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A Comparison of Peak Ground Reaction Forces of Pitches From the Stretch and Windup

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A COMPARISON OF PEAK GROUND REACTION FORCES OF PITCHES FROM THE STRETCH AND WINDUP

A Master's Thesis

Presented to

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In Partial Fulfillment

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Master of Science, Kinesiology

By

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ABSTRACT

Ground reaction forces can help coaches and players understand the lower extremity biomechanics of pitching in baseball. Research has told us that there are repeatable characteristics of ground reaction forces that pitchers produce during a pitch. This study examines the differences in peak ground reaction forces produced from pitching from the stretch versus pitching from the wind-up. Five variables were recorded for each pitch from the push-off leg and the landing leg. Landing forces were then compared to landing forces of the other pitching style and the same comparison was made for the push-off leg. This was achieved by altering a pitching mound to hold force plates that monitored each leg's forces. Data was compiled and organized then paired sample t-test were used to find any statistically significant difference between any of the variables. A significant difference was discovered between two variables. Despite the difference found in this study, these variables have little impact on how pitches are viewed because of what the variables represent.

KEYWORDS: baseball, pitching, biomechanics, stretch, wind-up, pitchers, pitching style, ground reaction forces, MLB, college baseball

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Professional sports often utilize exercise and movement sciences to improve the performance of athletes. Much has been learned about specific movements throughout a variety of sports. One major takeaway from baseball has been how to improve hitting performance. Many aspects of a hitter's swing have been analyzed and broken down to give coaches and hitters the information to make better swings to allow more and better contact with the ball, thus providing more hits and more runs and giving teams better chances at winning games. Biomechanics of hitting have always been the main interest when it comes to baseball and exercise science. This may be because decent hitting statistics have a better chance of producing wins, or that hitting is what the fans come to see so it is important to sell tickets and get fans in seats. However, pitching is a key factor in baseball. Play does not start until the pitcher has thrown the ball. Much like decent hitting statistics give teams a better chance to win, decent pitching statistics provide a similar chance. Pitchers in Major League Baseball (MLB) have always been at a disadvantage. MLB tends to promote hitters because of the tickets they can sell from big name sluggers. The mound height has been lowered to increase the difficulty of pitching, baseball weights and sizes have changed to make the ball travel further off the bat, and pitchers are ridiculed for using foreign substances in an order to get a better grip on the ball. This may have to do with some lacking research and analytics of pitching in baseball.

Current Research

While there is ample information about the upper body mechanics of pitching, since arm strength and pitch velocity are significant factors of successful pitching, there is a lack of information about the lower body mechanics. However, there may be some importance to the lower extremities and how it influences a pitch. In a 1998 study conducted by MacWilliams et al (1998), this was found to be true. In this study, it was hypothesized that there were characteristic patterns in ground reaction forces produced by pitchers that were repeatable within the same subject trials. This study is often touted as the first to look at ground reaction forces in baseball pitching. Results were then verified in subsequent studies by Kageyama et al (2014), Oyama & Myers (2018), and McNally et al (2015). All of these were able to show similar results in regards to the characteristics of ground reaction forces produced by pitchers. However, only one of these studies, McNally et al (2015), included the styles in which the pitchers used to produce their results.

Purpose

The purpose of this study is to examine any differences between ground reaction forces produced when pitching from the stretch versus pitching from the windup. Based on the current research available, it is unlikely that any significant differences will be apparent due to the repeatability of the pitching motion. Pitchers train from an early age to be able to repeat the process of pitching continuously during play. Consistent practice and execution of pitches should result in few differences between the pitching styles

LITERATURE REVIEW

This review of literature provides a detailed review of current research done on ground reaction forces in baseball pitching. There is little research done for lower extremity biomechanics of pitching.

Articles were chosen for their specific research on lower leg biomechanics in baseball pitching. When no more relevant research could be attained, research articles regarding upper body mechanics were selected to assist in learning more about whole body in pitching.

Lower Extremity Biomechanics

To better understand the importance of the lower extremities, we must first understand what role, if any, does the lower have in pitching. This is exactly what MacWilliams et al (1998) set out to find. “These data indicate that leg drive is an important aspect of the overarm throwing motion (MacWilliams et al 1998).” This study was the first to examine the speculation that the lower extremities did play an important role within pitching. These findings were then supported by a study conducted by McNally et al (2015). “This study supports the hypothesis that ground reaction forces likely play a critical role in the development of maximum pitching velocity (McNally et al 2015).” This study focused primarily on the effect that ground forces have on pitch velocity and will be examined later in this review. The overall importance of the lower extremities was consistently supported in the few studies that examined ground reaction forces.

Comparison of Pitching Styles

Pitching is an action that involves the whole body. Pappas et al (1985) describes the action as, “A total body activity with sequential activation of body parts through a link system which, in a right-handed pitcher, goes from left foot to right the right hand. Through the coordinated action of all body segments, ballistic energy is applied to the baseball resulting in the greatest velocity at the time of release (p. 216).” This explanation plays a large role in thinking about the mechanics of pitching in general. The study by Pappas et al (1985) goes on to break the pitching action down into three distinct phases: cocking phase, acceleration phase, and follow through phase (p. 217). These phases are represented in both the wind-up pitching style, as well as pitching from the stretch. Only one study has been identified that compares these two styles. However, the study conducted by Dun et al (2007) compared the pitching from the wind-up and the stretch kinematically. Their findings indicated that there are no statistical differences in joint kinetics and clinically insignificant differences in ball velocity (p. 141). This could be an indicator that there may not be any significant differences in ground reaction forces, which is the sole purpose of this study.

METHODS

Participants

Participants of this study are members of a large Midwest Division 1 baseball team, specifically, pitchers. Participants were recruited through connections with the baseball team and coaching staff. There are a total of 7 participants ranging in age from 18 to 25 years old. Six pitchers were right handed and one was a left handed pitcher. Pitchers were given unlimited warm-up time followed by their normal practice routine preceding data collection. Informed consent was collected before the study began. The purpose of these participants was solely for the production of pitches. The pitches themselves will be used as the sample for this study. The study was submitted to the Institutional Review Board of Missouri State University on November 19, 2021 (IRB-FY2022-316) and approved on December 20, 2022 (See Appendix A: Research Compliance).

Materials

In order to collect effective readings of ground reaction forces, a wood/fiberglass composite mound was used as the mold and mounts for force plates were constructed. Two Bertec force plates mounted to the pitching mound were used to collect ground reaction forces. One plate was mounted to the rear of the mound, just in front of the pitching rubber. This is where the push-off forces were collected. The second force plate was mounted approximately 5 feet from the front of the pitching rubber. This is the plate that records the landing forces (See Figure 1: Mound Diagram) and (See Appendix B: Mounds).

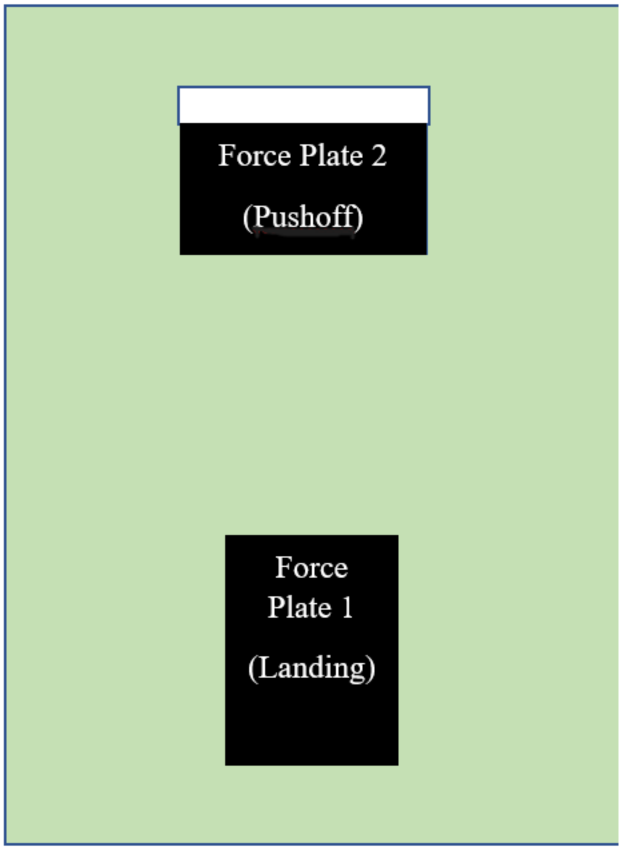

Figure 1: Mound Diagram

Note: Force Plate 2- X values are left and right, Y values are forward and back. Force Plate 1- X values are forward and back, Y values are left and right.

Data Collection

Participants completed a total of 10 pitches each. The first 5 pitches were pitched from the stretch and the last 5 were pitched from the windup. The criterion for a successful pitch was that the pitcher made complete contact with each force plate and the catcher had to deem the pitch a strike. During each pitch, the force plates collected the ground reaction force data for two seconds at 500hz through the accompanying programming system. Each pitch was closely monitored and more pitches were repeated if any mistrials were recorded. This could include missing the force plate entirely or not getting an effective read on either of the force plates.

Following data collection, data was organized and normalized by dividing each trials results by body weight in order to easily compare results across each pitch. The normalized data will then be put into charts and the differences in pitching style was analyzed. The statistical program JASP was used to run Paired Sample T-tests to compare each force direction to its counterpart.

Statistical Analysis

A series of paired sample t-tests were performed to compare the stretch and windup pitching styles for both the push off and landing of the pitch. For the push off, the variables were HomeMin(P), HomeMax(P), 1-3Min(P), 1-3Max(P), and ZMax(P). For the landing, the variables were HomeMin(L), HomeMax(L), 1-3Min(L), 1-3Max(L), and ZMax(L). The "Home" variables represent anterior/posterior forces (towards/away from home plate) while the "1-3" variables represent medial/lateral forces (towards 1st base and 3rd base). Z variables represent forces applied straight down. A series of paired sample t-tests were run to compare the means for stretch and windup in each variable. The variables of HomeMax(P), 1-3Min(P), and ZMax(L) did not pass normality, so a Wilcoxon signed-rank nonparametric test was run.

RESULTS

Descriptive Statistics

The sample in this study are the pitches and not the pitchers. Each pitcher threw five pitches for each pitching style. One set of pitches had to be removed due to issues transferring the data from the original download into the location where it was organized. Therefore, the total number of pitches for each pitching style is 30 pitches. It is also important note that negative values in the HomeMin, HomeMax, 1-3Min, and 1-3Max indicate direction. HomeMin/Max represent the forces towards or away from home-plate (forwards and backwards) whereas 1-3Min/Max represents forces towards first or third base (left and right). The ZMax value represents the downward forces. Only the ZMax value was recorded for the Z value as a "ZMin" value would be zero. There was no significant difference within the means and standard deviations on each value (see Table 1).

Data Screening

The data was screened for accuracy, missing values, outliers, and normality. The data was accurate and there were no missing values. Outliers were assessed univariately using standardized z-scores and a cutoff score of ± 3 ($p < .001$ criterion). There were two outliers present in the data set. Pitch 1 had an outlier for both HomeMax (landing, stretch) and ZMax (landing, windup). Both values were deleted from the dataset before statistical analysis. Normality was assessed using the Shapiro-Wilk Test of Normality and distributions plots. Most variables met the normality assumption ($p > .001$), except for HomeMax (landing, stretch), 1-

3Min (landing, stretch), and ZMax (landing, windup). Thus, nonparametric tests (i.e., Wilcoxon signed-rank test) were performed for these variables (see Table 2).

Table 1. Descriptive Statistics

	Stretch		Windup	
	Mean	SD	Mean	SD
Push-Off				
HomeMin(P)	-0.301	0.074	-0.304	0.073
HomeMax(P)	0.116	0.056	0.132	0.035
1-3Min(P)	-0.098	0.064	-0.127	0.028
1-3Max(P)	0.142	0.040	0.169	0.039
Zmax(P)	1.336	0.178	1.302	0.203
Landing				
HomeMin(L)	-0.234	0.061	-0.232	0.060
HomeMax(L)	0.357	0.066	0.352	0.071
1-3Min(L)	-0.218	0.072	-0.214	0.054
1-3Max(L)	0.170	0.084	0.169	0.089
Zmax(L)	1.197	0.243	1.787	0.164

Table 2. Paired Samples t-test

	Test Statistic	*p*	Effect Size
Push-Off			
HomeMin(P)	*t*=0.335	0.740	*d*=0.061
HomeMax(P)	*z*=-1.471	0.146	*r*=-0.308
1-3Min(P)	*z*=3.425	<0.001	*r*=0.716
1-3Max(P)	*t*=-3.013	0.005	*d*=-0.550
ZMax(P)	*t*=1.300	0.204	*d*=0.237
Landing			
HomeMin(L)	*t*=-0.346	0.732	*d*=-0.063
HomeMax(L)	*t*=0.736	0.468	*d*=0.137
1-3Min(L)	*t*=-0.340	0.737	*d*=-0.062
1-3Max(L)	*t*=0.226	0.822	*d*=0.041
ZMax(L)	*z=1.524*	0.132	*r=0.324*

Parametric t-test test statistic is t, Wilcoxon signed-rank nonparametric test statistic is z; parametric t-tests use Cohen's d for effect size, Wilcoxon signed-rank nonparametric test use matched rank biserial correlation (r)

When controlling for Type I error, significance is altered to p = .005

Table 2 shows that there was a statistically significant difference in the 1-3Max(P) and 1-3Min(P). Table 1 will show that there is not a large difference between means for 1-3Max(P). Table 2 also shows and effect size for 1-3Max(P) of *d*=-0.550. This means that the mean difference between the two pitching styles are approximately 0.55 standard deviations apart, which equates to a moderate effect size.

DISCUSSION

This study is the first to examine differences between the two common pitching styles that are used throughout baseball. After normalizing the data received from the force plates, similarities emerged between the pitches in this study, similae to the study by MacWilliams et. al. (1998). This is not just another confirmation study for MacWilliams et. al., but it also shows that results recorded in this study were in agreement with previously published data.

Differences

There were statiscally significant differences in two of the recorded values (1-3Max(P), and 1-3Min(P), however, there is no direct evidence for the cause. This variable is going to change, not only pitcher to pitcher, but also pitch to pitch. Ideally, there should not be a significant difference in this value as it speaks to the balance of the pitcher. The closer this value is to zero, the more balance and control the pitcher posseses during the delivery of the pitch. MacWilliams et al (1998) referred to the 1-3Max/Min values as Medial-Lateral Shear and says that, "Push-off medial-lateral (ML) shears are negligible, indicating that push-off forces are concentrated in the plane of the pitch. Landing forces reflect the rotational motion of the trunk and torso. Initially, after foot contact, a medially directed force is applied to halt the rotation of the landing leg, it then changes to a lateral direction as weight is fully transferred to the lead leg and the arm is coming forward, reaching a maximum of about 0.1 BW at ball release" (MacWilliams et al, 1998). The majority of forces that pitchers use during a pitch are, generally, directed in the direction of the pitch. This speaks to what would have been the expected outcome from the pitches in this study. The means and standard deviations would suggest that there would not be a significant difference in the 1-3Max/Min values, especially considering the results from this study closely replicated those produced in the study conducted by MacWilliams et al (1998).

Consistency

One important finding is how consistent each pitch was. This could be a result of the consistent coaching that has taken place throughout the pitchers' years of training. This also shows how indifferent high-level pitching is and how replicable the results are. It is important to note that each pitcher in this study threw with a traditional style of pitching. This style is widely used and taught throughout all levels of baseball and is how young athletes are taught to begin throwing. It would be interesting, however, to see how the ground reaction forces of a traditional style pitcher compare to a non-traditional style pitcher.

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APPENDICES

Appendix A: Research Compliance

Date: 12-20-2021

IRB #: IRB-FY2022-316
Title: Comparison of pitching styles and the effect on ground reaction forces produced by baseball pitchers.
Creation Date: 11-19-2021
End Date:
Status: Approved
Principal Investigator: Daniel Wilson
Review Board: MSU
Sponsor:

Study History

Submission Type	Review Type	Decision
Initial	Expedited	Approved

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Appendix B: Mound