

# What Is the Best Launch Angle To Hit a Home Run?

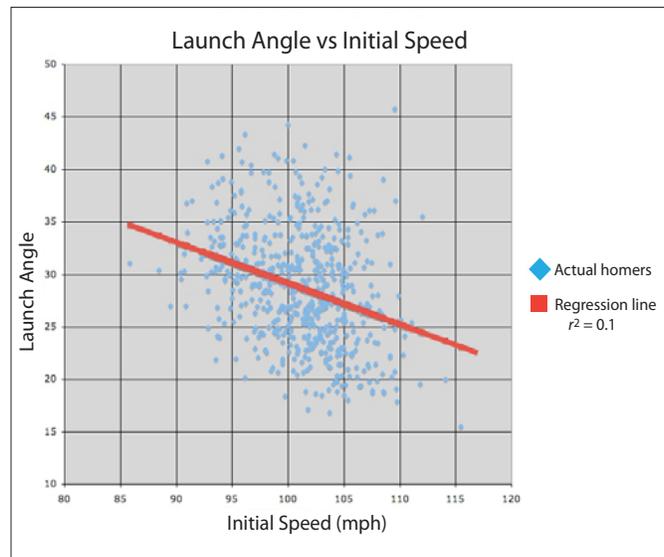
David Kagan, University of California–Chico, Chico, CA

Your students will proudly raise their hands and answer, “45 degrees!” They are, however, answering a different question. It is true that in the absence of air resistance, for a given initial speed, the launch angle that maximizes the range is  $45^\circ$ . For a real homer, there are many complicating factors that make the question far more challenging to answer. Here is a partial list:

1. The initial speed off the bat is not fixed. Garvey’s law, “The harder you hit it, the further it goes,” is definitely at play.
2. Air resistance is a substantial influence on the flight of the ball.
3. The backspin on a well-hit ball creates lift due to the Magnus effect.
4. Atmospheric conditions such as humidity, temperature, air density, and the wind affect the motion as well.
5. Baseball parks are unique in size and shape. So, a homerun in one park may not be a homerun in another.

There are many good theoretical papers that address the factors influencing the flight of the ball, but your students know that experiment is nature’s umpire and makes the final call. Thanks to the efforts of SportVision and Major League Baseball Advanced Media, the experiment has been done! Using the same technology as PitchFX, they have built HitFX, that finds to high accuracy the initial trajectory of the ball off the bat.

The graph shows a scatter plot of the launch angle versus the speed off the bat for 586 home runs hit in the major leagues during April 2009.



The average homerun is launched at an angle of  $29 \pm 5^\circ$  at a speed of  $101 \pm 4$  mph. This angle is dramatically less than  $45^\circ$  and, in fact, only a few homers left the bat anywhere near  $45^\circ$ .

The red line is the least-squares fit to the data, which clearly has a low correlation coefficient (0.1). Yet, the trend is that the lower the angle, the harder you need to hit the ball, consistent with the simplistic ideas of projectile motion without air resistance.

Here is another interesting tidbit from the data set. The average height of the ball when it left the bat was  $2.7 \pm 0.5$  ft. Every pitcher knows that you have to “keep the ball down” against power hitters. This data clearly shows that homers are hit when the ball is in the upper part of the strike zone.