**A Biomechanical Comparison of Long & Short Stride Lengths of the Baseball Swing**

**Introduction**

Hitting a pitched baseball is a complex, dynamic movement coupled with having to perceive and predict the ending location of a moving object at varying speeds, locations, and movement. Coaches since the beginning of the game have tried to find optimal mechanics for hitting a baseball. Optimal mechanics would theoretically maximize bat speed and precision of bat-to-ball skills to transfer the most amount of energy to the ball. Maximizing bat speed would increase the amount of energy transfer to the ball would result in faster and further hit baseballs, which are desirable by players and coaches as it would reduce the chance of a defender fielding the ball and resulting in the batter making an out (**8**).

Various studies have attempted to quantify the biomechanics of the swing to bridge the gap in knowledge of coaches on the mechanics of the swing (**2-3, 5, 9**). Typically, these studies look at ground reaction forces (GRFs), joint and segment kinematics, joint torques, and bat speed of a batter’s preferred technique (**2-3, 5, 9**). Timing is possibly the most crucial aspect of hitting, and that not only includes the baseball itself but also the segment kinematic sequence. One such study that looked at this found that batters achieved peak rotational velocity at the pelvis before the torso. This rotation should ideally utilize the muscles’ stretch shortening cycle to optimize force and velocity for bat speed, which is achieved when a muscle is pre-stretched then contracts. For the muscles to stretch, the segments connecting them must separate. Thus, quantifying the amount of separation is vital to understanding swing performance. Studies in baseball and other sports such as golf, which has similar rotational movement to a bat swing, have quantified hip-torso separation which is often referred to as the “X-Factor” and has been found to have an average of 14º of separation **(1, 3)**. Few studies have looked at the influence of the stride on the mechanics of the swing, albeit in regard to closed, parallel, and open strides (**6, 10**). That is why this research focuses on stride length and how it influences swing mechanics.

The purpose of this study is to understand how the length of a batter’s stride effects the mechanics to give coaches a better understanding of technique and its implications in performance. It is hypothesized that the Long Stride condition would have higher linear bat speed, greater magnitude of GRFs and knee torque, and that both conditions would have a similar Kinematic Sequence (KS) and Hip-Torso Separation angle.

**Methods**

**Subjects**

One 21-year-old right-handed batter with experience playing baseball at the high school level was used as the subject. The subject was 1.83m tall and had a mass of 75kg. The subject was healthy with no current injuries.

**Protocol**

One right-handed batter with experience playing baseball at the high school level was used as the subject. To allow for consistent stride length, there was tape placed on the force plates for initial stance, short stride, and long stride. The stance width was measured at 57cm, short stride at 11cm, and long stride at 31cm. The batting tee and ball were set up to belt buckle height and center of strike zone. The subject was allowed warm-up swings until he was ready for collection. Once ready, the subject was instructed to take three swings at full effort while attempting to hit a line drive towards center field for both conditions. One of the short-stride trials had to be excluded from the analysis due to marker error that was identified after digitization and processing.

**Equipment**

The equipment used include Vicon Nexus motion capture software, as well as AMTI force plates both recording at 1000Hz. Instead of adding markers to the baseball bat, a PRGR Launch Monitor, which uses radar technology, was used to measure the linear velocity of the barrel (**7**).

Vicon Nexus used 10 infrared cameras to capture the motion of the swing by flashing light at the passive reflective markers placed on the subject. The marker-set used was Vicon’s Plug-in-Gait (PiG), which comprised of 42 markers placed on the subject’s body. Once data was collected, each trial was digitized in Vicon Nexus and processed into Microsoft Excel and C3D files. Once C3D files were created, they were loaded into Visual 3D Professional biomechanics software for further analysis.

Diagram

Description automatically generated

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**Image 1.** Front (A) and Back (B) reference for the PiG marker-set (**4**).

**Results**

**Figure 1.** Average bat speed of both conditions.

Figure 1 above shows the difference in linear velocity of the bat head between the two conditions. The Short Stride condition averaged 58.5 MPH, compared to 54.3 MPH for the Long Stride. This is a significant difference that has in-game implications for performance.

Push-off

Push-off

**Figure 2.** Average Rear Leg GRF in the X plane.

Figure 2 shows the average push-off, or medial-lateral, force of the rear leg. It is important to look at the force in this direction because it is in the direction of the pitched ball. This matters because the reaction force would provide momentum to the body and ultimately transfer this energy to the bat.

**Figure 3.** Average Stride Leg GRF in the Z plane.

Figure 3 is a graph of the average vertical GRF of the stride leg. The Long Stride condition has a higher magnitude of GRFs, however appears to have a more gradual increase in comparison to the sharp impact of the Short Stride.

**Figure 4.** Single trial of Stride Leg Knee Moment of both conditions.

|  |  |  |
| --- | --- | --- |
| **Long Stride** | **Short Stride** | **% Difference** |
| 103.1607463 | 114.1237715 | 9.6% |

**Table 1.** Average Knee Moment for both conditions.

Figure 4 and Table 1 show that the knee moment was similar in both conditions. However, the Short Stride did contribute a noticeable difference at almost 10% greater on average. Figure 4 only shows one trial of each condition because the timing of each trial was not normalized, therefore the peaks were at different times and contributed to skewed averages throughout the time-series.

**Figure 5.** Long and Short Stride Kinematic Sequence Comparison.

The graphs in Figure 5 show the KS of a single trial of both conditions for comparison. Similar to the knee moment graphs, only a single trial is given because the time was not normalized. With that being said, the graphs show that in the Long Stride condition the lead upper arm velocity peaks first, whereas in the Short Stride it is achieved after the pelvis and torso. Another part to note is the way in which the lead hand peaks. For the Long Stride, it has a gradual increase in rotational velocity, but it much sharper in the Short Stride. So while they achieve similar velocities, the subject accelerates his hand at a higher rate in that condition.

**Figure 6.** Degree of Separation between the Pelvis and Torso.

|  |  |  |
| --- | --- | --- |
| **Long Stride** | **Short Stride** | **% Difference** |
| 24.18893867 | 23.13349933 | 4.3% |

**Table 2.** Average Degree of Separation of the Pelvis and Torso.

The time-series graph shown in Figure 6 demonstrates that the subject achieved approximately 10º greater Hip-Torso Separation in the Long Stride in comparison to the Short Stride condition of the first trial. The subject also appears to come out of this separation quicker in the Long Stride, evidenced by the steeper slope after peak separation. The first trial was used again because averaging made the graphs show incorrect data. However, the peak averages were calculated, shown in Table 2., and show that there is not a large difference between the two conditions for this variable.

**Discussion**

The reason for this research was to compare the effects of stride length on the biomechanics and performance outcomes in the baseball swing. These variables included Bat Speed, GRFs, stride leg Knee Moment, the Kinematic Sequence, and Hip-Torso separation. As shown above, there were some differences between the two stride techniques. While it is possible that the differences were caused by the condition, there is also the possibility that it is due to inherent variability in movement. This is relevant with having only one subject, as there are not trends that can be looked at across multiple batters.

In reference to the hypotheses stated earlier, some were supported by the data and others were not. The hypotheses that the data supported were the Long Stride conditions having greater GRFs and both conditions having similar Hip-Torso Separation angle and rotational velocities in the segments of interest. The ones not supported include the Long Stride conditions having a greater Bat Speed and greater Knee Moment. Because Bat Speed was the outcome metric and obvious end to the chain, starting from the ground-up, we will work backwards from there.

Bat Speed, as seen in Figure 1., was significantly higher in the Short Stride condition. This was previously mentioned to have a large influence on batted ball distance and has major implications for in-game performance. The farther a batter can hit a ball, the more likely they are to hit the ball over the fence for a home run, which is guaranteed offense for the team.

Generally, baseball coaches want more Hip-Torso Separation. The main reason being a pre-stretch of the muscles and an assumed powerful contraction to produce higher bat speeds. The results of this study demonstrated that even with a significant difference in Bat Speed, there was not much of a difference in the degree of separation between segments. This suggests that the magnitude of the angle alone is not a major contributor to energy transfer to the bat.

The Kinematic Sequence is another purportedly important part of achieving high bat speeds and exit velocities. Ideally, an athlete would sequence their peak segmental velocities in order of the pelvis, torso, lead arm, and hand. The sequencing, as well as the magnitude of the velocities, are seen as important. This study found that there were very little differences in peak velocities of each segment, and therefore are not significant contributors to the Bat Speed variable. With that being said, the subject did have a different sequence between conditions. In the Long Stride, the batter started with his lead arm peaking first, the pelvis and torso at approximately the same time, and finally the hand. The Short Stride condition on the other hand demonstrated a different sequence, starting with the pelvis and torso at the same time, lead arm, and then hand. This better sequenced swing, as well as a higher angular acceleration of the hand in the Short Stride condition could explain the faster Bat Speed.

Continuing down the chain, we will look at the Knee Moment. The Long and Short Strides showed about a 10% difference in the average peak moment. One would expect that having greater GRFs would cause a larger joint moment, a possible explanation is that this subject in particular uses a movement pattern that would cause the difference to be larger in the ankle or hip. However, neither of those joints were analyzed in this study. The slightly greater moment in the Short Stride condition is noticeable but not large enough to explain the difference in bat speed.

Finally, Ground Reaction Forces are the last variable we will be discussing. As evidenced by the time-series graphs, the subject produced a greater magnitude of GRFs in both the rear and stride leg. The X plane was chosen for the rear leg because it is in the direction of the pitch, therefore would have more importance than the other two directions. As for the stride leg, Z was chosen because when the stride foot contacts the ground it is important for the reaction force to travel vertical up chain. Because the Long Stride condition had greater GRFs but lower Bat Speed, this suggests that GRFs have little to no contribution to that performance output.

**Conclusion**

This project focused on the biomechanical differences between two different stride techniques. The data did show differences in some variables, such as GRFs. Having higher GRFs with lower Bat Speed is inefficient and could contribute to injury. The reason for this is that the lower extremity is experiencing higher reaction forces without the desired performance output. Over time these forces could cause wear-and-tear on the joints and is not worth the injury risk based on performance outcomes. The sequencing of the Short Stride was better timed in comparison to the Long Stride, as well as having higher hand acceleration. This could be an explanation as to why Bat Speed was higher in those conditions. However, it is not conclusive as to what caused the improved performance output. It would be important to look at segment energy transfer, especially in the upper extremity to find a more conclusive answer.

**Limitations**

Some limitations include having one subject, having to throw out a trial from analysis, and hitting a stationary ball. Due to error in marker placement, there were problems with the data which also exacerbates the single subject issue. The final number of trials used was five between both conditions. Having the batter hit a stationary ball is also a limitation because it is not specific to the in-game task. In competition the ball is moving at changing velocities, spin, and horizontal and vertical movement. It can be assumed that a batter having to visually perceive a moving object and decide his movement pattern to have a desirable outcome would be different than being able to maximally swing at a ball that is stationary on a tee.

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