EXPLORATION OF THE RELATIONSHIP BETWEEN BALL SPEED AND MOTUS BASEBALL SLEEVE OUTPUT FOR TORQUE

by

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Background:

Injuries to the Ulnar Collateral Ligament are common among baseball pitchers. Biomechanical measuring devices, such as motion capture, can be used to identify risk factors for injury, like levels of torque placed on the UCL during a pitch. The Motus Baseball sleeve is a relatively new device used to measure elbow varus torque during the pitching motion. Because of its relative newness, there are few studies exploring the relationships between different outputs from the Motus Baseball sleeve.

Purpose:

The Purpose of this thesis is to explore a relationship between ball speed and elbow valgus torque using the Motus baseball sleeve.

Method:

Twenty seven collegiate pitchers were recruited from University of Southern California and Pepperdine University. Each pitcher was fitted with an Motus sleeve adhered where the IMU is situated over the UCL. A radar gun was also used to measure ball velocity. Following a full dynamic and pitcher specific warm-up, each

pitchers was allowed up to 5 warm up throws. Once the warmup was complete, each participant took ten full-effort pitches using a standard fast-ball technique. The radar gun was used to collect data on ball speed during each pitch while the Motus baseball sleeve collected data on elbow valgus torque. Data were compiled into a spreadsheet, and analyzed using linear regressions to explore relationships between ball velocity and elbow torque.

Results:

The linear regression analysis showed that there was a positive correlation between ball speed elbow valgus torque when analyzing both the data set as a whole and the averages from each pitcher only. Analysis from all data points as well as pitcher averages, produced linear regressions with positive slopes. Low R^2 values of 0.187 for all data points, and 0.167 for pitcher averages were also observed

Conclusion:

Although the results would suggest that there is a positive relationship between ball speed and elbow valgus torque when using the Motus baseball sleeve, there is not enough evidence to justify a definitive relationship. There are other technical variables throughout the kinetic chain to be considered that this protocol did not account for. Further testing that analyzes pitching technique across the whole kinetic chain would be necessary to conclude that this data was significant.

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Exploration of the Relationship Between Ball Speed and Motus Baseball Sleeve Output for Torque

Introduction:

The upper extremity is used in almost every day to day activity, and has a wide range of capabilities due to the complexity of the kinetic chain. The shoulder is one of the most frequently used joints in the body, and is a part of a complex joint system, consisting of 6 different articulations that all provide different types of movement and stability. In addition, the elbow acts as the fulcrum for the arm, and allows the wrist and hand to perform activities of daily living.

A baseball pitch can be broken down into different phases that each utilize a different segment of the kinetic chain. During the initial arm cocking phase, shoulder external rotation (ER) is significant and a great amount of stress is placed on both the shoulder and the elbow. The degree of shoulder external rotation a pitcher is able to achieve will affect the ball speed, with more ER correlating with a higher velocity. However, an increase in shoulder ER also increases the forces throughout the shoulder and can lead to a higher risk of injury. The elbow is also put under a great deal of strain during the arm cocking phase, with the highest amount of strain placed on the ulnar collateral ligament (UCL). During the arm acceleration and follow-through phase, which includes ball release,

the rotator cuff experiences the most strain through shoulder abduction and extension of the elbow.

While injuries of the rotator cuff during this phase are possible, they are far less common than injury to the UCL. The UCL is the most commonly injured part of the upper extremity in baseball pitching, which is typically caused by poor pitching mechanics, overuse, and throwing higher stress pitches that require additional movements at the wrist, such as the curveball and slider.

Limiting pitch count and avoiding higher stress pitches are relatively simple approaches that is easy to monitor, unlike the mechanics of pitching. Even a slight variation in mechanics can result in a potentially significant injury. Currently, there are a few methods used to study the mechanics of baseball pitching with the goal of reducing UCL injury by identifying errors in the pitcher's mechanics. One common method is motion capture, which uses reflective markers and multiple cameras, to capture video data of elbow valgus torque, shoulder external rotation, arm slot angle, and other aspects of pitching mechanics. While this is considered the gold standard to collect kinematic data, the nature of the collection and analysis is complex and relatively hard to perform in a clinical setting.

Recently, the Motus Baseball Sleeve has been used as an alternative method to capture this kinematic data. This device

contains a small inertial measurement unit (IMU) placed inside of an elbow compression sleeve just below the UCL. This device is easily worn by pitchers during practice or a game. Motus compiles its data through Bluetooth to an app and provides data on peak valgus torque, as well as the overall workload of the pitcher. Not only can this device provide the mechanical data that has previously been difficult to obtain in a clinical setting, but it breaks down the data into daily, acute, and chronic workload so that a pitcher can ensure they are not over-stressing the UCL.

Because of the limited exposure of the Motus baseball sleeve, there is a gap in literature exploring the relationship between ball speed and torque when using the Motus baseball sleeve. Based on published findings from other studies that used motion capture or an alternative measuring device, we would expect to see a positive linear correlation between an increasing ball speed and increasing torque.

Literature Review:

In current society, sport has become a large aspect of the lives of youth, and the level of competition continues to increase in younger ages. In baseball specifically, the highest rates of UCL injury and reconstruction occurred in youth pitchers when compared

to collegiate and professional pitchers (Luera, 2018). Most UCL injuries result from a large amount of elbow valgus torque that occurs during the pitching motion. Additionally, elbow valgus torque has been shown to increase with ball speed and the rise in UCL injuries is likely associated with a recent demand for rise in ball velocity throughout Major League Baseball (MLB). This may also be a factor in lower level pitchers (Slovik, 2019). Biomechanical errors made when pitching, including abnormal elbow valgus torque, can also lead to various injuries along the kinetic chain. (Chalmers, 2017).

Current methods of biomechanical analysis during the pitching motion most commonly use retroreflective markers as a tool for kinematic collection and have shown that elbow valgus torque is a significant factor that leads to injury of the UCL (Reiman, 2019). Recently, the Motus baseball sleeve has been used to study the biomechanics of the pitching motion across different distances and pitch types to determine a relationship between those variations and elbow valgus torque (Dowling 2018). Fatigue and overuse are other variables that could affect injury likelihood and the Motus baseball sleeve is capable of tracking this risk by providing data on pitch count side by side to data on torque (Okoroha, 2018). Additionally, by studying MLB player rosters, athlete statistics, and injury reports,

it has been determined that injury to the UCL is more common among pitchers who throw at a higher velocity (Bushnell, 2010).

Although multiple researchers have used the Motus sleeve to obtain kinematic data on baseball pitchers, in order to determine a relationship between variations in pitchy type and elbow valgus torque, little research has been done to explore trends between ball speed and elbow valgus torque. One researcher compared data obtained from the sleeve to the data obtained from motion capture and found similarities with the exception of elbow extension velocity (Nimphius, 2019). There are also other sensors similar to the Motus baseball sleeve where the reliability of the device has been tested and verified (Makhni, 2017). This research aims to fill the gap in literature by exploring the relationship between ball speed and elbow valgus torque when using the Motus baseball sleeve.

Methods:

Researchers from the University of Southern California and Pepperdine University recruited 27 collegiate baseball pitchers from their university's official rosters. All 27 participants went through a standard informed consent procedure, consisting of both verbal and written acknowledgement of their role in the study. Each of the 27 pitchers began the study by performing a full dynamic, and pitcher specific mobility warmup that was consistent with their usual warmup routine. Following the

warmup, each participant was fitted with the Motus Baseball Sleeve. The IMU device was adhered to the skin on top of the UCL, using tape. The sleeve was then fitted and placed to be worn over the IMU, fully covering the elbow. Prior to the start of data collection, a radar gun was also set up in the pitching area, in order to measure ball speed. Once both the radar gun, and the Motus Baseball sleeve were set up, each pitcher took up to 5 warm-up pitches, or fewer if they were ready to pitch at full-effort. Data was collected during these pitches, but were not used for data analysis. Following the 5 warm up pitches, each participant threw 10 full-effort pitches, consecutively, where ball speed from the radar gun, and elbow valgus torque from the Motus baseball sleeve were captured each pitch. All pitches were thrown as a typical fast ball technique and were completed in one session.

Following the completion of data collection, results were compiled into a spreadsheet. One scatterplot was generated that evaluated all 10 pitches across all 27 pitchers, for a total of 270 data points. A linear regression analysis was performed to determine a line of best fit and r^2 values. A second scatterplot was then generated comparing only the average pitch (both ball speed and elbow valgus torque) for all 27 pitchers, for a total of 27 data points. Again, a linear regression analysis was performed to determine a line of best fit and r^2 values.

Results & Analysis:

When analyzing all the data as a whole, a linear regression with equation $Y=0.009x - 0.1178$ and an R^2 value of 0.187, was fitted (figure 1). The positive slope of 0.009 indicates that elbow varus torque does increase as ball velocity increases, as

expected. However, an R^2 value of only 0.187 implies that only 18.7% of the increase in elbow valgus torque can be attributed to an increase in ball speed. When analyzing the linear regression for the averages from each pitcher only, an equation of Y=0.0091x - 0.1259 and an R^2 value of 0.167 was produced (figure 2). As expected, these numbers vary only slightly from the analysis of the full data set with a slope of 0.0091 and an R^2 value of 0.167. Again, and R^2 value of only 0.167 implies that only 16.7% of the increase in elbow valgus torque can be attributed to an increase in ball speed.

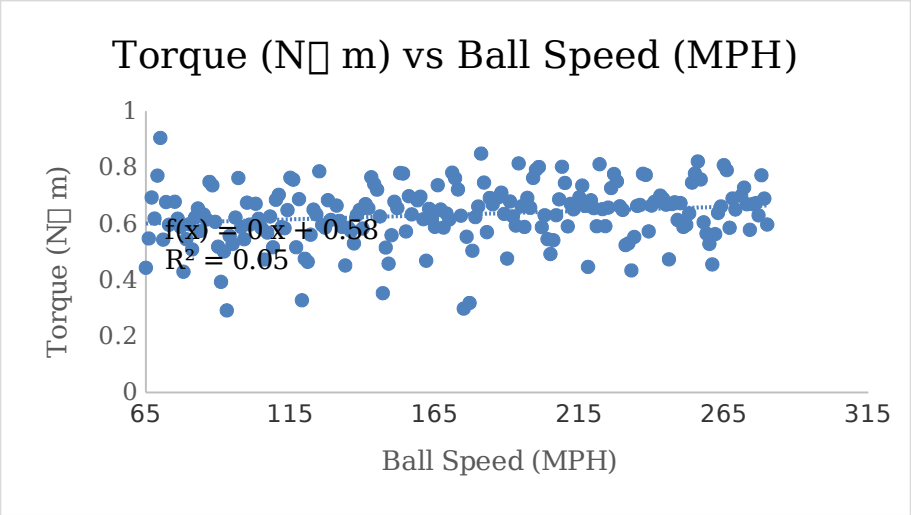

Figure 1: A graphical representation of the relationship between ball speed and elbow valgus torque for all 270 pitches. The graph is fitted with a linear regression with equation Y=0.009x - 0.1178, and an R^2 value of 0.18653.

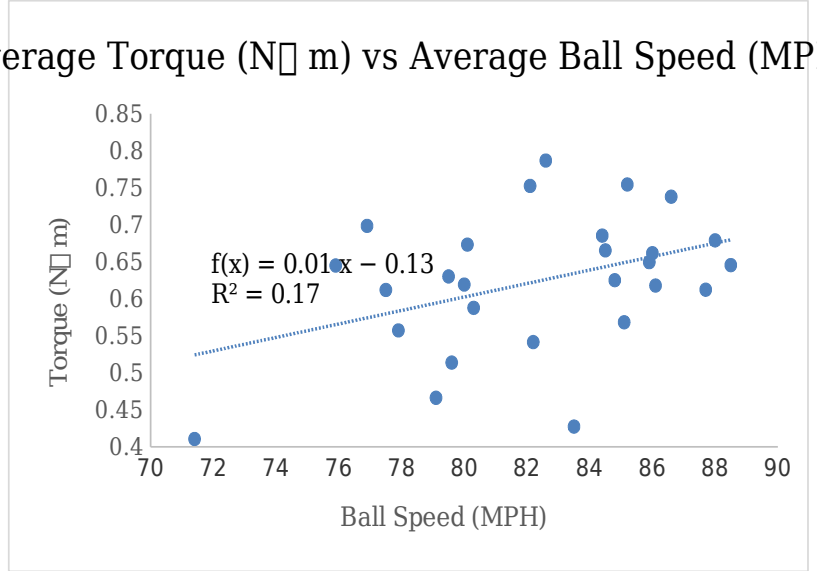

Figure 2: A graphical representation of the relationship between ball speed and elbow valgus torque using the average pitch for each of the 27 participants. The graph is fitted with a linear regression with equation Y=0.0091x - 0.1259, and an R^2 value of 0.16732.

Conclusion:

Linear regressions and an analysis of results matched the initial hypothesis that balls speed and elbow varus torque would have a positive correlation when using the Motus baseball sleeve. A slope of 0.009 when all data points were compiled, and 0.0091 when data was averaged by pitcher, provide numerical evidence showing the positive correlation between the two variables. R^2 values however, showed that only 18.7% of the data points showing an increase in elbow varus torque, could be justified with increasing ball speed. This data point was even lower at 16.7% when averages for each pitcher were used only. While these data still aligns with the initial hypothesis, there is not enough justification to confirm a definite relationship between ball speed and elbow varus torque.

One factor that is not taken into consideration using the Motus baseball sleeve, is variations in technique between pitchers, and even individual pitches from the same pitcher. The entire kinetic chain is used during the pitching motion, and any changes made throughout that chain, such as degree of trunk rotation, could affect the elbow valgus torque output from the Motus baseball sleeve, even if there was no significant effect on the ball speed. (Luera, 2018). Although less likely than injury to the UCL, injuries throughout other areas of the kinetic chain do happen among baseball pitchers. Shoulder injuries at the rotator cuff are most common during the arm acceleration and follow-through phases of a pitch, because this is when the forces throughout the shoulder are at their peak (Chalmers, 2017). This is another indicator that technical differences from earlier regions of the kinetic chain could affect valgus torque seen at the UCL. For all pitchers, no two pitches are exactly the same, which could have an affect on Motus baseball sleeve outputs and their relationship to ball speed.

Other outputs provided from the Motus sleeve could also be useful when judging how technical variations affected elbow valgus torque and ball speed. SER and arm stress are also Motus outputs we would expect to see an increase in along with increased ball speed, but again we cannot see how other parts of the kinetic chain play a factor in these outputs.(Chalmers, 2017). While tools such as motion capture are not practical for everyday use and require a full laboratory setting, they do offer the benefit of collecting data from many points along the kinetic chain in order to evaluate a pitcher's technique as a whole.

Although our data would indicate a weak correlation that can be explained by variations in ball speed, the Motus baseball sleeve could still be a useful device for injury prevention among baseball pitchers. More studies need to be done on the biomechanical outputs produced by Motus. However, its high accessibility, and complementary functions, such as daily pitch count and work load measurements, could result in significant changes to injury likelihood among pitchers who regularly use Motus baseball sleeve in their training. (Nimphius, 2019).The low accountability of the relationship found between ball speed and elbow valgus torque when using the Motus baseball sleeve may not be significant enough to make a definitive conclusion, but should not discredit the device in its entirety, and rather open the door for further research.

Bibliography

Bushnell, Brandon D., et al. “Association of Maximum Pitch Velocity and Elbow Injury in Professional Baseball Pitchers.” *The American Journal of Sports Medicine*, vol. 38, no. 4, 2010, pp. 728–732.

Chalmers, Peter N., et al. “The Relationship Between Pitching Mechanics and Injury: A Review of Current Concepts.” *Sports Health: A Multidisciplinary Approach*, vol. 9, no. 3, 2017, pp. 216–221.

Dines, Joshua S., et al. “The Relationship of Throwing Arm Mechanics and Elbow Varus Torque: Within-Subject Variation for Professional Baseball Pitchers Across 81,999 Throws.” *Orthopaedic Journal of Sports Medicine*, vol. 5, no. 7_suppl6, 2017.

Dowling, Brittany, et al. “Changes in Throwing Arm Mechanics at Increased Throwing Distances During Structured Long-Toss.” *The American Journal of Sports Medicine*, vol. 46, no. 12, 2018, pp. 3002–3006.

Fabian, Lauren M., and Stan A. Conte. “Epidemiology of Elbow Ulnar Collateral Ligament Injuries.” *Elbow Ulnar Collateral Ligament Injury*, 2015, pp. 35–41.

Luera, Micheal J., et al. “Role of Rotational Kinematics in Minimizing Elbow Varus Torques for Professional Versus High School Pitchers.” *Orthopaedic Journal of Sports Medicine*, vol. 6, no. 3, 2018, p. 232596711876078.

Makhni, Eric C., et al. “Assessment of Elbow Torque and Other Parameters During the Pitching Motion: Comparison of Fastball, Curveball, and Change-Up.” *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, vol. 34, no. 3, 2018, pp. 816–822.

Nimphius, S. “Peer Review #3 of ‘Exploring Wearable Sensors as an Alternative to Marker-Based Motion Capture in the Pitching Delivery (v0.1)".” 2019.

Okoroha, Kelechi R., et al. “Effect of Fatigue on Medial Elbow Torque in Baseball Pitchers: A Simulated Game Analysis.” *The American Journal of Sports Medicine*, vol. 46, no. 10, 2018, pp. 2509–2513.

Reiman, Michael P., et al. “Risk Factors for Ulnar Collateral Ligament Injury in Professional and Amateur Baseball Players: a Systematic Review with Meta-Analysis.” *Journal of Shoulder and Elbow Surgery*, vol. 28, no. 1, 2019, pp. 186–195.

Rothermich, Marcus A., et al. “Incidence of Elbow Ulnar Collateral Ligament Surgery in Collegiate Baseball Players.” *Orthopaedic Journal of Sports Medicine*, vol. 6, no. 4, 2018, p. 232596711876465.

Slowik, Jonathan S., et al. “Fastball Velocity and Elbow-Varus Torque in Professional Baseball Pitchers.” *Journal of Athletic Training*, vol. 54, no. 3, 2019, pp. 296–301.