Changeup Analysis

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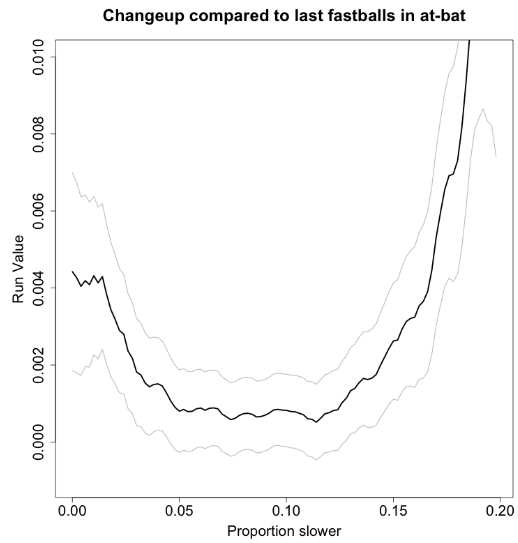
Introduction
Previous knowledge suggests that the most effective changeups achieve separation from the fastball in terms of both velocity and movement. We are interested in finding the ideal amount of separation for both measures.



Studies with MLB data have found that the optimal changeup is between 5% and 12% slower than a preceding fastball, and changeups less than 5% slower or more than 12% slower were drastically less effective[1]. The plot to the right illustrates the parabolic trend between run value and proportion slower.

There have been contrasting ideas about the importance of vertical break separation in determining the effectiveness of a changeup. Some studies have found that better changeups had more vertical movement[2], while other studies concluded that the vertical break difference between changeups and fastballs had minimal effect on changeup success[3].

The goal of this study is to determine the optimal velocity differential between a changeup and a fastball, to examine the effects of changeup vs. fastball vertical break, and to analyze the effectiveness of certain methods of pitch sequencing.

Methods
We will assess Trackman data from a sample of 2019 Division I games. The metrics used to measure the success of changeups are exit velocity and whiff rate. For each part, bunts are excluded in the analysis.

<u>Part I-II: Velocity and Vertical Break</u>
We will analyze changeups in two ways: all change ups from pitchers who threw more than 30 changeups, and only changeups preceded by a fastball within the same at bat. Evaluating all of the changeups a pitcher has thrown will examine the overall effectiveness of the pitch, while examining changeups that are thrown immediately after a fastball in the same at bat will amplify the contrasting effect between the two pitches.

For each pitcher and each changeup preceded by a fastball, we calculated the following:

	Velocity Differential	**Proportion Slower**	**Vertical Break Proportion**
Formula	*FB Velo - CU Velo*	$1 - \frac{Changeup\ Velo}{Fastball\ Velo}$	$1 - \frac{Changeup\ VB}{Fastball\ VB}$
All Changeups rounding	1 mph	0.01 (1%)	0.05 (5%)
CU preceded by FB rounding	0.5 mph	0.005 (0.5%)	0.05 (5%)

Once we determined the above values for each pitcher/changeup, we broke them down into groups based on the above rounding methods, finding the whiff rate and average exit velocity within each group. Only groups with over 5 pitchers/100 pitches were selected to reduce variability error. Then, we plotted whiff rate and average exit velocity against each one of the three explanatory variables.

Part III: Changeup Sequencing

We are interested in testing the effectiveness of throwing multiple changeups in the same at bat, due to conventional wisdom suggesting that changeups generally require a fastball as a foil and could lose value when thrown consecutively.

Each changeup was categorized as either 1st, 2nd, or 3rd changeup thrown in a row to the same batter in the same at bat. Then, we compared the average exit velocity and whiff rates between the three groups using a two-sample z-test.

We will only analyze changeups thrown with two strikes from pitchers with changeups with greater than 20% whiff rates. Pitchers with better changeups could be more likely to throw multiple changeups in a row, so we will reduce this bias by isolating pitchers with high whiff rates. A higher percentage of 3rd changeups will occur later in counts (more likely to have two strikes), so the 3rd changeup could appear to be more successful than the 1st or 2nd changeup because batters are generally less successful in two-strike counts. Isolating our analysis to two-strike counts will eliminate how the count affects the hitter's approach at the plate and the pitch's success.

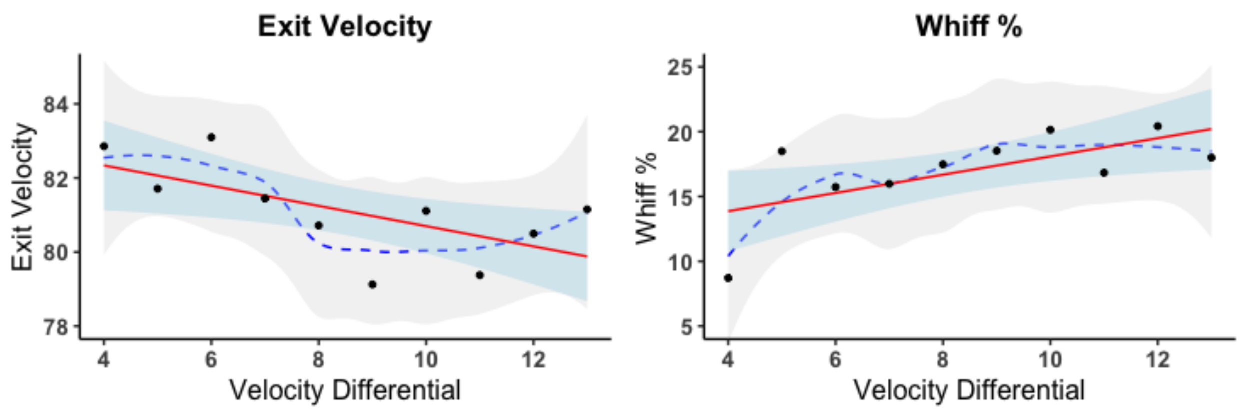
Results

Part I: Velocity

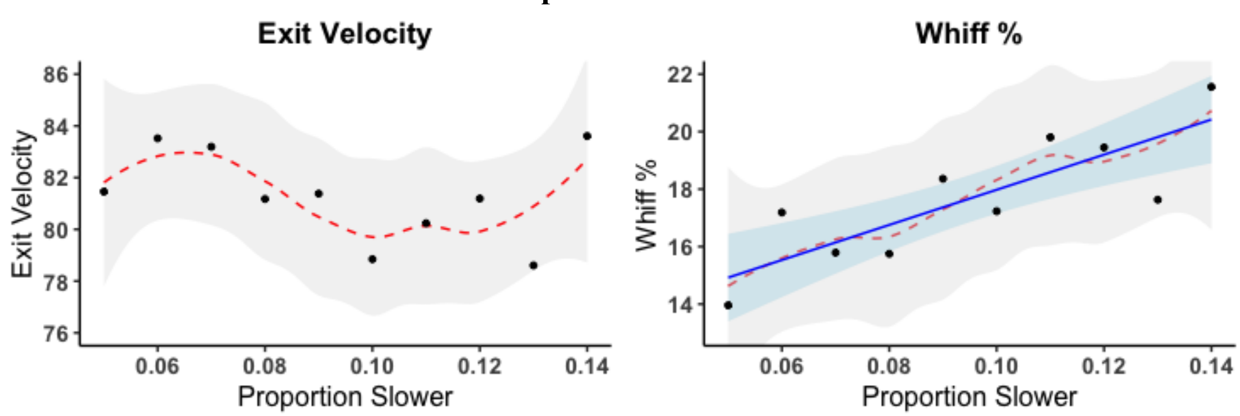
<u>All Changeups:</u>

The solid lines denote linear models and the dashed lines represent a smooth curve fit. Blue and gray shaded areas are the confidence intervals for the linear and smooth fits, respectively.

Velocity Differential



Proportion Slower



The linear models for exit velocity and whiff rate compared to velocity differential are statistically significant ($p < 0.05$ and $R^2 = 0.41$ for both). Whiff rate and proportion slower also has a statistically significant linear relationship ($p < 0.01$ and $R^2 = 0.69$). Exit velocity and whiff rate can be predicted by the following equations:

$$Exit\ Velo = 83.43 - 0.27(Velo\ Diff)$$

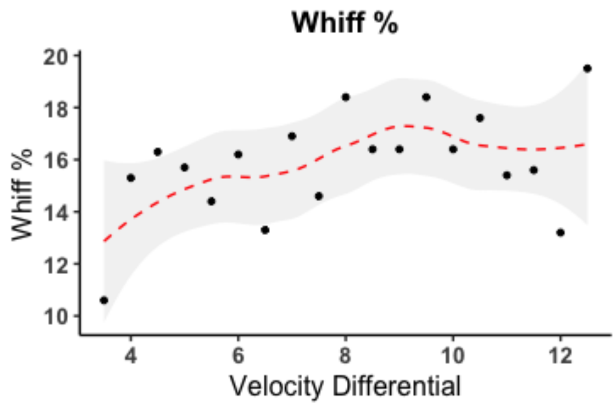
$$Whiff\ \% = 11.05 + 0.70(Velo\ Diff)$$

$$Whiff\ \% = 11.87 + 61.11(Prop\ Slower)$$

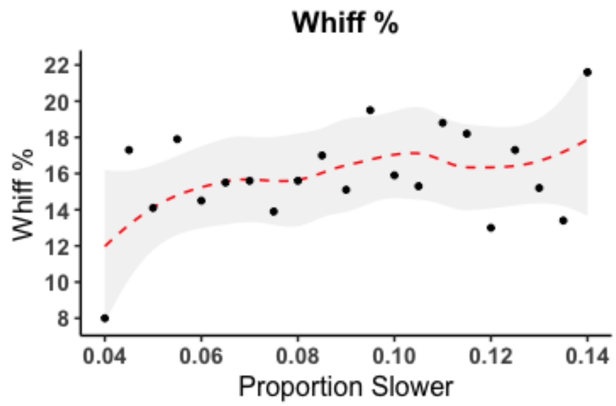
In other words, for every 1 mph differential between a fastball and a changeup, exit velocity decreases by 0.27 mph and whiff rate increases by 0.70%. For every 1% slower, whiff rate increases by 0.61%.

Changeups Preceded by Fastballs:

Velocity Differential



Proportion Slower



At first glance, there appears to be a correlation between whiff rate and velocity, but the trend lines are highly skewed by the points at 3.5 mph velocity differential and 0.04 proportion slower, creating the illusion of a positive trend. Therefore, we can conclude that for changeups following fastballs, there is not a significant relationship between whiff rate and velocity differential or proportion slower.

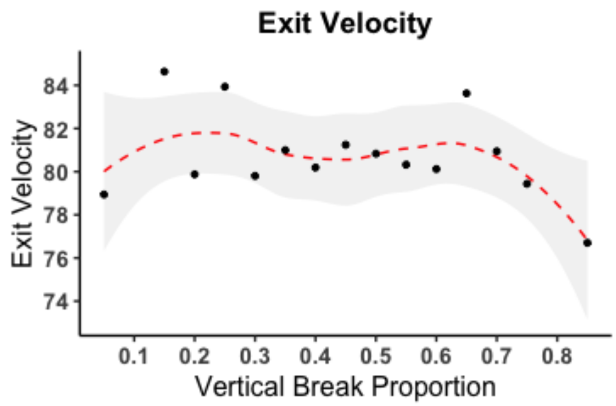
In general, there is a negative trend between exit velocity and proportion slower, and a positive trend between whiff rate and proportion slower. The slower the changeup, the higher the whiff rate and the lower the exit velocity.

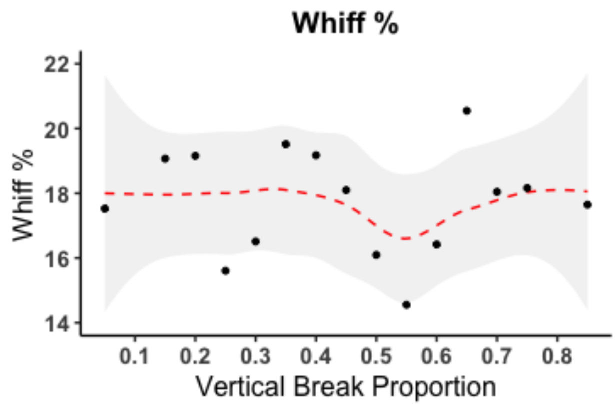
The best performing changeups in regards to whiff rate are 9 or more mph slower than its preceding fastball. From this data, it appears that the optimal changeup is 14% slower than its preceding fastball (ex: 90 mph fastball followed by an 77.4 mph changeup)

Contrasting from the study on MLB data, changeup effectiveness does not seem to diminish at extreme velocity differentials on the higher end but it does on the lower end. This could be due to the fact that the proportion slower maximum for college data is 0.14, while the MLB data has a maximum of 0.20.

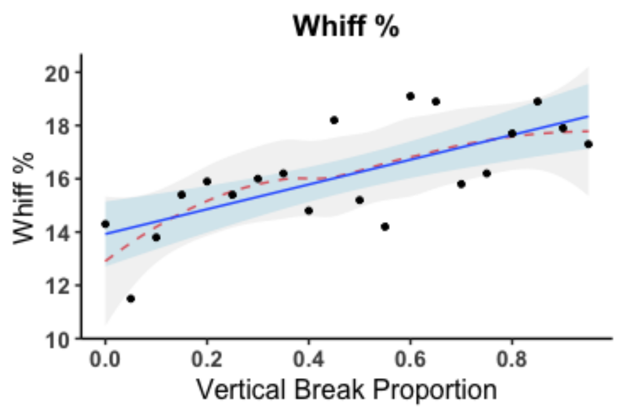
Part II: Vertical Break

<u>All Changeups:</u>





<u>Changeups Preceded by Fastballs:</u>



Vertical break proportion produced some mixed results about changeup effectiveness. For all changeups, vertical break proportion does not appear to have an affect on either exit velocity or whiff rate.

For changeups preceded by a fastball, whiff rate has a statistically significant linear relationship with vertical break proportion ($p < 0.01$ and $R^2 = 0.46$). The greater the vertical break separation, the higher the whiff rate. Using a linear model, we can predict whiff rate from vertical break proportion based on the following equation:

$$Whiff\ \% = 13.9 + 4.6(VB\ Proportion)$$

For every 10% increase in vertical break separation, whiff rate increases by 0.46%.

Vertical break separation is important when throwing changeups directly after fastballs, but not as important as velocity differential when analyzing the overall effectiveness of the pitch.

Part III: Changeup Sequencing
Changeups analyzed were thrown with 2 strikes by pitchers with over 20% whiff rates in 2019.

Exit Velocity:

Changeup	Exit Velo	Pitch Count
1st	83.98 mph	111
2nd	78.41 mph	30
3rd	83.08 mph	23

At a 95% confidence level, the 2^{nd} changeup exit velocity is less than the 1^{st} and 3^{rd} changeups' exit velocities. 1^{st} and 3^{rd} changeup exit velocities are not statistically different from each other. However, the sample sizes for 2^{nd} and 3^{rd} changeups are small, so the exit velocities may not be an accurate reflection of all 2^{nd} and 3^{rd} changeups.

Whiff Rate:

Changeup	Whiff Rate	Pitch Count
1st	29.22%	640
2nd	30.05%	213
3rd	44.00%	125

At a 99% confidence level, 3^{rd} changeup produces the highest whiff rate compared to the 1^{st} and 2^{nd} changeups. 1^{st} and 2^{nd} changeup whiff rates are not statistically different from each other.

Conclusion
Velocity differential has the most significant effect on changeup success, and vertical movement has minimal influence compared to what we previously thought. From our analysis, pitchers that maximize the separation between fastball and changeup velocity generally have lower exit velocities and higher whiff rates. Larger vertical break separation induces higher whiff rates only when the changeup is thrown immediately after a fastball. Additionally, the 3^{rd} changeup thrown in a row with 2 strikes has the highest whiff rate compared to the 1^{st} or 2^{nd} changeup.

Our findings are summarized in the following table:

Velocity	Most successful changeups have > 9 mph differential
Vertical Break	For changeups preceded by a fastball: Increased vertical break proportion → increased whiff rate
Changeup Sequencing	3^{rd} changeup has the highest whiff rate 2^{nd} changeup has the lowest exit velocity

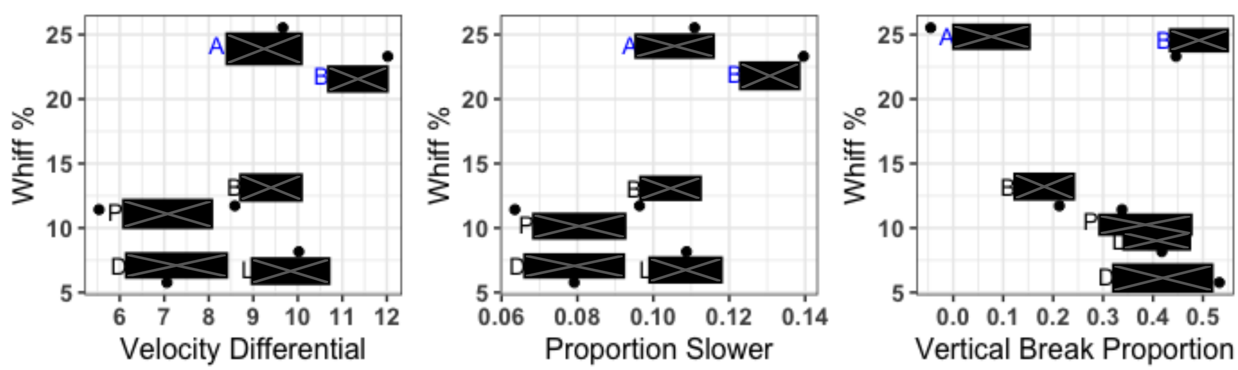
Additional Comments
We also examined "fast" changeups (velocity differential < 5 mph) and "slow" changeups (velocity differential > 11 mph) to determine if vertical break affected these subgroups. However, there was not enough data to make any meaningful conclusions about these changeups.

Application to Our Staff:
The following table and plots include Gaucho pitchers who threw more than 30 changeups in 2019 (Winter and Spring).

Ordered by Descending Whiff %:

Pitcher	# Changeups	# In Play	Avg Velo	Velo Diff	Prop Slower	VB Prop	Whiff %	Exit Velo
A[redacted]	47	5	77.5	9.7	0.11	-0.05	25.5	76.5
B[redacted]	399	62	74.1	12	0.14	0.45	23.3	74.6
B[redacted]	256	51	80.5	8.6	0.10	0.21	11.7	77.3
P[redacted]	70	14	81.6	5.5	0.06	0.34	11.4	75.7
L[redacted]	49	3	82.2	10	0.11	0.42	8.2	76.9
D[redacted]	52	9	82.2	7.1	0.08	0.53	5.8	78.5

Whiff % vs. Velocity Differential, Proportion Slower, and Vertical Break Proportion:



A[redacted] and B[redacted] had the best performing changeups with whiff rates of 25.5% and 23.3%, respectively. Their changeups have significant velocity differentials (A[redacted] = 9.66 mph, B[redacted] = 12.02 mph), justifying our claim from Part I that changeups with velocity differentials over 9 mph have more success than those with smaller differentials.

L[redacted] had a high velocity differential (10.02 mph), but a less successful changeup, which could in part be due to the fact that his average fastball velocity was 92.2 mph, so his proportion slower was less than A[redacted] and B[redacted]'s. Additionally, L[redacted] only threw a changeup 49 times (13 in 2019 Home Games), so his small sample size could affect his changeup effectiveness.

Corresponding to our results from Part II, the Gaucho pitchers' vertical break proportions do not seem to follow a trend regarding overall changeup success. There was not enough data to make conclusions about changeup sequencing for our pitching staff.

References

1. Allen, Dave. “Optimal Fastball-Changeup Speed Separation.” The Baseball Analysts. May 22, 2009. Accessed July 13, 2019. baseballanalysts.com/archives/2009/05/optimal_fastbal.php.
2. Hale, Jonathan. “Inside the change-up.” Fangraphs. May 28, 2009. Accessed July 13, 2019. https://tht.fangraphs.com/inside-the-changeup/
3. Kalk, Josh. “Anatomy of a Pitch: Change Up.” Fangraphs. July 1, 2008. Accessed July 13, 2019. tht.fangraphs.com/anatomy-of-a-pitch-change-up/.