together, I could go to the park with him and go into the locker room. Then my adrenaline started flowing like never before in my life, other than when I got married—I was going to the San Francisco Giants locker room!

We took a cab to the stadium, drove down underneath to the visitors entrance, and went into the locker room with Will Clark, Matt Williams, Kevin Mitchell, Robby Thompson, and all the other players. Wow! Dusty introduced me to some people at a table nearby and I sat down with Wendell Kim, third base coach, Bob Lillis, bench coach for then-manager Roger Craig, and Syd Thrift, who was employed at that time as a consultant to the Giants.

Syd Thrift may not be a familiar name but with Barry Shapiro he wrote a book *The Game According to Syd* (See the REFERENCES at the end). When he was general Manager of the Pittsburgh Pirates, Syd studied scientific ways his teams could get an edge on the competition.

Dr. John Nash Ott was a team consultant to the Pirates. Ott was an expert on environmental health and light research. Ott found that light influences the pituitary gland, which controls the endocrine system, which in turn governs the production and release of body hormones, which control body chemistry. Ott also discovered that a player's performance will improve if the underside of the bill of the baseball cap is gray instead of green. There came a time when most Major League Baseball teams adopted the use of gray under the bills of their caps.

Another edge was Syd's knowledge that a four-seam fastball is 4 mph faster than a two-seam fastball. This doesn't mean that the hide of a baseball is sewn differently, or that you can go to a sporting goods store and buy ball with two seams or one with four seams. Rather, it refers to the placement of the pitcher's fingers on the ball in relation to the ball's stitches.

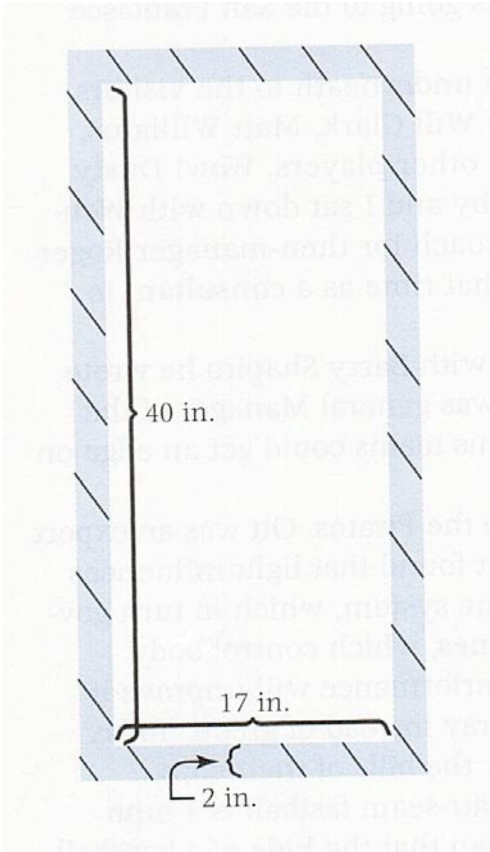


Three of Dusty Baker's baseball cards: with the Dodgers, Giants, & Athletics.

Not being sure how to start a conversation with these men, I said to Syd, "I read in your book that the four-seam fastball is 4 mph faster than the two-seam fastball." Syd's eyes lit up and he asked me, distance-wise, how much faster did one ball get to the plate over the other? I was so excited to be in that locker room that (for once) I did *not* want to do math. I tried to escape the issue by asserting that I needed a calculator. But right away Bob Lillis handed me the calculator-organizer in which he kept his scouting data. I finally got the answer: The two-seam fastball comes in 30 inches behind the four-seam fastball. (We do the math later.)

This was the first of my baseball and mathematics applications. Through all the subsequent time I spent with Dusty and his players, many other applications cropped up. Believe me, major-league players do math in the dugout! These ideas formed the basis of a math talk that I give at many mathematics education conventions and culminates with this article. We begin with one of those applications as follows.

THE STRIKE ZONE



A very elementary application concerns the strike zone.

The strike zone is an area of about 17 in. by 40 in., depending on the height of the hitter. What is the effect on its area of adding a 2-inch border to the zone?

The inside, or actual, area is

$$(17 \text{ in.})(40 \text{ in.}) = 680 \text{ in.}^2.$$

When the 2 in. is added, we get a new outside zone,

21 in. by 44 in.

The new area is

$$(21 \text{ in.})(44 \text{ in.}) = 924 \text{ in.}^2$$

The new area has been increased by

$$924 \text{ in.}^2 - 680 \text{ in.}^2, \text{ or } 244 \text{ in.}^2$$

Thus, there is an increase of

$$\frac{244}{680} \approx 0.36 = 36\%$$

How is this relevant to a major league hitter? I once heard Ted Williams being interviewed by Bob Costas on a radio program. Williams mentioned a theory that he had developed on his own but checked with other baseball players and several umpires: “When a major league hitter swings and misses on strike three, 70% to 80% of the time the pitch is out of the strike zone.” I checked with Dusty and he agreed with Williams. In connection with the 2 inches added to the strike zone, the hitter may be allowing the pitcher 36% more area to pitch to. A pitcher and the hitter should be aware of this change. It supports a new baseball theory: “Give a pitcher 36% and he will strike you out!”

EXERCISES

Baseball's Strike Zones. Major league rules define the true strike zone to be the rectangle *ABCD* shown in Figure 1—knees to name between the sides of the plate. Somehow, prior to 2001, the strike zone had evolved to a diminished region, *AQRST*. In 2001 the major leagues mandated that the umpires return to enforcing the true strike zone. Figure 1 represents the zones for a normal-sized player. The height changes with the height of the player.

1. Find the area of the true strike zone, *ABCD*.
2. Find the area of the altered strike zone, *AQRST*.
3. How much larger is the true strike zone than the altered strike zone?
4. By what percentage had the area of the strike zone *ABCD* been diminished when it evolved to *AQRST*?

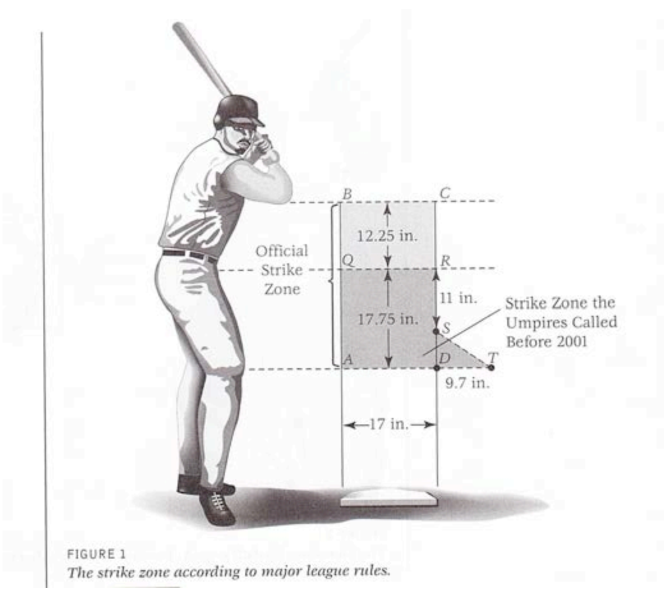


FIGURE 1 *The strike zone according to major league rules.*

FOUR SEAMS VS. TWO SEAMS

Here we solve the four seams vs. two seams problem as posed to me in the Giants locker room. According to the results of Thrift's studies, the four-seam fastball travels 4 mph faster than the two-seam fastball. But how much faster, distance-wise, does a four-seam fastball get to the plate than a two-seam fastball? We start by trying to understand the difference between the two kinds of pitches. The answers lie with the seams and the grips.

Four-Seam Fastball

In Figure 2A, we see how the forefinger and middle finger are placed on the baseball in order to throw a four-seam fastball. The ball is thrown toward the batter as if the hand is pointing toward the hitter. The pitch is released with backspin. With this grip imagine two horizontal seams on this side of the ball and two on the side we can't see. When the ball rotates with its -backspin, each rotation creates "four seams." See Figure 2B. Thus, we call this a four-seam fastball. To further understand hold a baseball as shown in Figure 2A, and imagine rolling it off the tips of your fingers with backspin toward the hitter.

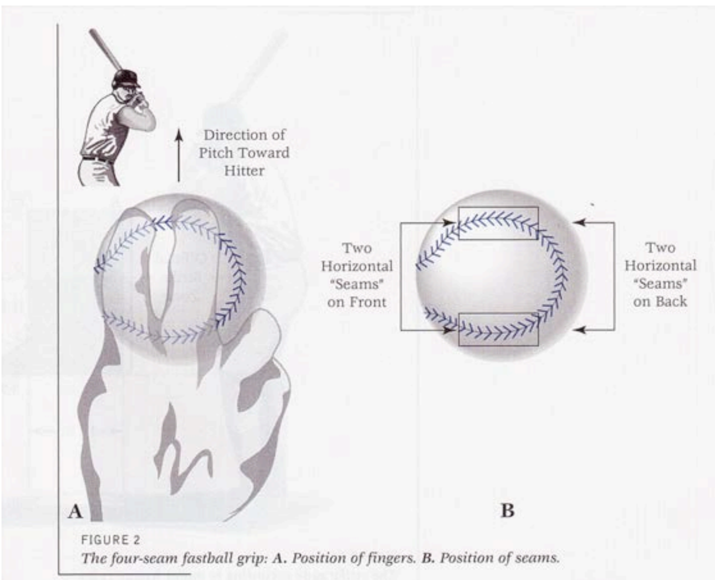


FIGURE 2 *The four-seam fastball grip: **A**. Position of fingers. **B**. Position of seams.*

Two-Seam Fastball

In Figure 3A we see how a two-seam fastball is gripped. But, now only two horizontal seams go against the wind with the backspin; hence, the term for such a pitch is "two-seam" fastball. See Figure 3B. The four-seam grip is compared to the two-seam grip in Figure 4.

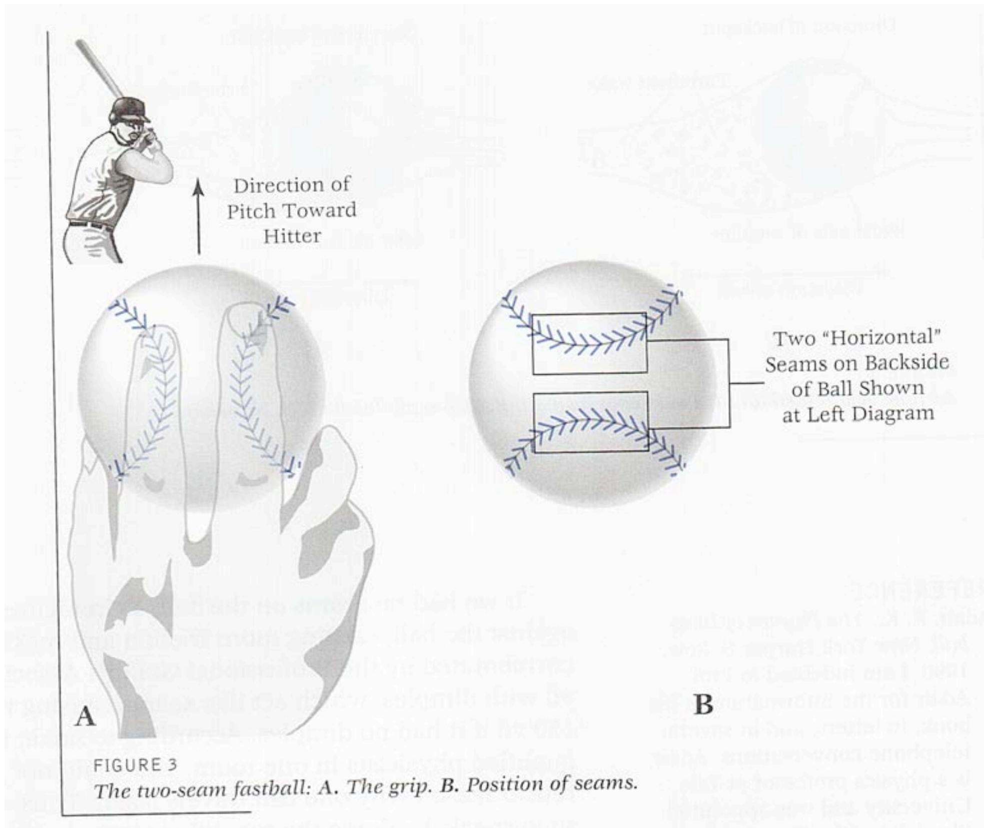


FIGURE 3 *The two-seam fastball grip:* ***A****. The grip.* ***B****. Position of seams.*

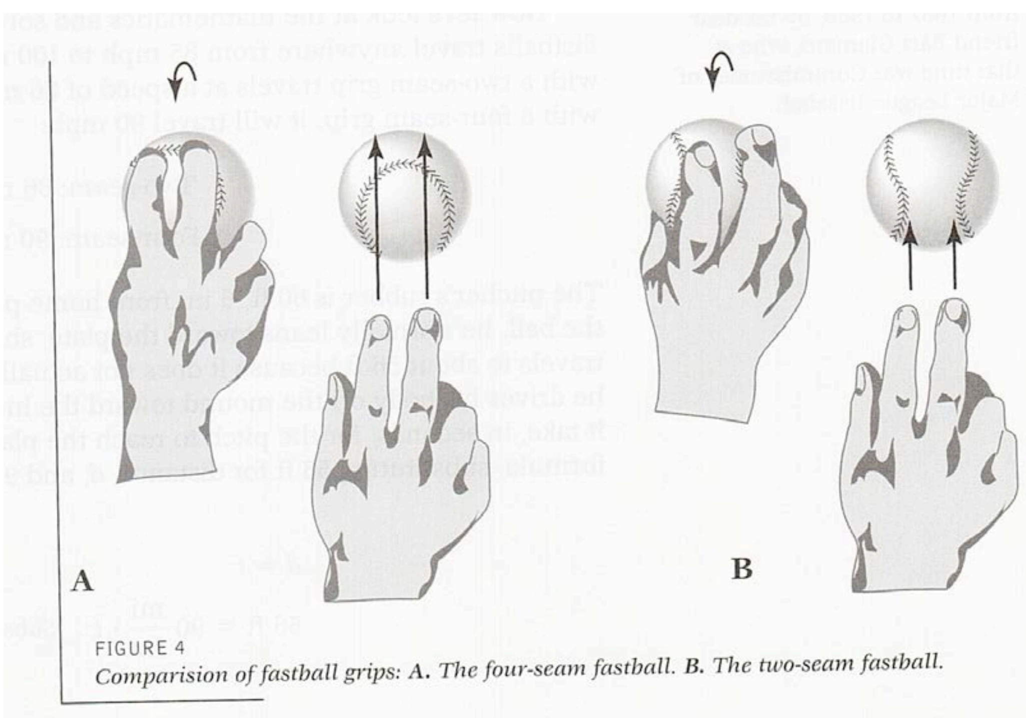
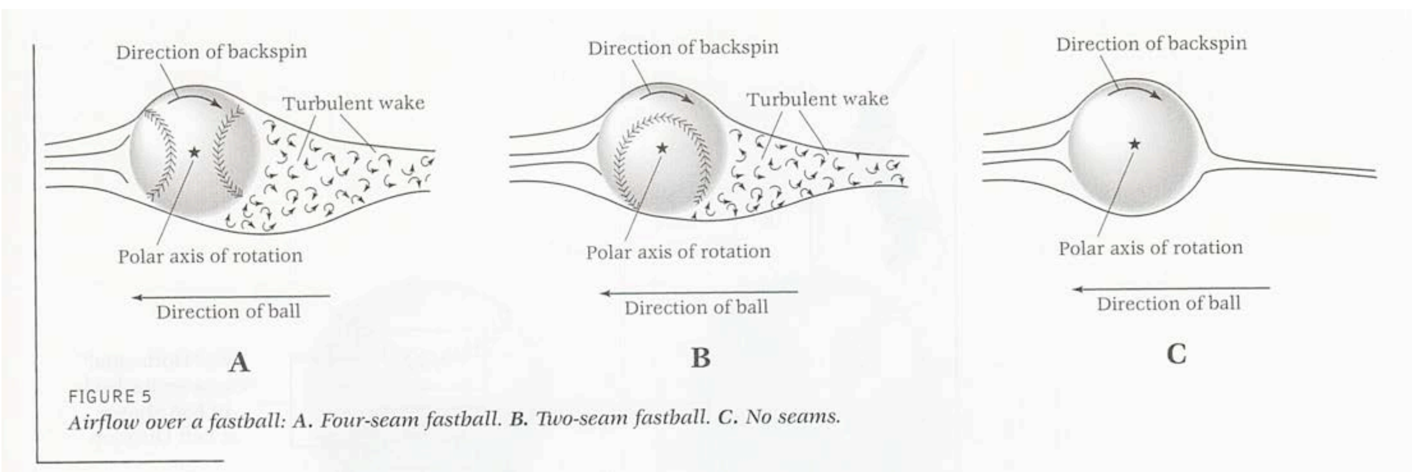


FIGURE 4 *The four-seam fastball grip:* ***A****. The grip.* ***B****. Position of seams.*

Why does one ball travel faster than the other? The simplest answer comes by proving it through repetitive testing with throwing machines. But let us try to examine the situation using some physics. Look at the drawings in Figure 5. When the balls are thrown, a turbulent wake is created behind each ball. The wake from a four-seam pitch is greater than the wake from a two-seam pitch. One conclusion we can draw is that the wake tends to create a molecular "push," causing the ball with more wake, or push, to go faster. In my limited knowledge of physics, I think of the seams creating a vacuum around the ball. There is more vacuum with the four-seam fastball than with the two-seam fastball. Thus, the four-seam fastball goes faster.

FIGURE 5



*Airflow over a fastball: **A**. Four-seam fastball. **B**. Two-seam fastball. **C**. No seams.*

If we had no seams on the ball, as in Figure 5C, the air would be right up against the ball, causing more friction and making it travel slower. This idea is corroborated by the Professional Golfer's Association: A golf ball that goes 260 yd with dimples, which act like seams causing turbulence, would travel only 150 yd if it had no dimples. According to Adair, if you had a hundred highly qualified physicists in one room, you could not get them to agree on the theoretical reason why one ball travels faster. Thus, the "proof is in the pudding," so to speak, by doing the repetitive testing with a throwing machine.

Now let's look at the mathematics and solve the problem. Major league fastballs travel anywhere from 85 mph to 105 mph. Suppose a ball thrown with a two-seam grip travels at a speed of 86 mph. If the same ball is thrown with a four-seam grip, it will travel 90 mph:

Two-seam: 86 mph

Four-seam: 90 mph

The pitcher's rubber is 60 ft, 6 in. from home plate. When a pitcher delivers the ball, he normally leans toward the plate, shortening the distance the ball travels to about 56 ft because it does not actually leave the pitcher's hand until he drives his body off the mound toward the hitter. At 90 mph, how long does it take, in seconds, for the pitch to reach the plate? We use the distance formula, substituting 56 ft for distance, d, and 90 mph for the speed, or rate, r:

$$d = rt$$

$$56 \text{ ft} = 90\ \frac{\text{mi}}{\text{hr}} \cdot t \qquad \text{Substituting}$$

Next we solve for t, in seconds, by multiplying on both sides by $\frac{1 \text{ hr}}{90 \text{ mi}}$, and convert the result to seconds by making the appropriate unit conversions:

$$56 \text{ ft} = \left(90\ \frac{\text{mi}}{\text{hr}}\right) \cdot t$$

$$56\ \cancel{\text{ft}} \cdot \frac{1\ \cancel{\text{hr}}}{90\ \cancel{\text{mi}}} \cdot \frac{1\ \cancel{\text{mi}}}{5380\ \cancel{\text{ft}}} \cdot \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hr}}} \cdot \frac{60 \text{ sec}}{1\ \cancel{\text{min}}} = t$$

Simplifying, we get

$$t = 0.424242\ldots \approx 0.42 \text{ sec}.$$

Thus, the four-seam fastball travels 56 ft, or 672 in., in 0.42 seconds. The two-seam travels how far in 0.42 sec? To find out, we use the distance formula and substitute $86\,\frac{\text{mi}}{\text{hr}}$ for r, and 0.4242 for t. Then we make unit changes to get the distance in inches.

$$d = rt$$

$$d = 86\,\frac{\text{mi}}{\text{hr}} \cdot (0.4242\ \text{sec})$$

$$d = 86\,\frac{\cancel{\text{mi}}}{\cancel{\text{hr}}} \cdot \frac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}} \cdot \frac{12\ \text{in.}}{1\ \cancel{\text{ft}}} \cdot \frac{1\ \cancel{\text{hr}}}{60\ \cancel{\text{min}}} \cdot \frac{1\ \cancel{\text{min}}}{60\ \text{sec}} \cdot (0.4242\ \cancel{\text{sec}})$$

$$d = 642.07\ \text{in.}$$

Subtracting the two-seam distance, 642.07 in., from the four-seam distance, 672 in., we see that the two-seam fastball is about 30 in. behind the four-seam fastball. These computations confirm the result I determined in the Giants locker room in Cincinnati, though I must admit that I was cautious about my calculations at the time.

Aroldis Chapman pitching the Cincinnati Reds
Photo Courtesy, Joe Robbins/Brian Spurlock Photography

Why were these coaches so interested in the answer to the question? Getting "jammed," meaning not getting the bat off your shoulder or barely starting a swing, is the ultimate embarrassment to a batter. Of course, a pitcher loves to "jam" a batter in this way. The 30 inches can mean all the difference in the world to a hitter and a pitcher. Evidence of this comes from the Red's, Aroldis Chapman, the "Cuban Missile," who can throw pitches above 100 mph. Comparing 100 mph to 90 mph, means 5 intervals of 30 in. each in distance, or a whopping 6 ft in swing distance between the two pitches. No wonder he is such a feared pitcher.

There are two sidelights to this rather simple application of mathematics. One occurred when I saw Bob Lillis, then Dusty's bench coach, at a Giants game a year or two after that initial locker-room challenge. He again asked and I confirmed the 30-inch difference. Sometime later I also shared this information with Tom Beyers, then minor batting coach for the Los Angeles Dodgers, and Dave Wallace, who was the pitching coach for the major league Dodgers and later became the pitching coach for the Boston Red Sox. Both were fascinated with the results.

EXERCISES

1. Consider: Four-seam: 86 mph; two-seam: 82 mph.
How much faster, distance-wise, does the four-seam fastball get to home plate than the two-seam fastball?

2. Consider: Four-seam: 94 mph; two-seam: 90 mph.
How much faster, distance-wise, does the four-seam fastball get to home plate than the two-seam fastball?

3. Compare your results from item 2 with what we found in this section. Does it matter what speed we start with on the four-seam - fastball?

4. Once at a Reds game in Cincinnati Dusty allowed me to be on the field for batting practice. The coaches typically throw batting practice to the players, but at slower speeds than most active major league pitchers. This is because the coaches are older and many were not pitchers in their playing days. To compensate for their slowness, teams move the pitching rubber 10 ft closer to the plate to a distance of about 50 ft, 6 in., the goal being to emulate the faster pitches they see in real games. Wendell Kim, one of Dusty's coaches at the time, told me he estimated that he threw 55-mph pitches to the players in batting practice.

a. From 46 ft, the release point of Kim's pitches, estimate the time for Kim's pitches to cross the plate.

b. What amount of time does it take for a 90-mph pitch to reach the plate from the standard 60 ft, 6 in.?

c. How should the 50 ft, 6 in. distance for the batting-practice pitching rubber be changed so the time for a 55-mph pitch to cross the plate is the same as that for a 90-mph pitch?

Note the location of the batting practice pitcher.

TALE OF THE TAPE

Recall that I seem to be a cat on the prowl for applications of mathematics. Well, I found yet another when I was attending a baseball game in Cincinnati. After a player had hit a home run into the stands over the 375-ft sign, an announcement ran across the scoreboard saying, "IBM Tale of the Tape—the ball would have traveled 415 ft had the ball not hit the stands." The subtle implication was that there was some kind of computerized method of making these calculations. As it turns out, the method was rather simple, involving some linear formulas.

How did I find out? Well, my co-author, Judy Beecher, asserts that it takes about ten phone calls to get to the root of an application and we are never afraid to make phone calls. I called IBM in Armonk, New York, and was quickly put in touch with John J. McMahon, then Manager of Corporate Promotions. He sent me a copy of a letter that had been sent to Roger Angell, noted baseball author, who was then associated with *New Yorker Magazine.* That letter and a subsequent conversation with its author, Robert K. Adair, gave me most of the answers to the question.

The Mathematics Behind the Tale of the Tape

In Figure 6, we see the trajectories of a well-hit baseball. Such a ball has backspin, which tends to make the trajectory look like a parabola, which is skewed away from home plate.

FIGURE 6

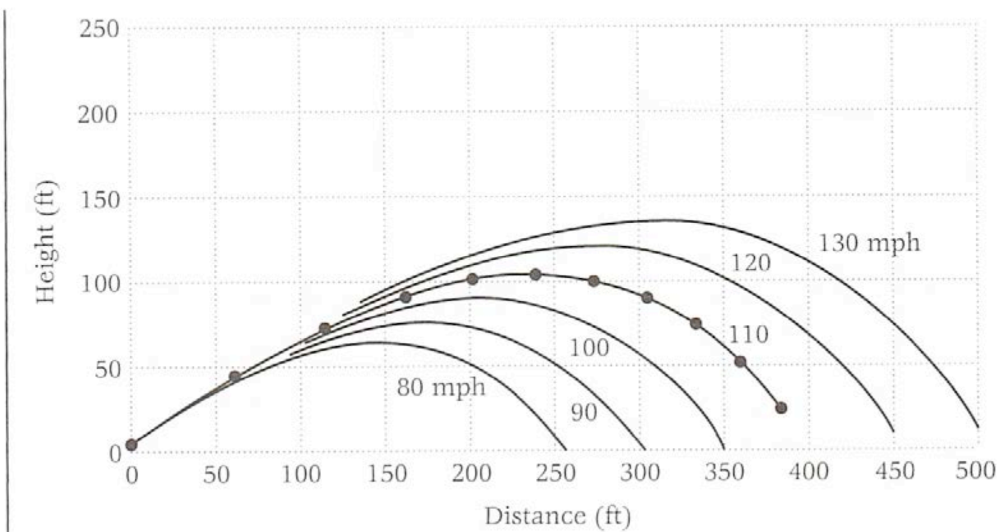


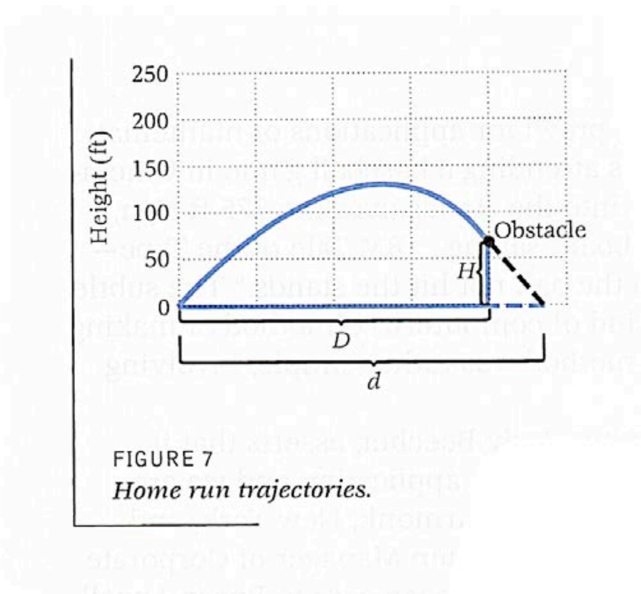
FIGURE 6
Trajectories of well-hit baseballs.

Trajectories of well-hit baseballs.

It should be emphasized that the trajectory, or flight, of a well- hit baseball (or golf ball) is *not* modeled by a parabola such as

$$h(t) = -\frac{1}{2}gt^2 + (v_0 \sin\alpha)t + h_0$$

a model often seen in calculus. In the case of this example, we will not develop the equations of the flight of a baseball; we will just consider Adair's results.



Look at Figure 7. Note the flight of the ball. It hits an obstacle at a point, where the horizontal distance from home plate to where the ball is obstructed, and the vertical distance from the ground to where the ball is obstructed. We want to estimate the distance, d, that the ball would have traveled had it not been obstructed. We do so with the following linear formula, which was developed by Adair.

FIGURE 7 *Home run trajectories.*

IBM Estimate of Distance

$$d = kH + D,$$

where

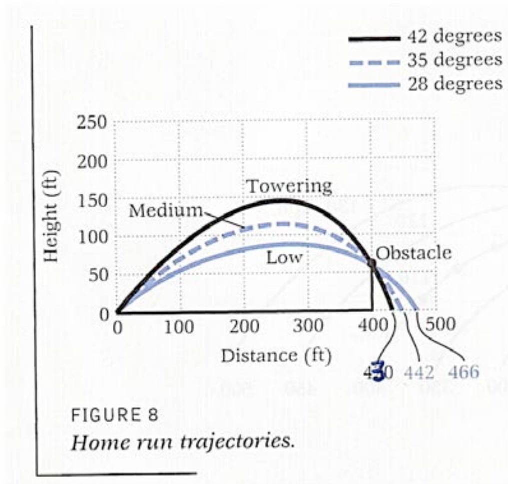
D = horizontal distance, in feet, of the ball when obstructed,

H = vertical height, in feet, of the ball when obstructed,

d = estimated distance, in feet, ball would have traveled had it not been obstructed. Error: ±10 ft, and

k = constant determined by the trajectory of ball.

We use three values of k, determined by the type of trajectory of the ball. See Figure 8. We make a judgment of the type of trajectory based on the



launch angle of the ball when hit. This gives an estimate for k.

FIGURE 8 *Home run trajectories.*

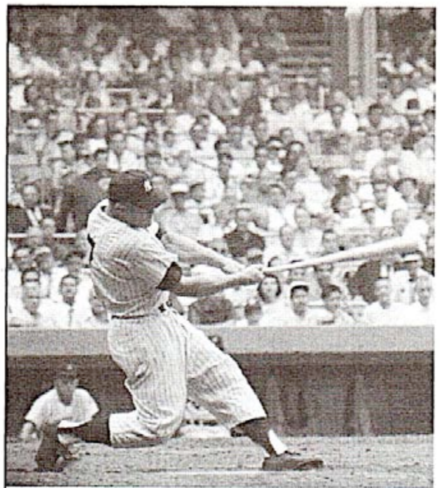
Distance Predictors

$$\textbf{Low trajectory } (28°): \quad d = 11\%\ d = 110\%\ H + D = 1.1H + D,$$
$$\textbf{Medium trajectory } (35°): \quad d = 70\%\ H + D = 0.7H + D,$$
$$\textbf{High trajectory } (42°): \quad d = 50\%\ H + D = 0.5H + D.$$

Suppose $D = 400$ ft and $H = 60$ ft. Then, using distance predictors, the estimated distances would be

$$\textbf{Low trajectory } (28°): \quad d = 110\%\ (60) + (400) = 466 \text{ ft},$$
$$\textbf{Medium trajectory } (35°): \quad d = 70\%\ (60) + (400) = 442 \text{ ft},$$
$$\textbf{High trajectory } (42°): \quad d = 50\%\ (60) + (400) = 430 \text{ ft}.$$

Admittedly, deciding how to classify the trajectory of a home run ball requires an instant decision. Adair said, “If in doubt, take 70% of the height H and add it to D.” In this way, you can guess the Tale of the Tape from your seat. Once after discovering this formula, during a Reds–Dodgers playoff, I did this after a home run and estimated the answer before it was given later on the scoreboard. People around me couldn’t believe it. You can do this as well! And, yes, this certainly was a great fun.



Mickey Mantle swings the bat.

Mantle'Griffith Stadium Blast

There is an enduring grand story of a towering home run ball off the bat of Mickey Mantle in old Griffith Stadium in Washington, D.C. The ball hit a 40-ft high beer sign 460 ft from home plate. Our estimate would be that it would have traveled 480 feet. But the press blew the home run out of proportion, announcing that it would have traveled 565 feet. According to Adair, with a 20 to 40 mph tailwind, it could have traveled no farther than 511 feet.

Standard Conditions and the Distance of a Batted Ball

Adair thinks that under standard conditions—70° temperatures, sea-level altitude, and no wind—450 ft is about the limit a normal man can hit a baseball. Of course a world-class weight lifter (say 6'8", 300 lb; built like Arnold Schwarzenegger) with catlike speed, taking two steps at the plate, using a 42", 56 oz bat, might be able to hit a batting-practice baseball more then 500 ft. In reality, though, if such a baseball player ever took two steps at the plate, the next pitch might be at his head because no pitcher would tolerate the insult of a hitter taking the extra step.

The Rest of the Story

The question remained in my mind: What actually happens at the stadium when they announce the Tale of the Tape? I got the answer when I visited Dusty Baker after he became manager of the Giants. We were at Coors Field in Denver, home of the Colorado Rockies. I was given a press pass by the Giants. This allowed me to roam the ballpark at will, which I did with great joy. I ended up in the press box, where I watched players hitting homers. I decided to track down the source of announced "Tales of the Tape." What really happens is that the announcer is given a chart of the ballpark that lists the predicted lengths of home runs. He watches where the home runs go, checks the chart, and makes an announcement. To my chagrin, no computer enters the picture at the time of the home run and I am sure the trajectory of the ball was not considered. Oh well, such is the nature of marketing.

Mickey, Billy and the Cows. *I love baseball stories. One of my favorites was told by Mickey Mantle about his friend, Billy Martin. Billy was a* fiery *ball player, and he brought his temperament with him into his managing days, getting into fights with his players or anybody who crossed him in a bar or elsewhere. He and Mickey Mantle were like brothers. One time they went hunting at the farm of a friend of Mickey's. Mick left Billy in the car and went inside to ask the farmer permission to hunt on his place.*

The farmer said yes, but as a favor would Mick please shoot that mule out in the barnyard—the mule was old, he was attached to it, and did not have the heart to kill it himself.

Mickey, being the fun-lover and kidder he was, decided to play a trick on Billy. Mick went to the car and told Billy that the farmer would not let them hunt and that he was so mad, he was going to shoot the farmer's mule. So, off Mick went and shot the mule. At about the same time, he heard 3 other shots and went running back to Billy in concern. Billy said, "I shot 3 of his cows as well!!"

EXERCISES

1. *Mantle's Homerun.* As the photo shows, on May 22, 1963, Mickey

Mantle hit a home run off the facade of the upper right-field deck of Yankee Stadium. It was a towering shot off Kansas City pitcher Bill Fischer. How far would it have traveled had it not hit the facade? Let D = 367 ft, though it is shown otherwise.

THE LOST WAR YEARS

I met Bob Feller, Hall-of-Fame Pitcher for the Cleveland Indians, at a Los Angeles Dodgers Adult Fantasy Camp, being coached by all Hall-of-Fame players. That is when I had to go to the plate when Bob Gibson was pitching.

I was a Cleveland Indians fan as a boy growing up in the early fifties when Feller was nearing the end of his career. I was thrilled to meet him at the camp. Prior to that, I had read Feller's book, *Now Pitching: Bob Feller*, in which he discusses the war years when he and several prominent players such as Ted Williams, Johnny Mize, Joe DiMaggio, and Hank Greenberg left the playing field to serve in World War II. Feller explained that an analyst in Seattle, Ralph Winnie, had analyzed his records and deduced that Feller would have had five no-hitters instead of three if the war had not interrupted his career. Winnie also projected that Feller would have had

Bob Feller, Cleveland Indians

Ted Williams, Boston red Sox, Best hitter of All Time.

373 career wins instead of 266. Winnie also analyzed Ted Williams's case and projected that Ted would have had 743 home runs instead of 521 (see Table 1), and 2,663 runs batted in (RBI) instead of 1,839 (see Table 3), and would have been the all-time career leader ahead of Hank Aaron, who then held the record at 2,297. Williams also would rank second to Aaron in career home runs with 743 to Aaron's 755.

Once again I set out on my own to agree or disagree with Winnie's results mathematically. Using a graphing calculator, I analyzed the data in Table 1 by fitting the data to a linear function by regression. The function is given by

$$y = -0.402x + 813.785,$$

where $x =$ the year, and $y =$ the predicted number of home runs in year x. Then I used the function to estimate the home runs in the war years of 1943, 1944, and 1945 (World War II), and 1952 and 1953 (Korean War). I deleted the HRs he got, 14, for the predicted ones. The total of these predicted HRs was 662.

Interestingly, if we just take the average for the complete years Williams played, we get 30 home runs per year.

$$507 / 17 = 30, \qquad 30 \times 5 = 150,$$

$$521 - 14 + 30 \times 5 = 657$$

Multiplying by 5, subtracting 14, and adding to 521, we get a third estimate, 657, which was close to the estimate found using the preceding linear function.

Table 1 Ted Williams Home Runs

Year	Actual Home Runs	Home Runs Predicted by $y = -20.402x + 1\,813.785$	Home Runs Predicted by Averaging
1939	31		
1940	23		
1941	37		
1942	36		
1943	0 (WWII)	(33)	(30)
1944	0 (WWII)	(32)	(30)
1945	0 (WWII)	(32)	(30)
1946	38		
1947	32		
1948	25		
1949	43		
1950	28 (hurt)		
1951	30		
1952	1 (Korean War)	(29)	(30)
1953	13 (Korean War)	(29)	(30)
1954	29		
1955	28		
1956	24		
1957	38		
1958	26		
1959	10		
1960	29		
Totals	521	662	657
		$662 < 743$	$507 / 17 = 30, \quad 30 \times 5 = 150,$
			$521 - 14 + 30 \times 5 = 657,$
			$657 < 743$

Comparing all the estimates in the last line of Table 1, I could not corroborate the results Winnie predicted for Williams, which was 743 home runs.

No other reference was given to Ralph Winnie in Feller's book other than that he lived in Seattle, so I decided to contact Feller. I wrote one letter to his publisher and another without a street address to his home city of Gates Mills, Ohio.

A man has to have goals—for a day, for a lifetime—and that was mine, to have people say, 'There goes the greatest hitter who ever lived.'

—TED WILLIAMS

There's only one way to become a hitter. Go up to the plate and get mad. Get mad at yourself and mad at the pitcher.

—TED WILLIAMS

I called Feller and asked about Ralph Winnie. Feller told me Winnie was in an organization known as SABR, *Society for American Baseball Research*, an organization for baseball enthusiasts who analyze the game to its absolute literary-historical-statistical depths. Its publications include articles about such diverse topics as the history of the Negro leagues and the effects of the DH (designated hitter) on the game. I knew about SABR because I was a member. He gave me Winnie's phone number.

Elaine & Bob. *I must tell a related, amusing story. My beloved wife, Elaine, has never had an interest in baseball and knows very few famous players. One Saturday, after returning from running errands, I asked as usual if there had been any calls. She said in a very casual manner, "Bob Feller called." I reacted in amazement, "Bob Feller? Bob Feller called me? Wow!" To me, it was like I had just gotten a call from the President. To Elaine, it was like a call from a friend down the street.*

I called Winnie and informed him that my mathematical results seemed to refute his predictions. Winnie was irritated with me, telling me that I had not come anywhere close to the careful analysis he had carried out, but he sent me his book. Without offering details of the mathematics used, Winnie asserts that he considered many factors such as the effects of playing 162 games versus 154 games per season in the era of Feller and Williams. He also considered odd facts such as the practice of many teams keeping top-notch players hidden in the minor leagues and the effects of catastrophic problems that shortened careers of excellent players like Lou Gehrig (ALS disease) and Herb Score (hit in the eye by a shot off of the bat of Gil McDougald). If Winnie were to repeat his study today, it might include the effect of the designated hitter.

According to Winnie's calculations, Table 2 shows the would-be home run totals four top home run hitters at the time.

Table 2

Player	Actual Career Home Runs	Projected Career Home Runs
Ted Williams	521-10th	780
Hank Aaron	755-1st	768
Babe Ruth	714-2nd	752
Lou Gehrig	493	742
Frank Robinson	586-4th	670

Source: What If?, *by Ralph Winnie, p. 46.*

I also did my analysis of the career RBI totals of Ted Williams. Although my stats were again short of Winnie's (Table 4), I did corroborate that Williams would hold the all-time RBI record over Aaron. My results are in Table 3.

In his book, Bob Feller noted that he had not one regret about the playing time or the statistics he lost serving in World War II. He was proud to have served his country in the U.S. Navy. Even the damage he suffered to his feet and legs standing on the hard decks of ships did not deter his patriotism.

The projections are, in truth, a great application to the baseball-math enthusiast, but only God knows what might have happened without interruptions for military service.

Table 3 Ted Williams RBIs

Year	Actual RBIs	RBIs Predicted by $y = -3.354x + 6{,}646.484$	RBIs Predicted by Averaging
1939	145		
1940	113		
1941	120		
1942	137		
1943	0 (WWII)	(130)	(106)
1944	0 (WWII)	(127)	(106)
1945	0 (WWII)	(123)	(106)
1946	123		
1947	114		
1948	127		
1949	159		
1950	97 (hurt)		
1951	126		
1952	3 (Korean War)	(100)	(106)
1953	34 (Korean War)	(96)	(106)
1954	89		
1955	83		
1956	82		
1957	87		
1958	85		
1959	43		
1960	72		
Totals	1839	2378	2402
		$2378 > 2297$	$1802/17 = 106$, $106 \times 5 = 530$, $1839 - 37 + 106 \times 5 = 2332$

[The function used in the predictions is $y = -3.353892124x + 6{,}646.484217$. The rounded version will give values different from the ones in the table.]

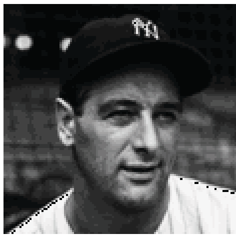
Table 4 Actual vs. Projected RBIs

Player	Actual	Projected Career RBIs
Ted Williams	1839	2795
Lou Gehrig	1990-3rd	2659
Joe DiMaggio	1537	2357
Hank Aaron	2297-1st	2336
Babe Ruth	2209-2nd	2327

Source: What If?, *by Ralph Winnie, pp. 65–66*.

EXERCISES

1. *Lou Gehrig.* Use the following data on Lou Gehrig's career and a graphing calculator for the years 1925–1938, excluding 1939 when he was ill. Fit a linear regression function to the data and predict Gehrig's home runs for years 1939–1942, and his career home run total.


Lou Gehrig, first base

Gehrig's Hitting Stats

SEASON	TEAM	G	AB	R	H	2B	3B	HR	RBI	TB	BB	SO	SB	CS
1923	Yankees	13	26	6	11	4	1	1	9	20	2	5	0	0
1924	Yankees	10	12	2	6	1	0	0	5	7	1	3	0	0
1925	Yankees	126	437	73	129	23	10	20	68	232	46	49	6	3
1926	Yankees	155	572	135	179	47	20	16	112	314	105	73	6	5
1927	Yankees	155	584	149	218	52	18	47	175	447	109	84	10	8
1928	Yankees	154	562	139	210	47	13	27	142	364	95	69	4	11
1929	Yankees	154	553	127	166	32	10	35	126	323	122	68	4	4
1930	Yankees	154	581	143	220	42	17	41	174	419	101	63	12	14
1931	Yankees	155	619	163	211	31	15	46	184	410	117	56	17	12
1932	Yankees	156	596	138	208	42	9	34	151	370	108	38	4	11
1933	Yankees	152	593	138	198	41	12	32	139	359	92	42	9	13
1934	Yankees	154	579	128	210	40	6	49	165	409	109	31	9	5
1935	Yankees	149	535	125	176	26	10	30	119	312	132	38	8	7
1936	Yankees	155	579	167	205	37	7	49	152	403	130	46	3	4
1937	Yankees	157	569	138	200	37	9	37	159	366	127	49	4	3
1938	Yankees	157	576	115	170	32	6	29	114	301	107	75	6	1
1939	Yankees	8	28	2	4	0	0	0	1	4	5	1	0	0
	Career Totals	2164	8001	1888	2721	534	163	493	1995	5060	1508	790	102	101

Source: Major League Baseball; www.mlb.com

2. *J. R. Richard.* An imposing 6'8" figure on the mound, J. R. Richard had a fastball clocked up to 100 mph. His career ended on July 30, 1980, when he suffered a stroke. Dusty Baker said he was the pitcher players feared most in his era. The following table shows his career stats from 1971 to 1980. Use the data for Richard's wins in the years 1975–1979 and a graphing calculator to fit a linear regression function to the data. Then predict his wins for the years 1980–1991 and compute his career win total.


J.R. Richard

Richards's Pitching Stats

SEASON	Team	W	L	ERA	G	GS	CG	SHO	SV	IP	H	R	ER	HR
1971	Astros	2	1	3.43	4	4	1	0	0	21.0	17	9	8	1
1972	Astros	1	0	13.50	4	1	0	0	0	6.0	10	9	9	0
1973	Astros	6	2	4.00	16	10	2	1	0	72.0	54	37	32	2
1974	Astros	2	3	4.18	15	9	0	0	0	64.2	58	31	30	3
1975	Astros	12	10	4.39	33	31	7	1	0	203.0	178	107	99	8
1976	Astros	20	15	2.75	39	39	14	3	0	291.0	221	105	89	14
1977	Astros	18	12	2.97	36	36	13	3	0	267.0	212	94	88	18
1978	Astros	18	11	3.11	36	36	16	3	0	275.1	192	104	95	12
1979	Astros	18	13	2.71	38	38	19	4	0	292.1	220	96	88	13
1980	Astros	10	4	1.90	17	17	4	4	0	113.2	65	31	24	2
Totals	107	71	3.15	238	221	76	19	0	0	1606.0	1227	625	562	73

Source: Major League Baseball; www.mlb.com

BASEBALL STATISTICS

Since baseball is the sport in which statistics are most analyzed, I am going to relate them to my experiences with Dusty Baker when he was with the San Francisco Giants and we were writing our book.

A player's *batting average,* BA or AVG, is defined as follows:

$$BA = AVG = \frac{\text{Total Number of Hits}}{\text{Official at Bats}} = \frac{H}{AB}$$

where walks, sacrifice-fly RBIs, sacrifice bunts, times being hit by a pitch, are not official at bats (AB). Dusty refers to the latter as *non-at-bats.*

For example, a player who gets 3 hits in 10 official at bats has a 0.300 batting average. Note that he has actually failed in 7 out of 10 attempts. Where else can you fail that often and make a salary of several million dollars playing a kid's game? Any hitter with a 0.300 batting average or better is considered an excellent hitter. An average of say 0.270 to 0.299 is a good hitter, and below 0.270, a marginal or weak hitter. Table 5 shows the batting averages of the top seven players in the major leagues in 2011.

Table 5 MLB Leaders: Batting Average, 2011 Regular Season

Rank	Name	AVG	AB	H
1	Miguel Cabrera,Tigers	.344	572	197
2	Adrian Gonzalez, Red Sox	.338	630	213
3	Michael Young, Rangers	.338	631	213
4	Jose Reyes, Mets	.337	537	181
5	Ryan Braun, Brewers	.332	563	187
6	Victor Martinez, Tigers	.330	540	178
7	Matt Kemp, Dodgers	.324	602	195

AVG = batting average, AB = at bat, H = hits.

At the beginning of the season the numbers in H/AB are small allowing great variation in a player's batting average, but at the end of the season the numbers are very large, in the hundreds, and the variations are small. For example,

$$\text{Effect of 1 hit early:} \quad \frac{3}{8} = 0.375 \quad \Rightarrow \quad \frac{3+1}{8+1} = \frac{4}{9} \approx 0.444$$

$$\text{Effect of 1 hit late:} \quad \frac{189}{504} = 0.375 \quad \Rightarrow \quad \frac{180+1}{504+1} = \frac{190}{505} \approx 0.376$$

Figure 9 is a graph of what I consider a typical batting average over a season. Suppose a player's batting average for the season ends up at 0.280. The wavy blue line represents the changes in the true batting average of a player. The solid blue curve represents a continuously decreasing function which might be used to "model" the player's batting average over the season in relation to his final average.

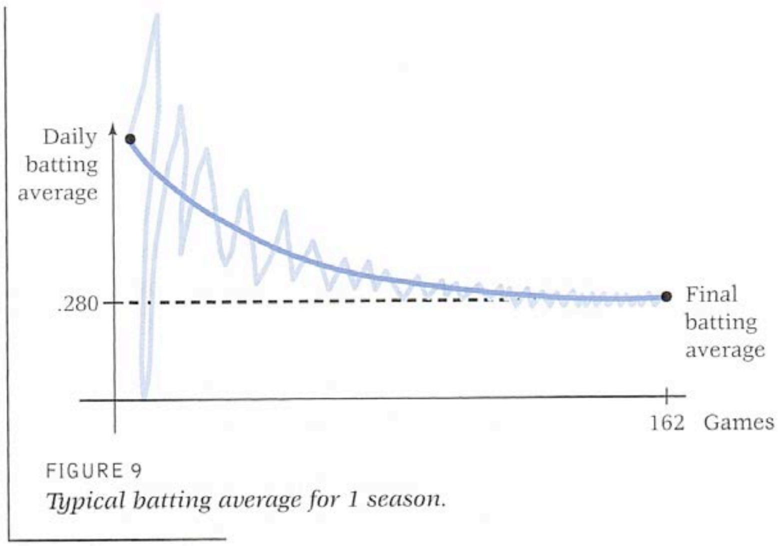


FIGURE 9

Typical batting average for 1 season.

This model has been drawn from my experience following baseball over 50 years. No extensive data analysis has been done, though the model is somewhat corroborated by the following graphs of BAs for two players. Few players start with a low average and increase it over a season.

The solid blue curve in Figure 9 is not a perfect model and is conceived out of my intuition, not a careful statistical analysis. Nevertheless, you will see how Dusty Baker and his players use and corroborate this model. What happens is that a player's BA starts out, in this case, quite high and wavers rapidly early in the season. Over the course of the season, as shown by the blue curve, the BA tends to *decrease* to the final BA. If you know statistics, you will recognize the *Law of Large Numbers* in this idea, but we will not discuss that here.

Dusty Baker was aware of this as a player, and in his capacity now as a manager, he makes his players aware of results drawn from the curve. In effect, players are taught to realize that when you get a non-at-bat, you tend to keep your batting average higher, because BA tends to be a decreasing function for players with early high averages. So if you make

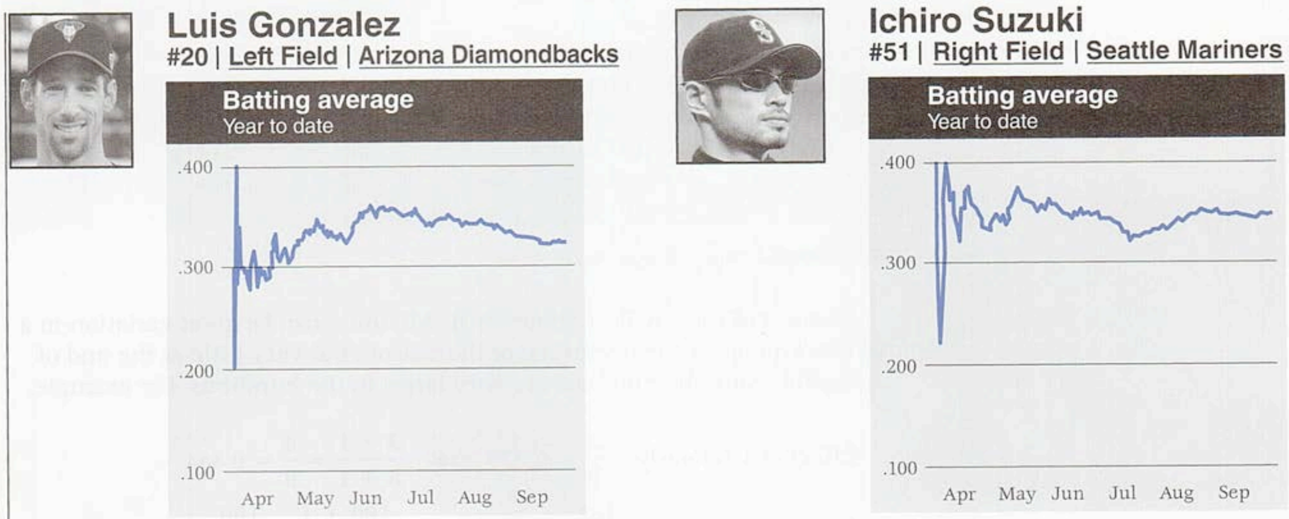


FIGURE 10
Batting averages of Luis Gonzalez and Ichiro Suzuki in a recent year.

any kind of non-at-bat, draw a walk, make a sacrifice bunt, and so on, you are keeping your average higher. Quite simply, you have not received a regular at bat, which tends to decrease your average. Compare these two situations:

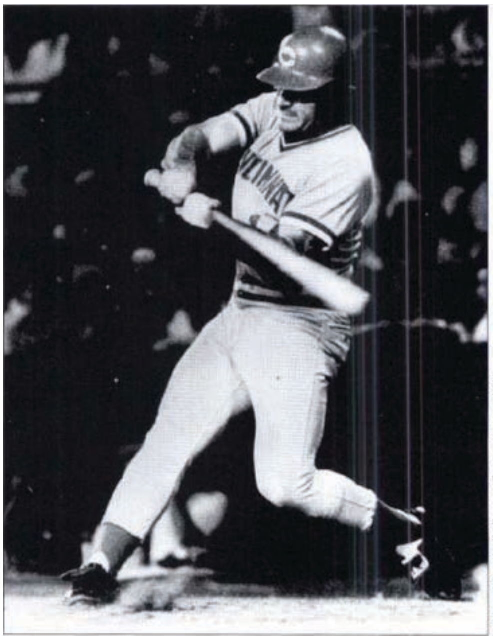
3 hits in 9 at bats in 3 games gives a 0.333 BA.

3 hits in 12 at bats in those three games gives a 0.250 BA.

Suppose the hitter had 3 non-at-bats out of those 12 opportunities. Then the hitter would look a lot better at 0.333 than at 0.250. To say this another way by not taking an at-bat that might reduce your average you keep it where it is and don't reduce it. You gain by not losing.

Pete Rose is probably my favorite all-time player on the field. Off the field his character has left something to be desired. (And, yes, I do think he should be forgiven for his gambling allegations and voted into the Hall of Fame). Dusty said, and I agree from all the Reds games I followed during Rose's career, that Pete Rose was probably the "greediest" hitter to ever play the game. If he got 1 hit in his first at bat, you could almost count on him going 2/3, 3/4, or 4/4 for the game. He always went to the plate eager, intense, and aggressive no matter how many previous hits he had made or the score of the game.

According to Dusty, immature players often fall into a trap. Say a player gets 2 hits in his first 2 at bats and ends up 2/4 for the night; he has a very



National Baseball Library, Cooperstown, N.Y.

Pete Rose

respectable .500 for the game. Young players in those situations often do what I call "hit and giggle" for the rest of the game. They know after those first two at bats that they will have a good night, so they don't bear down on the next at bats. But suppose that hitter faces a tough pitcher the next night. Then

$$\left.\begin{matrix} 2/4 \\ 0/4 \end{matrix}\right\} \Rightarrow \quad 2/8 = 0.250$$

for the two nights—not so good! If that player had played greedy the first night like Pete Rose, then maybe the situation would have changed to

$$\left.\begin{matrix} 3/4 \\ 0/4 \end{matrix}\right\} \Rightarrow \quad 3/8 = 0.375$$

for the two nights—looking good!

The moral of the story from Dusty is, no matter what your playing level, *never, ever give away an at bat!* For more on this discussion of *non-at-bats* see

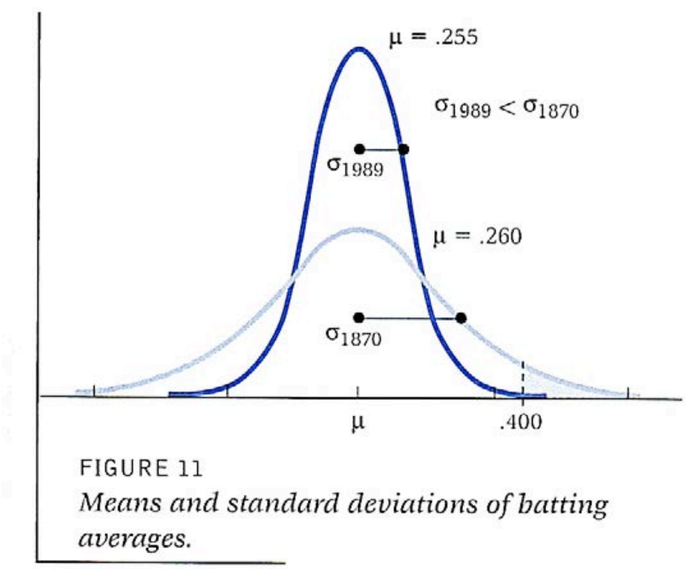
p. 277 of *Dusty Baker's Hitting Handbook.*

Standard Deviations and the Demise of the 0.400 Hitter

George Will, in his book *Men at Work,* referred to studies by the late Stephen Jay Gould, eminent Harvard social scientist and baseball fan, on evolutionary processes in batting.

$$\text{BA in 1870s} = \mu = 0.260$$

$$\text{BA in 1989} = \mu = 0.255$$



According to Gould, the batting averages of players have essentially not decreased by much over the years. But the variation, or standard deviation, of the batting averages has decreased considerably, as modeled in Figure 11.

FIGURE 11

Means and standard deviations of batting averages.

This is a fascinating result to those who know the mathematics, but unfortunately it is difficult to explain standard deviation to the average person on the street who has no training in the concept. Certainly, no announcer comments about changes in a hitter's standard deviation. When explaining standard deviation to someone not mathematically sophisticated, I like to use the notion of a "spread" number and try to tell how numbers are spread out on both sides of the mean, or average.

Jay Johnstone, Jerry Reuss, Tommy LaSorda, and the Rope. *Jay Johnstone and Jerry Reuss played for Tommy LaSorda when he was manager of the Dodgers. Johnstone and Reuss were born pranksters. Once the two of them borrowed clothes from the Dodgers' field maintenance crew and went out and raked the infield between innings. LaSorda was livid when he discovered the deed.*

Johnstone was once my manager at Dodger Baseball camp, but we weren't hitting very well. He actually took all our baseball bats, stacked them in a pile, poured gasoline on them, and lit them in order to "fire up our hitting." He got our attention, but our hitting continued in futility.

Johnstone was a prankster extraordinaire. One prank he tells at Dodger Camp involved Tommy LaSorda and his enjoyment of food.

Tommy never missed a meal. One night during spring training, Johnstone and Reuss snuck into his room and removed the voice-transmitting device from the telephone. Thus, Tommy could hear the operator but she could not hear him.

After Tommy went to bed that night, Johnstone and Reuss got some rope, tied one end to the door knob and the other end to a tree; there was no way Tommy could get out of his room the next morning. When Tommy failed to get the door open, he tried the windows, but they were too small to crawl through. Furious, he called the front desk and yelled into the phone but the operator could not hear him. After some time, someone saw the rope and let him out. He not only missed his breakfast, but he was late to the team bus, a major no-no he impressed on his players.

Think of the probability of a hitter batting 0.400 or better as the area under each curve to the right of 0.400 on the x-axis in Figure 11. Note that in the 1870s the spread number was quite large and the shaded area to the right of 0.400 under the curve for the 1870 hitters is much higher than the blue to the right of 0.400 under the curve for the 1989 hitters. These areas are probabilities. Thus, there was a much smaller chance of a hitter batting 0.400 in 1989 than in 1870. Gould asserts that the reasons for the demise of the 0.400 hitter is that the game has refined itself, the equipment is better, the fields are better, and the instruction is better. But to me, these assertions would apply to pitching as well as hitting, which further supports Gould's reults.

Look back again at the solid blue curve in Figure 9. I find it amusing, if not irritating as a fan, that if a player has a 0.400 batting average or better in June or July, then the media go crazy analyzing and discussing the possibility. Since that blue curve is a decreasing function, the media shouldn't involve themselves in such foolish distractions unless the player is hitting over 0.400 by the first of September. This overreaction occurred with George Brett in 1980 with the Kansas City Royals; Brett finished with a 0.390 BA. The overreaction occurred again with Tony Gwynn of the San Diego Padres in 1994; Gwynn finished with a 0.394 BA. I'm inclined to think that there will never be another .400 hitter.

Slugging Percentage

Slugging Percentage

$$\text{Slugging Percentage} = \text{SLG} = \frac{\text{Total Bases}}{\text{Official at Bats}} = \frac{4(HR)+3(T)+2(D)+S}{AB}$$

where for the season,

$HR =$ the total number of home runs,

$T =$ the total number of triples,

$D =$ the total number of doubles, and

$S =$ the total number of singles.

SLG is the average number of bases attained per each at-bat.

Barry Bonds, of the San Francisco Giants, had probably the most incredible season in the history of baseball in 2001, highlighted by his record-breaking 73 home runs, eclipsing the all-time season total record of 70 then by Mark McGwire. He also broke the all-time record for slugging average in a season. Let's compute his SLG. His hitting statistics are in Table 6.

Table 6 Career Batting Statistics of Barry Bonds

BATTING Regular Season Career Stats

YEAR▲	TEAM	LG	LEVEL	G	AB	R	H	TB	2B	3B	HR	RBI	BB	IBB	SO	SB	CS	AVG	OBP	SLG	OPS	GO/AO
1986	PIT	NL	MLB	113	413	72	92	172	26	3	16	48	65	2	102	36	7	.223	.330	.416	.746	-
1987	PIT	NL	MLB	150	551	99	144	271	34	9	25	59	54	3	88	32	10	.261	.329	.492	.821	-
1988	PIT	NL	MLB	144	538	97	152	264	30	5	24	58	72	14	82	17	11	.283	.368	.491	.859	-
1989	PIT	NL	MLB	159	580	96	144	247	34	6	19	58	93	22	93	32	10	.248	.351	.426	.777	-
1990	PIT	NL	MLB	151	519	104	156	293	32	3	33	114	93	15	83	52	13	.301	.406	.565	.970	-
1991	PIT	NL	MLB	153	510	95	149	262	28	5	25	116	107	25	73	43	13	.292	.410	.514	.924	-
1992	PIT	NL	MLB	140	473	109	147	295	36	5	34	103	127	32	69	39	8	.311	.456	.624	1.080	-
1993	SF	NL	MLB	159	539	129	181	365	38	4	46	123	126	43	79	29	12	.336	.458	.677	1.136	-
1994	SF	NL	MLB	112	391	89	122	253	18	1	37	81	74	18	43	29	9	.312	.426	.647	1.073	-
1995	SF	NL	MLB	144	506	109	149	292	30	7	33	104	120	22	83	31	10	.294	.431	.577	1.009	-
1996	SF	NL	MLB	158	517	122	159	318	27	3	42	129	151	30	76	40	7	.308	.461	.615	1.076	-
1997	SF	NL	MLB	159	532	123	155	311	26	5	40	101	145	34	87	37	8	.291	.446	.585	1.031	-
1998	SF	NL	MLB	156	552	120	167	336	44	7	37	122	130	29	92	28	12	.303	.438	.609	1.047	-
1999	SF	NL	MLB	102	355	91	93	219	20	2	34	83	73	9	62	15	2	.262	.389	.617	1.006	0.71
2000	SF	NL	MLB	143	480	129	147	330	28	4	49	106	117	22	77	11	3	.306	.440	.688	1.127	0.61
2001	SF	NL	MLB	153	476	129	156	411	32	2	73	137	177	35	93	13	3	.328	.515	.863	1.379	0.66
2002	SF	NL	MLB	143	403	117	149	322	31	2	46	110	198	68	47	9	2	.370	.582	.799	1.381	0.67
2003	SF	NL	MLB	130	390	111	133	292	22	1	45	90	148	61	58	7	0	.341	.529	.749	1.278	0.66
2004	SF	NL	MLB	147	373	129	135	303	27	3	45	101	232	120	41	6	1	.362	.609	.812	1.422	0.82
2005	SF	NL	MLB	14	42	8	12	28	1	0	5	10	9	3	6	0	0	.286	.404	.667	1.071	0.47
2006	SF	NL	MLB	130	367	74	99	200	23	0	26	77	115	38	51	3	0	.270	.454	.545	.999	0.65
2007	SF	NL	MLB	126	340	75	94	192	14	0	28	66	132	43	54	5	0	.276	.480	.565	1.045	1.06
MLB Totals			MLB	2986	9847	2227	2935	5976	601	77	762	1996	2558	688	1539	514	141	.298	.444	.607	1.051	0.71

From Table 6 we see that $HR = 73$, $T = 2$, $D = 32$, and $S = 49$. Table 6 does not list the actual number of singles. We must take total hits, 156, and subtract home runs, triples, and doubles, to get the singles. Then

$$
\begin{aligned}
\text{SLG} &= \frac{4(HR)+3(T)+2(D)+S}{AB} \\
&= \frac{4(73)+3(2)+2(32)+49}{476} \\
&\approx 0.863.
\end{aligned}
$$

A hitter is considered to have an excellent slugging percentage if it is 0.600 or better. So, Bonds set a phenomenal record, though his career has since been tainted by allegations of illegal substance abuse.

OBP and OPS Statistics

Baseball statisticians also analyze a statistic called *on-base percentage*, OBP. It is an adaptation of BA that takes into account other ways of getting on base such as walking and being hit by a pitch.

On-Base-Percentage, *OBP*, is defined as follows.

$$OBP = \frac{H + W + HBP}{AB + W + HBP + SF}$$

where

$H =$ total number of hits,

$W =$ total number of walks (often abbreviated BB, for number of bases on balls),

$HBP =$ total number of times batter was hit by a pitch,

$SF =$ total number of sacrifice flys, and

$AB =$ total at bats.

Most books and Internet references do not list HBP.

Bruce Froemming, Pete Rose, and the Birds. *Another of my favorite baseball stories was told often by major-league umpire Bruce Froemming at the Dodger Fantasy Camp. Retired now, many players consideed Froemming to be the finest ball-strike umpire in the game.*

Bruce came to the major leagues in 1970 and served his first year with Al Barlick, the noted umpire, who was completing his last year in the majors. It is typical of players and umpires to play pranks on rookies. Earlier that season, Nate Colbert of the San Diego Padres had had the misfortune to have a fly ball hit a bird in the outfield on its way to what might have been a home run. No ground rule covered this play. It caused quite a controversy.

To pull a prank on rookie Froemming, Barlick informed him that for a couple of weeks he should go out on the diamond one hour before each game and "look for birds." Wanting to impress, Froemming did as instructed with diligence, until finally unraveling the prank. I imagine him out there staring at the sky.

Not long after this, the umpire team went to Cincinnati for a series between the Reds and the Mets. Pete Rose, the captain of the Reds at the time, brought out his lineup card to meet with the umpires and the opposing umpire, Gil Hodges. This time the prank was on Rose and was committed by Hodges and *the other umpires.*

To put Froemming on the other side of the joke, the umpires told him to tell Rose something like the following, "Pete, because of the bird incident in San Diego, I have been assigned to watch for birds in the ballparks. I noticed here that there are two pigeons flying around in right field so we need a ground rule to cover the situation." Pete agreed and asked what the rule would be. Froemming says, "There are two birds, a male and a female. If you hit the male, it is a ground rule double. If you hit the female, it is all you can get."

Ted Williams extolled the use of the statistic he called *production.*

Production, *OPS*, defined simply as on-base percentage plus slugging percentage. That is,

$$\begin{aligned} OPS &= OBP + SLG \\ &= \frac{H+W+HBP}{AB+W+HBP+SF} + \frac{4(HR)+3(T)+2(D)+S}{AB} \end{aligned}$$

where for the season,

HR = the total number of home runs,

T = the total number of triples,

D = the total number of doubles,

S = the total number of singles,

H = total number of hits,

W = total number of walks (often abbreviated BB, for number of bases on balls),

HBP = total number of times batter was hit by a pitch,

SF = total number of sacrifice flys, and

AB = total at bats.

Williams asserted adamantly, "I realize that everyone has a different idea of what constitutes a great hitter. For some it's a high batting average. For others, it's the guy with the most total hits, or home runs, or *RBI*s. I've always believed that slugging percentage plus on-base percentage is absolutely the best way to rate the hitters."

To me Ted Williams is "absolutely" the greatest hitter to ever play the game. If he says *OPS* is the best stat to rate a hitter, I cannot disagree. In most books and Internet sources both *OBP* and *SLG* are given, so we can simply add to find *OPS*.

For Barry Bonds's outstanding 2001 season, his *OBP* was 0.515 and his SLG was 0.863. Thus, his *OPS* was 0.515 + 0.863, or 1.378. Williams asserts that any player with an *OPS* above 1.0 has an excellent season. In their careers, very few players had an OPS above 1; Babe Ruth had 1.163, Lou Gehrig had 1.080, Mickey Mantle had 0.979, and Willie Mays had 0.944. Table 7 shows the OPS statistics for the top five players in the major leagues in 2011.

Table 7 MLB Leaders: Sorted by Production OPS; On-Base plus Slugging Percentages, (OPS), 2011 Regular Season

Rank	Name	Team	OPS	AVG	RBI	AB	HR	OBP	SLG
1	Jose Bautista	Tor	1.056	.302	103	513	43	.447	.608
2	Miguel Cabrera	Det	1.033	.344	105	572	30	.448	.586
3	Ryan Braun	Mil	0.994	.332	111	563	33	.397	.597
4	Matt Kemp	LAD	0.986	.324	126	602	39	.399	.586
5	Price Fielder	Mil	0.981	.299	120	569	38	.415	.566

Pitcher's Earned Run Average

A pitcher's win–loss record is the first statistic used to evaluate the player. The second most used statistic is the earned run average, *ERA*. In 2001 the outstanding pitcher for the Arizona Diamondbacks, Randy Johnson, gave up 69 earned runs in $249\frac{2}{3}$ innings of pitching. The mixed numeral $249\frac{2}{3}$ means that he pitched 249 full innings and plus 2 outs of 3 possible outs of another inning. The *ERA* is based on how many earned runs the pitcher gives up every 9 innings. To find the ERA, we set up a proportion:

$$\frac{\text{ERA}}{9} = \frac{69}{249\frac{2}{3}}$$

Then we solve the proportion by multiplying both sides by 9, and carry out the calculations:

$$\frac{\text{ERA}}{9} = \frac{69}{249\frac{2}{3}}$$

$$\text{ERA} = 9 \cdot \frac{69}{249\frac{2}{3}}$$

$$= 2.49 \qquad \text{Rounded to the nearest hundredth}$$

This leads us to the definition of a pitcher's earned run average, ERA:

$$ERA = 9 \cdot \frac{ER}{IP},$$

where

ER = the number of earned runs allowed, and

IP = the number of innings pitched

A pitcher with an ERA below 3.00 is considered excellent, although in the present era of weaker pitching an ERA of 4.00 or less is considered good. Table 8 shows the ERA statistics for the top five pitchers in the major leagues in 2001.

Table 8 MLB Leaders ERA, 2001 Regular Season

Player	TEAM	W	L	ERA	IP	H	R	ER	HR	
1.	R. Johnson	ARI	21	6	2.49	249.2	181	74	69	19
2.	C. Schilling	ARI	22	6	2.98	256.2	237	86	85	37
3.	J. Burkett	ATL	12	12	3.04	219.1	187	83	74	17
4.	F. Garcia	SEA	18	6	3.05	238.2	199	88	81	16

5.	G. Maddux	ATL	17	11	3.05	233.0	220	86	79	20

Note: When reading such a table for pitchers, 249.2 *IP means* $249\frac{2}{3}$.

EXERCISES

1. Below are the career totals of five all-time leading players in the major leagues through June 23, 2003. In each case compute their batting average, AVG, on-base percentage, OBP, slugging percentage, SLG, and their OPS.

Player	AB	H	2B	3B	HR	W	SF	HBP	AVG	OBP	SLG	OPS
Hank Aaron	12,364	3771	624	98	755	1402	121	32				
Babe Ruth	8399	2873	506	136	714	2062	N/A	43				
Willie Mays	10,881	3283	523	140	660	1464	91	44				
Barry Bonds	8725	2595	536	74	658	2070	84	84				
Mark McGwire	6187	1626	252	6	583	1317	78	75				

N/A = Not available; use 0.

2. What is the highest that a slugging percentage can be? the lowest?
3. Below are the career totals of five all-time leading pitchers in the major leagues through June 23, 2003. Compute each ERA.

PLAYER	YRS	G	IP	H	ER	W	L	ERA
1. Ed Walsh	14	430	2964.1	2346	598	195	126	
2. Addie Joss	9	286	2327.0	1888	488	160	97	
3. Mordecai Brown	14	481	3172.1	2708	725	239	130	
4. John Ward	7	292	2461.2	2317	575	164	102	
5. Christy Mathewson	17	635	4780.2	4218	1133	373	188	

4. Below are five all-time single-season ERA record-holding pitchers as of June 23, 2003. Compute each ERA.

PLAYER	YRS	G	IP	H	ER	W	L	ERA

1. Dutch Leonard, Bos	1914	36	224.2	139	24	19	5	
2. Mordecai Brown, Chi	1906	36	277.1	198	32	26	6	
3. Bob Gibson, StL	1968	34	304.2	198	38	22	9	
4. Christy Mathewson, NY	1909	37	275.1	192	35	25	6	
5. Walter Johnson, Was	1913	48	346.0	232	44	36	7	

5. *Limits and ERA.* Suppose in the *ERA* formula that we fix the number of earned runs allowed at 4 and let $IP = i$. We get a function given by

$$E(i) = 9 \cdot \frac{4}{i}$$

a. Complete the table that follows, rounding to two decimal places.

b. Find $\lim_{i \to 0^+} E(i)$.

c. On the basis of parts (a) and (b), conjecture a pitcher's earned run average if 4 runs were allowed and there were 0 outs.

Innings Pitched (*i*)	Earned Run Average (E)
9	
8	
7	
6	
5	
4	
3	
2	
1	
$\frac{2}{3}$ (2 outs)	
$\frac{1}{3}$ (1 out)	

THE PHYSICS OF THE BASEBALL BAT

The physics of a baseball bat and of a batter's swing are the basis of our next three topics.

Kinetic Energy

A swing of a bat appears as a circular motion, as shown in Figure 12. A body of mass m moving with a speed, or velocity, v possesses a kinetic energy, KE, due to its translational motion given by

$$KE = \frac{1}{2}mv^2$$

That is,

$$\text{Kinetic Energy} = \frac{1}{2}\cdot(\text{Mass})\cdot(\text{Velocity})^2$$

The equation tells us that the velocity, or speed, of the bat is much more important than its mass, or simply stated, weight. I have done enough coaching at lower levels to know that it is virtually impossible on a "dusty" playing field to explain that increasing v, because it is squared, has a greater effect than increasing m, which is first power only.

Dusty Baker, Tommy LaSorda, and the Missed Flight. *Dusty Baker told me a true story about Tommy LaSorda, his manager of the Dodgers at the time. Tommy was a rather demanding and intense manager—the subject of many stories by his former players.*

During spring training in Florida the Dodgers used a rather large commercial jet to travel to their games around the state. Tommy had the rule that if you did not get to the team plane on time after a game, you were responsible for your own transportation back to Vero Beach, their spring training base.

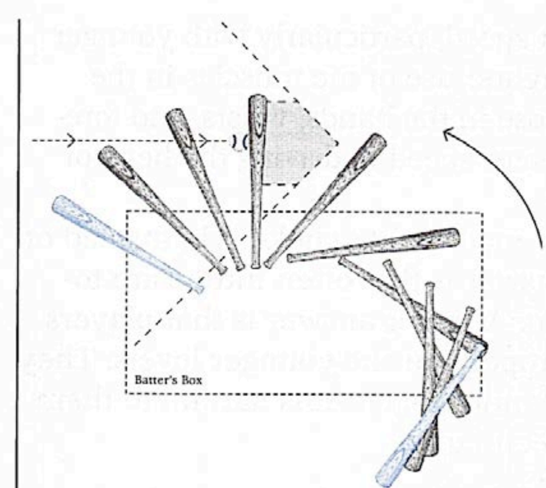


FIGURE 12
Movements of bat through a swing.

After one game, Dusty and fellow player Ken Landreaux took time to stop for cocktails. Time was fleeting, and Dusty kept prodding Landreaux to leave so they would not miss the *plane and incur Tommy's wrath. But Landreaux kept procrastinating, time got away from them, and they were late.*

Meanwhile, at the airport, Tommy was fuming and finally told the pilot to leave without Baker and friend; who arrived as the plane was taking off. They began to comment about being the object of Tommy's ire when they got back to Vero.

A pilot standing nearby responded to their grief, saying he had a Lear Jet and would be glad to fly them back to Vero as fast as possible. They hopped in the plane and got back to the Vero Beach airport before the Dodgers' plane. (This happened because a large commercial jet consumes more flying time because of the intricate flight patterns it must follow.)

Baker and Landreaux were at the gate as Tommy and the players disembarked. Off came Tommy, steaming about the missing players, only to look up and hear them say, "Hi guys! Where have you been?"

The Grip

In our book, *Dusty Baker's Hitting Handbook (DBHH,See Chapter 2, Section 5)*, Dusty and Jeff emphasize teaching the proper grip on the bat to increase speed, v. There are three types of grip: the *standard*, the *modified*, and the *choke*.

With the *standard grip*, which we prefer for the young hitter, the player aligns the middle knuckles on both hands (see Figure 13A). A simple tip for setting up this grip is to lay the bat down in the fingers, not in the palms, across the calluses in the hands (see Figure 13B). The standard grip is somewhat similar to a golf grip, but without the thumbs on the bat. If the hitter lays the bat down in his fingers as though he were gripping a golf club and then picks it up, he will normally find that the middle knuckles on both hands are aligned.

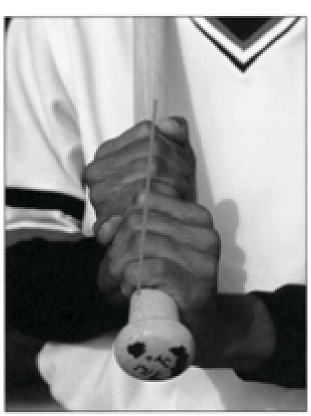
The goal of the standard grip is to achieve as much quickness and speed as possible with the hands and bat. Think of "quickness" as how the bat starts. Think of "speed" as how fast it moves through the strike zone. The energy equation says that the distance a ball travels depends on the amount of energy applied to the ball when hit, and the energy applied to the ball is one half times the mass times the velocity squared; that is

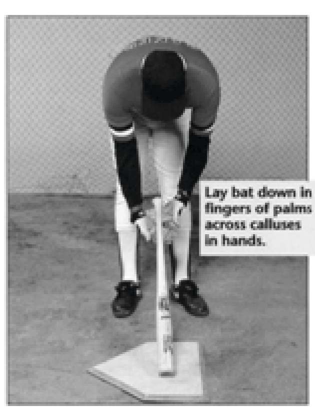
$$\text{Kinetic Energy} = \frac{1}{2} \cdot (\text{Mass}) \cdot (\text{Velocity})^2$$

Thus bat speed has a greater bearing on how far the ball travels than does the weight of the bat. A player who is not a power hitter and not primarily concerned with distance can still make the ball come off the bat a lot harder if he develops quickness and speed. Although they may not understand why, most young hitters will notice a big improvement in bat quickness and speed if they move to the standard grip.

In the past, many major league players, such as Babe Ruth, Willie Stargell, and Dick Allen, used heavy bats. Now many power hitters in the major leagues are looking for lighter bats since most of them have been brought up using metal bats. Some even go so far as to hollow out the end of the bat. Weight of the bat should not be completely ignored—it is part of the equation for hitting the ball hard. With good technique, a hitter can be successful using a heavier bat, but learning the proper techniques is far more important than moving to a heavier bat.

With the *modified grip*, the middle knuckles on the bottom hand align between the back knuckles and middle knuckles on the top hand (see Figure 13C). This grip tends to cause a loss in quickness and bat speed as well as a slight uppercut in the swing.





Gripping the bat: ***A****. The standard grip.* ***B****. Positioning the standard grip.*

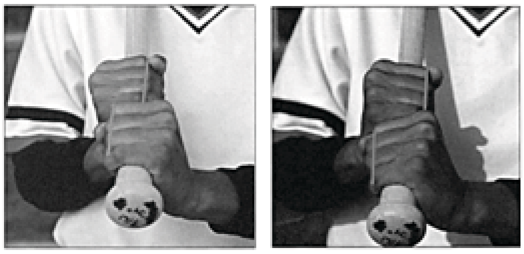


FIGURE 13

C*. The modified grip.* ***D****. The choke grip.*

The third grip is the *choke grip*, which should not be confused with choking up on the bat. Grasping the bat in a choke grip is comparable to strangling the handle of the bat (see Figure 13D). The choke grip aligns the middle knuckles of the bottom hand with the back knuckles of the top hand. Many strong major leaguers use this type of grip, and since it does require some strength, some players aged 16 to 18 might be able to use it. The choke grip forces even more of an uppercut than does the modified grip, whether the hitter wants it or not. It also tends to cause a greater loss in quickness and bat speed, particularly with younger hitters, because it tends to force greater use of the muscles in the shoulders and back rather than those in the hands, wrists, and forearms. These muscles allow for greater speed in driving the head of the bat through the strike zone.

> *Finding a standard grip on a bat is similar to gripping a golf club. Be careful, however, that this does not lead you to think that swinging a golf club will enhance your baseball hitting. The swing of a baseball bat is not necessarily compatible with the swing of a golf club, even though the grips may be compatible. In fact, some major league managers have not allowed their players to play golf for this reason. Consult your hitting coach.*
> [*A golf coach once told your author that professional baseball players are the toughest to teach.*]
>
> — DUSTY BAKER, MANAGER, CINCINNATI REDS

Why do some players use the modified or choke grip instead of the standard grip? One simple answer is that often hitters are totally unaware of the standard grip. Another answer is that players simply have not been coached properly at the younger levels. They tend to grab a bat in a choking manner that seems natural to them but is in fact poor fundamental technique.

There is one more positive result of using the standard grip asserted by Dusty and Jeff. The bat swung with the standard grip stays flatter longer through the swing than the bat swung with the choke grip. As a mathematician, I explain this assertion with two graphs. The standard grip is represented by the graph of the equation $y = x^{12}$, the choke grip by the graph of the equation $y = x^2$, and the flight of pitch as a ball traveling along the x-axis. See Figure 14.

FIGURE 14
Paths of bat using standard vs. choke grips.

FIGURE 15
Comparison of balance points of an aluminum bat (A) and a wooden bat (B).

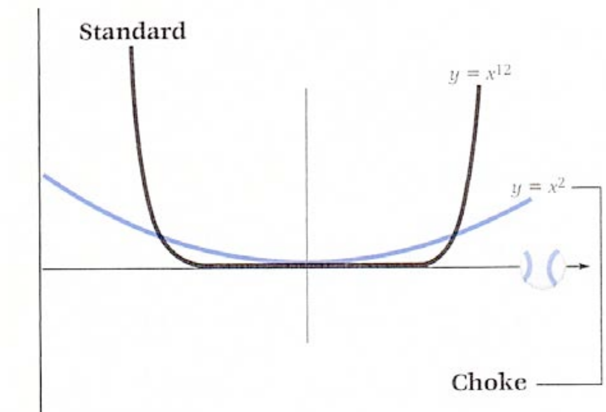


FIGURE 14
Paths of bat using standard vs. choke grips.

Metal vs. Wooden Bats*

All other variables remaining constant, a player can swing an aluminum bat faster than a wooden bat, and thus attain the advantage of extra speed.

Compare a wooden bat and an aluminum bat in terms of balance point (center of gravity, *CG*), and you will find the balance point of an aluminum bat farther out toward the end of the bat than the *CG* of a wooden bat. See Figure 15. There is more weight in the handle of a metal bat. This also gives the hitter an advantage because he will hit inside pitches with more power, and will usually not break the bat above the handle, which often happens with a wooden bat. (Metal bats do break. I actually saw it happen once in a softball game.)

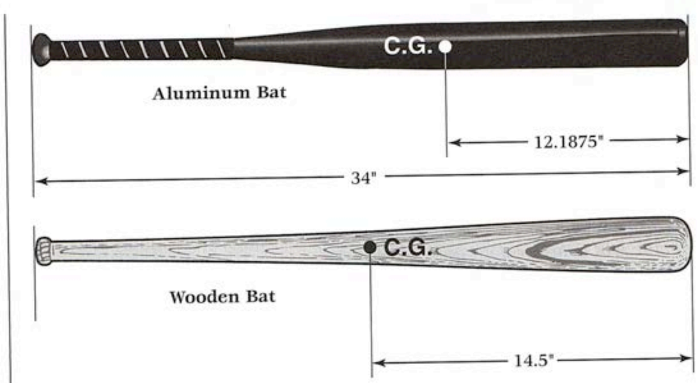


FIGURE 15
Comparision of balance points of an aluminum bat (A) and a wooden bat (B).

*I wish to thank Robert K. Adair, again, and Mark Reuber of Grove City College for their kind and helpful conversations regarding this topic.

Bat Vibrations and Sweet Spots

Have you ever heard a player saying "I hit the sweet spot" or "I hit that ball so well I barely felt it"? Considering the physics of a baseball bat as it hits a ball helps us understand what this means. First of all, when it is swung at a ball, a bat is a firm *rotating* object. It makes sense then that the speed and quickness of that rotation have an effect on the ball.

But after it hits the ball, the bat becomes a *vibrating* object. Although this vibration is not visible to the naked eye, the batter definitely feels it to one degree or another. To understand how the vibration takes place, take a piece of metal sheeting about 2 inches wide and 5 feet long. Hold it in the middle and shake it. The result resembles a vibrating bat (see Figure 16). Note that vibrations can be seen in the middle, where it is being shaken

FIGURE 16
The nodes and antinodes of a vibrating strip of metal.

and on the ends, but there are two locations where there seem to be no vibrations. These locations are called *nodes*, and locations of greatest vibration are called *antinodes*.

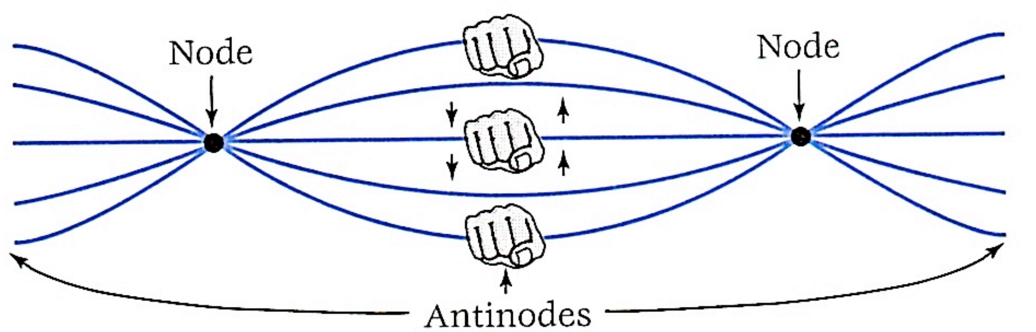


FIGURE 16
The nodes and antinodes of a vibrating strip of metal.

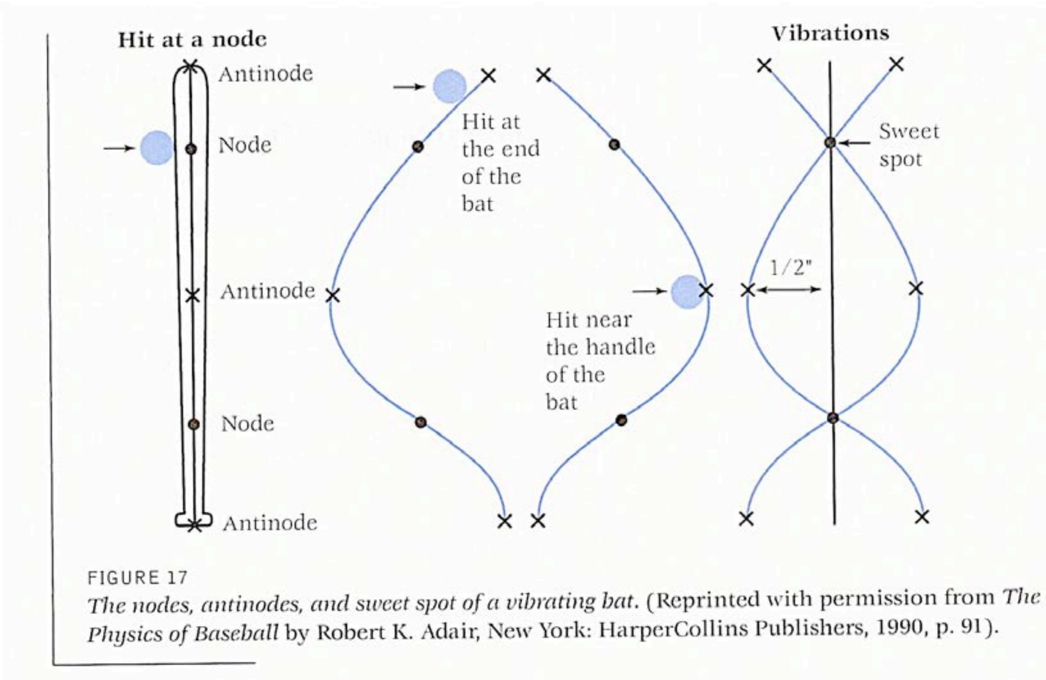


FIGURE 17

The nodes, antinodes, and sweet spot of a vibrating bat.

(Reprinted with permission from *The Physics of Baseball* by Robert K. Adair, New York: HarperCollins Publishers, 1990, p. 91).

Although they are not visible, vibrations occur when the bat hits the ball. There are two nodes on a bat, one in the handle and one up in the barrel. Hopefully, the ball does not hit the handle node because that is where the bat is held. But the ball can hit the barrel node. That node is called the *sweet spot* (see Figure 17).

If the ball hits near a node, there is very little, if any vibration. If the ball hits an antinode, there is maximum vibration, possibly as much as one half inch. This explains why the greatest stinging effect occurs if a ball is hit on the antinode just above the handle. If it hits anywhere other than on a node, a vibration is created. Any vibration, no matter how slight, takes energy away from the ball, shortening the distance that it travels off the bat.

You can actually “hear” where the nodes are on a wooden bat by screwing a hook into the top end of the bat and hanging it vertically from the ceiling. Put some adhesive tape on the end of a hammer and move from one end of the bat to the other, tapping the bat with the hammer. The changes in sound will indicate the position of the nodes and places in between. The hitter could place a piece of tape on the sweet spot. The node or sweet spot on a metal bat is longer than on a wooden bat, but it cannot be discovered in the manner we just described because of the air shaft inside the bat. The longer sweet spot on a metal bat is another hitting advantage of metal over wooden bats.

THE FORMULAS OF BILL JAMES

The *Society for American Baseball Research*, SABR, is an organization of baseball enthusiasts who analyze the game to its utter depths in a literary--historical-statistical manner. One of SABR’s most famous members, baseball statistician Bill James, is the author of numerous analytical books dedicated to baseball. James’s credibility is attested by the fact that he was once employed by the Boston Red Sox as an analyst of baseball talent. Billy Beane, general manager of the Oakland Athletics, is a proponent of James’s methods, so much so that Beane now enjoys an outstanding reputation for building a quality team, Oakland Athletics, on a low budget. For example, one thing Beane discovered through James is that on-base percentage, *OBP,* is three times more important than slugging percentage, *SLG*, in determining a hitter’s contributions. Another is that a team should only draft pitchers with college as well as high school experience. A great movie, *Moneyball* starring Brad Pittis based on the book by the same title by Michael Lewis, tells Beane’s storyWe now consider two of James’ formulas.

The Pythagorean Theory

I enjoy this one because it has a unique comparison to the Pythagorean Theorem for right triangles, but the analogy stops there.

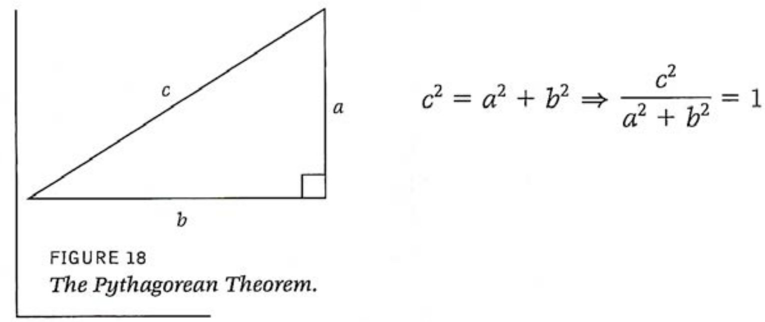


FIGURE 18
The Pythagorean Theorem.

An old baseball adage says that "pitching and defense will beat offense every time." James uses what he calls a Pythagorean Theory to refute this adage. He conjectures that the ratio of a team's wins to the sum of its wins and losses (winning percentage) is approximately the same as the ratio of the square of its runs scored to the sum of the square of its runs scored plus the square of the opposition's runs scored:

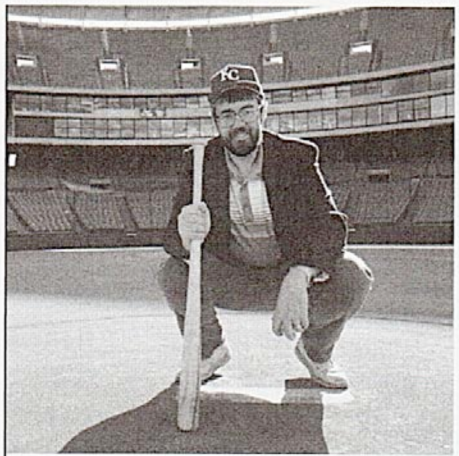
$$\frac{\text{Runs}^2}{\text{Runs}^2 + (\text{Opposition Runs})^2} \approx \frac{\text{Wins}}{\text{Wins} + \text{Losses}} = \text{Winning Percentage}$$

James asserts that an improved approximation, which he found by a statistical technique, is given by

$$\frac{\text{Runs}^{1.83}}{\text{Runs}^{1.83} + (\text{Opposition Runs})^{1.83}} \approx \frac{\text{Wins}}{\text{Wins} + \text{Losses}} = \text{Winning Percentage}$$

$$\text{Standard Error} = \pm\ 4.15 \text{ Wins}$$

For example, the final standings of the National League West in a recent year are shown in Table 9. The winning percentage of the Giants is given by



Bill James

$$\frac{\text{Wins}}{\text{Wins}+\text{Losses}}=\frac{90}{162}=0.556$$

Table 9

NL WEST	W–L	PCT	GB
Arizona	92–70	.568	—
San Francisco	90–72	.556	1
Los Angeles	86–76	.531	6
San Diego	79–83	.488	13
Colorado	73–89	.451	19

W = Wins, L = Losses; PCT = Winning Percentage; GB = Games behind first place team.

Let's see how this compares to the Pythagorean Theory. The Giants scored 799 runs. Their opposition scored 749. Then

$$\frac{\text{Runs}^{1.83}}{\text{Runs}^{1.83}+(\text{Opposition Runs})^{1.83}}=\frac{799^{1.83}}{799^{1.83}+749^{1.83}}=0.530$$

The results are fairly close. Note that the latter result really has only offensive statistics on runs scored by each team; there are no pitching or defensive statistics in the formulas. James asserts that this formula is close enough to deduce that pitching and defense are *not* more important than offense.

James' Favorite Toy Formula

Career home run records and the possibility of getting 3,000 hits are two goals of outstanding players. Is there a way to make a prediction about outstanding players reaching a very difficult goal? James has developed a way, called his *Favorite Toy Formula*, which is best explained by working through an example.

ALBERT PUJOLS. Considered one of the most outstanding players in the game today, can he reach 3,000 hits in his career? Let's look at his hit total for all the years he has played through Sept 18, 2012. Refer to Table 10 as we work through the following five questions.

Table 10 Career Batting Statistics of Albert Pujols

BATTING Regular Season Career Stats

YEAR▲	TEAM	LG	LEVEL	G	AB	R	H	TB	2B	3B	HR	RBI	BB	IBB	SO	SB	CS	AVG	OBP	SLG	OPS	GO/AO
2000 ⊞			Minors	133	490	74	154	266	41	7	19	96	46	7	47	4	5	.314	.378	.543	.920	-
2001	STL	NL	MLB	161	590	112	194	360	47	4	37	130	69	6	93	1	3	.329	.403	.610	1.013	0.92
2002	STL	NL	MLB	157	590	118	185	331	40	2	34	127	72	13	69	2	4	.314	.394	.561	.955	1.09
2003	STL	NL	MLB	157	591	137	212	394	51	1	43	124	79	12	65	5	1	.359	.439	.667	1.106	1.02
2004	STL	NL	MLB	154	592	133	196	389	51	2	46	123	84	12	52	5	5	.331	.415	.657	1.072	0.93
2005	STL	NL	MLB	161	591	129	195	360	38	2	41	117	97	27	65	16	2	.330	.430	.609	1.039	0.90
2006	STL	NL	MLB	143	535	119	177	359	33	1	49	137	92	28	50	7	2	.331	.431	.671	1.102	0.75
2007	STL	NL	MLB	158	565	99	185	321	38	1	32	103	99	22	58	2	6	.327	.429	.568	.997	0.98
2008	STL	NL	MLB	148	524	100	187	342	44	0	37	116	104	34	54	7	3	.357	.462	.653	1.114	0.92
2009	STL	NL	MLB	160	568	124	186	374	45	1	47	135	115	44	64	16	4	.327	.443	.658	1.101	0.87
2010	STL	NL	MLB	159	587	115	183	350	39	1	42	118	103	38	76	14	4	.312	.414	.596	1.011	0.89
2011	STL	NL	MLB	147	579	105	173	313	29	0	37	99	61	15	58	9	1	.299	.366	.541	.906	1.15
2012	LAA	AL	MLB	140	550	80	155	288	43	0	30	96	48	15	67	8	1	.282	.342	.524	.865	0.98
MLB Totals			MLB	1845	6862	1371	2228	4181	498	15	475	1425	1023	266	771	92	36	.325	.415	.609	1.024	0.95

Let's calculate the probability of Pujols getting 3,000 hits in his career.

How old is he? Born Jan 16, 1980, Age 32

Total number of hits = 2228

How well is he doing lately?

How much longer can he play?

Albert Pujols © *Alan Crosthwaite | Dreamstime.com*

1. *Distance.* How far away from the goal of 3,000 hits is he? The number of hits he needs, N, is given by

$$N = 3000 - 2228 = 772.$$

2. *Momentum.* How fast is Pujols approaching his goal? James answers that using a "What have you done for me lately?" weighted average given by

$$EPL = \frac{3(H_1) + 2(H_2) + H_3}{6}$$

where

H_1 = Total number of hits last season,

H_2 = Total number of hits season before last, and

H_3 = Total number of hits three seasons ago.

In Pujol's case,

$$\begin{aligned}EPL &= \frac{3(H_1)+2(H_2)+H_3}{6}\\ &= \frac{3(\text{Hits in 2012})+2(\text{Hits in 2011})+(\text{Hits in 2010})}{6}\\ &= \frac{3(155)+2(172)+(183)}{6} \qquad \text{Substituting from Table 10}\\ &= 165 \text{ hits per year}\\ &= \text{Pujols Established Performance Level}\end{aligned}$$

3. *Time*. How much longer can Pujols play? That number of years, Y, is given by

$$\begin{aligned}Y &= 24 - (\text{Present Age})\\ &= 24 - 0.6(32)\\ &= 4.8\end{aligned}$$

(A player 37 years or older is given exactly 1.5 years left to play.)

4. *Projected Remaining Hits.* The number of remaining hits, H_p, we can predict for Pujols is

$$\begin{aligned}H_p &= (\text{Years Pujols Can Play}) \cdot (\text{Pujols EPL})\\ &= (4.8)(165)\\ &= 792\end{aligned}$$

5. *Probability of Attaining 3,000 Hits.* We then compute the probability, P, of Pujols getting 3,000 hits as given by

$$\begin{aligned}P &= \frac{Y \cdot EPL - 0.5N}{N}\\ &= \frac{(4.8)\cdot(165) - 0.5(772)}{772}\\ &\approx 0.526, \text{ or } 52.6\%\end{aligned}$$

Based on James's "What have you done for me lately?" Favorite Toy Formula, we must conclude that there is a better than 50% probablity that Pujols will reach 3,000 hits. His age and outstanding performance are to his advantage. Note in the formula that his performance fell off after he received a large contract and moved to the Los Angeles Angels in 2012. Note the "3 times" part of the *EPL* formula reflects how "What have you done for me lately?" comes into play.

It is of interest to look at other outstanding players to see how valid this formula was in making predictions before their careers ended.

Robin Yount: By 1990, age 35, he had 2,747 hits.
$P = 151\%$ "=" 97% (97% is as high as James allows).
He passed 3,000 hits.

Alex Rodriguez: By 2012, age 37 he had 2,887 hits.
$P = 131\%$ "=" 97.1%.
He should pass 3,000 hits with ease in 2013.

Eddie Murray: By 1992, age 37, he had 2,646 hits.
$P = 53\%$.
He passed 3,000 hits in 1995.

Andre Dawson: By 1992, age 39 he had 2,502 hits.
$P = -0.3\%$ "=" 0% (0% is as low as James allows).
He retired, not passing 3,000 hits.

Tony Gwynn: By 1992, age 32, he had 2,021 hits: $P = 33\%$.
By 1996, age 36, he had 2,560 hits: $P = 44\%$.
By 1997, age 37, he had 2,780 hits: $P = 84\%$.
He retired after 2001, with 3,141 hits.

Conclusions Regarding James' Formulas

I had the good fortune to be able to contact Bill James by e-mail and discuss with him how he developed these formulas. In the case of the Pythagorean Theory, he said he checked records of several hundred teams, including minor league teams, to figure out what the error was. He had been working on the problem so long that when he finally hit upon the solution, he “basically knew it would work even before” he tested it.

James went on to say that the Favorite Toy Formula is hard to verify because the field of players who meet the standards is so small. James reinforced that the formula can only be applied to *outstanding* players. James said, “It is impossible to know whether an exceptional player’s chances of hitting 3,000 hits is 37% or 39% or 40%. We know it is somewhere in there. We know that if you take a group of players whose chances of reaching 3,000 hits total up to 7.04, it is very likely that 6 to 8 of them will, in fact, get 3,000 hits. We know that if you take a group of players who have about a 60% chance of hitting 500 homers, a little more than half of them will. I think this is as much as can be known about verifying the Favorite Toy Formula.”

EXERCISES

1. Use the data for Pujols in Table 10 and the Favorite Toy Formula to determine the probability of Pujols breaking Bonds’ career home run record of 762.

2. Use the data for Bonds in Table 6 and the Favorite Toy Formula to determine the probability of Bonds getting 3,000 hits, should he not have retired when he did. (His final total was 2935.)

3. Examine the data in Table 3, on Ted Williams’s career prior to his going into World War II. Determine the probability of Williams breaking Ruth’s career home run record of 714. Ted was born in 1918.

THE MAGIC NUMBER

In September, TV and radio announcers start talking about the “magic number.” Suppose the Reds are in first place and the Cardinals are in second. They might say something like the Reds’ magic number is 12. That means that any combination of Reds wins and Cardinal losses that total 12 will guarantee the pennant for the Reds. Each day the magic number is less than or equal to the day before. For example, if the Reds win and the Cardinals lose, the magic number goes down by 2. If both teams lose, this means that the Cardinals lost so the magic number goes down by just 1. If the Reds lose and the Cardinals win, there is no change in the magic number. If the Reds win, and the Cardinals win also, the magic number goes down just by 1, because we consider only the win by the Reds. If there is a day where the Reds win and the Cardinals do not play, the magic number still goes down by 1. The magic number is always a whole number. When the magic number is 1, a tie is clinched; when it is 0, the pennant is clinched.

I always wondered how the magic number was computed, but never saw a formula until one appeared in the sports pages of *USA Today*, as shown in the following box.

Magic Number

The *magic number*, M, is given by

$$M = G - P - L + 1,$$

where

$G =$ the total number of games in the season, 162 for the major leagues,

$P =$ the total number of games that the first place team has played, and

$L =$ the number of games the leading team is ahead in the loss column.

Suppose these are the standings:

Team	Wins	Losses	Pct.	GB
Cincinnati Reds	87	60	0.591	—
St. Louis Cardinals	84	64	0.568	$3\frac{1}{2}$

Then

$$G = 162,\ P = 87 + 60 = 147, \text{ and } L = 4,$$

so

$$\begin{aligned} M &= G - P - L + 1 \\ &= 162 - 147 - 4 + 1 \\ &= 12 \end{aligned}$$

I was not satisfied with this formula because it did not reflect what the announcers kept saying, "any combination of Reds wins and Cardinal losses that total 12 will guarantee the pennant for the reds." I wanted to find a better formula. The development is as follows. Let

W_1, L_1 = Wins, Losses for the first place team, and
W_2, L_2 = Wins, Losses for the second place team.

Then the *magic number, M,* for the first place team is

$$\begin{aligned} M &= G - P - L + 1 \\ &= G - (W_1 + L_1) - (L_2 - L_1) + 1 \\ &= G - W_1 - L_1 - L_2 + L_1 + 1 \\ &= G - W_1 - L_2 + 1 \\ &= G - (W_1 + L_2) + 1 \end{aligned}$$

This formula reflects what the announcers were saying. You can apply it easily when reading the sports pages; add the wins of the first place the to the losses of the second place team, subtract from 162, and add 1.

This was an epiphany for me because I was able to make this deduction on my own, even though the announcer's statisticians may have been using the same method.

Another way to understand the magic number is to look again at the Red's situation. What is the most number of games the Cardinals can win?

$$162-64=98=G-L_2.$$

Then how many games must the Reds win to exceed the number of wins that the Cardinals can get?

$$98-87+1=12=(G-L_2)-W_1+1$$

So, 12 is the magic number.

We can create another proof with variables by reasoning from this concrete example to the abstract. What is the most number of games the second place team can win?

$$G-L_2$$

Then how many games must the first-place team win to exceed the number of wins that the second-place team can get?

$$M=(G-L_2)-W_1+1$$

$$M=G-(W_1+L_2)+1.$$

The answer, M, is the magic number.

EXERCISES

Compute the magic number for each first-place team, given the standings.

1.

AL WEST	W-L	PCT	GB
Seattle	88–64	.579	—
Oakland	84–67	.556	$3\frac{1}{2}$

2.

AL EAST	W-L	PCT	GB
NYY	102–58	.638	—
Boston	101–59	.631	2

3.

NL EAST	W-L	PCT	GB
Atlanta	96–43	.691	—
Philadelphia	72–66	.561	$13\frac{1}{2}$

4.

NL CENTRAL	W-L	PCT	GB
Milwaukee	90–37	.709	—
St. Louis	89–42	.679	$5\frac{1}{2}$

Marv and his two favorite baseball players, sons Chris (left) *and Lowell* (right) *attending Los Angeles Dodger Adult baseball camp in November of 2001.*

Marv & Bart Kaufman at Los Angeles Dodger Camp. 2000

Marv at Reds Camp, 2011.

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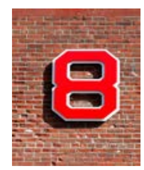

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