1 Introduction

Over the course of a Major League Baseball game, there are many situations that may be classified as "high-pressure". We defined these situations to include a runner on 3rd, two outs in an inning, two strikes, three balls, etc. These high-pressure situations can be viewed from either the batter or pitcher's perspective, as a pitcher's high-pressure situation often differs from a batter's. However, in this analysis, we focused on high pressure situations from a batter's perspective with the goal to view deviations in player's bat speed and swing length as a response to that situation. Specifically, we are interested in batter strategies for these high- pressure situations. In the following analysis we attempt to analyze each batter's current strategies, as well as potentially conflicting optimal strategies that maximize run and win expectancy.

2 Game-Time Strategy in Practice

We focused on two high-pressure cases for this analysis. These include:

i. Runner on 3rd, less than 2 outs
ii. 2 strikes, runner on base

These were identified as some of the most critical high-pressure situations during a Major League Baseball game, although many more could be analyzed in a similar way.

Utilizing linear mixed-effects modeling, we modeled these two conditions' effect on bat speed and swing length independently. A binary indicator was made to determine whether the specified condition was met, and a random effect to control for player-to-player variability in response to the condition was incorporated.

It must be noted for both of the below analyses, we focus mainly on observing implications of bat speed. There are many other considerations that go into hitting the ball successfully, such as hit location, angle, etc. However, we decided to look at it from a speed point of view, as that is one of the main aspects of batting that an MLB player can control. This allows the potential application of some of the strategies mentioned to optimize both run and win expectancies in high-pressure situations.

2.1 High-pressure situation (i)

From the linear mixed-effects models, we observe the average effect of high-pressure situation (i) on player's bat speeds is -0.496, indicating players may slow their speed during this situation. This incorporates some of the variability between players, as the condition variance for high-pressure situation (i) is 0.1943, thus indicating some of the players are more or less affected by this condition than the average effect. This variability can be viewed in the following visualization.

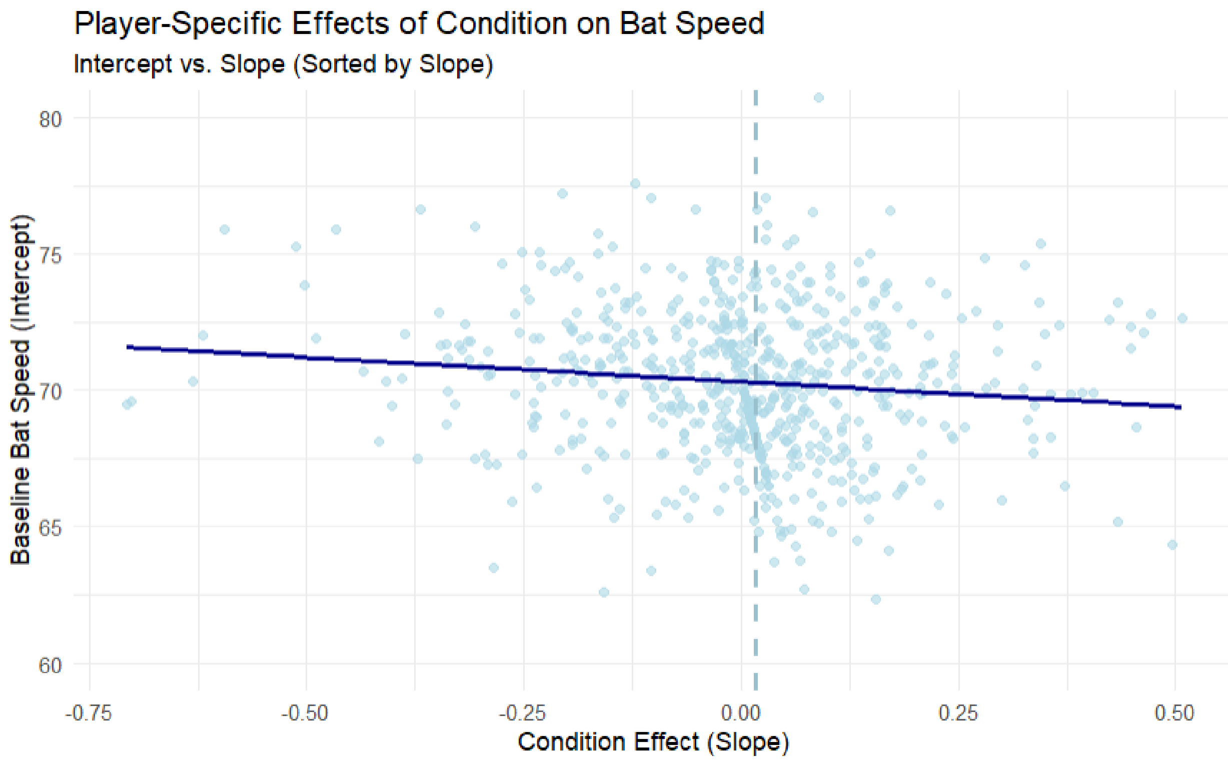

Fig. 1 The x-axis portrays the effect of high-pressure situation (i) on each player's baseline bat speed, as well as their baseline bat speed compared to the average of 70.31.

Viewing Fig. 1, we can notice there is a very weak correlation between baseline bat speed and the effect of high-pressure situation (i). This correlation is represented by the solid blue line of best fit in Fig.1. It should be noted the R^2 value for the above correlation is 0.0129, indicating there is likely no correlation at all. If we were to assume a correlation, the interpretation would be as follows: for every 1-unit increase in condition (i)'s effect, the player's baseline bat speed decreases by 1.79mph. However, given the extremely low R^2 value, as well as the apparent lack of trend in the above visualization, we cannot conclude there is a trend to how much a player changes their based speed based on condition (i). We can, however, notice that although the greatest density of points lies around a condition effect of 0.0 (given by the vertical dashed line), the spread is incredibly large, suggesting varying strategies for the players.

The range of strategies employed for high-pressure situation (i) could indicate the reason behind the large spread viewed in Fig.1 . Some players tend to value accuracy over speed, thus slowing their speed in these situations to attempt to score a run. These players would more than likely attempt to hit towards first base, away from their runner on 3rd, accepting the chance of receiving an out themselves. This may be why most of the players with a negative effect to condition (i), meaning they slow down their baseline bat speed in response to high-pressure situation (i), have a higher baseline bat speed than those with a positive effect to condition (i). This suggests players trade off accuracy with bat speed, thus players who employ this strategy attempt to raise accuracy by lowering their speed as a result of encountering high-pressure situation (i).

It should be noted that pitch type is also a consideration potentially resulting in the unintentional slowing of bat speeds. However, when added as a random effect to this model, there was low variation in the effect of condition (i) on bat speed due to pitch type, and thus this consideration was excluded from the final discussion.

Contrary to the strategy prioritizing accuracy, some players choose to employ a "home-run strategy", valuing instead the velocity of the hit. This is indicated by the players with a positive effect to condition (i) in Fig. 1, suggesting they increase their bat speed as a result of encountering high-pressure situation (i). As viewed in Fig. 1, there are more players with lower baseline bat speeds that employ a positive effect to condition (i), suggesting they could potentially value speed over accuracy in this situation. Given this, we can suggest a potential trade-off between speed and accuracy when considering these individual players, as well as observing their strategy to favor one over the other.

It should again be noted that there is no obvious correlation between baseline bat speed and the effect of condition (i), although there are some patterns, described above, that suggest varying strategies are employed in a game-time situation.

Similar considerations were made for swing length, although they closely mirrored results from bat speed. Considering the models previously described, shorter swing length almost always corresponded to a slower bat speed, in which high-pressure situation (i) supported a shorter swing length, with a plot similar to Fig. 1. Thus, the primary focus of our study is bat speed, given the fact that swing length often, although not always, can be an indicator of speed and vice versa.

2.1 High-pressure situation (ii)

From the linear mixed-effects models, we observe the average effect of high-pressure situation (ii) on players' bat speeds is -1.59, indicating players typically slow their speed during this situation. The average effect for situation (ii) is noticeably more negative than situation (i), indicating high-pressure situation (ii) may be more drastic to a player's swing speed deviance than high-pressure situation (i). Again, this model incorporates some of the variability between players, as the condition variance for high-pressure situation (ii) is 0.4583, indicating some of the players are more or less affected by this condition than the average effect. This variability is larger than the variability found in high-pressure situation (i), and can be better viewed in the following visualization.

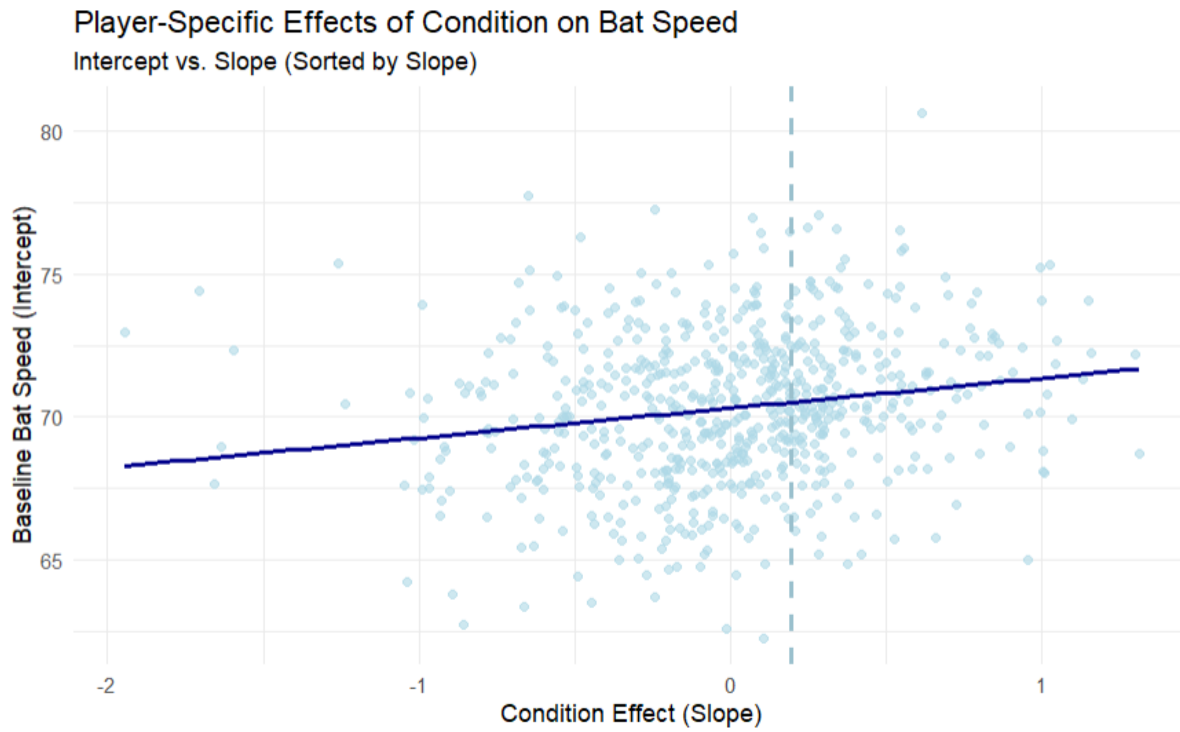

Fig. 2 The x-axis portrays the effect of high-pressure situation (ii) on each player's baseline bat speed, as well as their baseline bat speed compared to the average of 70.54.

Fig. 2 displays a slightly stronger, although still small, potential correlation between condition effect and baseline bat speed, stratified by player. The R^2 value of the line of best fit, displayed by the solid blue line in Fig. 2, is 0.033, which is still too small to conclude any reliable correlation from the data. However, if we were to assume correlation between condition effect and baseline bat speed when considering high-pressure situation (ii), the following would be the interpretation: for every 1-unit increase in condition (ii)'s effect, the player's baseline bat speed increases by 1.04mph. This would suggest the lower the player's baseline bat speed, the more they slow down their swing when encountering high-pressure situation (ii). Again, there is no indication of a true correlation occurring, so we have to rely on additional metrics to gauge game-time strategy.

Similar to Fig. 1, the area of highest density within Fig. 2 is slightly positive, but positioned around a condition effect of 0.0, given by the vertical dashed line. Thus, although many players employ similar responses to high-pressure situation (ii), the spread is sill large enough to support varying strategies for the players.

This prompts the inquiry of game-time strategies for 2 strikes and a runner on base. Here, there are many considerations to follow. The first is to get a hit; the batter likely wants to prioritize hitting the ball over specifying how to hit it in order to avoid an out. Another is to hit the ball hard enough to force the defense to make a play. This employs a different trade-off than the one mentioned earlier: attempt to hit the ball hard, and risk a strikeout, or focus on hitting the ball, which could benefit from a slower swing, but with the risk of either yourself or the other runner being tagged out.

As Fig. 2 weakly suggests, players with a lower baseline bat speed respond to high-pressure situation (ii) by slowing down their bat speed further. This is suggested by more players in Fig. 2 that have lower baseline bat speeds with negative condition effects than positive condition effects. This could potentially suggest players with a lower baseline bat speed lack the confidence to make contact with the ball at a faster speed. Thus, they are more likely to employ the strategy of slowing down their bat speed to prioritize making contact with the pitch rather than the speed or style of the hit.

On the contrary, Fig. 2 displays more players with a higher baseline bat speed that have positive condition effects. These players are likely confident with the speed at which they hit the ball, and believe the faster they swing, the more likely they will assist the runner on base, rather than focusing entirely on making contact. This could potentially be the reason they are more likely to have positive condition effects as opposed to negative ones.

These are only hypotheses as to what is occurring in real game situations. There is likely a variety of additional strategies that are employed by players and suggested by coaches/teams for high-pressure situation (ii). It should also be noted, given the commonality of the situation in many Major League Baseball Games, there are likely more strategies suggested for high-pressure situation (ii) than high-pressure situation (i). To reduce complexity of the overall explanation, we naïvely narrowed it down to the two described above.

3. Suggested Game-Time Strategy

3.1 High-Pressure Situation (i)

Although a uniform strategy is not employed when encountering condition (i), we suggest the “home-run strategy” may be more successful than opposing ones.

To determine this, we computed each player’s average bat speed, as well as each swing’s deviance from that speed, respective to the player. We utilized the run expectancy and win expectancy variables provided in the dataset to compose the following visualizations.

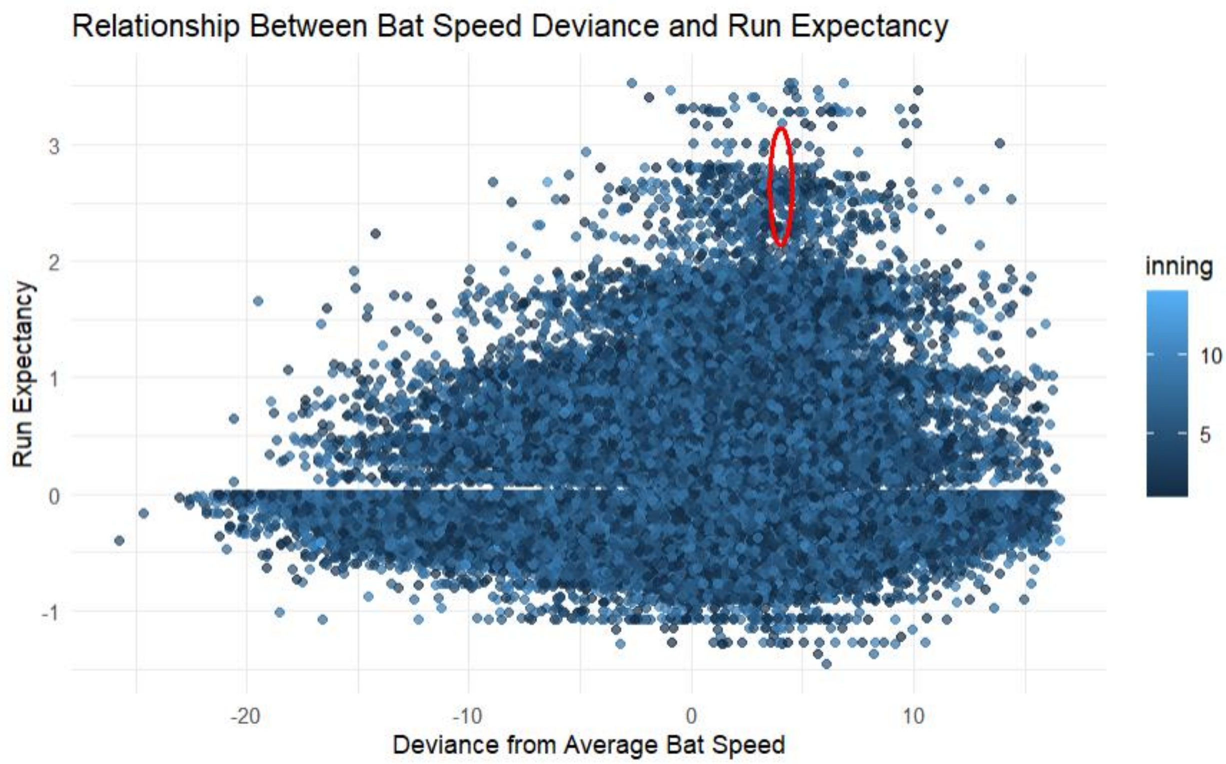

Fig. 3 Run expectancy plotted against each swing's deviance from the respective player's average bat speed.

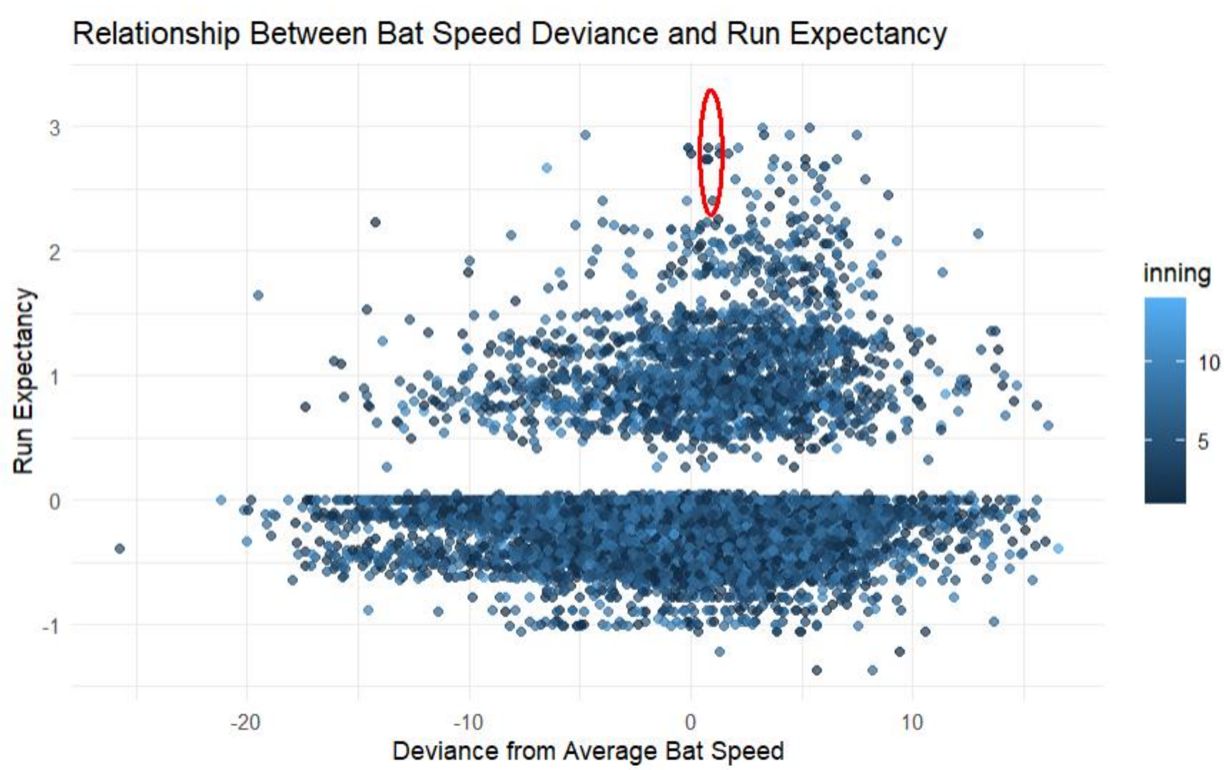

Fig. 4 Run expectancy plotted against each swing's deviance from the respective player's average bat speed, considering only swings pertaining to high-pressure situation (i).

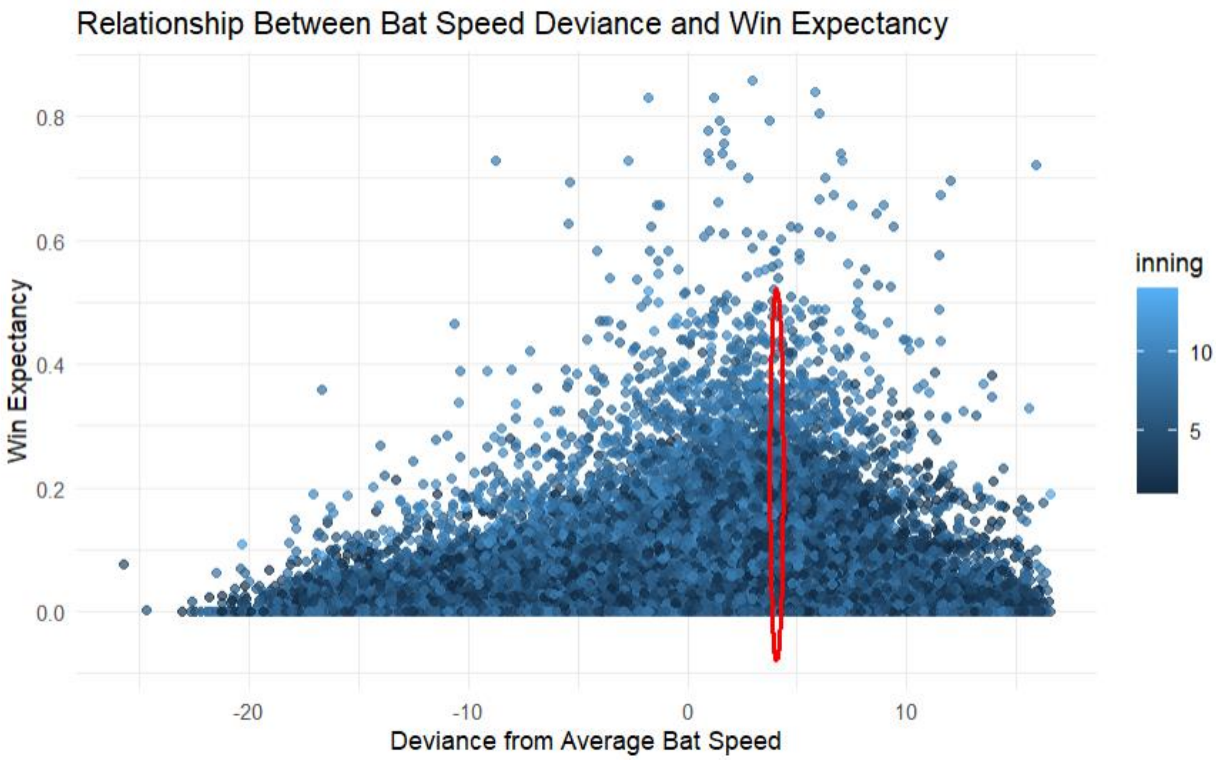

Fig. 5 Win expectancy plotted against each swing's deviance from the respective player's average bat speed.

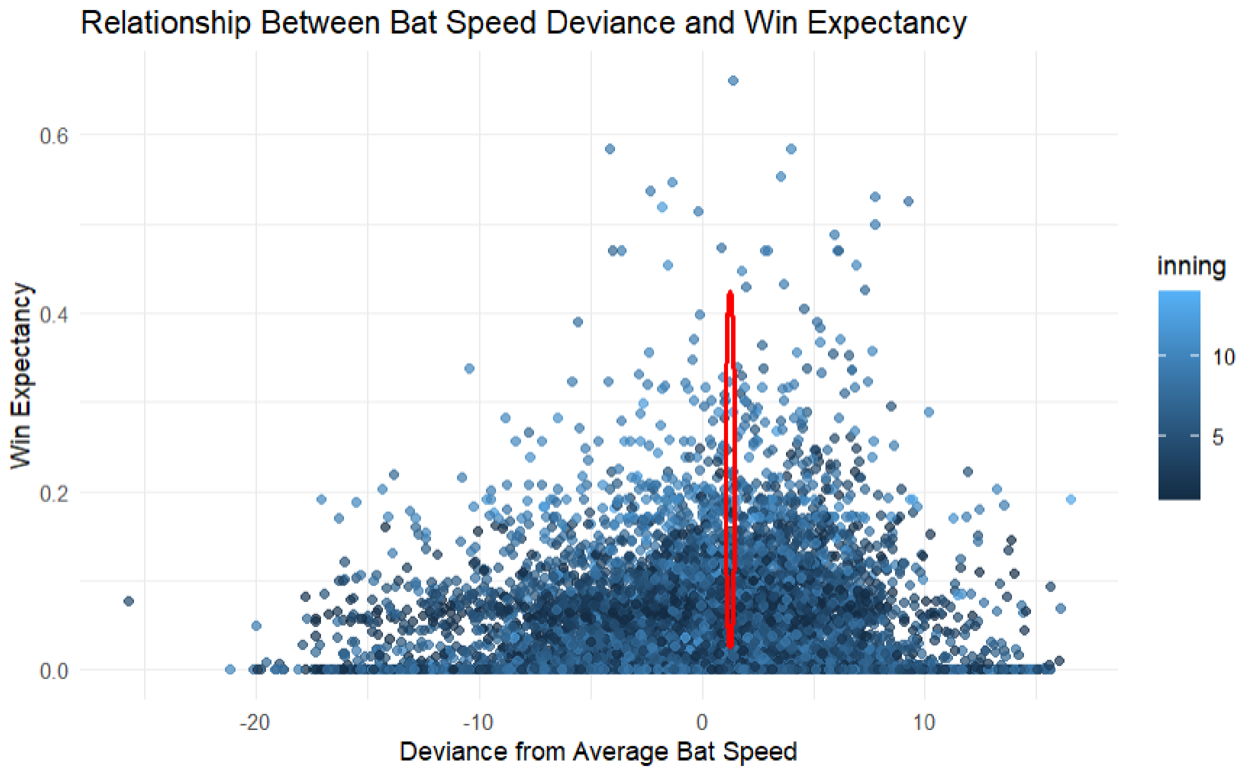

Fig. 6 Win expectancy plotted against each swing's deviance from the respective player's average bat speed, considering only swings pertaining to high-pressure situation (i).

As seen in both Fig. 3 and Fig. 4, run expectancy is the highest when deviance from the average bat speed, respective to each player independently, is slightly positive. The highest density of run expectancies over 2.5 are circled in red on both figures, corresponding to deviances between 0 and 5. This indicates that an increase in bat speed increases run expectancy, both in the overall game, and in high-pressure situation (i). This strategy aligns with the "home-run strategy" of swinging the bat faster to attempt to score a run, potentially sacrificing accuracy as a trade-off.

A similar pattern can be viewed for Fig. 5 and Fig. 6, where win expectancy is the highest when deviance from the average bat speed, respective to each player independently, is slightly positive (between 0 and 5). Again this suggests support for the "home-run strategy" of swinging the bat faster to attempt to score a run, in both the game as a whole and specifically pertaining to high-pressure situation (i). It should be noted win expectancies in the data were given both positive and negative values, favoring the home team. Thus, to view the change in win expectancy after each plate appearance, regardless of home/away teams, the absolute value was taken, explaining the nature of the visualizations.

Now that we have examined the "home-run strategy" we can take a look at the strategy that prioritizes accuracy over speed. Ideally, players who slow down their bat speed will have higher success with their accuracy. Thus, in high-pressure situation (i), players should aim to hit the ball towards the right half of the field (somewhere in the range from first to second base), but should avoid bunting if possible to allow the runner on third to score. In theory, this strategy should perfectly allow your team to score a run, albeit potentially sacrificing an out. Fig. 7 displays the actuality of hit coordinates, and their correspondence to bat speed in high-pressure situation (i).

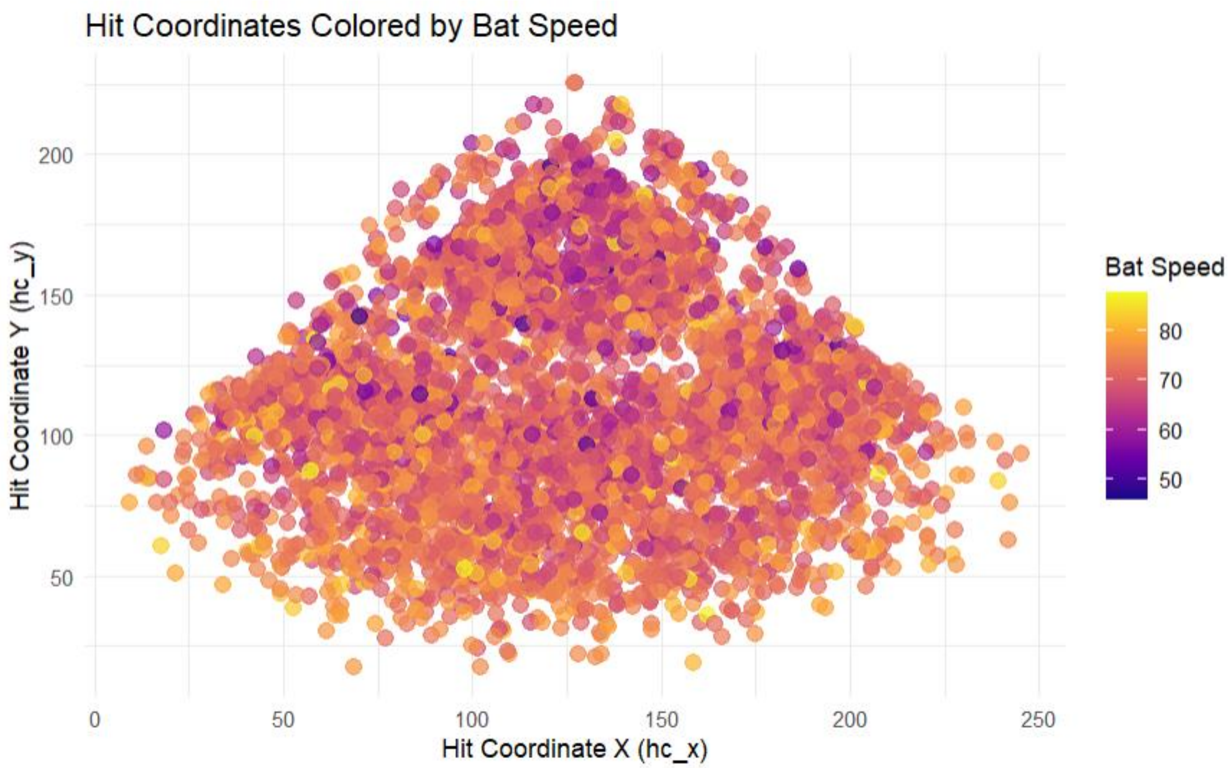

Fig. 7 Location of hit on a swing-by-swing basis, colored by bat speed. Pertains only to hits occurring during high-pressure situation (i).

Thus, although in theory accuracy is a worthwhile trade-off, players with a lower bat speed, even pertaining only to high-pressure situation (i), hit sporadically instead of towards first base, as one would expect.

Then, given the above figures, there is convincing evidence to uphold a "home-run strategy" to prioritize swing speed over accuracy in high-pressure situation (i). It should be noted this strategy is not guaranteed to increase run expectancy or win expectancy, even in high-pressure situations. Each batter can find success in a different way, and it should be up to the batter themselves to find what works for their swing. For example, in Fig. 4, many swings with negative deviances pertaining to the player's average swing speed result in high run expectancy values. Although this is not the overwhelming analytical recommendation, the sport of baseball is heavily individualized, thus considerations should be made in practice and preparation to find the true optimal strategy for high-pressure situations for each individual player.

3.2 High-Pressure Situation (ii)

Although there are many suggested strategies for handling high-pressure situation (ii), we suggest attempting to increase bat speed to maximize the ability to swing faster (similar to the "home-run strategy" in 3.1) may be more successful when considering run and win expectancies than opposing strategies.

To determine this, we utilized each player's average bat speed, as well as each swing's deviance from that speed, respective to the player. We utilized the run expectancy and win expectancy variables provided in the dataset to compose the following visualizations.

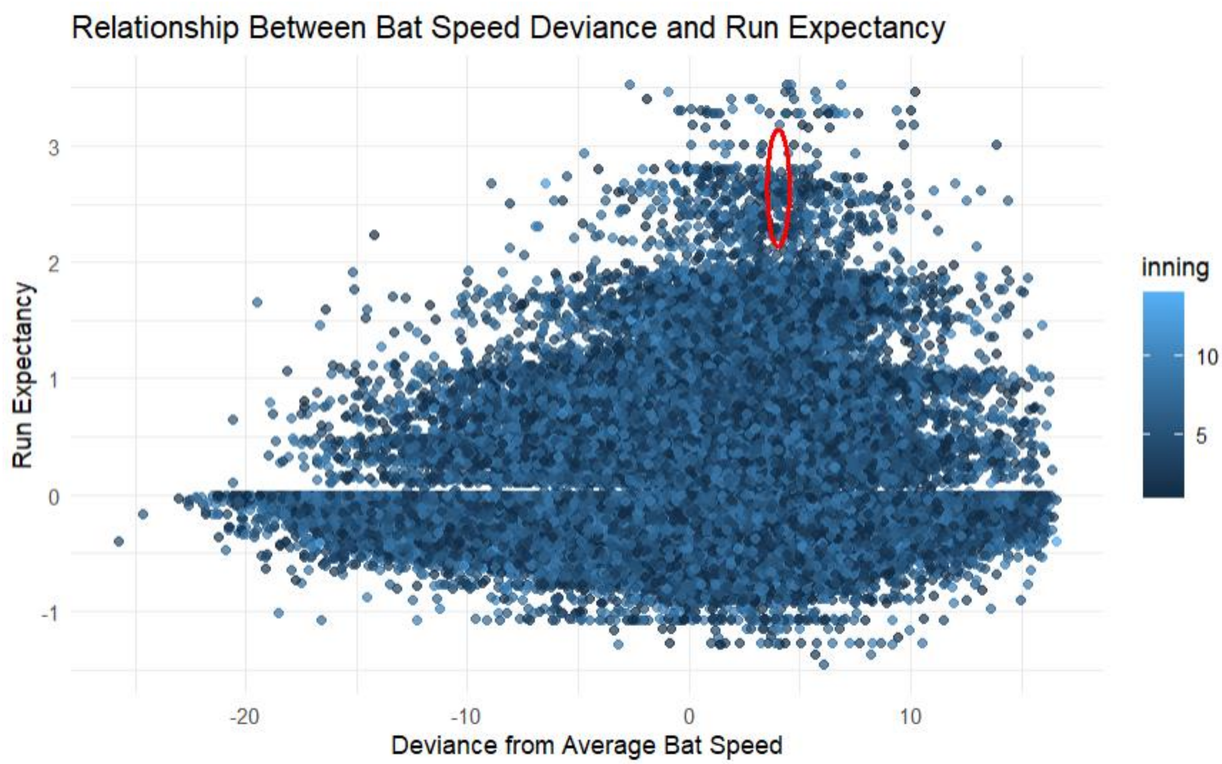

Fig. 8 Run expectancy plotted against each swing's deviance from the respective player's average bat speed.

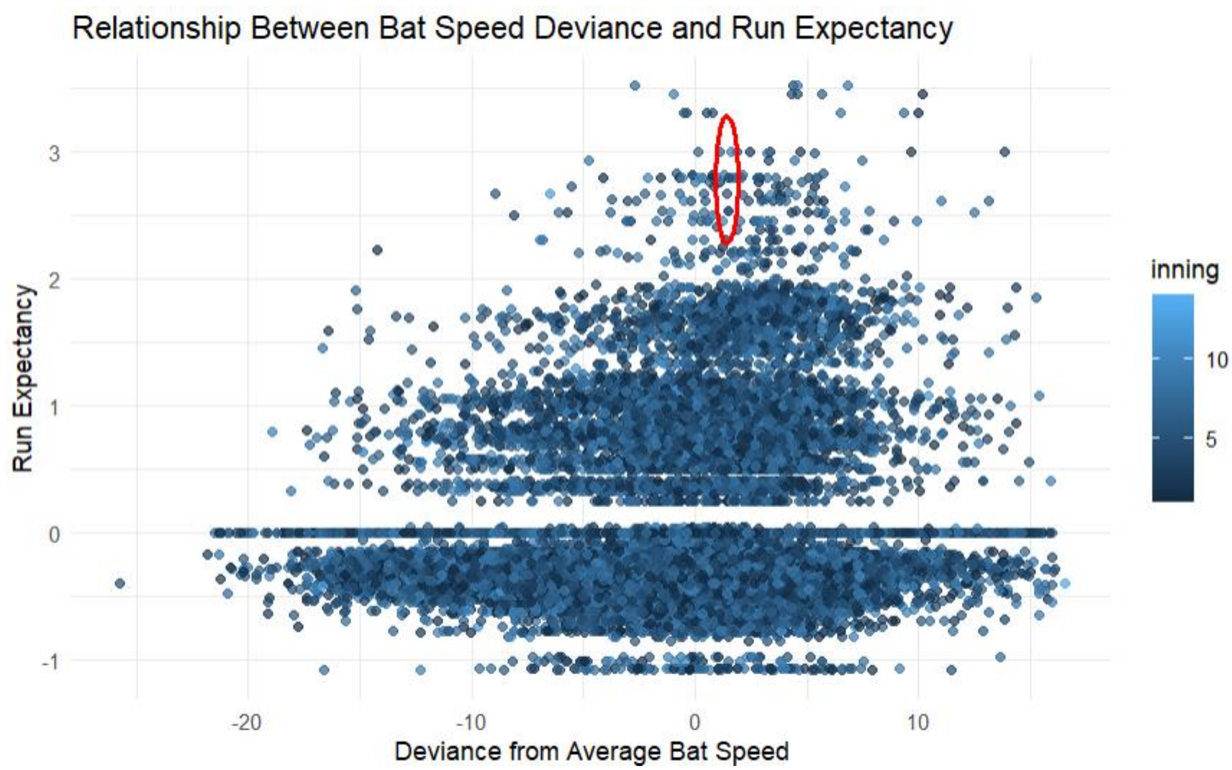

Fig. 9 Run expectancy plotted against each swing's deviance from the respective player's average bat speed, considering only swings pertaining to high-pressure situation (ii).

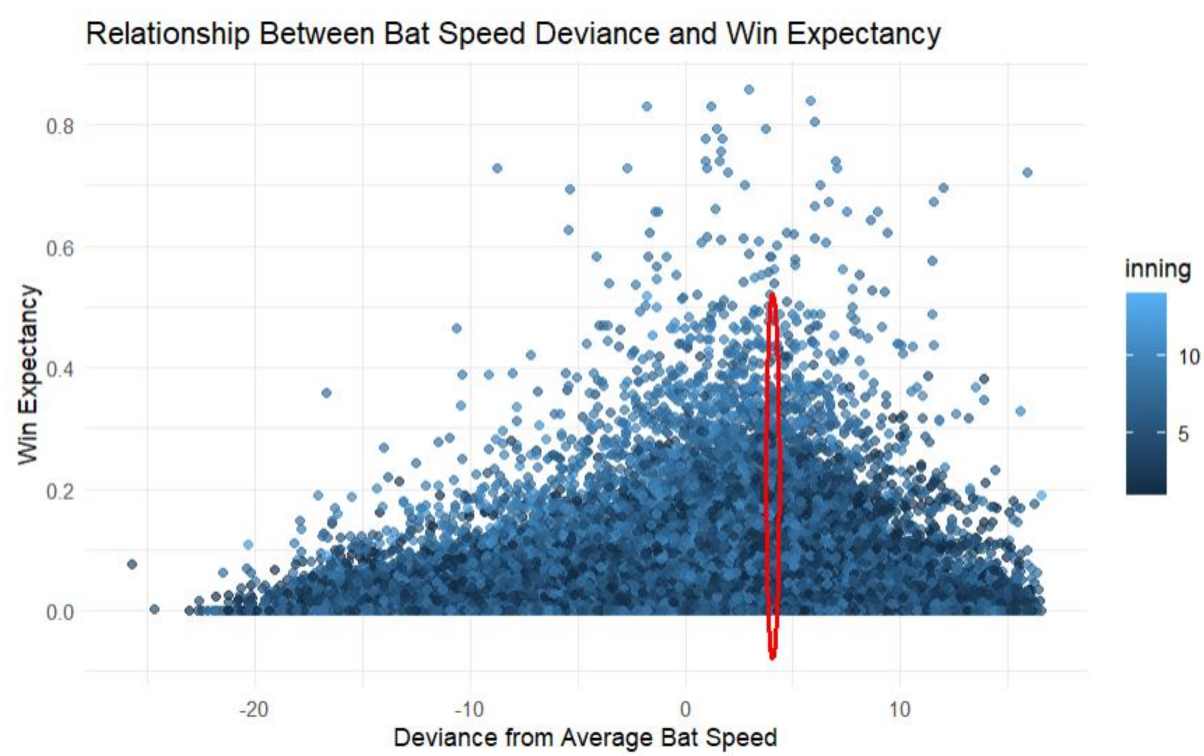

Fig. 10 Win expectancy plotted against each swing's deviance from the respective player's average bat speed.

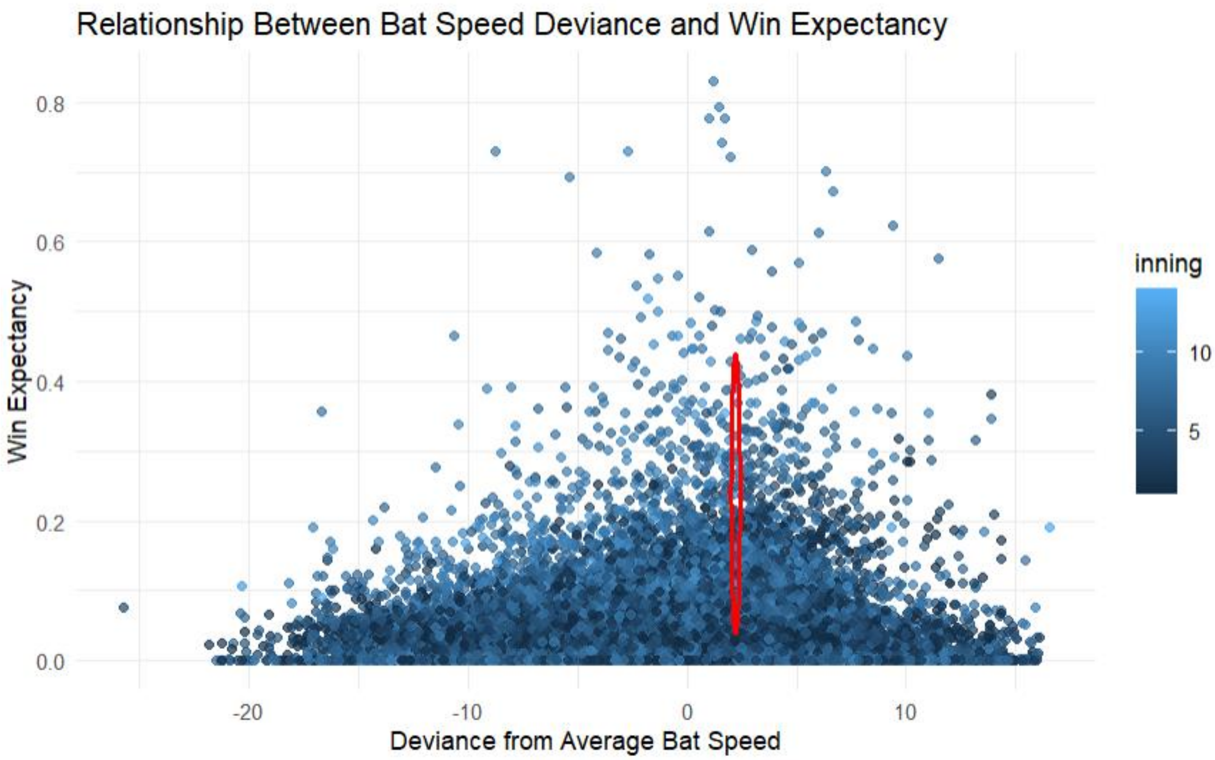

Fig. 11 Win expectancy plotted against each swing's deviance from the respective player's average bat speed, considering only swings pertaining to high-pressure situation (ii).

As observed in both Fig. 8 and Fig. 9, run expectancy is the highest when deviance from the average bat speed, respective to each player independently, is slightly positive, similar to Fig. 3 and Fig. 4. The highest density of run expectancies over 2.5 are circled in red on both figures, corresponding to deviances between 0 and 5. This indicates that an increase in bat speed increases run expectancy, both in the overall game, and in high-pressure situation (ii). This strategy aligns with the strategy of swinging the bat faster to attempt to increase hit velocity and assist the runner on base, potentially risking a strikeout as a trade-off.

A similar pattern can be viewed for Fig. 10 and Fig. 11, where win expectancy is the highest when deviance from the average bat speed, stratified by player, is slightly positive (between 0 and 5). Again, this suggests support for the strategy of increasing bat speed to attempt to increase hit velocity and assist the runner on base, in both the game as a whole and specifically pertaining to high-pressure situation (ii). Once again it should be noted win expectancies in the data were given both positive and negative values, favoring the home team. Thus, to view the change in win expectancy after each plate appearance, regardless of home/away teams, the absolute value was taken, explaining the nature of the visualizations.

Now that we have examined the first strategy of attempting to swing faster, we can take a look at the strategy that prioritizes contact over speed. Typically, players who slow down their bat speed will have higher success making contact with the ball. However, this hypothesis is not supported by Fig. 12 below, thus suggesting a slower swing has less of a positive impact than a faster one.

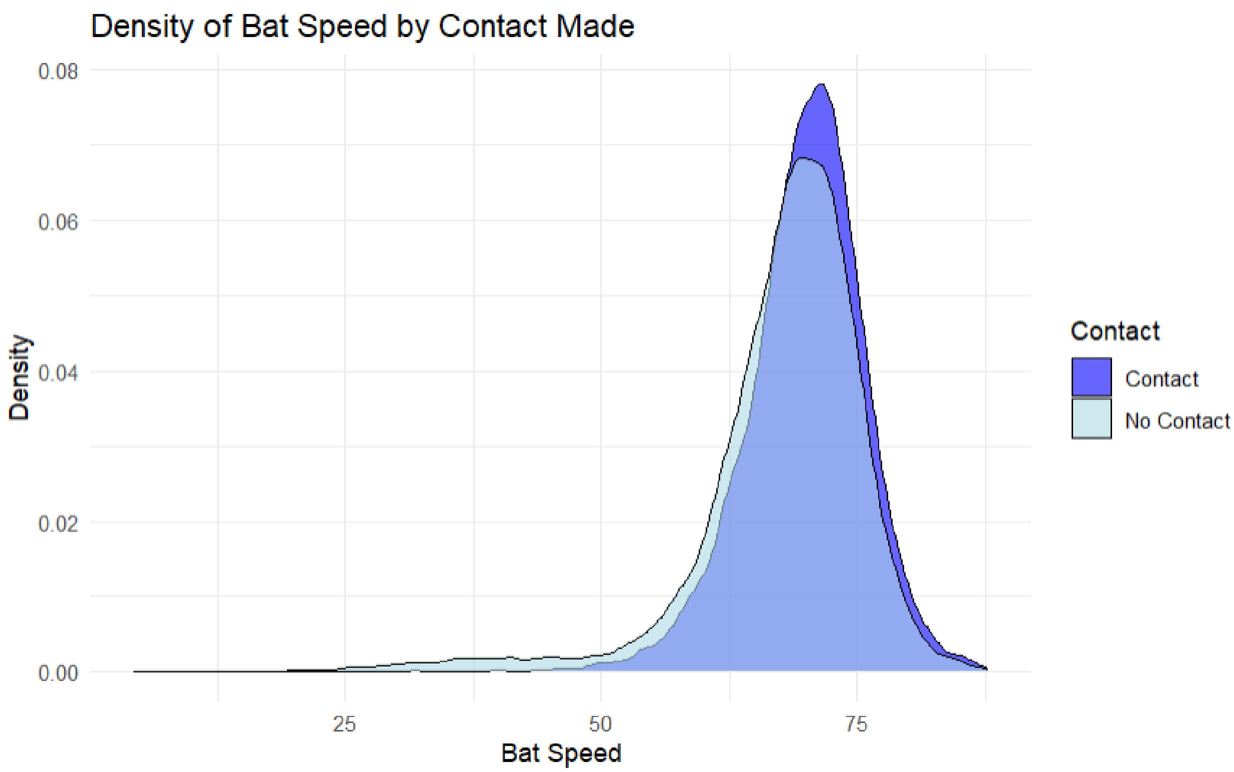

Fig. 12 Density of bat speed by a binary indicator for contact when considering high-pressure situation (ii).

Thus, the above suggests a faster bat speed will increase both win and run expectancies, with less of a chance to strikeout than originally hypothesized. However, once again, there are many strategies that are individualized for specific player archetypes, and a generalized strategy may not work for their response to high-pressure situation (ii).

Conclusion

Overall, we observe current game-time strategies display players slowing their swings for both high-pressure situations. However, the strategies that provide the most evidence for optimizing run and win expectancies support faster bat speeds. These considerations must be taken into account when practicing for high-pressure situations that ultimately have a large impact on the game.