Kinematic Variable Analysis of Player Backup Plays: How Does the Player Backup Impact Kinematic Variables During Fly-ball Catch Attempts?

https://github.com/CJK15/SMT2023

Abstract

The outfield fly-ball is an important offensive and defensive opportunity to move runners, prevent base advancement, hit a home run, or make an easy out. To maximize outfield effectiveness and minimize base runner movement, during fly-ball catch attempts outfielders often position themselves behind one another. This paper aims to examine how outfield fly-ball plays in which two players backup one another differ. Variables examined include: player position, acceleration velocity as well as ball acceleration and velocity. From anonymized game information, data was extracted, filtered, and net deviation from the median is compared for each variable. Results show that 10/16 variables displayed larger deviations during fly-ball drops in backup plays: left field acceleration, right field acceleration, left field velocity, right field velocity, left field x-position, right field x-position, center field x-position, right field y-position, and center y-position. 6/16 variables displayed larger deviations during fly-ball catches in backup plays: left field y-position, ball acceleration, center acceleration, ball velocity, and center velocity. Consequently, teams can benefit by using such analysis to examine outfielder weaknesses and improve outfielder coordination. Offenses can employ the analysis to improve batting strategy and target defensive weaknesses.

Introduction

Fly-balls are often associated with home runs or easy outs. Hitting fly-balls can also better optimize player base movement. This "fly-ball revolution" has resulted in higher batting averages and slugging percentages in the United States Major League Baseball League [2]. Kato et al. (2022a) discover a similar trend in Japan's Professional League [2]. Furthermore, Kato et al. (2022b), examine how fly-ball path impacts catchability in the outfield: "pulled fly balls" are harder to catch [3].

When a fly-ball is hit, two players typically approach the ball. To maximize outfield effectiveness and minimize baserunner movement one player usually backs up the other. Although backup plays provide a defensive advantage, back up plays may increase player miscommunication regarding who catches the ball. Simultaneously, offensive advantages exist when the fly-ball results in outfielder miscommunication. Despite presumably higher communication skills of professional baseball players, shared fielding zones still present situational communication and positional uncertainties.

Optimization models to examine player performance and optimize outfielder positions is discussed in previous research [1,4]. However, examining the successes and failures of outfield backup plays lacks research attention. This paper addresses this gap by investigating how player characteristics, such as position and velocity, differ during caught and dropped fly-balls in backup plays.

Methods

74 of the 91 randomized game data provided by SMT were used. Datasets excluded from the sample either contained missing outfielder data or lacked backup plays (4/17). Of included datasets, all plays were analyzed during which an outfielder acquired the ball directly after the ball was hit. This excludes plays during which the ball bounced or hit the wall before being acquired.

Initial Analysis - An Overall Picture

An initial analysis examined outfielder positions, player and ball velocity and acceleration at the ball acquisition point, regardless if a backup play occurred or not. The distance between right field and center field was also calculated. Variables were separately recorded for dropped and caught balls and analyzed in Python using Two-Sample T-Tests.

Evaluating all plays in the outfield helps display typical outfielder behavior during fly-ball hits. Importantly, in this paper the initial data analysis above cannot be easily cross-compared to backup play data, but in future research could be more easily cross-comparable. However, this was outside the timeframe available for the authors.

Backup Plays

For each extracted play, a python script prompted the user to input whether or not a backup play was present and if so, who backed up whom: right behind center (RC), left behind center (LC), center behind right (CR), center behind left (CL). The authors defined a backup as a situation in which a second player moves, according to the ball path, to a position to acquire a missed ball faster than the player attempting to catch it.

Players were not judged on effort to move into the backup position. In some cases, a player displayed a clear effort to back up another outfielder; however, their final position would not result in a quicker recovery. If a player covered a large lateral distance but did not end up in the ball path, this play did not qualify as a backup (figure 1.D). Clear examples of non-backup plays are displayed in Figure 1.A-B. Plays in Figure 1. C-D display unclear player movement and did not qualify as backups. Plays in Figure 2 were included in the analysis.

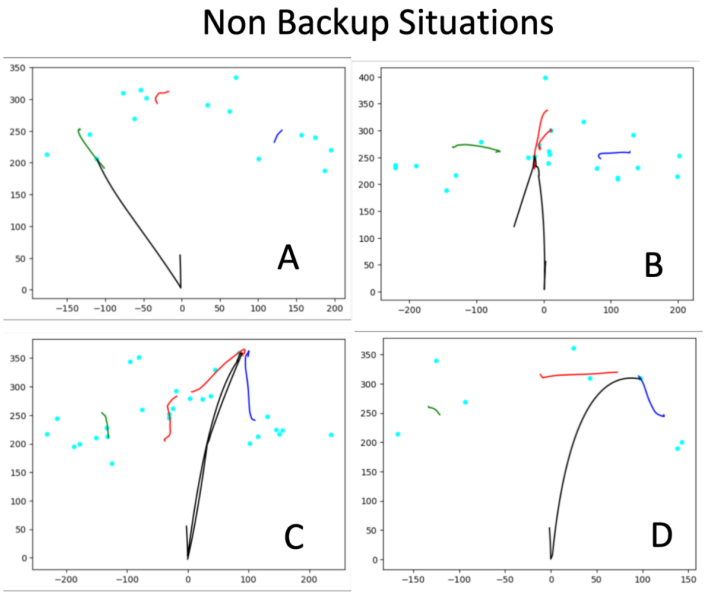


Figure 1. Evaluations of player movement in each play determined that no backup situation was present in the

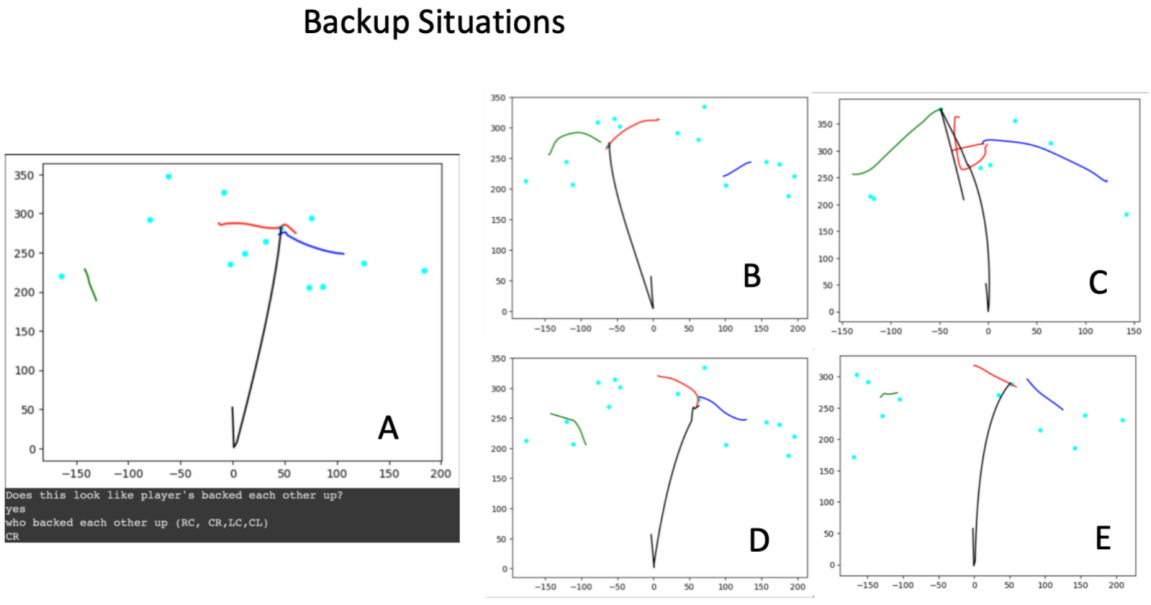


Figure 2. The plots show plays in which a backup situation occurred. Plot A displays the user prompt interface used to record the user's responses. The x-axes display the x-position and the y-axes display the y-position.

134 backup plays included fly-ball catches and 205 backup plays included fly-ball drops. Player x and y positions, and both player and ball acceleration were extracted for the entirety of each play–from the moment the ball was hit to the moment of acquisition. Each variable underwent min-max normalization with a range of -1 to 1 or 0 to 1 depending on the presence of negative numbers. For example, center field moves in both the positive and negative x-directions, which means the normalization requires a range of -1 to 1.

The data displayed signal behavior, which prompted the use of a Fast Fourier Transform (FFT) to filter the data (Figure 3). After filtering, the variable's median value was computed. The median acted as the new "baseline" value from which distances at each datapoint were calculated and aggregated. Therefore, the area under the curve, relative to the median, represents the variable's net deviation from the median (Figure 4).

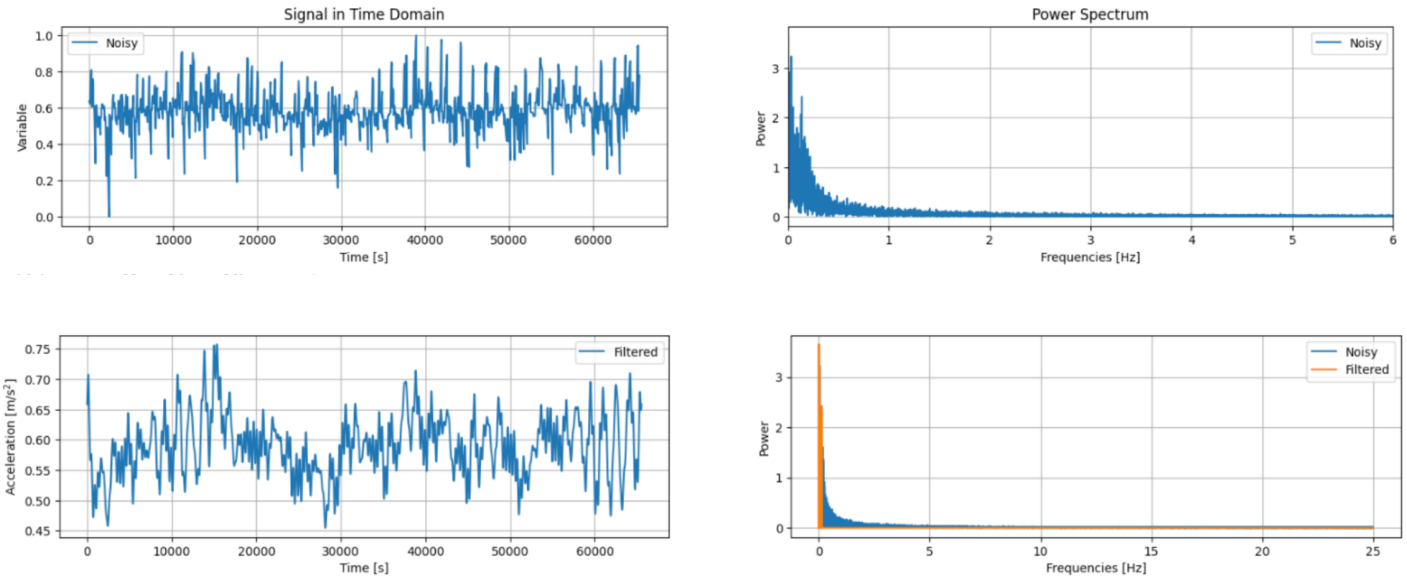


Figure 3. This figure shows the progression from noisy to filtered data. Data is displayed for left field y-position in player backup situations in which the fly-ball was not caught. Frequency amplitude cutoff was 2.

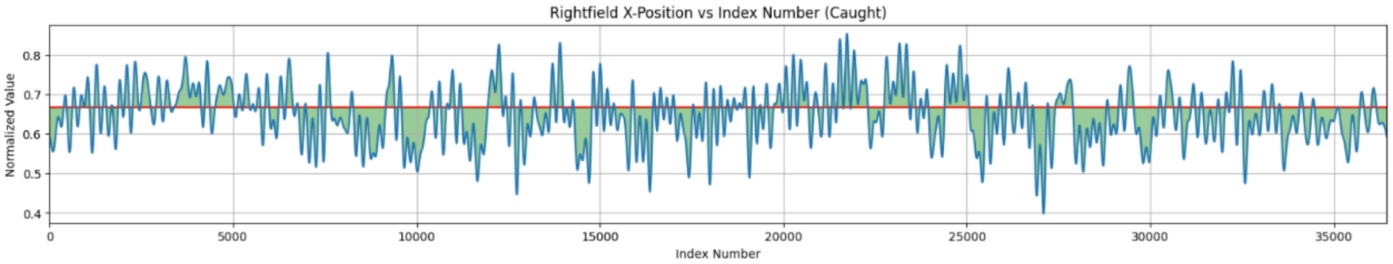


Figure 4. This plot visualizes right field x-position total deviation from the median when the ball was caught (green shade). The red line represents the median. The y-axis is the normalized x-position, while the x-axis is the index number.

Initial Analysis

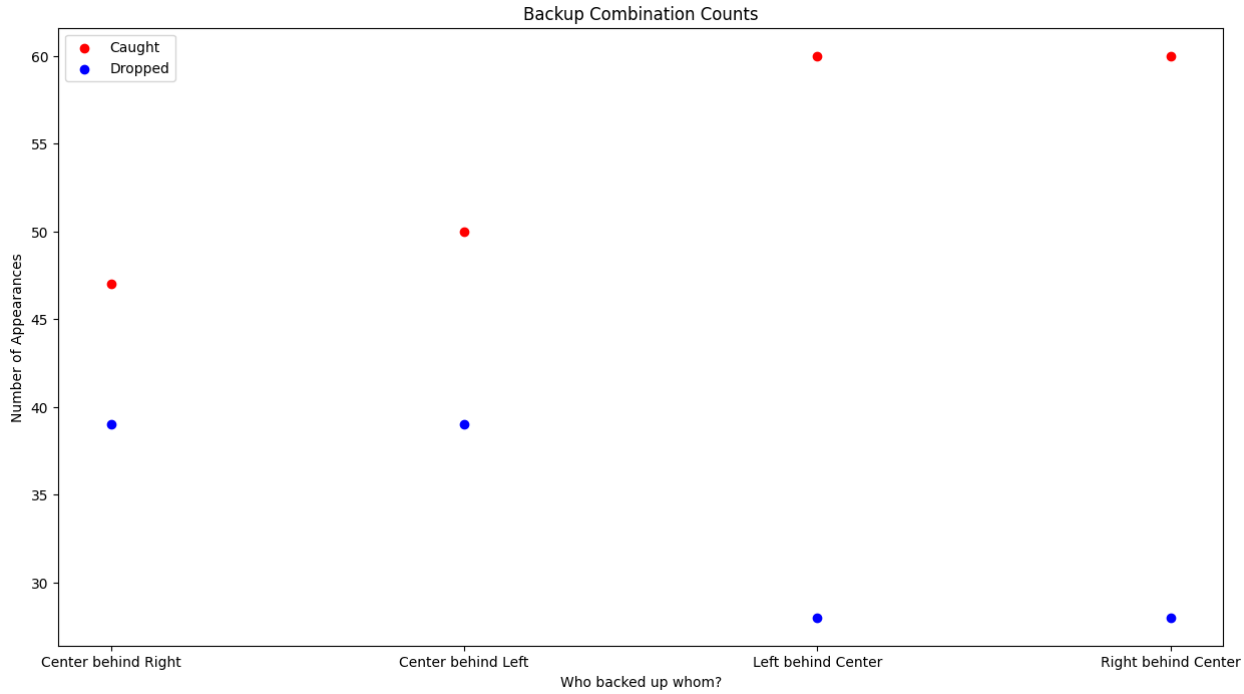
The following data includes all outfield fly-ball plays regardless of player positioning and represents the instantaneous values at ball acquisition. Two-Sample, unequal variance T-Tests conclude that right field acceleration and distance between right and center field is not significantly different between fly-ball outcomes (Table 1). For all other variables examined, values were significantly different (Table 1). Center field acceleration and velocity displayed the greatest differences in sample means, while the right field acceleration and distance between center and right field displayed the smallest differences (Table 1).

	Ball Velocity	Ball Acceleration	Right Acceleration	Left Acceleration	Center Acceleration	Right Velocity	Left Velocity	Center Velocity	Distance Between Right and Center
Stats	-72.831951	-83.053255	1.140241	-22.060575	-1027.234809	9.969721	-13.750238	-2189.705098	1.719605
P-Value	0.000000	0.000000	0.254187	0.000000	0.000000	0.000000	0.000000	0.000000	0.092262

Table 1. Two-sample unequal variance t-tests were conducted between all non-caught and caught fly-balls in the outfield recorded at the timestamp the ball was caught. The blue highlighted cells indicate that the variable displayed non-significant differences in mean between non-caught and caught values.

Backup Play Results

The outside outfielders (left and right) backed up the center fielder 108 (60 (LC) 48 (RC)) times during backup plays resulting in dropped fly-balls. The center fielder backed up the outside outfielders 78 (28(CR), 50(CL)) times. Generally, left field backed up center field more, although the initial analysis suggested distance between right and center field is not significantly different between outcomes. During fly-ball catch plays, center field backed up outside outfielders more often: 78 times (39 (CR), 39 (CL) as compared to the opposite: 56 times (28 (RC), 28 (LC)).



X and Y Position: Backup plays

	Left X Position	Right X Position	Center X Position	Left Y Position	Right Y Position	Center Y Position
Caught	1550.600000	76.960000	81.990000	95.250000	544.270000	-36.210000
Dropped	4237.520000	-4971.380000	805.860000	70.830000	1272.900000	-141.700000
Difference	-2686.920000	5048.340000	-723.870000	24.420000	-728.630000	105.490000

Table 2. This table shows the total variation from the median in x and y outfielder positions for player backup situations in which a fly-ball was caught and uncaught. Difference is the total variation from the median when the ball is caught minus the total variation from the median when the ball is uncaught. Values under 100 are highlighted brown, positive values are highlighted purple, and negative values are highlighted red.

Table 2 displays positional deviation from the median for fly-ball outcomes. A positive deviation in the x-direction means the player's net deviation occurred in the right-ward direction. Conversely, a negative sum means net deviation was to the left. For example, left field displayed net deviation toward center during fly-ball drops (4237.52) as opposed to fly-ball catches (1550.60). Right field displayed a similar relationship in the x-direction (76.96 (Caught) and -4971.38 (Dropped)). In contrast to left field, right field (76.96) displayed greater net movement away from center field when the ball was caught: left field moved toward center (1550.60). Center displayed the smallest variation from the median x-position during fly-ball drops and the second smallest variation during fly-ball catches.

A positive y-direction sum indicates net movement backward. A negative sum indicates net movement forward. Overall, net deviations were smaller in the y-direction, except right field (-728.63). Center field is the only outfielder to display net forward movement. Center field's greater forward movement during fly-ball drops reflects the information in figure 5, which shows that outside outfielders often backup center more often during fly-ball drops than catches.

Acceleration and Velocity Results: Player Backup Situations

	Ball Acceleration	Left Acceleration	Center Acceleration	Right Acceleration	Ball Velocity	Left Velocity	Right Velocity	Center Velocity
Caught	23.560000	1302.000000	1275.400000	886.760000	13.070000	1214.060000	872.510000	894.770000
Dropped	20.950000	1529.300000	520.770000	2060.970000	9.510000	1543.110000	1959.130000	445.140000
Difference	2.610000	-227.300000	754.630000	-1174.210000	3.560000	-329.050000	-1086.620000	449.630000

Table 3. This table shows the total variation from the median in x and y outfielder acceleration and velocity for player backup situations in which a fly-ball was caught and uncaught. Difference is the total variation from the median when the ball is caught minus the total variation from the median when the ball is left uncaught. Values under 100 are highlighted brown, positive values are highlighted purple, and negative values are highlighted red.

Center field displayed greater variation in acceleration and velocity during fly-ball catches, whereas right and left field displayed smaller variations. Across all outcomes, ball acceleration and velocity deviated the least. Right field acceleration and velocity displayed the greatest absolute difference between fly-ball outcomes: 1174.21 and 1086.62, respectively.

10/16 variables displayed larger deviations during fly-ball drops in backup plays: left field acceleration, right field acceleration, left field velocity, right field velocity, left field x-position, right field x-position, center field x-position, right field y-position, and center y-position.

6/16 variables displayed larger deviations during fly-ball catches in backup plays: left field y-position, ball acceleration, center acceleration, ball velocity, and center velocity.

Discussion

In the initial analysis of all outfield fly-ball plays, T-Test T-statistics indicated a large difference in mean center acceleration and mean velocity between fly-ball outcomes (Table 1). However, when only backup scenarios were considered, the center fielder's velocity showed the 5th and 6th largest net deviations from the median (Table 3). Although Table 3 is median based as opposed to mean-based (Table 2), results still suggest that backup plays influence center fielder movement. Table 2 further demonstrates this, as the center fielder's x and y positions display the 2nd and 3rd smallest absolute difference between outcomes. However, comparing the data has limitations, as the T-tests are based on data at the ball acquisition point, whereas Table 2 and 3 are based on all data collected during the backup play.

Overall, when only backup plays were considered, the right fielder's x-position displayed the largest difference in deviation from the median and displayed greater net movement leftward during fly-ball drop outcomes versus fly-ball catch outcomes.

Presumably, larger net deviations may occur in dropped fly-balls plays due to player miscommunication or difficult flight paths, which cause difficulty in moving to a backup position or ball location. A machine learning approach to determine a fly-ball's catchability would add context. However, the method employed in this paper assumes that players were able to position themselves as a backup, thus indicating a catchable fly-ball.

User error and definition of backup plays may unintentionally exclude plays from analysis. Users could modify constraints and introduce positional filters to limit error and improve data processing speed. However, this approach was not employed due to the large range of possible backup scenarios. Furthermore, fly-ball plays are already limited in volume, so a filter merely introduces risk of filtering out backup plays.

Evaluating absolute deviation instead of net deviation may improve outfielder to outfielder comparisons. However, net deviation focuses on directional player movement, which requires positive and negative values. Importantly, the ball's net deviation in acceleration and velocity may be explained by the physics of an arced flight. As the ball approaches the peak, it decelerates to zero and then re-accelerates. Here, evaluating absolute deviation may improve data analysis. Player acceleration profiles will change from play to play, which supports use of net deviations and can potentially be used to evaluate consistency.

Net deviation is a metric to which can highlight player relationships in the outfield. For example, during fly-ball drops, center field's net deviation was leftward. This suggests that improving backup action between center and left field may improve team fly-ball performance. Furthermore, offenses can capitalize by understanding outfield weakness points.

Furthermore, center fielder acquired the ball more often during fly-ball drops, which indicates that further confining the analysis to plays in which fly-balls are caught by center field may improve understanding of how right and left field backup center field.

Consequently, comparing backup play data to non-backup play data can highlight how player backup scenarios alter player behavior. However, data for non-backup plays were not recorded in this study, so this analysis could not be completed.

Furthermore, the positions of the different players at the moment the ball was caught was not examined for backup plays because timestamps were not extracted. Therefore, future research should examine positional data at ball acquisition. This may better highlight players' interactions at ball acquisition which may provide deeper insight than examining player position throughout the entire backup play. This is because most communication between players likely occurs just before the ball is acquired.

Overall, such research can improve team coordination in the outfield and identify which player relationships in the outfield may require further examination to improve defensive performance. On the offensive side, teams can also use such data to improve batting strategy, as the analysis can be specified by team and player identity.

Conclusion

For all fly-ball plays acquired in the outfield, distance between right and center field is not significantly different during caught and dropped fly-ball plays. During backup plays, the right fielder displayed greater net movement toward the center fielder during fly-ball drops and larger movement toward the foul line during fly-ball catches. Left field moved toward center field in both play outcomes. Center field displayed the smallest and second smallest net movement for dropped and caught results. 10/16 variables displayed larger net deviation from

the median in fly-ball drops and 6/16 variables displayed larger net deviation in fly-ball catches. Future research should examine the absolute difference from the median or focus on certain players/positions. Findings from this research highlight potential weaknesses in the outfield, which can be used to improve defensive performance and communication as well as improve offensive batting strategy.

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