Optimizing the Swing from Peak Launch Angle

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Launch angle and exit velocity are the two primary factors in baseball that define the outcome of a play. These factors are controlled in part by where the ball makes contact with the bat. If the batter is able to generate a high bat speed and square up the barrel on the ball, it will likely produce a high exit velocity with a decent launch angle, resulting in a hit. In addition, the so-called attack angle of the bat at impact also affects the outcome of the batted ball. A batter with an uppercut swing tends to produce more home runs than a batter with a level swing. This is related to the fact that each batter's swing has a unique launch angle that allows him to maximize their exit velocity. Let us define this launch angle as the "peak launch angle". The following paragraphs explore how the batter's peak launch angle is associated with various batting statistics and demonstrate why it is an important metric in batting.

The method of obtaining the peak launch angle was referenced from a presentation at the 2019 SABR Analytics Conference given by Alan M. Nathan, Professor Emeritus of Physics at the University of Illinois. His talk and more of his research in baseball can be found here: http://baseball.physics.illinois.edu/swing.html.

To determine the peak launch angle of batters, MLB Statcast data from the 2017 to 2023 seasons (excluding 2020) were employed, and batters with a sufficient number of appearances (at least 200 balls in play, or BIP) were chosen. Subsequently, for each of the xxx batters, the BIP data were divided into 5° launch angle bins. Within each bin, the top 15% of the data was selected based on exit velocity. A quadratic regression analysis on EV vs. LA was conducted using the selected data, from which the launch angle corresponding to the peak of that fit was taken as the peak launch angle for that batter.

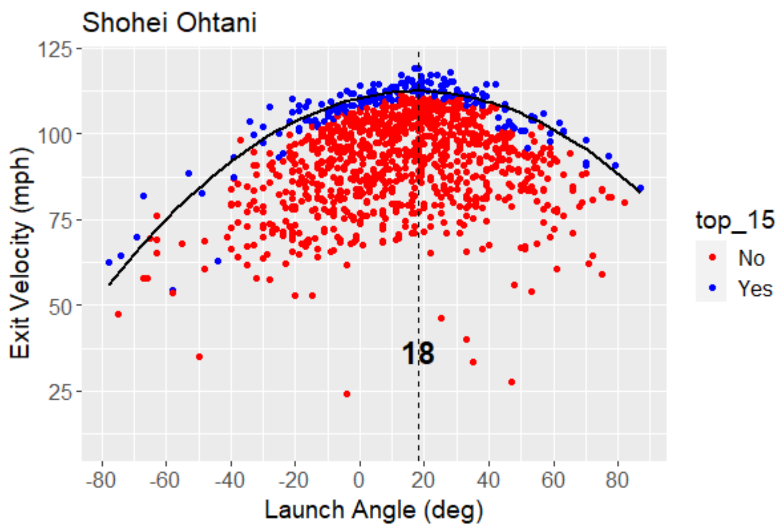

Fig. 1. Scatter plot of BIP data for Shohei Ohtani with exit velocity on the y-axis and launch angle on the x-axis. For each 5° launch angle bin, the top 15% based on exit velocity are in blue, and the rest are in red. The black curve is a parabolic fit to the blue points.

An example is shown in Fig. 1, illustrating the relationship between EV and LA for Shohei Ohtani. His peak launch angle is 18°, which is slightly higher than the MLB average peak launch angle of 14°. Fig. 2 displays the distribution of peak launch angles for MLB batters.

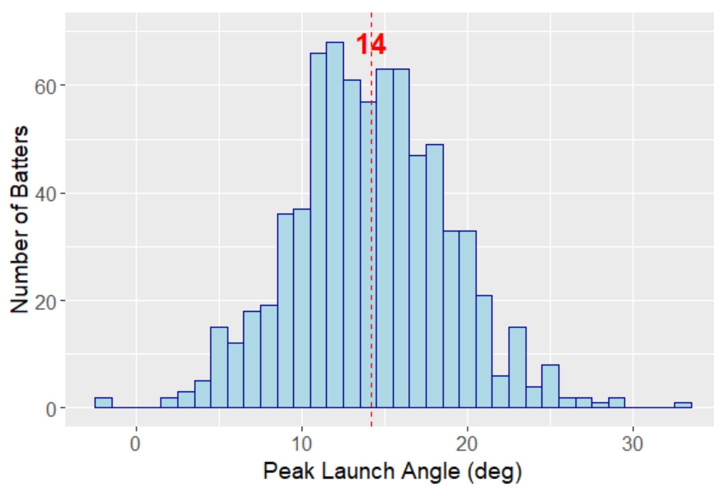

Fig. 2. Histogram of the distribution of peak launch angle for MLB batters in 1° bins. The dashed red line indicates the MLB average.

Low vs High Peak Launch Angle Batters

In the recent MLB seasons, **Yuli Gurriel** has the lowest peak launch angle at -2°, while **Joey Gallo** has the highest at 33°. Fig. 3 illustrates the relationship between EV vs LA for these batters, color-coded by event outcomes: singles in blue, doubles and triples in red, home runs in green, and outs in black.

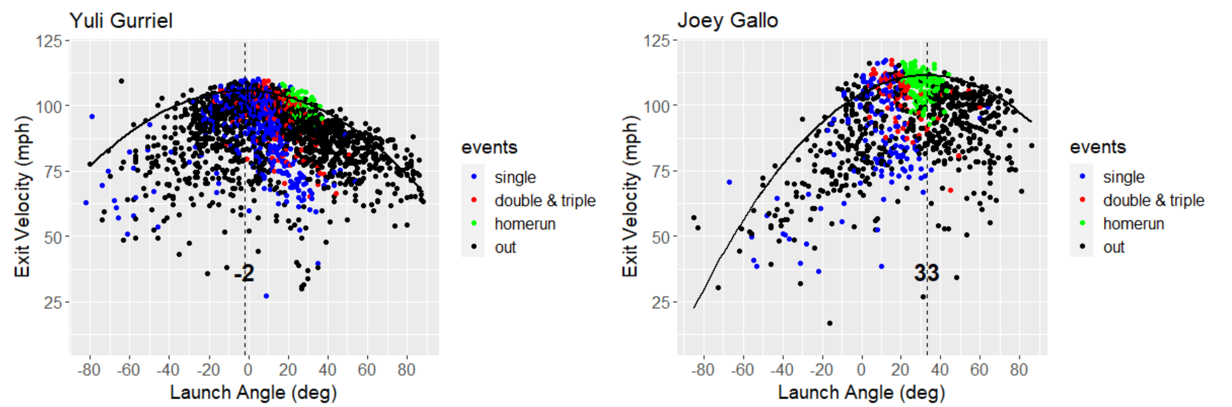

Fig. 3. Scatter plots of EV vs LA displaying the comparison of peak launch angle for two MLB batters: Yuli Gurriel on the left and Joey Gallo on the right. Each point is color-coded by events. A quadratic fit was applied to the top 15% data, similar to Fig. 1.

In the left-hand plot of Fig. 3, when **Gurriel** hits the ball near his peak launch angle (-2°) at high exit velocity, the result tends to be singles. In contrast, the right-hand plot indicates that **Gallo**'s swing is more conducive to producing home runs when the ball is hit at high exit velocity near his peak launch angle (33°). This extreme example is a dramatic demonstration of how the outcome of a batter's plate appearance is shaped by his peak launch angle.

The differences in the swings of these two batters are visually evident. Take a look at their slow-motion swings:

- **Yuli Gurriel**: https://youtu.be/vAtb2XjA4Q4?si=A8eBTzwy_6GYR0vc&t=1

- **Joey Gallo**: https://youtu.be/-sBE5U6FAnA?si=_6S6ulHmyZ21Upeb&t=26

Gurriel has a level swing with a very low attack angle, close to 0°. In contrast, **Gallo** has a non-level, uppercut swing with a high attack angle. Thus, there is a definite relationship between a batter's peak launch angle and his attack angle. But what exactly is that relationship?

Peak Launch Angle vs Attack Angle

To answer that question, it is instructive to consider a simpler problem where the bat is swung at a stationary ball (e.g., off a tee). Under such conditions, the expectation is that the peak launch angle of the ball occurs when the motion of the bat is directed through the center of the ball (i.e. perfectly "squared up"), in which case the resulting launch angle is exactly equal to the attack angle. Indeed, this very experiment was done in a controlled laboratory setting (see http://baseball.physics.illinois.edu/ObliqueCollisionsWSU-AJP.pdf) and the expectation was confirmed. Things are more complicated when the bat is swung at a pitched ball, since the peak launch angle will depend to some extent on the speed, direction, and spin of the incoming pitch. Nevertheless, detailed calculations using Nathan's ball-bat collision model and shown by Nathan in his presentation at the 2019 Saberseminar (see http://baseball.physics.illinois.edu/swing.html) show that there is a strong positive correlation between attack angle and peak launch angle, with a larger attack angle leading to a greater peak launch angle. In the near future, it is hoped that the new Statcast bat-tracking data might be used to further investigate the relationship between attack angle and peak launch angle.

Peak Launch Angle vs Batting Statistics

In this section, the relationship between a batter's peak launch angle and his batting statistics will be observed. Fig. 5 shows home run percentage for balls in play versus the peak launch angle for each batter. The points were categorized into three groups based on exit velocity: high, medium, and low exit velocity in blue, green, and red, respectively. Furthermore, each group was fitted using a generalized additive model (GAM).

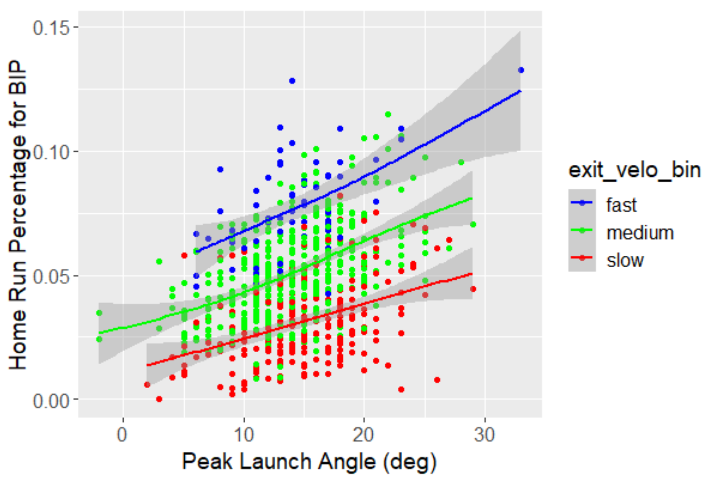

Fig. 4. Scatter plot of home run percentage for BIP with respect to peak launch angle for each batter. Each point was color-coded by the exit velocity corresponding to that batter's peak launch angle, and each group was fitted with a GAM.

In addition to showing that higher exit velocities result in a larger in-play home run rates, as expected, the plots also show that all three groups have a positive slope, indicating that a higher peak launch angle corresponds to a higher in-play home run percentage. A similar result was observed when examining the slugging percentage for balls in play.

Next, two types of weighted on base average (wOBA) were explored. On the left of Fig. 6 is wOBA for balls in play and on the right is wOBA for all events. These plots were once again divided into three groups based on exit velocity.

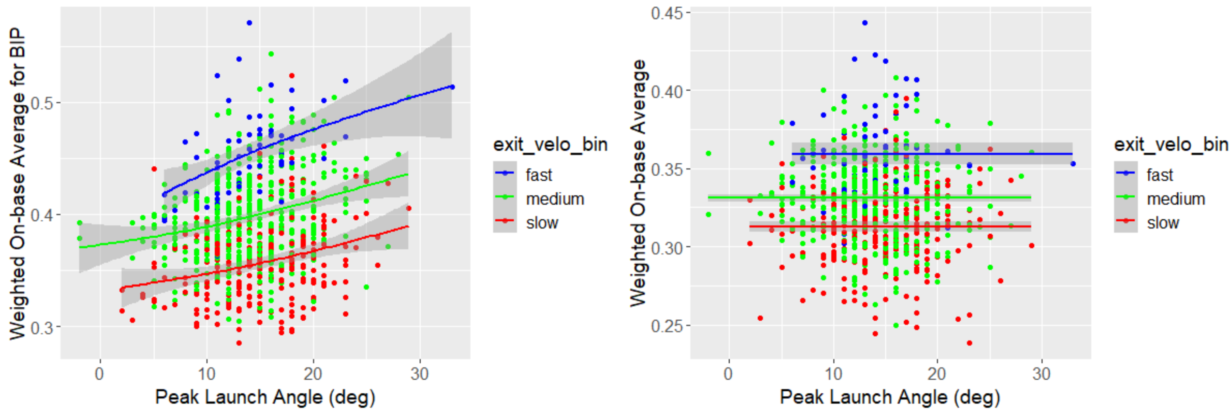

Fig. 5. Scatter plots of wOBA with respect to peak launch angle for each batter. The left plot shows wOBA for BIP, while the right plot shows wOBA for all events. Each point was color-coded by the exit velocity corresponding to that batter's peak launch angle, and each group was fitted with a GAM.

From both plots in Fig. 6, it is evident that wOBA increases with higher exit velocity. What is intriguing here is that wOBA for balls in play increases with higher peak launch angle, whereas wOBA for all events doesn't vary with respect to peak launch angle. Why is that the case?

To answer this question, let's consider additional batting statistics: whiff rate and strikeout percentage. In Fig. 7, you can observe the relationship between these statistics and the peak launch angle.

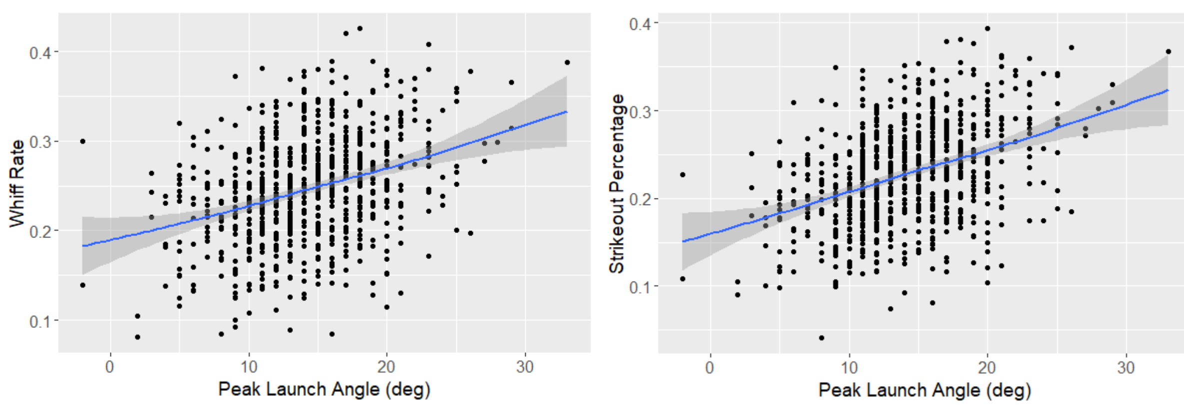

Fig. 6. Scatterplots displaying the whiff rate on the left and strikeout percentage on the right with respect to the peak launch angle for each batter. Both plots were fitted with a GAM, as shown by the blue line.

Although there is considerable scatter in the data, both statistics increase with respect to peak launch angle. The reason for this is, as mentioned earlier, batters with a low peak launch angle have a level swing, giving them longer duration of time to make contact with the ball. In contrast, batters with a high peak launch angle have an uppercut swing, resulting in a shorter duration of time to make contact with the ball. This explains why, even though wOBA for balls in play increases with a higher peak launch angle, when all events are factored in, including strikeouts, wOBA becomes independent of the peak launch angle.

Ultimately, the optimal attack angle for a batter depends on their desired batting style. If the batter aims to get on base and secure as many hits as possible with minimal strikeouts, then he should aim for a lower attack angle (resulting in a low peak launch angle). Conversely, if the batter prioritizes hitting as many home runs as possible and is less concerned about striking out, then he should aim for a higher attack angle (resulting in a high peak launch angle). This illustrates why, in today's MLB, batters exhibit a wide range of attack angles, yet many of them can achieve success.