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The Effects of "Sticky Stuff" on the Spin Rate and Break of a Baseball Pitch

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The Effects of "Sticky Stuff" on the Spin Rate and Break of a Baseball Pitch

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by

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Abstract

In June 2021, Major League Baseball cracked down on the use of foreign substances by pitchers on the ball (Castrovince, 2021a). It is believed the sticky substances give the pitchers an unfair advantage over batters since they increase spin rate, consequently, through the Magnus Effect, creating more movement or "break" in the pitch, making it harder to hit. There are existing gaps in empirical research on this topic, thus the goal of this project was to determine the effect the banned substances have on the spin rate and related break of the pitches. By using pitch tracking technology, two types of pitches were tested with three substances in addition to the null. Comparing the pitch types with the spin rate of each added substance, this project focused on the relationship between the consequential increased spin rate due to "sticky stuff" and the associated break. The data collected showed that while sticky substances did increase the spin rate, it did not necessarily increase the break of the pitch. Further research could be conducted on spin efficiency to explain inconsistencies.

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Acknowledgements

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I. Introduction

While I have always had an adoration for the sport of baseball, I was never particularly interested in the nitty gritty details of pitching. For me it was all about the offense: hitting, running, and scoring. This past summer, 2021, I managed to secure a job working in Player Development for my hometown team, the Los Angeles Dodgers. It was truly a dream come true, however I had to quickly learn about minute details of pitching since my job was to track pitches. I spent the summer sitting in front of a computer reading data, including spin rate and break measurements, from every pitch and tagging the pitch types. The 2021 Major League Baseball season took an interesting turn in mid-June when the league announced a ban on the use of foreign substances by pitchers. They provided guidance to the 30 clubs which outlined which substances were banned as well as how they would be doing checks on the pitchers going forward (Castrovince, 2021a). It was a sudden change and unprecedented due to its implementation in the middle of the season. The MLB gave little warning, which lead to major changes in spin data for most pitchers, including the elite of the elite. Thanks to my responsibilities within the player development program, I was immediately interested in these data changes; increased (or decreased after the ban) spin rate being the biggest tell that a pitcher was using sticky substances. Immediately after the definitive ban date, pitchers' spin rates dropped between 100-300 rpms. My coworkers and I would spend pre-game downtime discussing pitch movement or "break", pitch types, and sticky substances, and how physics could explain the flightpath of the ball. I decided that I would conduct my senior thesis dedicated to the added movement and spin rate of a ball with different types of sticky substances. In this way, I hoped to justify the MLB substance ban through my own experiment in which I would compare the types of substances from legal to illegal to explore how the stickiness affected the relationship between increased spin rate and total movement of the pitch.

II. Background

Throughout the history of baseball, pitchers have consistently found ways to "cheat", consequently making their pitches harder to hit. This is baseball's worst-kept secret, and team managers and coaches even encourage the use of sticky substances (Apstein & Prewitt, 2021). These tactics include adding sticky substances to their fingers, scuffing one side of the ball (this has major physics implications), or even adding their own spit to the ball (S. Stroop, personal communication, September 19, 2021). In the 21st century, the most popular substances are sticky ones since they are easily hidden and reapplied to fingers and do not make a noticeable difference in the appearance of the ball. The mid-season ban highlighting the change in statistics was not the first time something similar had happened in baseball's history. Older fans may remember when spitballs were one of the most difficult pitches to hit, and when they were banned from the sport in 1920 (Barker, n.d.). Interestingly enough, spitballs were banned due to their unsanitary nature rather than the unpredictability and unfairness of the pitch movement. It is arguable they should have been banned due to how difficult they were to hit; a prime example of this being one of baseball's greats, Babe Ruth, who hit twice as many home runs in 1920 than he did the previous year (Barker, n.d.). Some attribute this to the lack of spitballs he had to face. Using substances on pitches has always been illegal based on the MLB rulebook - the league and umpires simply did not enforce the rules and pitchers got better and better at hiding their illegal substances on the insides of gloves, inside their belts, or under their hat brims. This meant that the spitball was not successfully outlawed until 1967 when Rule 6.02 was adopted (more on this rule later) (Castrovince, 2021b). Fast forward to present day, and the MLB took drastic action to stop the use of sticky substances by pitchers. The game had shifted to pitcher dominance, much to the chagrin of the fans and thus the business minds of the league. The league intended on reversing this shift to make the duel between pitcher and batter more equal again.

Initially, the league informed the teams during Spring Training that they would be conducting tests during the season on their way to fully banning substances. Teams had the whole season to wean their guys off the sticky stuff. This gave teams and their pitchers plenty of time to stop relying on the substances and prepare themselves for the future consequences of using them…expected to be the 2022 season. This timeline did not hold true. June 15, 2021, the MLB released their official guidance on enforcing the rulebook and what the punishments for using sticky stuff would be. The enforcements went into effect June 21. This was a quick turnaround, especially for pitchers who were using the substances. The league, in conjunction with the Commissioner's Office stated that they would be enforcing Rules 3.01 and 6.02 [c] and [d] (Anthopoulos et al., 2021). Rule 3.01 addresses the discoloring or damaging of a ball (See Appendix A). Any pitcher caught using sticky substances would be suspended for 10 days, and the team could not fill that roster spot during the time of suspension. Rule 6.02 concerns pitching prohibitions including illegal substances (See Appendix A). A statement from Commissioner Robert D. Manfred, Jr. explained that, "there's a history of foreign substances being used on the ball, but what we are seeing today is objectively far different, with much tackier substances being used more frequently than ever before" (Castrovince, 2021b). He went on to point out that foreign substance use had gone well past the need to get a better grip on the ball, thus giving pitchers an unfair advantage. The point of the ban was to level the playing field and allow batters' batting averages to go up again, since only 2 months into the season they were at pace to have the lowest league batting average in history. The enforcements of the rules happened routinely instead of waiting for a manager to ask the umpire to check a player for a violation, with starting pitchers checked multiple times in between innings, and relief pitchers either at the end of the inning they enter in or when they are removed from the game (whichever comes first). Umpires can also, at their own discretion, check players again if a ball feels sticky or the like. While rosin on its own is legal to use, pitchers are not allowed to intentionally mix it with any other substance (namely sunscreen) as this also creates a sticky substance that can aid the pitch. Other sticky substances like pine tar were used to give the pitchers better grip, as well as scientifically engineered substances like Spider Tack really give pitchers an edge (Hahn, 2021). This advantage due to “sticky stuff” is related to the increased spin rate of the ball. The spin is so significant that it acts similarly to performance enhancing drugs, but without the consequences to the body (Apstein & Prewitt, 2021).

III. The Magnus Effect

a) Spin and Break: How a Pitch Moves Through the Air

The most critical component of a baseball pitch is the spin. In order to fully understand why, we turn to physics to explain the flight of the ball. The Magnus Effect rules the “break” or movement of the baseball as it travels through the air based on whether it has backspin, topspin, or sidespin. The pitcher’s release affects the spinning direction and thus the forces on the ball. A fastball is thrown with backspin due to the downward flick of the pitcher’s wrist as he (or she) throws the ball. The backspin of the fastball can sometimes create what looks like a little “hop” or lift of the ball as it reaches the plate. This illusion of the ball “rising” is what makes the pitch harder to hit and ruins the “easy-to-hit” factor of a straight fastball. That rise is the break of the fastball. A curveball is thrown with topspin, which causes the ball to drop quickly as the downward force of the air pushes the ball down as it spins (See Figure 1). The slider is somewhere in the middle, as the grip is similar to a curveball, but not forced downwards like a curveball. Instead, the pitcher "cuts" the pitch, which allows the force to push the ball to the side opposite the hand they are throwing with (see Appendix A). As Figure 1 suggests, a knuckleball, which is "pushed" with the pitchers' fingers in order to have little or no spin, is unpredictable in nature and can dive or curve or literally go in a straight line. Not even the pitcher knows where it will end up. Any movement off a straight trajectory towards the plate is considered "break". For example, a right-handed pitcher has a slider that breaks left. The spin of the ball in conjunction with the Magnus Force determines the direction that the ball will break and by how much.

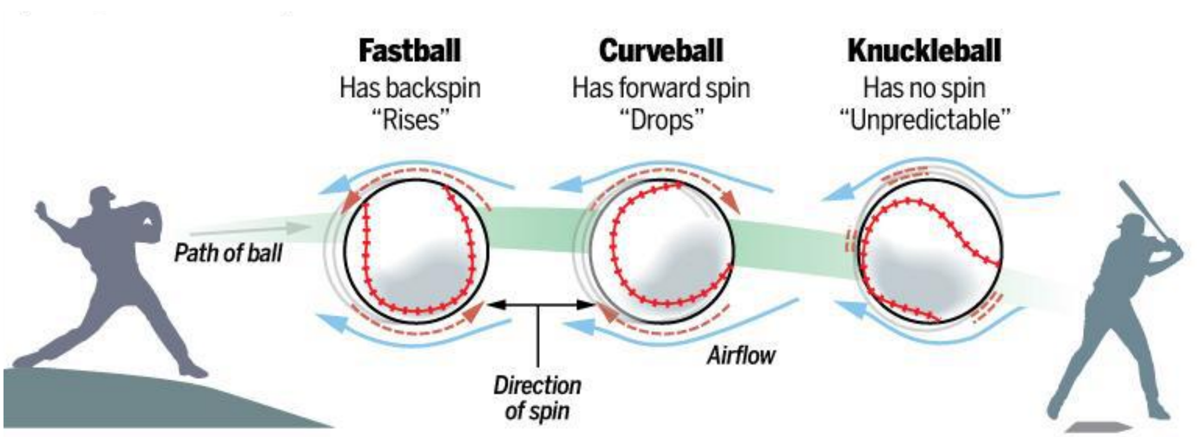

Figure 1. The path of a baseball with different spin based on pitch type. Shows the direction of spin and airflow (Peterson, n.d.).

b) The Magnus Effect or Force

The Magnus Effect was first researched in 1852 by Gustav Magnus, a German physicist seeking to understand why spinning artillery shells would unpredictably curve and move through the air (Nicolella, 2021). A spinning sphere develops a force at a right angle to the direction of the moving air which causes the sphere to deflect and curve away from the principal flight path (Nicolella, 2021). In more detail, Bernoulli's principle tells us that on the side that velocity is greater (i.e., where the motion of the spinning object is in the same direction as the airstream) the pressure is lower, and thus there is an imbalance in the forces acting at right angles to the airstream (Briggs, 1959). These same principles, of course, can be applied to the spherical baseball. When a spinning sphere or baseball travels through the air, it experiences the force of gravity as well as the drag and Magnus forces, $F_{D},$ and F_M (Figure 2) (Nathan, 2008). Every pitch experiences a Magnus Force during its path to the plate which dictates the amount of curve or break of the pitch. Additionally, the effect is responsible for how much the ball moves in the direction of the leading edge (Nicolella, 2021). The leading edge is known as spin direction, which is commonly referred to by the numbers on a clock (i.e., a 12-6 curveball). The Magnus Force can act on the top, bottom, or side of the ball. For example, a fastball travels through the air with backspin, which creates a high-pressure zone *under and ahead of* the ball, which deflects the ball upwards, counteracting gravity. This unsteady bottom-to-top pressure difference allows a fastball to reject some of the gravitational force due to the change in air flow momentum. Especially for a fastball, it is important to discuss what effects the seams have, adding to the ball's ability to develop a boundary layer between the ball and the air. This partially counteracts the effect of gravity as the "ball rides on – and into- increased air pressure" on its journey to the catcher (Nicolella, 2021). Because of this imbalance of molecules on top and below the ball, the ball "rises", just enough to fool a batter to get them to swing under an otherwise "straight" pitch. A curveball is opposite to a fastball with the high-pressure zone on top of the ball causing downward deflection and exaggerating the drop of the pitch. All these effects are exaggerated the higher the spin rate of the ball. Therefore, pitchers are trying much harder to increase their spin rates. Intuitively, it is much more difficult to hit a pitch that moves further, so pitchers want the biggest advantage they can get to find the most success. The faster the ball spins, the larger the Magnus force is.

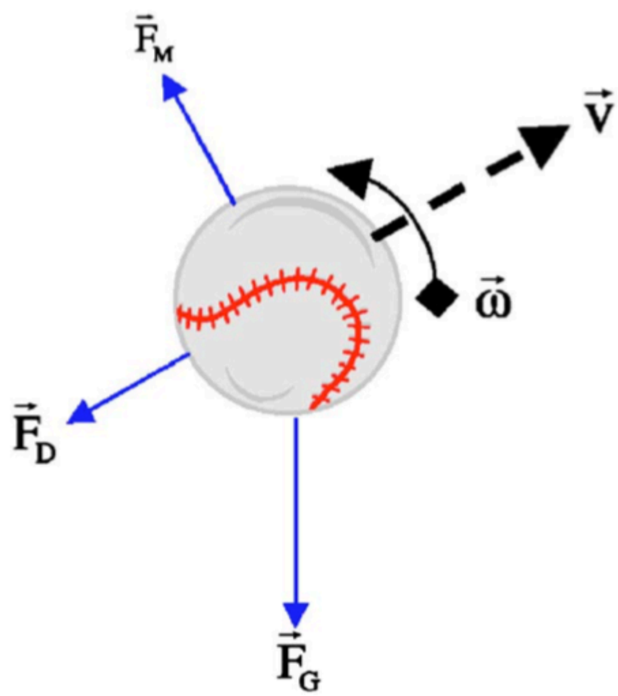

Figure 2. The Magnus Force on a spinning baseball through an airstream. The drag force F_D acts in the $-\mathbf{v}$ direction, the Magnus force F_M acts in the $\omega \times \mathbf{v}$ direction, and the force of gravity F_G acts downward (Nathan, 2008).

c) Friction and Sticky Substances

Physics also helps answer the question of *why* sticky substances would be helpful for an increased spin rate. The short answer: friction. Andy Andres uses the analogy of opening a jar. In order to open a jar, you need friction, and additionally you want to stick to the lid instead of all your force sliding off (Hahn, 2021). With more friction, we get more spin, measured in RPMs. As we have said before, the point of getting more spin is to accentuate the break of the ball, potentially making it just a little bit more difficult to hit. The increase of spin rate was noticed most drastically in 2019, creating the outcry that ultimately led to the 2021 crackdown. Within that time, sticky substances were getting even more sticky. Spider Tack, more commonly used by lifting athletes to get a better grip on atlas stones started making headlines due to its scientifically optimized tackiness (Hahn, 2021). With substances as sticky as Spider Tack, witnessing a pitch includes "[hearing] the friction" as the ball 'rips' off the pitchers' fingers (Apstein & Prewitt, 2021). Sticky substances also add to the pitcher's ability to throw 100% of their best stuff all the time. With more control over the ball based solely on grip, the need for perfect mechanics dwindles. However, the stickiest of substances are not necessary for the Magnus Effect to make the ball unhittable. Pitchers mix sunscreen with the rosin and create a more natural yet still tacky substance, which again creates enough friction to increase the spin rate. The addition of sticky substances improved some pitchers' fastball spin rates nearly 300 RPMs (Apstein & Prewitt, 2021). Most reviews of the increased spin rate phenomenon focus on the fastball (and sometimes the curveball), but I was interested in sideways break, i.e., the movement of the slider. To fully convince myself that the ban was needed, I chose to test rosin, rosin + sunscreen, and Spider Tack as my "sticky stuff" to explore the physical effects on the spin rate and movement of the ball.

IV. Technology

All Major League parks are equipped with Trackman, an optical enhanced dual (doppler) radar technology that tracks every single pitch and outputs a plethora of data points. It tracks data points for the pitcher such as velocity, spin rate, horizonal and vertical break, as well as even doing a calculation that can determine how far a ball goes once it has been hit. Trackman began as a golf technology, but it was quickly realized that it could be applied to baseball. When I was working for the Dodgers, I worked with the Trackman technology. Tracking technology like this can get very expensive, with Trackman allegedly costing around $30,000. There are also similar and more affordable tracking devices such as Rapsodo, which is the technology that was used to track pitches for this experiment.

a) Rapsodo

Rapsodo, a camera-radar piece of technology, is also used by all 30 Major League Baseball teams, and over 1200 colleges and training facilities across the US (*Baseball Training Equipment & Tools | Measure To Master*, n.d.). This system is not limited to pitching, but for the purposes of this experiment, we used their Pitching 2.0 operation system. Rapsodo is incredibly user-friendly and is one of the most widely used systems due to its size, portability, and affordability without losing any accuracy. The interface the user sees shows a multitude of data points and the user can choose which ones they want to display or not (See Figure 3). Rapsodo is purely a training device as the small camera is placed 15 feet in front of the pitcher's mound. This means that it cannot be used during games and is limited to bullpen use only (the distance between the mound and home plate is 60 feet). The system connects via Bluetooth to the Rapsodo app, importing data in real-time. Rapsodo is only focused on the pitcher, which means that the vertical break (induced) is measured off a straight line from the release point.

For the experiment, we focused on spin rate (under "total spin"), and horizontal and vertical break (top right-hand corner). The spin rate is calculated in rpms, and the horizontal and vertical break are measured in inches. Vertical break, measured as induced vertical break, ignores gravity. Since Rapsodo is focused on the pitcher only, the zero point is a straight line from the pitcher's release point, and the number output by the system is the drop down from that straight line. In reality, the ball will drop a little more than that due to gravity and the angle downwards that the ball is thrown at. Pitchers have 60 feet in which to make their pitch dive, curve, spin, or die before the batter takes their swing at it. Using the data points we collected, the goal was to determine whether the use of sticky substances made a significant difference in the spin rate of the pitch, and then in turn whether a raised spin rate contributed to more "break".

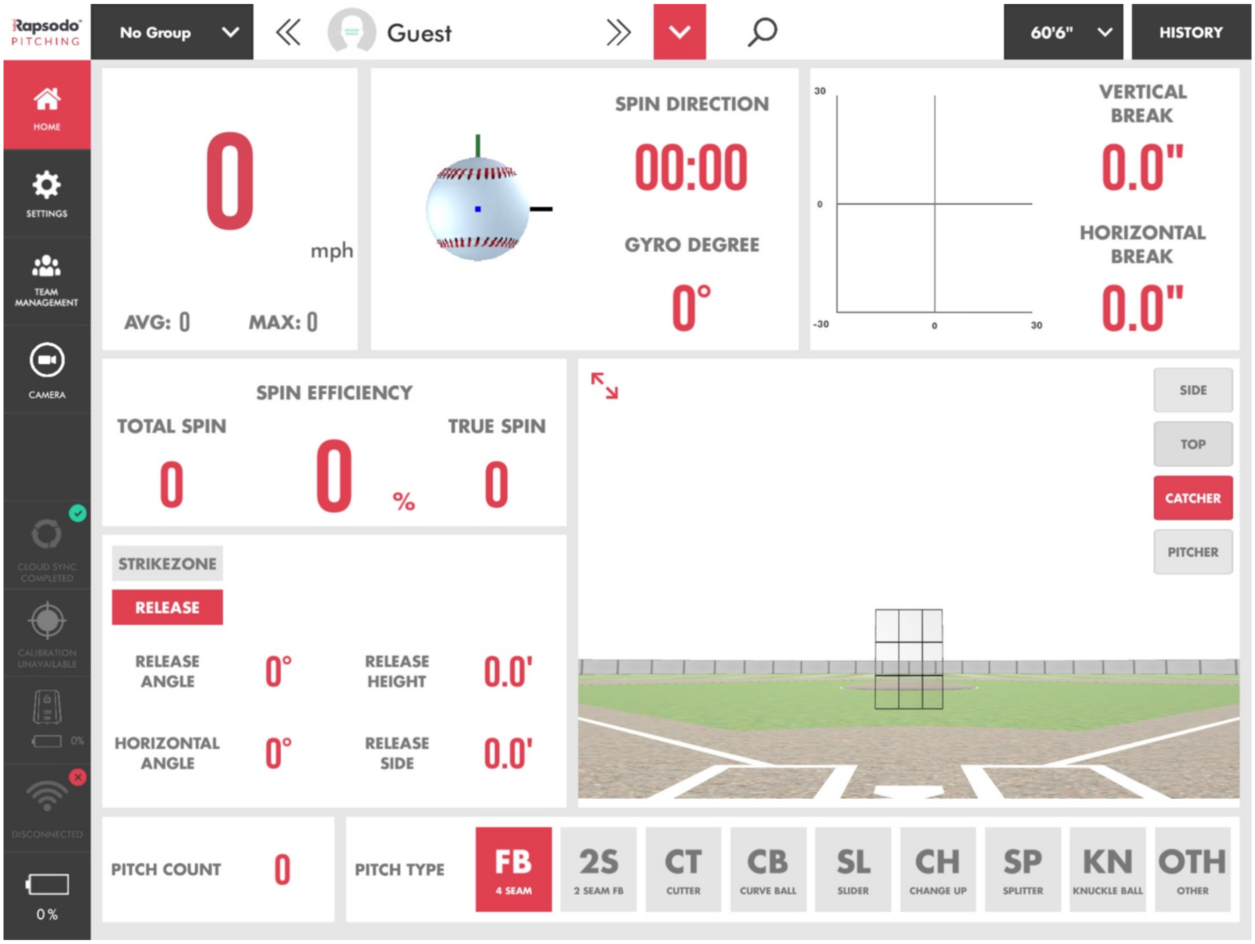

Figure 3. The Rapsodo interface before a ball is thrown in front of it.

V. Methodology

a) A Note About the Pitcher

For the experiment I enlisted the help of my friend Cody Smith, who pitches in college. We determined that due to the number of pitches he would have to throw, he would not throw to his full velocity and risk injury. He threw about 75% of his full potential with the goal being to create the proper spin on his pitches. Spin rate and velocity are relative to each other, therefore the relationship between Cody's spin and break would remain consistent throughout all the added sticky substances and any conclusions could be applied accurately. If the velocity was increased, his spin rate and break would proportionally increase as well.

b) Materials

i. Pitch Types

Two different types of pitches were thrown in the experiment: Fastball and Slider. The purpose of this was to cover the "straightest" pitch and a pitch with sideways movement. The fastball is the most standard pitch, with a mostly straight trajectory (pitcher dependent). The pitcher flicks his or her wrist creating backspin. The slider curves to the side with more horizontal movement than vertical movement. When throwing a slider, the pitcher keeps a more rigid wrist, cutting the ball across and creating more sideways rotation (Appendix B).

ii. Substances

A game-prepared Major League ball is rubbed with special mud from a top-secret area along a portion of the Delaware river (Apstein & Prewitt, 2021). This is due to the especially slick nature of a brand-new ball. Other than the already-applied mud, the only legal substance for pitchers to use to get a better grip on the ball is rosin, a natural substance derived from fir-tree sap. For the experiment, we prepared over a dozen baseballs with the Delaware mud and divided them up for use between each of the 4 substances being tested. Both no substance and rosin by itself are legal in baseball, but the rosin and sunscreen combo and Spider Tack are both illegal substances.

Null:

For the null, the baseball was pre-rubbed with only the special mud. This is the slickest a baseball will be in a game for the pitcher. Using no other substance on the pre-prepared ball is legal according to the rulebook.

Rosin:

For the pitches thrown using rosin only, the ball was still rubbed with mud beforehand. Then the rosin was reapplied to the pitcher's fingers every 2 pitches to his liking. The purpose of rosin, which is a legal substance, is to give the pitchers a little extra grip to prevent them from losing their hold and accidentally throwing at a batter's head.

Rosin and Sunscreen Mixture:

Pre-prepared with mud, the rosin and sunscreen mixture was re-applied every 2 pitches to the pitcher's liking, and his hand was cleaned before each application. The sunscreen was applied to the wrist while the rosin was applied to the throwing hand. Then the pitcher mixed the substances on his wrist to make it sticky. This mixture ends up pretty sticky, which drastically improves the grip. Making a mixture like this is illegal and faces suspension now with the ban.

Spider Tack:

Balls that were thrown with Spider Tack were also pre-prepared with mud. Spider tack is a scientifically engineered adhesive meant for gripping atlas stones in heavy lifting competitions (Apstein & Prewitt, 2021). The people working on the substance even used tracking technology to check that it truly gave them an edge. Spider Tack creates a ripping sound when coming off the pitchers' fingers. It is so sticky that it is possible to lift a baseball with the palm of your hand, and advertisements for the substance show a man lifting a cinderblock with his palm (Apstein & Prewitt, 2021). Due to its especially sticky nature, Spider Tack is illegal to use in the MLB. The substance was reapplied every 2 pitches, and the pitcher's hand was thoroughly cleaned between applications.

iii. Data Points

While pitch tracking technology can collect a bunch of data points per pitch, this experiment focused solely on spin rate, horizontal movement, and vertical movement. The purpose was to look at the correlation between spin rate and the total movement. Spin rate was measured for both fastballs and sliders. Vertical movement was measured for fastballs which are more up-and-down pitches, whereas horizontal movement was collected for sliders, which are sideways moving pitches. The vertical movement does not consider the downwards angle that the pitcher throws at nor does it account for gravity. The spin rate was measured in revolutions per minute, and the horizontal and vertical movement was measured in inches.

c) Experiment

For the data collection, Cody was instructed to throw 6 fastballs with no substance first. Then he threw 6 sliders with no substance. Next, he was given a rosin bag to apply the substance to his fingers. He threw 2 fastballs before reapplying rosin to his fingers. He repeated that process until he reached 6 fastballs. Then, he threw the sliders with the rosin, again reapplied every 2 pitches. The same process was used for the next substances. For the rosin and sunscreen mixture, Cody sprayed sunscreen on his wrist before patting his hand on the rosin bag. He would then touch his rosin coated fingers to his wrist to mix them and create the sticky substance. The reapplication process included both spraying more sunscreen and using the rosin bag. Cody's hand was cleaned each time before reapplying the substances. Spider Tack was applied to Cody's fingers straight from the container (as opposed to the in-game version of hiding it on his glove). To maintain consistency, for the two illegal sticky substances, Cody thoroughly cleaned his hand with Vaseline and peroxide before reapplying the substance. To preserve Cody's arm and not exceed the standard number of pitches he would throw in baseball practice, he only threw 6 pitches per substance per pitch type each session. In total, we had 5 sessions of data collecting.

VI. Results

The average spin rate for the fastballs was expected to increase with each sticky substance. The null average spin rate was 1605.96 rpms, the rosin average spin rate was 1633.94 rpms, the rosin and sunscreen average spin rate was 1689.68 rpms, and Spider Tack had an average spin rate of 1789.03 rpms. The standard error bars were small, so the data was statistically significant.

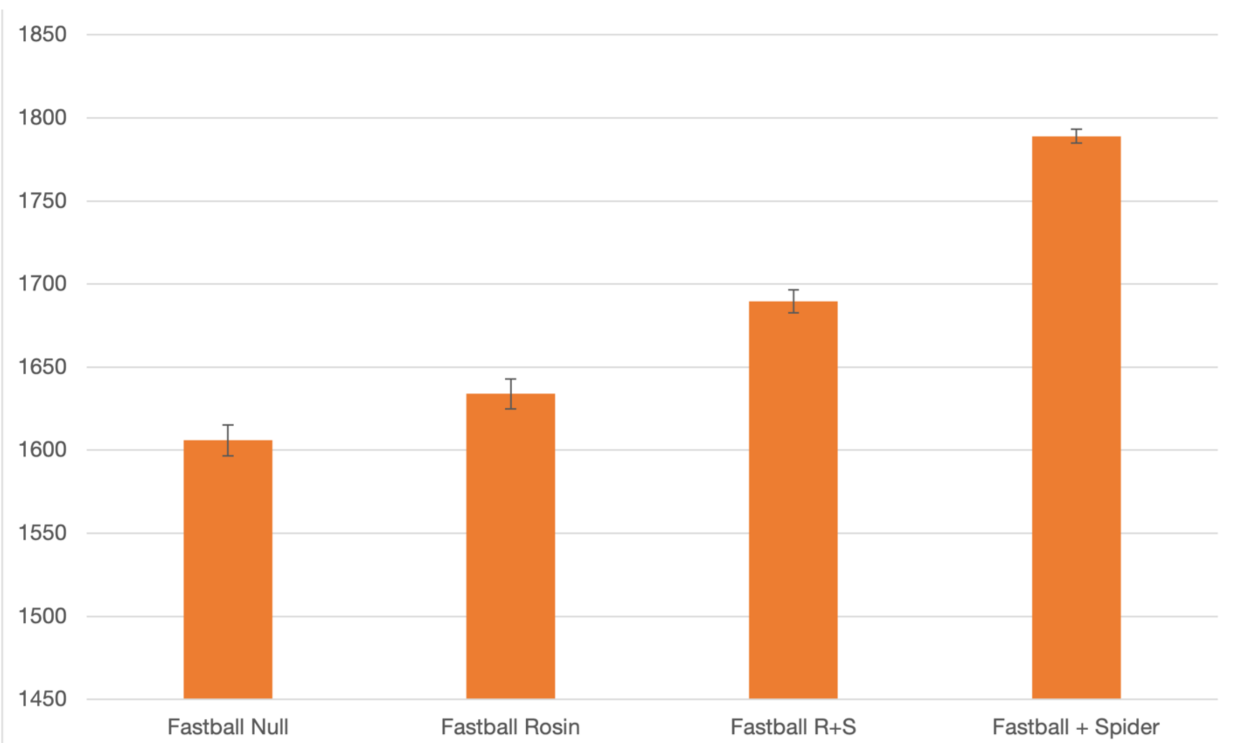

Figure 4. Average fastball spin rate of each substance with standard error of the mean bars. Calculated in revolutions per minute (rpms).

The average spin rate for sliders was expected to increase with each sticky substance. The average spin rate for the null was 1754.23 rpms, the average spin rate for rosin was 1753.09 rpms, the average spin rate for the rosin and sunscreen combo was 1736.06 rpms, and the average spin rate for Spider Tack was 1824.03 rpms. While the data was statistically significant, only Spider Tack was consistent with the expect outcomes.

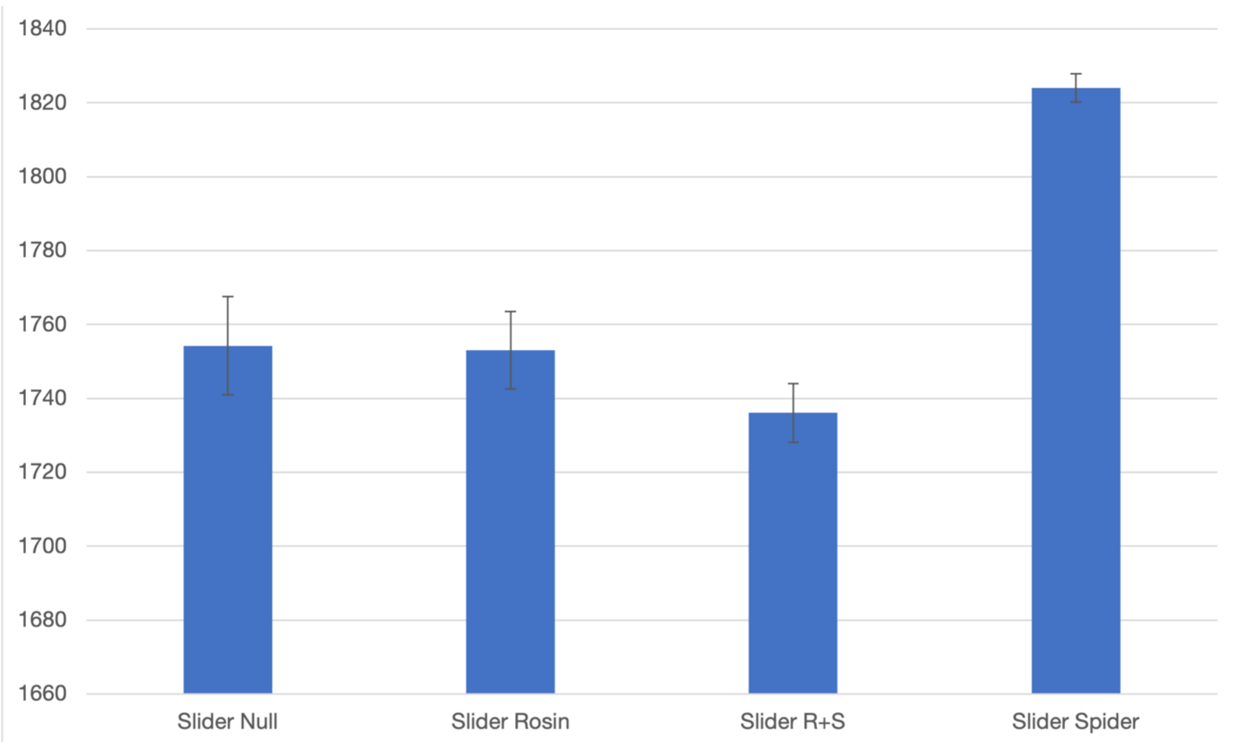

Figure 5. Average slider spin rate of each substance with standard error of the mean bars. Calculated in revolutions per minute (rpms).

The average vertical break for fastballs was expected to decrease with each substance as the increased spin rate would force the ball to "lift" or n oppose gravity. While the averages were mostly consistent with expected outcomes, the data was not statistically significant. The error bars (standard error of the mean) were very large, meaning that many of the pitches, regardless of which sticky substance they were thrown with, fell within the same range of induced vertical break measurements. With no substance, the average vertical break was 12.53 inches, the rosin average vertical break was 12.17 inches, the rosin and sunscreen average vertical break was 12.11 inches, and the Spider Tack average vertical break was 12.30 inches. The vertical break is measured off a straight line from the release point of the ball, and gravity is calculated out. This means that the vertical break reflected only the effects of the increased spin rate.

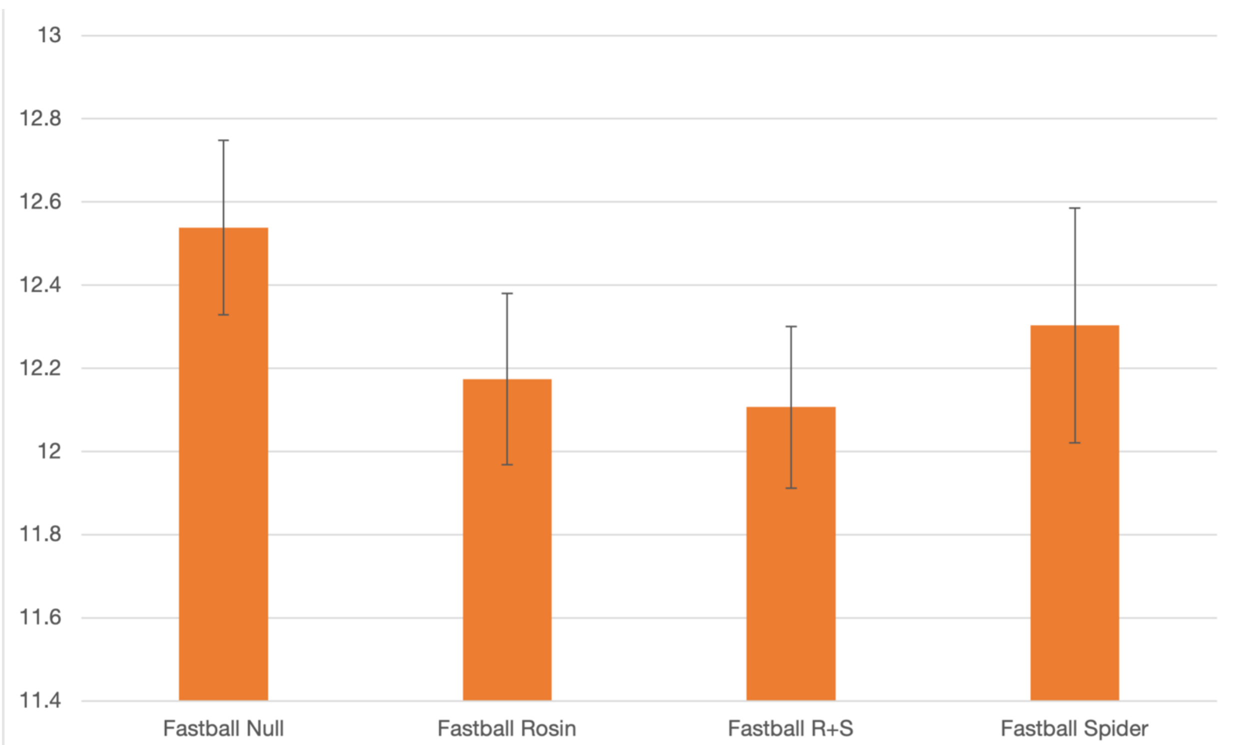

Figure 6. Average fastball vertical break of each substance with standard error of the mean bars. Calculated in inches the ball moved downwards, excluding gravity. Induced vertical break.

The expected outcome for the average horizontal break of sliders was an increase across the sticky substances. The average horizontal break for the null was 5.53 inches, the average horizontal break for the rosin was 5.37 inches, the average horizontal break for the rosin and sunscreen was 5.64 inches, and the average horizontal break for Spider Tack was 6.26 inches. While the average break for rosin decreased slightly, there was a steady increase for the other two illegal sticky substances. With small standard error of the mean bars, the data was statistically significant.

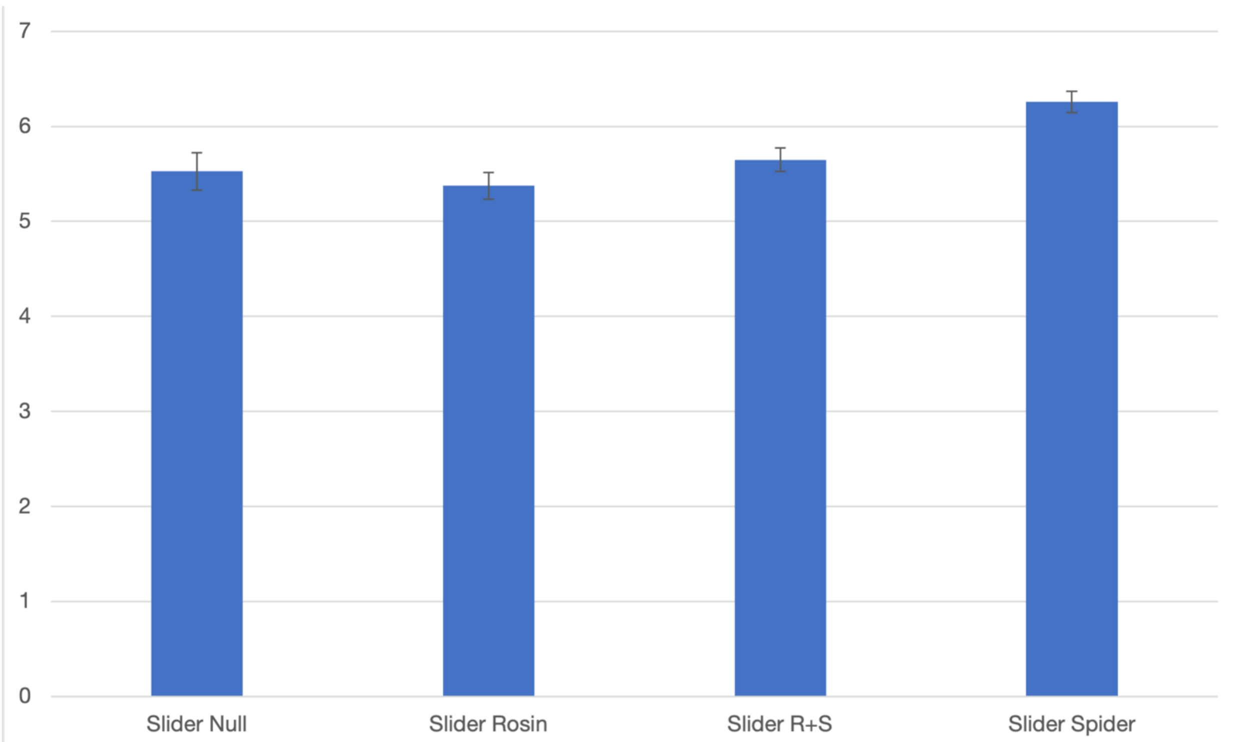

Figure 7. Average slider horizontal break of each substance with standard error of the mean bars. Calculated in inches the ball moved leftwards due to right-handed pitcher.

The expected outcome for the ratio of average vertical break to spin rate was to decrease due to an increased spin rate that opposed gravity and created a slight upwards movement. The purpose of the ratio of the break and spin rate was to put the two measurements in one chart for an overall understanding of the correlation between the two data points. With smaller vertical movement divided by a larger increasing spin rate, the trend of the chart should decrease with each sticky substance. The units of measurement for the data was inches divided by rpms. The null output was 7.81E-03, the rosin output was 7.46E-03, the rosin and sunscreen mixture output was 7.17E-03, and the Spider Tack output was 6.88E-03. The overall trend was consistent with the expected descreasing outcome, and was statistically significant. This showed that the substances were creating higher spin rate and more movement.

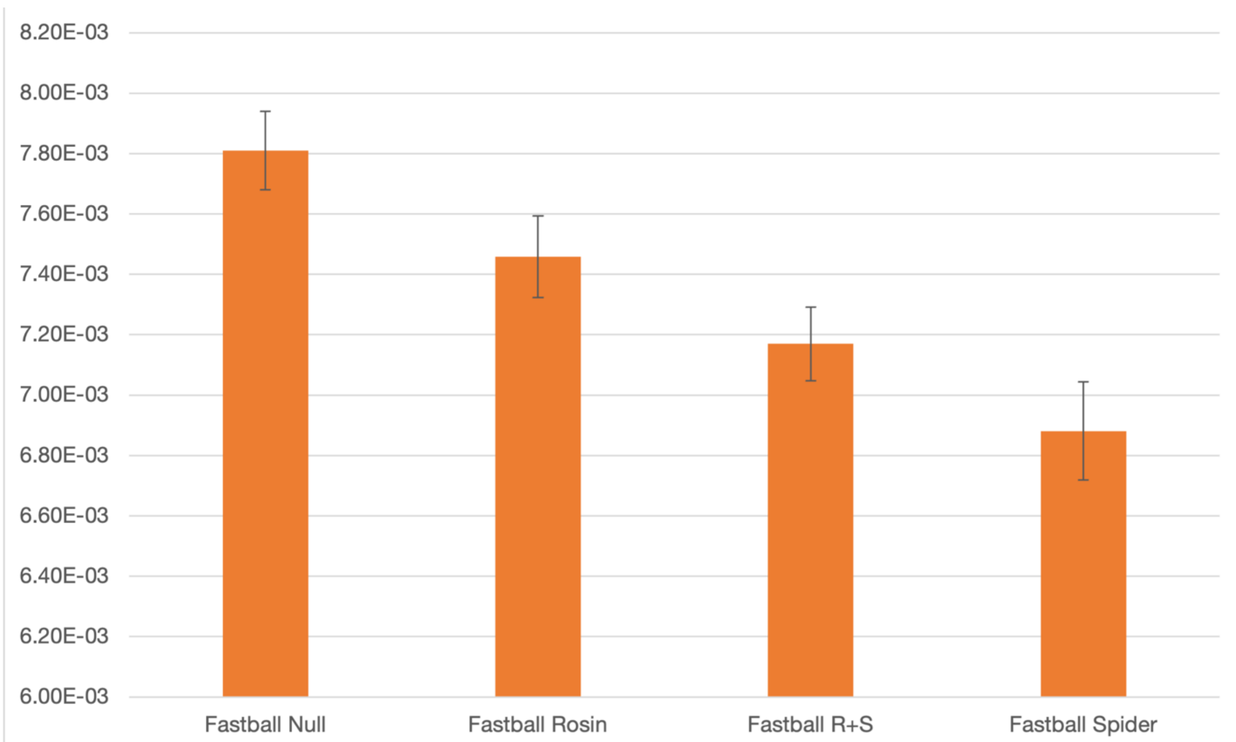

Figure 8. Ratio of average fastball vertical break divided by spin rate of each substance with standard error of the mean bars. Relates the vertical movement to the spin rate. Calculated in inches divided by rpms.

The expected outcome of the chart was to remain the same or increase due to the increased spin rate. By putting the horizontal break and spin rate together, it is possible to see the correlation between the two data points. With larger horizontal movement divided by larger spin rate, the ratio should have been equal or increase with each sticky substance. The chart showed an increase in the ratios as the sticky substances were added. The units of measurement were inches divided by rpms. While there was a decrease between the null and rosin, there was a statistically significant increase between the other substances. The null produced a ratio output of 3.15E-03, the rosin had an output of 3.07E-03, the rosin and sunscreen output was 3.26E-03, and the Spider Tack output was 3.43E-03. The overall trend was consistent with the increasing expected outcome. This showed that the substances were causing an increased spin rate and consequently an increased horizontal break.

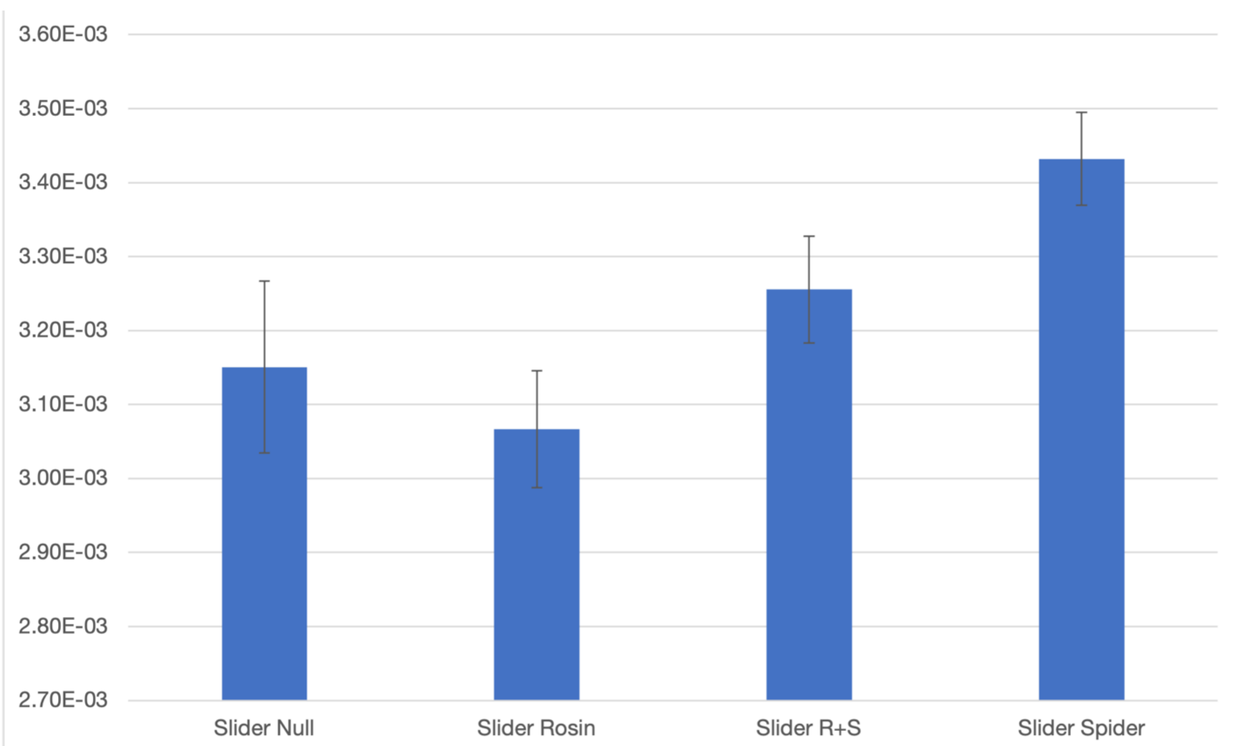

Figure 9. Ratio of average slider horizontal break divided by spin rate of each substance with standard error of the mean bars. Relates the horizontal movement to the spin. Calculated in inches divided by rpms.

VII. Discussion

Most fastball data was consistent with expected outcomes. As the substances got stickier, they caused an increase in spin rate, with optimized Spider Tack having created the largest spin rate. The fastball, the straightest pitch, is dictated by vertical movement which the tracking system calculates as induced vertical break, which ignores gravity. Data showed there was no statistically significant difference in the average vertical break alone, due to the large variation within each substance. When spin rate is increased, a smaller vertical break is expected as the high-pressure zone forces the spinning ball up to oppose gravity. While the Spider Tack fastballs had a higher average vertical break, opposite to expected outcomes, the large standard error of the mean showed that some of the pitches in the data set did fall within the expected outcomes. This would mean that if someone was asked to guess which pitches were thrown with which substances, it would be very difficult to do so correctly. Overall, the fastball data did show the unfair advantage pitchers get by using foreign substances to create higher spin rates and extra break.

Most slider data was consistent with expected outcomes. The spin rate drastically increased for Spider Tack, but the other substances did not have the expected effect off the null. The rosin appeared to make little difference in the spin rate, and the rosin and sunscreen mixture even decreased. The horizontal break chart showed a statistically significant increase across the sticky substances. Rosin did not increase the horizontal break, but the rosin and sunscreen mixture and Spider Tack did. The error bars were small which showed consistency within the substances. The ratio of horizontal break to spin rate increased, which showed that as the spin rate increased, the horizontal break also increased. The rosin ratio decreased from the null, however there was a significant increase for the other substances. The error bars were consistent except for the null which presented a larger standard error of the mean. The slider data statistically and accurately showed the unfair advantage pitchers get by using foreign substances, especially Spider Tack, to create extra break.

To further improve this experiment, more pitches should be thrown per substance to try to decrease the error bars. Additionally, it is known that fastballs can "run" meaning that they also can move slightly to the same side as the throwing arm of the pitcher. The run of a fastball has more to do with throwing mechanics rather than sticky substances, but it would be interesting to look at the effects of sticky substances on the horizontal movement of a fastball. Lastly, tracking systems like Rapsodo can calculate a data point called *spin efficiency*, which tells us what percentage of the spin is contributing to the movement of the ball. If the spin efficiency is low, the added spin rate from sticky substances may not effectively add more movement. Studying spin efficiency would help to better understand the relationship between spin rate and break once sticky substances have been added.

VIII. Conclusion

The addition of sticky substances to baseball pitches increases spin rate and movement, making the pitches harder to hit. The ban was necessary to take away the competitive advantage the pitchers received from the illegal use of foreign substances. Through this project, we saw that the fastball spin rate steadily increased with each stickier substance. The slider spin rate drastically increased with Spider Tack. While the vertical break for the fastballs mostly decreased with the foreign substances, which is the expected outcome, the error bars do not allow for the data to be statistically significant. Slider horizontal break mostly increased with the added substances with a slight drop for rosin before a steady increase. The fastball combined ratio of vertical break to spin rate decreased which was consistent with the expected outcomes. This meant that the higher spin rate was successfully causing a smaller downward break. The slider combined ratio of horizontal break to spin rate mostly increased, again consistent with the expected outcome. There was a larger sideways break as a consequence of the higher spin rate. Moving forward, the inclusion of spin efficiency into the data collection and analysis can improve the understanding of the effects of “sticky stuff” on the spin rate and break of a baseball pitch. As the pitchers adjust and batting averages begin to rise again, I am interested to see what the MLB will do to address the pitchers’ concerns about lack of grip. The MLB is currently testing a “pre-tacked” ball in the minor leagues hoping that it will increase grip but not spin rate (Associated Press, 2021). I look forward to seeing the pitching data if those balls are ever used in the major leagues.

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Appendix A

Justin Verlander throws a slider. His wrist is rigid as he "cuts" to the side of the ball, creating sideways spin.

Image: (Sullivan, 2017).

Appendix B

Expanded versions of Rule 3.01 and 6.02(c) and (d) (Anthopoulos et al., 2021).

3.00–EQUIPMENT AND UNIFORMS

3.01 The Ball

The ball shall be a sphere formed by yarn wound around a small core of cork, rubber or similar material, covered with two strips of white horsehide or cowhide, tightly stitched together. It shall weigh not less than five nor more than 5¼ ounces avoirdupois and measure not less than nine nor more than 9¼ inches in circumference.

No player shall intentionally discolor or damage the ball by rubbing it with soil, rosin, paraffin, licorice, sand-paper, emery-paper or other foreign substance.

PENALTY: The umpire shall demand the ball and remove the offender from the game. In addition, the offender shall be suspended automatically for 10 games. For rules in regard to a pitcher defacing the ball, *see* Rules 6.02(c)(2) through (6).

Rule 3.01 Comment: Should a ball come partially apart in a game, it is in play until the play is completed.

Rule 6.02

(c) **Pitching Prohibitions**

The pitcher shall not:

(1) While in the 18-foot circle surrounding the pitcher's plate, touch the ball after touching his mouth or lips, or touch his mouth or lips while he is in contact with the pitcher's plate. The pitcher must clearly wipe the fingers of his pitching hand dry before touching the ball or the pitcher's plate.

EXCEPTION: Provided it is agreed to by both managers, the umpire prior to the start of a game played in cold weather, may permit the pitcher to blow on his hand.

PENALTY: For violation of this part of this rule the umpires shall immediately remove the ball from play and issue a warning to the pitcher. Any subsequent violation shall be called a ball. However, if the pitch is made and a batter reaches first base on a hit, an error, a hit batsman or otherwise, and no other runner is put out before advancing at least one base, the play shall proceed without reference to the violation. Repeat offenders shall be subject to a fine by the Office of the Commissioner.

(2) expectorate on the ball, either hand or his glove;

(3) rub the ball on his glove, person or clothing;

(4) apply a foreign substance of any kind to the ball;

(5) deface the ball in any manner; or

(6) deliver a ball altered in a manner prescribed by Rule 6.02(c)(2) through (5) or what is called the "shine" ball, "spit" ball, "mud" ball or "emery" ball. The pitcher is allowed to rub the ball between his bare hands.

(7) Have on his person, or in his possession, any foreign substance.

Rule 6.02(c)(7) Comment: The pitcher may not attach anything to either hand, any finger or either wrist (e.g., Band-Aid, tape, Super Glue, bracelet, etc.). The umpire shall determine if such attachment is indeed a foreign substance for the purpose of Rule 6.02(c)(7), but in no case may the pitcher be allowed to pitch with such attachment to his hand, finger or wrist.

(8) Intentionally delay the game by throwing the ball to players other than the catcher, when the batter is in position, except in an attempt to retire a runner.

PENALTY: If, after warning by the umpire, such delaying action is repeated, the pitcher shall be removed from the game.

(9) Intentionally Pitch at the Batter.

If, in the umpire's judgment, such a violation occurs, the umpire may elect either to:

(A) Expel the pitcher, or the manager and the pitcher, from the game, or

(B) may warn the pitcher and the manager of both teams that another such pitch will result in the immediate expulsion of that pitcher (or a replacement) and the manager.

If, in the umpire's judgment, circumstances warrant, both teams may be officially "warned" prior to the game or at any time during the game.

(The Office of the Commissioner may take additional action under authority provided in Rule 8.04.)

Rule 6.02(c)(9) Comment: Team personnel may not come onto the playing surface to argue or dispute a warning issued under Rule 6.02(c)(9). If a manager, coach or player leaves the dugout or his position to dispute a warning, he should be warned to stop. If he continues, he is subject to ejection.

To pitch at a batter's head is unsportsmanlike and highly dangerous. It should be—and is—condemned by everybody. Umpires should act without hesitation in enforcement of this rule.

(d) *PENALTY:* For violation of any part of (c)(2) through (7):

(1) The pitcher shall be ejected immediately from the game and shall be suspended automatically. In the Minor Leagues, the automatic suspension shall be for 10 games.

(2) If a play follows the violation called by the umpire, the manager of the team at bat may advise the umpire-in-chief that he elects to accept the play. Such election shall be made immediately at the end of the play. However, if the batter reaches first base on a hit, an error, a base on balls, a hit batsman, or otherwise, and no other runner is put out before advancing at least one base, the play shall proceed without reference to the violation.

(3) Even though the team at bat elects to take the play, the violation shall be recognized and the penalties in subsection 1 will still be in effect.

(4) If the manager of the team at bat does not elect to accept the play, the umpire-in-chief shall call an automatic ball or, if there are any runners on base, a balk.

(5) The umpire shall be sole judge on whether any portion of this rule has been violated.

Rule 6.02(d)(1) through 6.02(d)(5) Comment: If a pitcher violates either Rule 6.02(c)(2) or Rule 6.02(c)(3) and, in the judgment of the umpire, the pitcher did not intend, by his act, to alter the characteristics of a pitched ball, then the umpire may, in his discretion, warn the pitcher in lieu of applying the penalty set forth for violations of Rules 6.02(c)(2) through 6.02(c)(6). If the pitcher persists in violating either of those Rules, however, the umpire should then apply the penalty.

Rule 6.02(d) Comment: If at any time the ball hits the rosin bag it is in play. In the case of rain or wet field, the umpire may instruct the pitcher to carry the rosin bag in his hip pocket. A pitcher may use the rosin bag for the purpose of applying rosin to his bare hand or hands. Neither the pitcher nor any other player shall dust the ball with the rosin bag; neither shall the pitcher nor any other player be permitted to apply rosin from the bag to his glove or dust any part of his uniform with the rosin bag.

Appendix C

Example of data sheet for the null fastball (no substance). Velocity was to make sure Cody was not throwing wildly different speeds. We also tracked whether the pitch he threw was a strike (S) or a ball (B).

Pitch Type	Velocity	Spin Rate	Vertical	S/B
Fastball	59.6	1583	13.4	S
Fastball	58	1543	14.3	S
Fastball	61.2	1592	12.6	B
Fastball	60.2	1586	12.4	S
Fastball	59.6	1567	13.5	B
Fastball	57.8	1748	14.6	B
Fastball	60.9	1974	14.3	S
Fastball	61.4	2001	15.6	B
Fastball	59.5	1578	11.6	B
Fastball	60	1566	13.5	B
Fastball	58.8	1688	12.9	S
Fastball	61	1598	13.6	B
Fastball	62.2	1601	12.3	S
Fastball	56.7	1589	10.3	S
Fastball	55.9	1603	11.4	S

Fastball	59.6	1623	12.5	S
Fastball	59.8	1566	13.2	S
Fastball	58.5	1586	12.3	B
Fastball	58.5	1687	11.7	S
Fastball	61.2	1599	14.6	S
Fastball	58.9	1578	12.5	S
Fastball	59	1605	11.8	B
Fastball	59	1688	13.7	B
Fastball	60.3	1655	12.4	B
Fastball	57.7	1595	11.2	S
Fastball	58.6	1602	13.4	B
Fastball	58.6	1698	12.4	S
Fastball	59.4	1554	11.8	S
Fastball	58.3	1567	12.2	B
Fastball	58.8	1584	10.4	S
Fastball	56.3	1544	11.1	S

Example of a slider data sheet for balls thrown with Spider Tack. Velocity was to make sure Cody was not throwing wildly different speeds. We also tracked whether the pitch he threw was a strike (S) or a ball (B).

Pitch Type	Velocity	Spin Rate	Horizontal	S/B
Slider	58.7	1790	7.3	S

Slider	56.7	1801	6.5	S
Slider	57.4	1804	7.1	B
Slider	56.8	1789	5.6	B
Slider	58.9	1798	5.4	B
Slider	59	1799	6.6	S
Slider	56.7	1803	6.6	S
Slider	57.4	1822	6.7	B
Slider	55.3	1814	6.9	S
Slider	56.8	1816	6.3	B
Slider	58.1	1836	6.8	S
Slider	57.6	1833	7.3	S
Slider	57.6	1821	6.5	S
Slider	56.2	1829	6.4	S
Slider	57.9	1812	6.1	B
Slider	54.3	1818	6.3	B
Slider	56.1	1834	6.7	B
Slider	57.2	1826	5.9	B
Slider	56.8	1822	6.1	S
Slider	55.5	1802	5.8	S
Slider	55.9	1808	5.7	S
Slider	56.7	1824	6.4	S
Slider	58.1	1834	6.6	B
Slider	56.3	1856	6.5	S

Slider	55	1844	5.7	B
Slider	57.2	1836	5.3	S
Slider	58.2	1855	4.3	S
Slider	56.2	1841	6.1	S
Slider	56.8	1864	6.2	B
Slider	58.4	1852	5.9	B
Slider	57.1	1862	6.4	S