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The Effects of Surface Pace in Baseball

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The Effects of Surface Pace in Baseball

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Thesis Acceptance

Linfield College

Thesis Title: The effects of surface pace in baseball

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Date Submitted: May, 2018

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Abstract

A baseball travels across different surfaces at different paces. The goal of this experiment is to find a percentage difference in speeds the ball will reflect off a given surface. The energy lost on the turf surface was far more significant than on dirt surface as the turf lost an average of 26% of its energy as compared to just 16% of the energy on dirt. In the Northwest conference, teams play on four turf based infields and five dirt-based infields. The results of this study suggest that kinetic friction forces are more significant in reducing ball rebound speed than inelastic collision losses, and that the ball pace across dirt surfaces is faster. These differences can affect player reactions and game play.

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I. Background

Playing sports on different surfaces can greatly affect performance. In baseball as in all sports, the way a ball rebounds off the ground depends on the surface. Major League Baseball has twenty-eight dirt infields and two turf infields. Players report that dirt and turf infields can feel like night and day [1]. While the surface can alter the movement of a ball in a lot of ways, this thesis investigates pace. Surface pace is defined as the speed at which a baseball travels after impact with a playing surface [2]. Because teams play on different surfaces, they can become accustomed to their environment. The goal of this thesis was to find the percentage of energy lost by a baseball after its first impact on a surface.

Players from other sports are known to have advantages playing on their "home" surface. For example, in tennis, Rafael Nadal and Chris Evert have been known as the "King /Queen of the Clay". Nadal went two years without losing a match on clay, and Evert went six years without losing. She dropped only six sets over that span [3]. Needless to say, surface pace can affect the action of the ball and can give advantage to individuals and or teams.

Across the Atlantic Ocean cricket is one of the most popular sports. D.M James, M.J. Carre, and S.J. Haake experimented with the effects a surface has on cricket bowling. Bowling is equivalent to pitching in baseball but the ball is bounced across the surface to the batter as opposed to thrown in the air. The experiment found that balls rebound fast off 'hard' surfaces and rebound slowly off plots with high surface friction characteristics. The reason is rooted behind energy loss, surface friction, and surface deformation [4].

Surface pace is important in baseball. There is not a required surface in any organized league. For example, the Northwest Conference has four turf surfaces and five dirt surfaces while the MLB has twenty-eight dirt infields and two turf infields. The players that play on the turf may experience different reactions from the ball as opposed to that on dirt and since the players practice on their home field, changing surfaces can result in more errors, and injuries, as well as fewer infield hits for the batter.

Ground crews constantly work the playing fields during the MLB season and the dirt surfaces are tended to multiple times throughout the game by the grounds crew to ensure the field is level and soft. This same treatment cannot be done on turf and can lead to bad hops throughout the games. The inconsistent turf surface has made players across the league upset. Troy Tulowitzki, a player for the Toronto Blue Jays claims; "The turf is extremely slow, making it very difficult to hit a groundball through the infield. It's also inconsistent, [making it] subject to odd bounces [1]." In one instance, Baltimore Orioles infielder Jimmy Paredes got hit in the face by a bad hop groundball and the Orioles contacted the MLB and considered boycotting the game due to poor field surface [1].

J.T. Brosnan, and A.S. Mcnitt of Penn State conducted a similar experiment to this one using their PennBounce apparatus [5]. The testing was done on the east coast of the U.S. and focused more on the components and density of the surface than energy loss. Brosnan and Mcnitt found that almost all stadiums had differing soil texture and even with gravel percentages differing, the dirt surfaces all yielded a higher surface pace than artificial turf and natural grass.

II. Theory

A ball skipping across a surface loses a percentage of its energy to heat during its interactions with the surface. The first law of thermodynamics, also known as Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another. Since the energy of a ball cannot be destroyed, it simply passes the energy along to the surface and is converted into heat. This is done by the kinetic (sliding) friction and inelastic collision. The law of thermodynamics gives us a simple formula for energy, denoted by equations 1 and 2, and most importantly in this experiment, kinetic energy, (K.E.) and shown in equation 3. The total energy is denoted by E, potential energy by P.E., acceleration due to gravity by g, and the height of the ball by h, the mass of the ball is denoted by m, and velocity by v.

$$E = K.E. + P.E. \tag{1}$$

$$KE = \frac{1}{2}mv^2 \tag{2}$$

$$PE = mgh \approx 0 \tag{3}$$

$$E = K.E. = \frac{1}{2}mv^2 \tag{4}$$

In this experiment, the ball is rebounding at such a shallow angle the potential energy is generally negligible. Equation 4 will be the main focus of this experiment and the velocity gathered from the data samples will be used to calculate the energy levels before and after impact. To calculate an energy percentage loss, the following equation will be used where V_i represents the velocity before impact, and V_f represents the velocity after impact with the surface.

$$\%\ energy\ loss = \frac{V_f^2 - V_i^2}{V_i^2}\ x\ 100 \qquad (4)$$

The energy loss percentage will allow us to compare the two surfaces and can easily be converted between velocities and energy.

As mentioned in the introduction, the surfaces that are 'hard' tend to retain more energy than those that are 'soft' and have high friction characteristics. Jonah Lehrer, a researcher for Grantland explains the theory around the matter with "The reason [turf] steals momentum is rooted in the friction of all that loose [material], which clumps around the ball. Each clump is like a little speed bump [6]. Artificial turf surfaces are composed of "monofilament polyethylene blend fibers tufted into a polypropylene backing. The infill is composed of a bottom layer of silica sand, a middle layer which is a mixture of sand and cryogenic rubber, and a top layer of only rubber" [7] . These surfaces have hundreds of thousands of little black rubber beads that cover the surface and with each of those beads acting as a speed bump; it is easy to see how the frictional forces tend to be greater on turf surfaces.

III. Experimental Methods

The goal of this experiment is to find the difference in energy loss of a baseball after its first impact with the differing surfaces, more specifically dirt and turf infields. To replicate this action a Triple Play Prime multi pitch-pitching machine was used. This machine provides a mix of pitches that simulates actual in game situations. A photo of the pitching machine can be found below in Fig. 1.

Figure 1: Triple Play Prime pitching machine[8]

The machine is being used to mimic a batted ball coming off a bat. To most accurately portray this, a 4-seam fastball is utilized since it is a straight pitch and does not have horizontal movement on it; this would give the most similar movement to a batted ball. The pitching machine has several settings to allow different pitches. For this experiment, change the settings to the lowest launch angle possible, which is done by clicking the button on the digital screen (seen in Fig. 2).

The 4-seam fastball velocity was set to 80 miles per hour to replicate a well-struck ball in a division III game. The digital inputs allows the same set up each time and provided consistent data to analyze. The data was collected using a slow motion camera. The camera used was capable of 240 frames per second. Finally the data was tracked and analyzed frame-by-frame using the program *Tracker*. An example of *Tracker* can be seen in Fig. 5 later in this section.

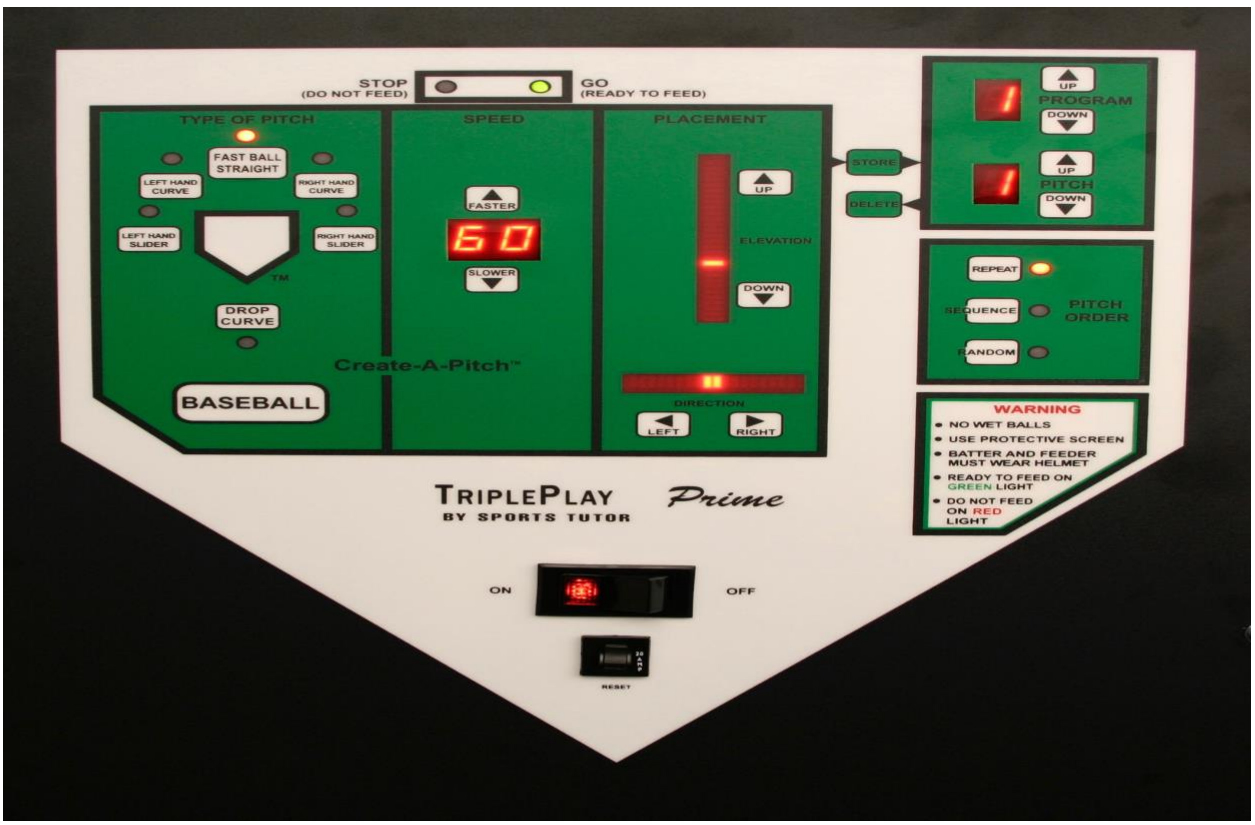

Figure 2: Digital input for pitch selections on the Triple Play Prime pitching machine [8]

After setting up the pitching machine to its correct inputs, test a few balls to find the common drop zone. The most common drop zone was found around 84 feet away from the pitching machine. Use this zone to align the camera a couple of feet away so that enough frames of the ball can be seen prior to impact and a few frames following impact can be seen. The set ups can be seen in Fig 3 and 4 below.

Figure 3: The location that I set up to record data from. Roughly 84 feet away from the pitching machine and 10 feet from the ball path.

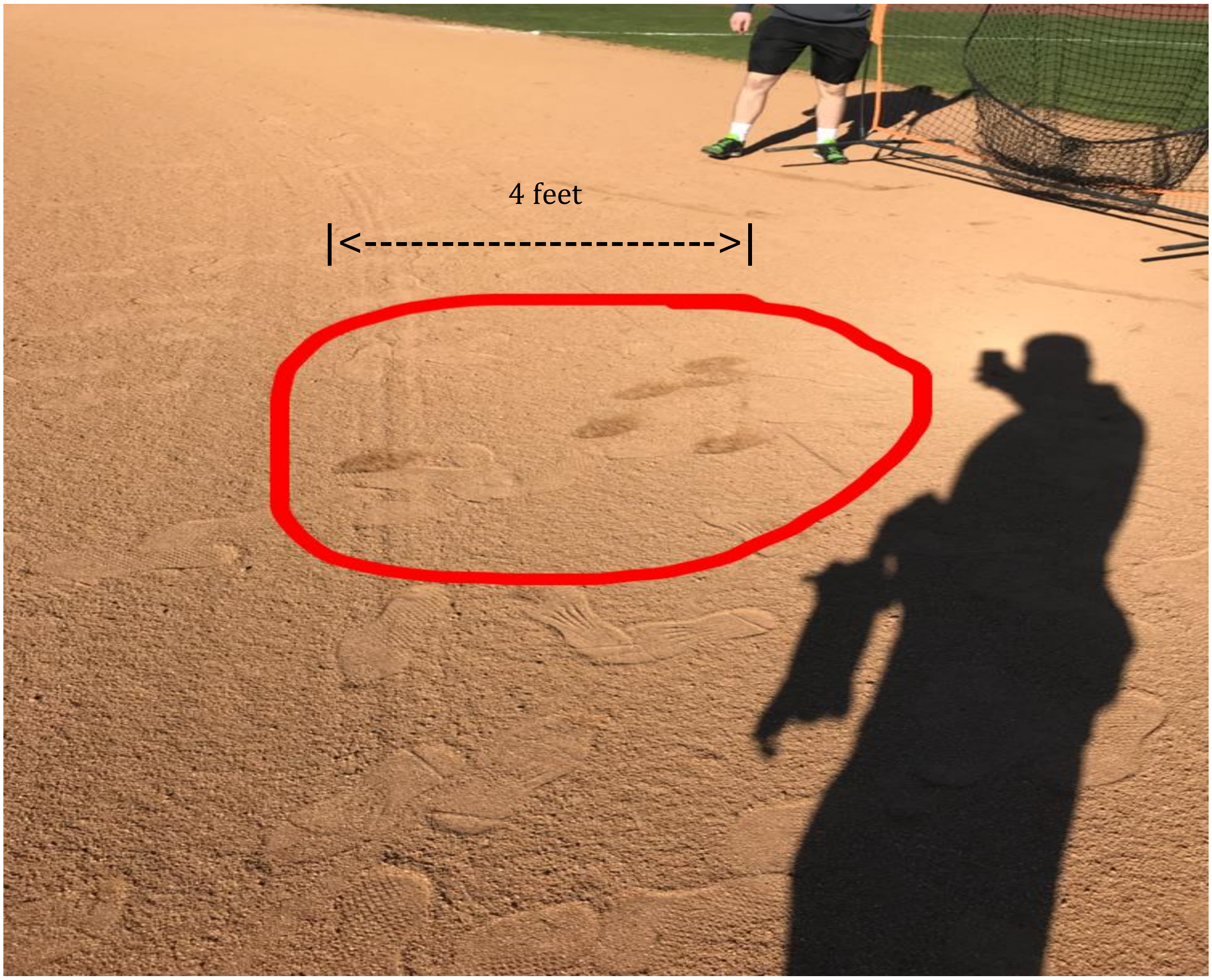

Figure 4: Photo showing the cluster of balls impacting the same area on the dirt surface.

Figure 4 shows the pitching machine produced a consistent ball path and a cluster of six balls hit within a small window of each other. These data were reassuring as the dirt allowed me to see just how close the balls actually were to one another.

The program *Tracker* was used to analyze the difference in velocity. Once the program is running, simply upload the data into the software and manually track the baseball frame-by-frame. To get accurate data track the same spot on the baseball in each frame. The software then analyzes the speed and angle at which the mass traveled. In this experiment, the backside of the baseball on the bottom of the ball was tracked and analyzed. In each of the samples, the bottom left area on the ball was tracked and the spot was held consistent throughout the track. Any spot can be used on the ball as long as you are consistent since tracker is measuring the distance between the spots you marked. Fig. 5 shows the tracking log for the first dirt surface sample. The figure shows that the ball traveled down a consistent path, hits the surface, and reflects at a new angle with a slower velocity.

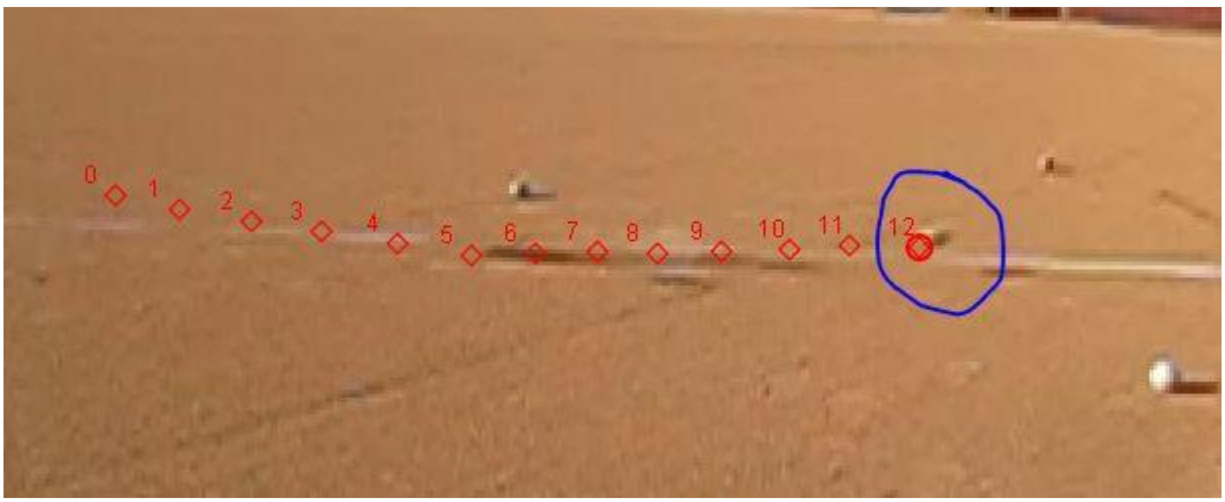

Figure 5: Image taken from *Tracker* representing the first sample of surface pace on dirt.

IV. Results and Analysis

The goal of this experiment was to discover the impact, if any, of the field surface on the surface pace of a baseball, focusing on comparisons between dirt and artificial turf surfaces. Since I am only testing the effects at Linfield College and their fields I cannot claim these values will be universal across all fields but should give a rough idea for the surface pace on both turf and dirt surfaces.

In all samples, the ball comes in with a high velocity, reaches a zero during its interaction with the surface, bounces and gains a small amount only to then lose velocity again during each subsequent interaction with the ground. This happens because the ball is skipping across the surface and losing energy to heat each time it compresses, as well as with any sliding friction.

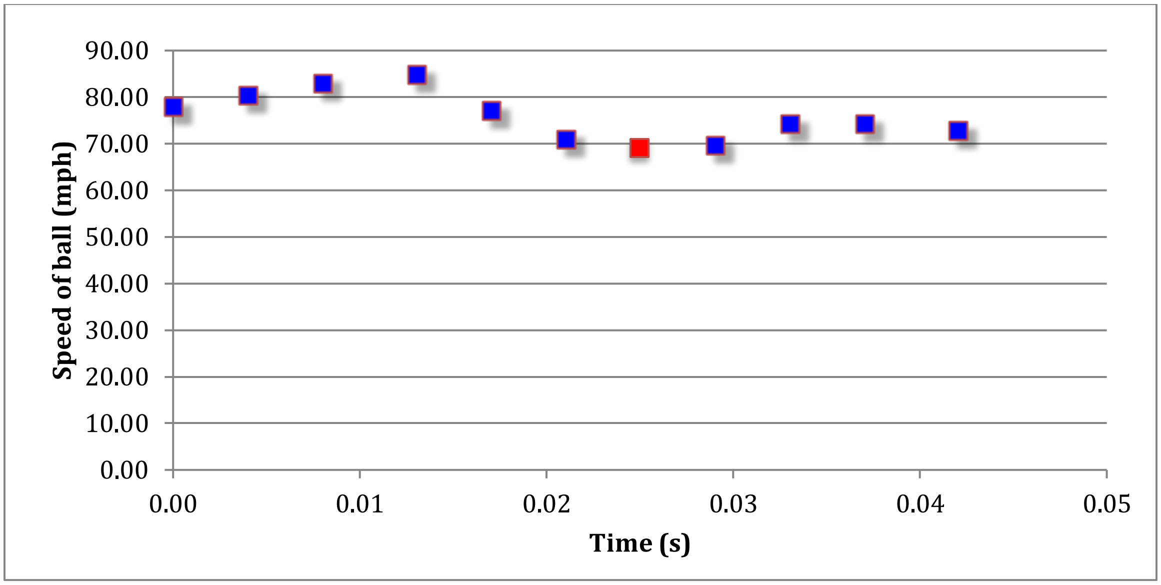

Figure 6: The graph representing the speed of the ball as it moves across a dirt surface.

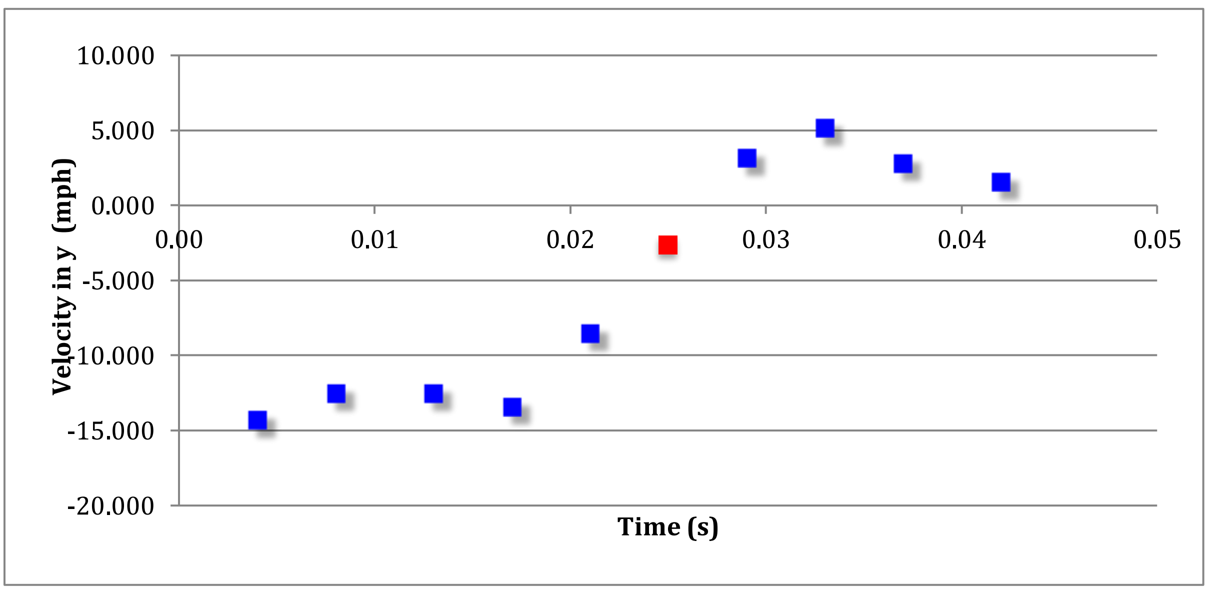

Figure 7: Graph lined up with Fig. 6 comparing the y's velocity as compared to the total speed.

Fig. 6 shows that the ball enters the frames at a high initial velocity; hits the surface, denoted by the red dot, and then regains velocity but at a lower value. This shows that the ball lost energy at impact and the impact was a non-conservative collision.

Using equation 4 from the Theory section, we can solve for the energy loss percentage in the different samples. Fig. 7 shows the velocity of the ball in the y-direction, the original velocity is negative since it is traveling toward the ground. The ball hits the surface between 3.0 and 3.5 seconds and rebounds at a slower rate.

$$\% \, energy \; loss = \frac{V_f^2 - V_i^2}{V_i^2} x \; 100 \tag{4}$$

Table 1: Chart showing average values of samples, along with the energy loss for each sample.

	Velocity Before (mph)	Velocity After (mph)	Energy Loss %
Turf Sample 1	66	56	-27
Turf Sample 2	68	59	-24
Dirt Sample 1	76	70	-16
Dirt Sample 2	79	72	-17

As you can see from Table 1, the energy loss percentage has a consistent difference between the surfaces. Dirt seemed to retain the energy at a much higher rate as it lost nearly ten percent less of its energy.

To put this into perspective, the average exit velocity, or speed the ball is put in play at, in the MLB last year was 88.73 mph. If a player hits a ball at 88.73 mph and the ball hits a turf surface, it will end up with a speed of 77.41 mph. If that same ball hit at 88.73 mph hits a dirt surface, the ball would end up with a speed of 81.81 mph. On the fielders perspective, if the average MLB hit lands in my range of 82-86 feet and lands at 85 feet, and the fielder is at 95 feet from the batter, the fielder would have 0.736 s to react to the ball on dirt while on turf under the same situation, the fielder would have 0.741 s to react. The difference in reaction time can determine whether or not a player gets to a ball hit up the middle, or whether a fielder can defend himself on a ball hit to him. The difference will get larger as the ball is hit harder so the reaction times alter with high exit velocities and can lead to more injuries.

IV. Conclusion

The data revealed that a baseball moves more quickly across a dirt surface than an artificial turf surface. The results showed nearly a ten percent difference in energy loss after first impact and can cause a dramatic change in outcome in a given situation. With decreasing speeds across turf surfaces, players can expect to see a decrease in hits through the infield. It could also result in more errors as the uneven turf surfaces can force bad hops. Players across the MLB are against the turf surfaces. However, they know nothing can be done in the northern cities such as Toronto. Since Linfield College has a brand new turf surface, the data may have resulted in quicker pace than older, beat up stadiums across the nation. The staggering difference in energy loss shows that there is a home field advantage when playing on a dirt surface as fielding on a quicker surface would allow more time to react when switching to a slower turf surface.

Experimental error comes from the *Tracker* program as I was forced to manually track each frame. With the ball being so small on the screen, *Tracker* did not recognize the mass and was unable to use the auto-tracking mode. I was also forced to calibrate the distance on *Tracker* by using the balls dimensions as opposed to a distance range on the field. Since the mass of the ball was so small, there is small error in consistency between samples, and since the data showed consistent values, I wouldn't look into this too much.

In the future, it would like to use this data and track the impact of surfaces in the MLB. For example, do road teams have more errors when playing on the unfamiliar, artificial surfaces? Are there more hits that travel through the infield on dirt than there are on turf? These questions will soon be used to evaluate players and defensive metrics in the MLB. The next step is to compare real in game footage with similarly hit balls on different surfaces and see how the ball reacts. The tracking program, *Statcast* is tracking all pitches and batted balls in the MLB and are becoming sortable by launch angle and exit velocity. Using these parameters, I believe tracking in game footage with the same parameters will allow a comparison of my model to that of the MLB.

V. Acknowledgements

I would like to thank the members of my faculty thesis committee and my peer thesis committee for their guidance and help throughout this process. Dr. Heath for her ideas and suggestions, as well as Dr. Crosser and Dr. Xie for taking the time to correct mistakes. I would like to thank all of my professors during my four years at Linfield for setting me up for success and encouraging me to get better each day. Thank you classmates who have struggled alongside me throughout our time and continued to support and help one another. Lastly, I would like to thank my parents for their love and support and for helping me get through college and my teammates and coaches from the football team for making my time here unforgettable.

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