Changing the Major League Baseball: A Whole New Ballgame

Baseball
1548715

1. Introduction

(NOTE: Much of the work presented here was first published in *The Athletic*.[1,2,3,4])

Major League Baseball (MLB) has a long and storied history, going back 150 years. In that time, the ball has changed—sometimes dramatically, often inexplicably—often leading to increased or decreased offense.[5] However, over the last five years we have seen a veritable epidemic of baseball changes, breaking records and introducing an unprecedented level of unpredictability.

Beginning in the second half of the 2015 season, home run rates began to rise, hitting an all-time high in 2017. This same period saw a rash of pitcher blisters—no small matter, as MLB rules consider a blister an injury, requiring a player to go on the Injured List.[i] After a small drop-off in home runs in 2018, a new ball was introduced in 2019 that produced even more offense, topping the 2017 home run record by 11%. 2019 also marked the first year that the Major League baseball was used in Triple-A, where the change was so dramatic that home runs increased by 60%. Then, at the start of the 2019 MLB postseason, the ball changed again—this time deadened, producing a sudden drop in offense.

Three changes in the last five seasons is, to say the least, uncharacteristic. In addition, two of those changes resulted in record-breaking home runs, and two occurred within one calendar year. In this paper, I examine baseballs from four time periods—pre-2014, 2016-2018, the 2019 regular season, and the 2019 postseason—in order to determine the physical characteristics unique to each. I offer hypotheses as to the sources of these differences and how they may have impacted offense. Sections 2-4 consider the 2017 Home Run Surge, the 2019 Regular Season Ball, and the 2019 Postseason; Section 5 discusses MLB's response; and Section 6 considers the current state of affairs and the necessary changes going forward.

2. The 2017 Home Run Surge

Home runs have always varied season-to-season. Before 2015, the most noticeable increase occurred during the first two years of the "Steroid Era," after which home run rates leveled off and even dropped, with 2014 producing the fewest home runs since 1993 (Figure 1). However, halfway through the 2015 season, home run rates began to increase dramatically, peaking in 2017.

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[i] This was known as the Disabled List until the beginning of the 2019 regular season.

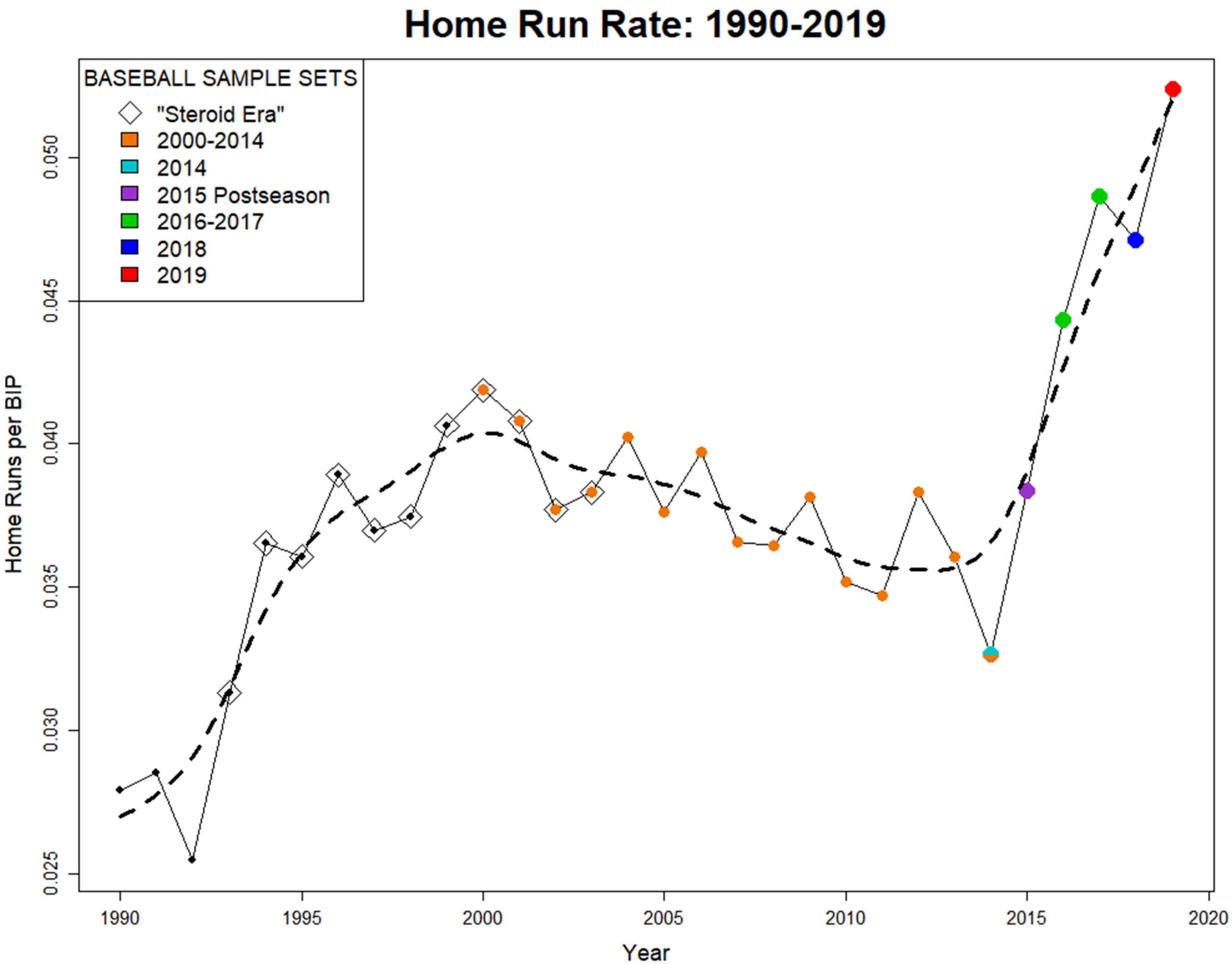

Figure 1: Regular season home runs per ball-in-play (BIP) from 1990 through 2019. A BIP is defined as an at-bat that did not result in a strikeout. For comparison, the "Steroid Era" years are marked with diamonds. For years with colored points, the colors correspond to a given sample. Note that 2014 appears in two samples.

At the time, a number of theories were considered as possible explanations of or contributors to the Home Run Surge. These included a resurgence of performance-enhancing drugs,[6] changes in hitting approach,[7] higher exit velocities,[8] decreased drag,[9] and even climate change.[10]

In response to these questions, MLB commissioned a scientific committee to determine the cause(s) of the Home Run Surge. In their 83-page report, the committee found that the increase in home runs was the result of a ball with a lower drag coefficient.[11] However, they were unable to find a physical difference that could account for this change.

2.1. Changes to the Ball

Contemporaneous to the work of MLB's Home Run Committee, I considered the construction of the baseball itself, hypothesizing that that pre-2015 balls were structurally different than those from 2016-2017.

2.1.1. Data and Methodology

To gather my data, I systematically disassembled two populations of baseballs—twelve from 2014 and fourteen from 2016-2017. A Major League baseball is made up of a core ("pill") surrounded by five layers: an inner layer of thick grey yarn; a middle layer of white yarn; an outer layer of thin grey yarn; a thin layer of cotton thread; and a leather cover. The cotton thread is held in place by glue, while the two pieces of the leather cover are stitched together by red laces (Figure 2).

Figure 2: An intact Major League baseball as compared to its structural components. These consist of a core ("pill"), three layers of yarn, a layer of cotton thread, and two leather covers stitched in place by red cotton laces.

I removed the leather covers by unstitching the laces, rather than cutting them. I then cut away the cotton thread layer (as the glue made unwinding the thread untenable), carefully unwound and separated the three yarn layers, and removed the pill. The goal was to keep the construction materials as intact as possible, so they could be measured and compared. I recorded sixteen independent variables, including the weight, size, and length of different components (Figure 3).

2.1.2. Findings

For the most part, the findings were consistent with those presented in the official MLB report. While some individual components showed a wide scatter, there were no statistically significant differences between the 2014 balls and the 2016-2017 balls for fifteen of the sixteen variables. The exception was the red cotton laces; those used to stitch the seams on the 2016-2017 balls were 9.0% thicker than those on the 2014 balls.

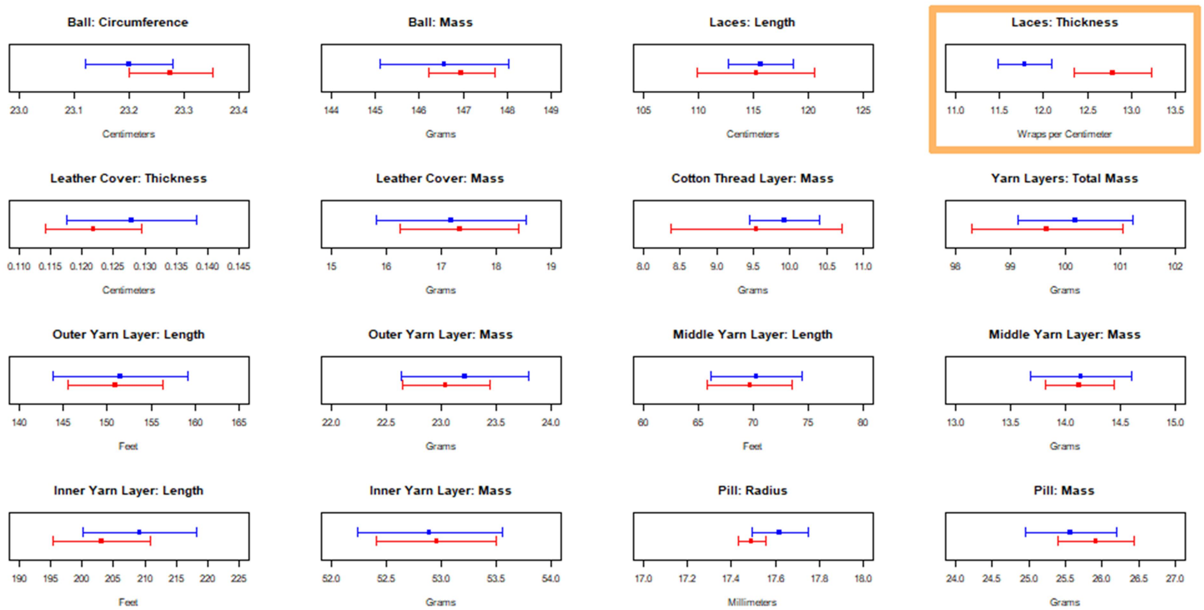

Figure 3: Comparison of sixteen independent structural parameters. Measurements in red are from the 2014 sample. Measurements in blue are from the 2-016-2017 sample. Uncertainties are one standard deviation. The plot at the upper right (highlighted in yellow) compares the thickness of the red cotton laces, and is the only parameter showing a statistically-significant difference.

Lace thickness was measured using a variation on the "Wraps per Inch" method commonly found in fiber arts. Since the laces are so thin, measurements here were done in "Wraps per Centimeter." Figure 4 shows that the laces from a 2014 ball wrap 40 times over 3 cm, whereas the 2017 laces wrap 36 times over 3 cm. As the units for "Wraps per Centimeter" are 1/length, thicker laces will produce a lower value. Therefore, 2014 baseballs have laces with a thickness of 0.78±0.030mm, while 2017 laces are 0.85±0.023mm thick.

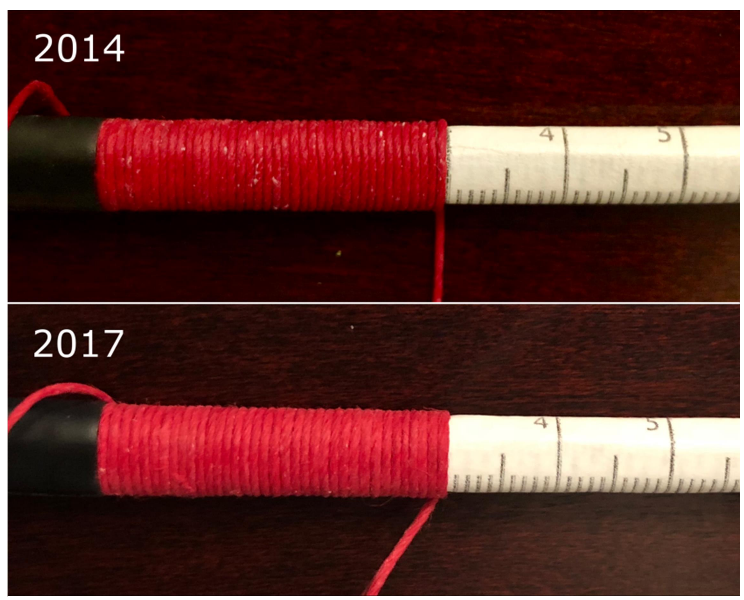

Figure 4: Comparison of lace thickness measurements from a 2014 ball and a 2017 ball. The laces from the 2014 ball wrap 40 times over 3 cm, while those from the 2017 ball wrap 36 times over 3 cm.

2.2. Effect on Pitchers

A likely consequence of thicker laces may be the "epidemic" of pitcher blisters that occurred during 2016-2018.[12] Increased lace thickness will produce slightly prouder stitches, creating a "bumpier" seam. Since blisters are often associated with tightly gripping or rubbing the seams, the rougher texture could be a strong factor in higher blister rates.

2.3. Effect on Aerodynamics

In its report and executive summary, the Home Run Committee considered which properties of the baseball might affect drag. Two were measured directly:

- Smaller size
- Lower seam height

However, neither was sufficiently different to account for increased carry. Therefore, the committee postulated three additional, as-yet-unmeasured sources:

- Smoother leather covers
- A more centered core (or "pill")
- Greater spherical symmetry (i.e. a rounder ball)

Based on my structural findings, I postulated that thicker laces might lead to a more spherically symmetric ball. This stemmed from the idea that the "weak point" on a baseball is along the seams, and therefore the most dramatic deviations from spherical symmetry should occur there. Since thinner laces have lower tensile strength, they are more likely to stretch and produce greater "seam bulging." Conversely, thicker laces would lead to less bulging, resulting in a more spherical ball.

2.3.1. Data and Methodology

I again examined two samples of baseballs—twenty from the 2000-2014 seasons and twelve from April-May 2018. Using calipers, I measured each ball's diameter at five points (Figure 5).

I measured across the center at the four widest leather sections and between the narrow strips perpendicular to those sections, and considered the mean as the ball's "average diameter." Since the seams are raised relative to rest of the ball, actual seam-to-seam diameters wouldn't provide a viable basis for comparison. Instead, I measured diameters within ~2mm of the seams on each end and took the average (the "seam-adjacent diameter".) A baseball with bulging seams would have a seam-adjacent diameter greater than the average diameter.

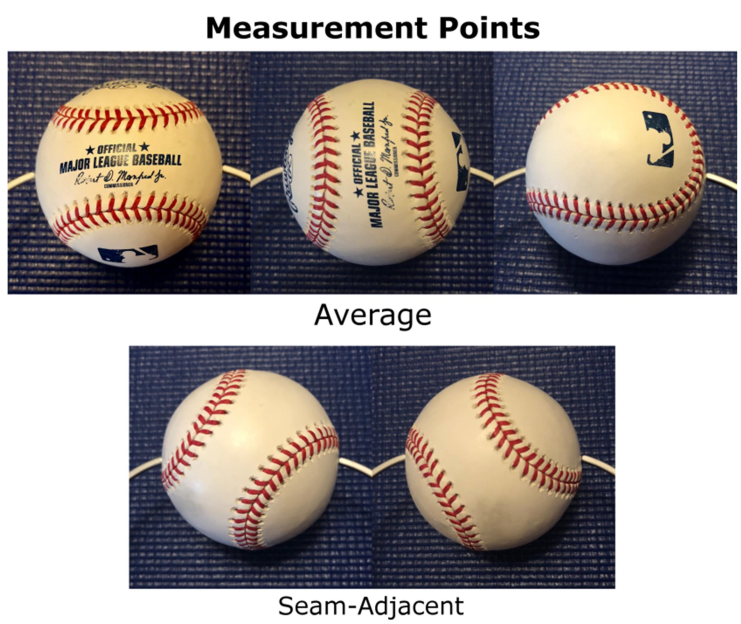

Figure 5: Location of the measurement points used to determine "seam bulging" and infer spherical symmetry. The top row demonstrates "average diameter", while the bottom shows "seam-adjacent diameter."

While less technologically-intensive, this method is not dissimilar from that used by Kensrud et al. (2015) to measure roundness and effective seam height.[13]

2.3.2. Findings

Figure 6 shows the difference between each baseball's average diameter and its seam-adjacent diameter. Since every baseball is a slightly different size, I compared percentage differences rather than absolute ones. The blue lines indicate instances where seam-adjacent diameter exceeded average diameter (and thus deformed farther from spherical symmetry), while the red lines show the reverse.

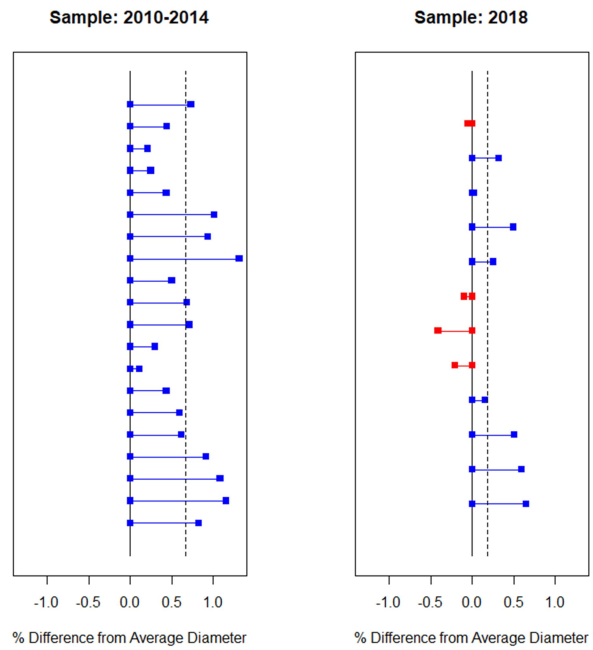

Figure 6: Percentage difference between average and seam-adjacent diameter, separated by population. Blue indicates a ball with greater seam-adjacent diameter. Note that all pre-2015 balls show bulging at the seams.

All of the 2000-2014 baseballs had greater diameters near the seams, with an average difference of 0.66% (~0.5mm). While those in the 2018 sample also showed a larger average seam-adjacent diameter, it was less pronounced (0.19%, or roughly ~0.15mm) and not systematic. These findings suggest that balls made after 2015 had less bulging at the seams, hence greater spherical symmetry and lower drag.

Since each baseball is made by hand and the diameters often vary by several millimeters from ball to ball, one would expect significant variability in the differences between average and seam-adjacent diameters. Therefore, this trend was not enough to provide a definitive conclusion. However, the fact that the entire pre-2015 sample showed bulging was telling.

2.4. Reason for the Change

The structural differences between the pre-2015 ball and the late 2015-2018 ball are remarkably subtle. While 9% is a noticeable increase in lace thickness, a change of 0.07mm is difficult to pick up visually. It is quite possible that Rawlings contracted with a different laces supplier without even being aware of the increased thickness. The very fact that the balls were introduced mid-season suggests that Rawlings did not anticipate any changes.

Even if Rawlings was aware of the thicker laces, it is unlikely they would have predicted an *increase* in home runs. Lace thickness is generally—and mistakenly—conflated with seam height, which is actually dependent on the fit and pliability of the leather covers. Working under that assumption, thicker laces would be expected to increase drag and decrease home runs.

However, the nature of the pre-2019 manufacturing process made it easier for thicker laces to preserve spherical symmetry. According to the Home Run Committee Report, the leather covers were moistened prior to being stitched in place, and afterwards the still-damp baseballs were "rolled between grooved wooden platens…to flatten the seams and maintain a spherical shape." This suggests that, during construction, the wet leather dampened the red cotton laces. Unlike wet wool, which—regardless of stretching—generally returns to its original dimensions, air-dried cotton does not "spring back." This means that wet cotton dried under tension will remain stretched. Since thicker laces have greater tensile strength, one would expect late-2015 – 2018 laces to stretch less under those conditions, mitigating deformation and resulting in a more spherically symmetric ball.

In short, the change that produced the 2017 Home Run Surge was probably unintentional.

3. The 2019 Regular Season Ball

At the start of the 2019 regular season, the ball changed again, and home runs skyrocketed (almost literally). However, unlike the late-2105 – 2018 ball, this change was sudden and dramatic. Not only was decreased drag observable within the first week,[14] but players reported that the ball felt different. The most noticeable changes were lower seams and leather so smooth that the mud used to "rub up" the balls before a game didn't stick.

As seam height and leather smoothness had already been cited as properties that effect drag, I examined four aspects of the 2019 ball—size, leather smoothness, seam height, and spherical symmetry—to see if those structural elements had changed in a way that would improve aerodynamics.[ii] Since it was a primary contributor to the 2017 Home Run Surge, I also considered lace thickness.

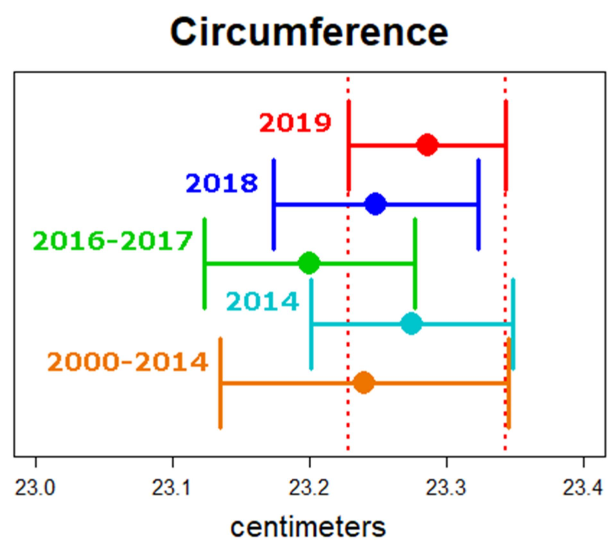

Figure 7: Average baseball circumference in cm for samples from 2000-2014, 2014, 2016-2017, 2018, and 2019. Uncertainties are one standard deviation, with the 2019 uncertainties extended as dotted lines to emphasize possible statistical significance. Note that no population shows a meaningful size difference.

[ii] Although pill-centeredness was also suggested by the committee, I did not have access to appropriate measuring equipment, and so did not include it in this study. However, since the completion of this initial research, the validity of pill-centeredness as affecting drag has been disproven.[15]

3.1. Data

I examined a population of 39 balls from the 2019 regular season, comparing my findings to samples used for the 2017 Home Run Surge research: 12 balls from 2014, 14 balls from 2016-17, 12 balls from 2018, and 20 balls from 2000-2014. In addition, I expanded my 2018 sample by six and added a 12-ball sample from the 2015 postseason. As a result, my complete pre-2019 data sets consist of 32 balls from before 2015 (13 with known years) and 44 late-2015 – 2018 balls.

3.2. Methods and Findings

3.2.1. Size

MLB's official rules state the dimensions of the baseball must "measure not less than nine nor more than 9 ¼ inches (between 22.9 and 23.5 centimeters) in circumference." Since a smaller ball would lead to lower drag, I measured the 2019 baseballs and compared their circumferences to samples from previous seasons. My results were similar to those of the Home Run Committee, in that I could find no systematic difference. If anything, the 2019 ball seemed slightly larger, although with such broad ball-to-ball variation that any systematic change would be indistinguishable. (Figure 7)

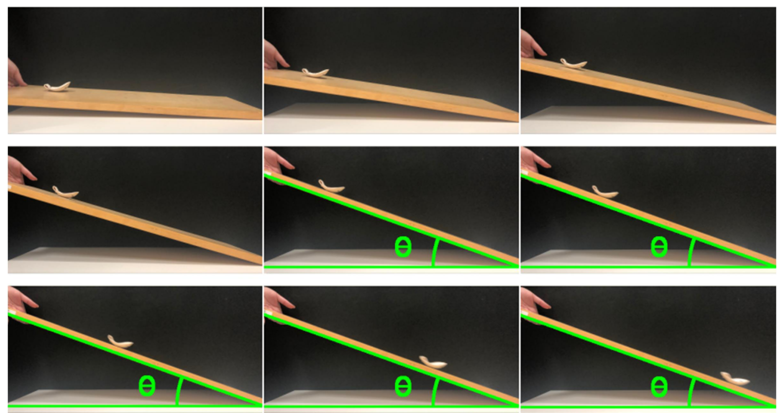

Figure 8: A demonstration of the method used to measure the coefficient of static friction. When the correct angle is reached, the folded leather cover slides down the board.

3.2.2. Leather Smoothness

Since absolute smoothness is difficult to quantify without advanced technology, I measured the coefficient of static friction ($\mu_s = tan\theta$) as a proxy for relative smoothness. Since the majority of balls were either unused or from batting practice, this meant the samples were generally unaffected by umpire-applied mud. However, some baseballs were eliminated due either to scuffs or excessive puckering. (In cases where covers are glued down very tightly, it is difficult to remove them without affecting surface texture.)

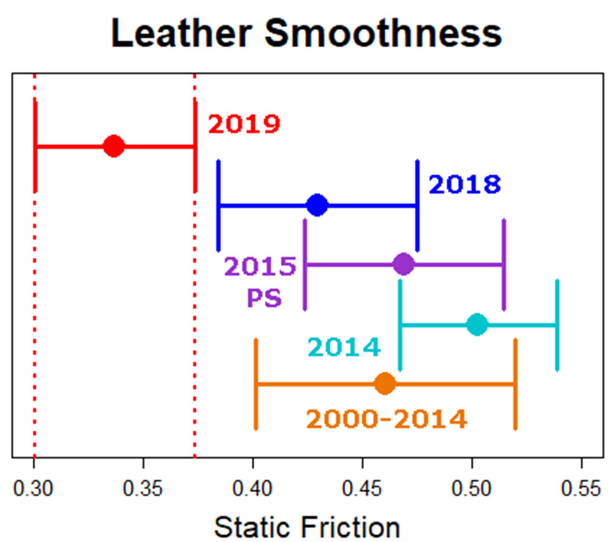

Figure 9: Average coefficient of static friction for samples from 2000-2014, 2014, the 2015 postseason, 2018, and 2019. Uncertainties are one standard deviation, with the 2019 uncertainties extended as dotted lines to emphasize possible statistical significance. Note that the coefficient of static friction for the 2019 population is significantly lower.

To ensure a uniform shape, each cover was folded in half, with the two sides held together by neodymium magnets. Each folded cover was placed on a piece of laminated pressboard, one end of which was raised until the cover began to slide. The height of the raised end of the board was then recorded. To keep the motion as uniform as possible, the board was moved along and against two laminated surfaces, with microfiber towels placed at each end (Figure 8).

Up through 2018, the baseballs showed the sort of ball-to-ball variation expected from a handmade construction process. However, the coefficient of static friction for the 2019 balls was 27.6% lower, a statistically significant result. This finding is consistent with smoother leather and therefore might contribute to a lower drag coefficient (Figure 9).

3.2.3. Seam Height

To find seam height, I used digital calipers to measure first the average thickness of each leather cover and then the average thickness at its edges. Because the interior surface of each cover is smooth (i.e. the seams do not protrude inward), the difference between these two thicknesses constitutes the seam height (Figure 10). With this method, I determined seam heights for five of my samples: 2000-2014, 2014, 2015 postseason, 2018 and 2019. As each ball has two covers, this gave me twice the number of data points.

Figure 10: A visual comparison of seam height from a 2018 ball and a 2019 ball.

For the period of 2000-2018, my findings tallied with those of the Home Run Committee, in that seam height showed no meaningful or consistent seasonal change. However, the seams on the 2019 balls were only 54.6% ± 15.0% that of the average from previous seasons (Figure 11). While these data cannot measure the extent of the effect, it is likely that lower seams would improve aerodynamics. These results were also consistent with anecdotal pitcher observations.

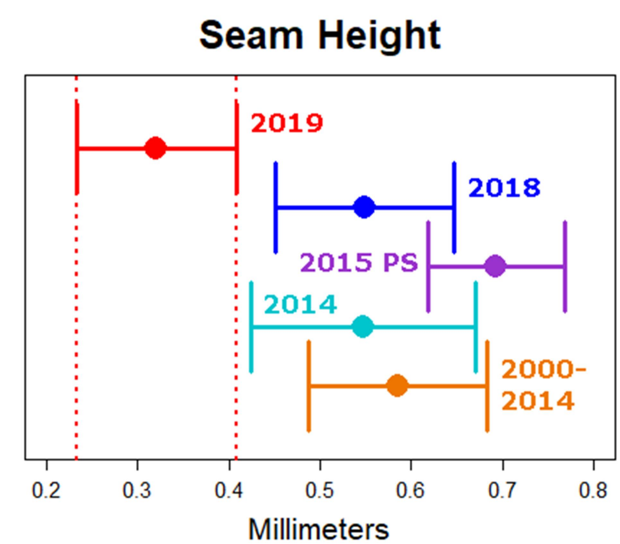

Figure 11: Average seam height in mm for samples from 2000-2014, 2014, the 2015 postseason, 2018, and 2019. Uncertainties are one standard deviation, with the 2019 uncertainties extended as dotted lines to emphasize possible statistical significance. Note that the seam height for the 2019 population is significantly lower.

3.2.4. Roundness

Using the same techniques as for the previous Home Run Surge, I measured seam bulging on the 2019 population and compared them to previous findings. I also added six balls to my 2018 sample.

While the 2000-2014 balls showed average bulging of 0.66% ± 0.34% and the updated 2018 population showed 0.28% ± 0.33%, those from 2019 deviated from spherical by only -0.04% ± 0.31%. Not only were the 2019 balls virtually round, what bulging they did show was slightly negative, suggesting that some seams could be slightly "embedded" in the leather. In addition, this change, though only a trend when compared to the 2018 sample, showed statistical significance when compared with 2000-2014 (Figure 12).

Here, the effect on aerodynamics could actually be two-fold. Not only were the balls rounder, but "embedded" seams might decrease the impact of the already-lower seam height. This double-whammy could produce a ball that traveled even farther.

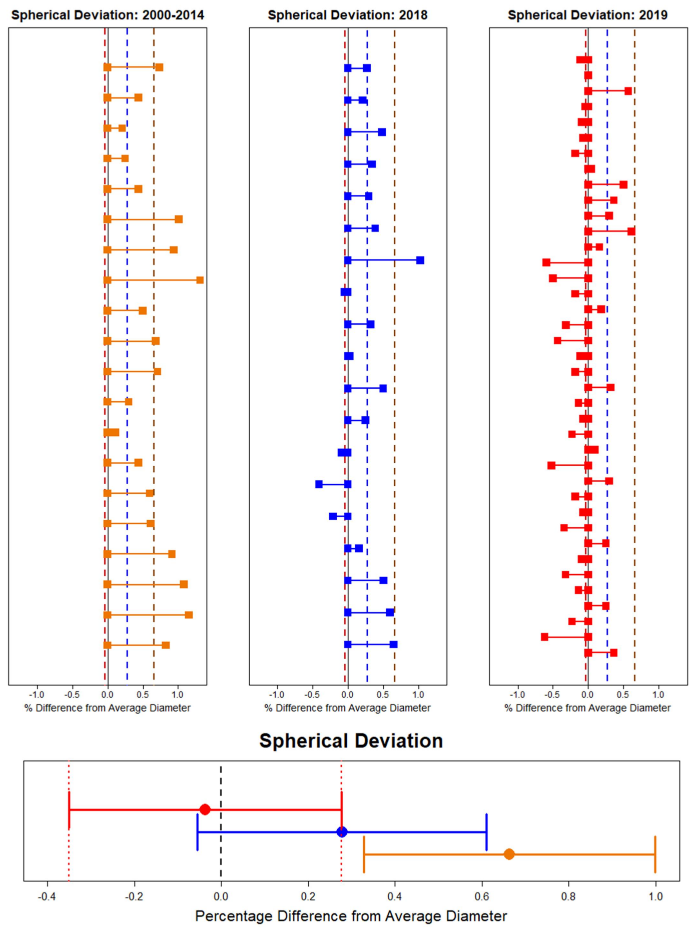

Figure 12: Percentage difference from average diameter for populations from 2000-2014, 2018, and 2019. The upper panels show the deviation for every ball in the sample. The lower panel shows the average percentage difference, where zero is marked as a black dashed line. Uncertainties are one standard deviation, with the 2019 uncertainties extended as dotted lines to emphasize possible statistical significance. Note that the average spherical deviation for the 2019 sample is almost zero, and that it is significantly different from the 2000-2014 average.

3.2.5. Lace Thickness

In order to compare with the findings for the 2017 Home Run Surge, I also measured lace thickness.

The previous results—comparing 2014 to 2016-2017 balls—were as expected. In addition, balls from 2018 and the 2015 postseason had lace thicknesses comparable to those of 2016-2017. (Note that the 2015 postseason results were consistent with a change occurring partway through the 2015 season.) The spread in lace thicknesses over 2000-2014 was interesting, in that its uncertainty overlapped with those of late 2015-2018. However, when one looks at home run rates over time (Figure 1), the idea that lace thickness undergoes periodic changes does not seem unreasonable. While the effect was more dramatic over late 2015-2018, one of the thicker lace measurements came from a ball that could be definitively dated to 2003. Since the home run rate in 2003 was much higher than that of 2014, this suggests that trends or fluctuations in home runs may correlate (at least in part) with lace thickness. However, the 2000-2014 laces were, on average, thinner than those from late 2015-2018.

As with the other measurements, the 2019 baseballs were markedly different, with lace thickness decreasing to that of pre-2015 (Figure 13). This result was inconsistent with the findings concerning pre-2015 and 2018 spherical symmetry and reliance on tensile strength. While it is possible the original seam-bulging supposition was incorrect, Figure 12 shows that, despite having comparably thinner laces, the 2000-2014 and the 2019 balls had marked differences in spherical symmetry. This suggested that lace thickness was no longer affecting shape (i.e. the laces on the 2019 ball were not being stretched.)

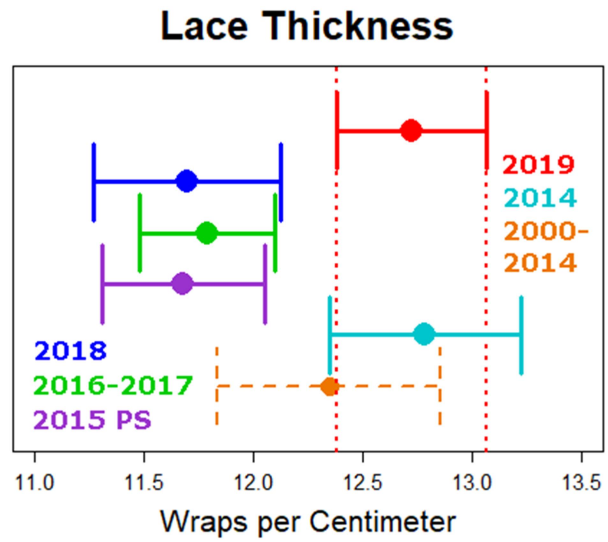

Figure 13: Average lace thickness, represented as wraps-per-cm, for samples from 2000-2014, 2014, the 2015 postseason, 2016-2017, 2018, and 2019. Uncertainties are one standard deviation, with the 2019 uncertainties extended as dotted lines to emphasize possible statistical significance. Note that the late-2015 – 2018 populations all have comparably thick laces, while the 2019 baseballs have laces more in line with those of pre-2015.

3.3. Source of Changes and Effect on Aerodynamics

Shortly after the release of the Home Run Committee Report, MLB announced that it was purchasing part of the baseball manufacturer, Rawlings. As part of his statement, MLB Executive Vice President Chris Marinak told reporters, "We are particularly interested in providing even more input and direction on the production of the official ball." These goals were consistent with the committee's recommendation that "MLB should re-evaluate the specifications on parameters of the baseball that affect the game," specifying size, weight and other properties known to vary, not only season-to-season but ball-to-ball. Such improvements to specifications and oversight were expected to result in baseballs that were more uniform and thus behaved more predictably.

3.3.1. Leather Smoothness

The changes to the leather smoothness on the 2019 regular season ball suggested that MLB might be moving forward with its promises. As baseball leather is skived (i.e. scraped down) by hand, increased smoothness could be the result of tighter specifications and more stringent quality control. However, recent work has shown that smoothness—particularly at the level typical of Major League baseballs—does not contribute to lower drag.[16]

3.3.2. Lace Thickness

The decrease in lace thickness may simply have been another economic decision. However, when one considers the 2019 laces were comparable to those used pre-2015, it is entirely possible that this change was an attempt to mitigate pitcher blisters caused by thicker laces. The evidence is anecdotal, but the fact that pitcher blisters largely disappeared from 2019 baseball media coverage suggests that, intentional or not, pitchers benefited from the new lace thickness.

3.3.3. Roundness and Seam Height

Greater roundness and lower seam height can be most readily explained by a single manufacturing change, specifically to the drying process. Pre-2019, making a single baseball took approximately one week, two days of which were dedicated to air-drying. As demonstrated earlier, air-dried cotton laces stay stretched. However, cotton dried under a hot air flow shrinks back to original shape. Were hot air introduced to the drying process, even thin laces would no longer stretch, producing a rounder ball. In addition, preventing lace stretching might also account for lower seams, since tighter laces could potentially "hold seams down."

Assuming such a manufacturing change, it may simply have been considered a "process improvement"—something Rawlings implements regularly. However, it is also consistent with a need for increased production of regular season balls since 2019 was the first year that Major League baseballs were introduced at the Triple-A level. While balls are reused in the Minor Leagues, the new policy would still require a ~20% increase in production. Under those circumstances, shortening the drying process may have been seen as a means of improving efficiency.

Moreover, studies have shown that lower seams do, in fact, decrease drag. Some of the most recent work demonstrates a connection between seam height and size of the aerodynamic wake.[17] There are conflicting reports on the effect of spherical symmetry,[18] although that may simply be due to how roundness is defined. With a disassembled ball, it is possible to measurement roundness and seam height independently; with an intact ball, the two variables are convolved, and are sometimes defined as "effective seam height."[13] Either way, spherical symmetry has, at best, no impact, and may help reduce drag.

As with the late-2105 – 2018 ball, the improved aerodynamics of the 2019 regular season ball are most consistent with a manufacturing change. In this case, it appears related to a process improvement rather than a new supplier, but as that process improvement would likely have been driven by a need to speed up production, it is hard to argue that there was any intent behind the 2019 Home Run Surge.

4. Studying the 2019 Postseason Ball

The 2019 postseason began October 1st. Almost immediately, it became clear that the ball was "de-juiced," meaning that drag had increased. In response to studies demonstrating this sudden change,[19] MLB issued the following statement:

"The baseballs used in Major League Baseball are manufactured in batches. Balls that are used in the Postseason are pulled from the same batches as balls used in the regular season. Regular season and Postseason balls are manufactured with the same materials and under the same processes. The only difference is the Postseason stamp that is placed on the ball. As has been previously acknowledged, however, the drag on the baseball can vary over different time periods."

However, follow-up studies found that not only was the postseason drag higher, it changed day-to-day.[20] Such game-to-game swings not only appeared inconsistent with the use of 2019 regular season balls, they did not fit the behavior associated with ball-to-ball variation. However, similar drag fluctuations had been seen in research looking at batch-to-batch differences.[21] Therefore, for this next (rather unexpected) study, I compared postseason balls from different batches.

4.1. Data Acquisition

After failing to obtain on-field balls from my usual sources or MLB, I purchased baseballs directly from Rawlings. Having never acquired balls in this manner, I was careful to verify that these were "game balls" (i.e. unused baseballs that were of game-, rather than memorabilia-quality.) This included checking online marketing, verbally confirming with several levels of Rawlings' retail division, comparing pricing to standard "memorabilia balls," and determining that each ball was authenticated. Ultimately, I purchased 36 baseballs—12 stamped "2019 Postseason" and 24 stamped "2019 World Series."

4.2. Methodology

As with other studies, I considered the construction of these baseballs, looking primarily for batch-to-batch differences. The thirty-six balls contained samples from four batches, each identified by a seven-letter designation stamped on the inside of a leather cover. The batches under consideration were BEBRBSR, ERBSLAK, ERBSLAO, and EOBSLAO. Because of the nature of my findings, analysis required only external examination, Batch Code identification, and lace thickness measurements.

Figure 14: Baseballs from Postseason Batch BEBRBSR. Game- and batting practice balls follow the stitching convention on the right. Balls with stitches going in the opposite direction have been stamped upside-down and are disqualified from on-field use.

4.3. Findings

4.3.1. Quality Control

The batch labeled BEBRBSR had materials and construction properties comparable to the 2019 regular-season ball. However, of twelve baseballs in question, seven would likely have failed Rawlings' game-ball quality control standards. In my research, I have found that MLB game- and batting practice balls are always stamped on the same side, with the stitches running clockwise. Balls with counterclockwise stitches have been stamped upside down, and are apparently disqualified and sold to the public (Figure 14). The presence of seven "upside-down" baseballs suggested that this quality control standard may have been relaxed for the 2019 postseason.

4.3.2. Date of Manufacture

The remaining three batches (ERBSLAK, ERBSLAO, and EOBSLAO) were stamped correctly. However, the entire sample had laces with thicknesses consistent with late-2015 – 2018 construction, rather than 2019 construction (Figure 15). This suggested they were not taken from 2019 regular season batches.

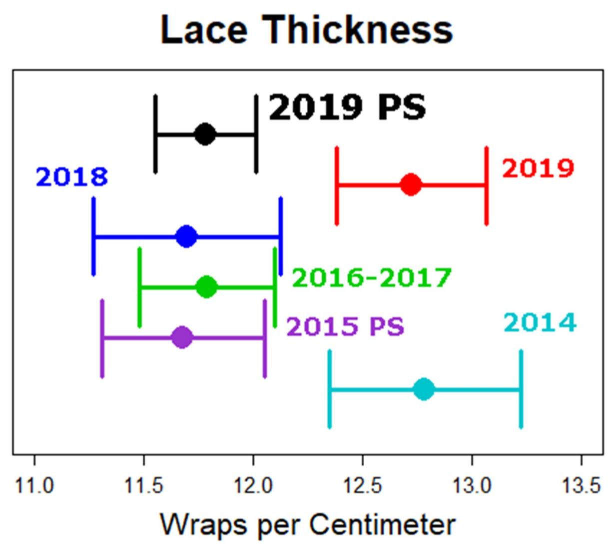

Figure 15: Average lace thickness, represented as wraps-per-cm. The data are the same as for Figure 13, with the removal of the 2000-2014 sample and the addition of lace thicknesses derived from Postseason Batches ERBSLAK, ERBSLAO, and EOBSLAO.

In order to verify production date, I compared the Batch Designation Codes with samples from previous years (Figure 16). Despite the fact that manufacturing information can be easily obtained and verified through Rawlings' Batch Designation rubric, it is not made available to the public. Fortunately, it is possible to spot patterns that are consistent with date of manufacture. For instance, codes on older balls contain six characters, with a transition to seven characters in 2017. In addition, certain letter combinations seem to correspond to specific time periods. For instance, the middle character changes from O to R to S, with each letter roughly corresponding to the years 2017-2019. The pattern B[x]BR[x][x] appeared in several 2019 batches, while the prefixes "ER" and "EO" showed up repeatedly in 2018 but nowhere in 2019. However, the use of "SL" as the fourth and fifth characters didn't begin until 2019. B[x]BR[x][x] was consistent with the first batch I tested. As for the remaining ones, ERBSLAK, ERBSLAO and EOBSLAO seemed like "transition designations," possessing otherwise-exclusive traits from both 2018 and 2019. The batch-code prefixes and thicker laces suggested that these balls may have been manufactured at the very end of 2018 regular season production, and thus were intended for use during 2018. Based on these findings, it seemed likely that the higher drag observed during the postseason was due to the presence of game balls manufactured for previous seasons.

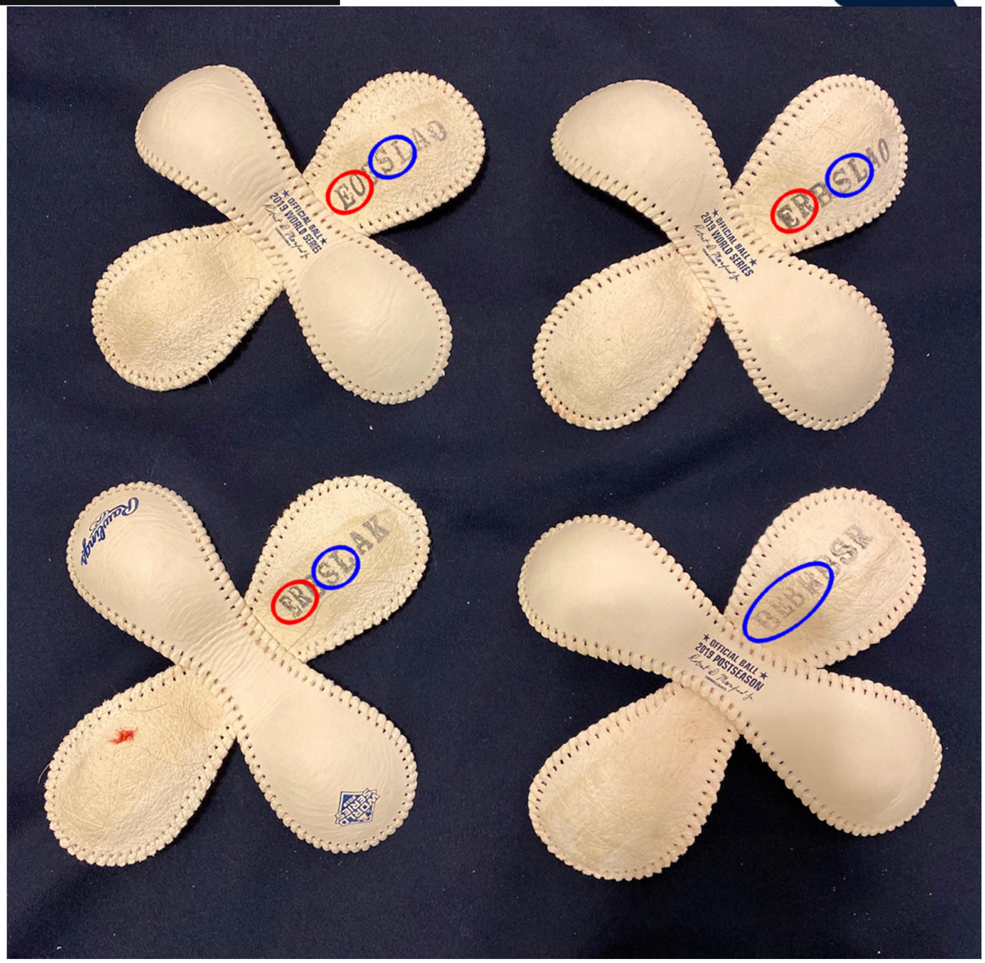

Figure 16: Leather covers from 2019 postseason balls. Character combinations in red appear elsewhere on 2018 balls, while those in blue appear on 2019 balls. Combinations from both years were likely among the last batches made for the 2018 regular season.

4.4. Reevaluation

In order to verify the rather unusual makeup of this postseason population, I reached out to MLB for comment. Pat Courtney, Chief Communications Officer for MLB, and Morgan Sword, Senior Vice President for League Economics and Operations, told me they had "confirmed with Rawlings prior to the beginning of this postseason that all of the game balls…used in the postseason were produced in the first quarter of 2019." Sword also insisted that—contrary to Rawlings' marketing claims, pricing, and authentication—the balls used for this study would have been designated as "memorabilia," and were therefore not representative of postseason game balls. I then contacted Rawlings Chief Operating Officer Dennis Sollberger, who confirmed that I had in fact purchased "commercial" baseballs, and these were "not balls that would be used on field." He further informed me that "commercial balls are inventoried as 'blanks' so that [Rawlings] can stamp-manage variability in customer demand. It is entirely possible that commercial balls produced in 2018 would be stamped for the 2019 postseason sales."

4.5. Implications and Ongoing Work

At present, studies of the 2019 postseason ball are ongoing, since it would appear that the "Authenticated 2019 Postseason Game Balls" Rawlings sells to the public are not 2019 postseason game balls, and cannot even be expected to have been from 2019, let alone part of the postseason production process.

However, the use of repurposed baseballs is still a valid hypothesis. In a recent statement regarding the 2019 postseason ball, Rawlings Chief Marketing Officer, Mike Thompson, confirmed that "[i]t is common and perfectly normal for baseballs to be produced in the previous year but not reach the field of play until the following year."[22] In addition, preliminary work involving actual 2019 postseason *game* balls shows that some part of the postseason population was taken from pre-2019 inventory.

5. Discussion

5.1. Official Statements and their Implications

When addressing the connection between changes in drag and baseball construction, MLB often reiterates specific phrasing, an approach sometimes described as "messaging." While official wording is not generally considered in context of research, in this case it is worthy of consideration, since such statements are often used to justify a lack of data or research results.

As early as 2017,[23] Commissioner Rob Manfred, league officials, and Rawlings executives have responded to questions about higher home run rates by asserting that the baseballs fall "within specifications,"[24] thereby implying that balls with lower drag might lie outside these tolerances. Since the Official Rules require that all Major League baseballs meet specifications, this claim fails to address *any* manufacturing changes, let alone those that might affect drag.

While Manfred did acknowledge a change in drag for the 2019 regular season ball, he also stated that "[t]hey [Rawlings] haven't changed their process in any meaningful way. They haven't changed their materials,"[25] and continued to use similar phrasing in interviews. The key word here may be "meaningful." The original Home Run Committee found that Rawlings regularly implements production improvements, including changes to the yarn (February 2014), the pill (March 2014, May 2015), the leather (June 2014, February 2017, August 2017) and the drying process (March 2016, February 2018). That being the case, things like enhancing leather smoothness or drying baseballs more efficiently might not be considered "meaningful." This justification is consistent with the committee report, which described such changes as "largely technical in nature and very unlikely to be in any way related to the (2017) home run increase."[11] Considering that the 2017 Home Run Surge appears connected to a new laces supplier and the 2019 Home Run Surge to a process improvement, this assumption that manufacturing only minimally affects drag is problematic.

When the 2019 postseason ball showed yet another change in drag, MLB's official statement said that, "[b]alls that are used in the Postseason are pulled from the same batches as balls used in the regular season." Manfred used similar language during a World Series Q&A, but the phrasing goes back as far as 2017.[26] In light of the comments from Thompson, it is interesting to note that the statement does not specify the *season* for which such batches are made. Therefore, Rawlings' policy of using game balls produced for previous years in entirely consistent and would account for my preliminary 2019 postseason results.

5.2. Findings of the 2019 Home Run Committee

During the 2019 Baseball Winter Meetings, MLB's new Home Run Committee released its preliminary report on the 2019 regular season and postseason balls.[27] The central findings confirmed much that had already been reported, including that 60% of the 2019 Home Run Surge could be accounted for by baseballs with lower drag.

Unfortunately, being only preliminary, the released report was not sufficiently rigorous to support many of its conclusions, particularly as relates to properties of the baseball. While data were presented showing a strong correlation between seam height and drag coefficient (C_d), this accounted for only 35% of C_d, with "factors other than seam height account[ing] for roughly 65% of the ball-to-ball differences." Other physical components—described as "alternate hypotheses discussed in the media (e.g. roundness, surface roughness, lace thickness)"—were discounted as affecting C_d, although only results addressing lace thickness were presented. This consideration of laces influencing drag is unexpected, as my results show that lace thickness in-and-of-itself appears unconnected with aerodynamics. While no quantitative justification was provided regarding roundness and leather smoothness, any effect from the latter has already been disproven by independent research.[16] In addition, any findings related to roundness merit special attention, since previous research by one of the committee members shows that roundness influences "effective seam height," and therefore drag.[13]

In regards to the postseason ball, the committee did find a higher average C_d than that of the regular season ball, but no evidence of a change in seam height. Since the sample sizes for the 2019 regular season and postseason were the same (20 dozen baseballs), they were unable to find a reason for the change. That being said, one of their six recommendations was the development of a system to track manufacturing and shipping dates. As there was no mention of mixing or confusing year-to-year populations, it is unclear why this was considered important.

Ultimately, much of the focus on the baseball concerned ball-to-ball and year-to-year variation. In fact, ball-to-ball variation, and the fact that the committee was unable to isolate its source, appeared to be such a dominant factor that statements made during the release press conference suggested that variability may be impossible to change or regulate.[28] While such a categorical conclusion seems unlikely, the influence of ball-to-ball variability seems inconsistent with overall season-to-season (or even regular season to postseason) drag changes.

6. Conclusions

Throughout MLB's official inquiry process—consisting of two Home Run Committees and covering three offensive changes—the solution has consistently pointed to the ball and the change in C_d. Data have come from aerodynamic testing, aerodynamic observations, and measurements of external physical properties. In no case has the reason for a change in drag been sufficiently isolated, leading to the conclusion that the sources of drag on a baseball are unknown, and perhaps unknowable.

What is lost in all of these studies is the question of standardization. One of the concerns of the original Home Run Committee was a lack of uniformity, such that several of their recommendations focused on improved standards and tighter specifications. Oddly enough, despite the problems continually presented by ball-to-ball variation, no one has questioned the manufacturing process itself or suggested direct intervention. Regardless of MLB's purchase and insistence on greater involvement, it would appear the Rawlings has been left largely to itself.

Even the recent Home Run Committee felt it unnecessary to question Rawlings' manufacturing and distribution process. In their section concerning the 2019 postseason ball, the report states:

"It is the understanding of the committee that Rawlings uses the same manufacturing process to create the baseball used in the postseason as they do to create the ball used in the regular season, save for the application of the postseason stamp. There would therefore be no reason to suspect a change in the performance properties of the baseball between the regular and postseason."

Note that the phrasing is identical to that of MLB's Official Statement. Whether the wording came directly from Rawlings or was paraphrased by the committee, Thompson's assertion that the 2019 postseason population may have included mixed inventory should have prompted an investigation into date of manufacture.

Unfortunately, it appears that the focus has been more on scientific solutions than practical ones. While precisely identifying drag sources may be difficult, standardizing the various steps of the manufacturing process is not. Even the premise that one cannot mitigate ball-to-ball variation is flawed. In a recent (yet-to-be-published) study, I have found that variation within the 2019 regular season population stems almost entirely from a single source: the leather covers. The inner ball, which is manufactured using an automated winding process, is remarkably uniform, varying by a fraction of a percent. Presumably, if an effort was made to standardize the covers, many of the issues would go away.

Perhaps MLB is unwilling to become so heavily involved in manufacturing. If so, they are doing a disservice to the players, the teams, and the fans. As things currently stand, the 2020 regular season ball is an unknown quantity. Perhaps it will be similar to the 2019 regular season ball; perhaps it will be as unpredictable at the 2019 postseason ball; perhaps it will be something else entirely. This has left teams unable to make roster decisions and players concerned about their futures. Across the game, the only standard piece of equipment, the only item used by every player, is the ball. If its use is global and its impact is global, MLB's response regarding the ball needs to be better than (in the words of Crash Davis):

"I don't know where it's gonna go."

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