COMPARISON OF FASTBALL AND CURVEBALL KINEMATICS AND MUSCLE ACTIVITY FOR ELITE BASEBALL PITCHERS THROWING FROM THE STRETCH

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The purpose of this study was to compare the muscle activation patterns for the Biceps Femoris, Gastrocnemius, Triceps Brachii, Biceps Brachii, Upper Trapezius, Lower Trapezius, shoulder rotation, elbow angular velocity, elbow flexion-extension & pelvis rotation between the curveball and fastball. Participants were current elite baseball pitchers. After the placement of electrodes, Maximal Voluntary Isometric Contractions (MVIC) were completed. Significant differences in elbow flexion-extension, shoulder rotation, and pelvis rotation for the stretch curveball when compared to the stretch fastball were found.The increase in muscle activity and the greater than MVIC values indicate that lower extremity muscles are beneficial in incorporating into the pitching literature and play a role in the dynamic muscle strength needed to complete a pitch from a specific delivery.

KEYWORDS: Electromyography, Biomechanics, Athletes

INTRODUCTION: Curveballs have been looked down upon by baseball pitchers and coaches in the past, because they have been thought to cause injuries or increase the likelihood of injury in the upper extremity. Different variations of baseball pitch types will be thrown throughout the duration of a baseball game; however, fastballs and curveballs are the most commonly used in an everyday game situation. Just like with variations in baseball pitch types, there are also different ways to deliver the pitch. There are two common forms of pitching: wind-up and stretch. The dissimilarities in the wind-up pitch and the stretch pitch with respect to the kinematics and temporal variables have been studied, but only in regard to the fastball (Dun, Kingsley, Fleisig, Loftice, & Andrews, 2008; Fleisig, Andrews, Dillman, & Escamilla, 1995; Keeley, Oliver, & Dougherty, 2012; Werner, Fleisig, Dillman, & Andrews, 1993). There has been one study that has looked into the muscle activation, kinematics and temporal variables between the fastball and curveball while also combining the wind-up delivery of the pitch(Smidebush, 2018). In previous baseball pitching literature, it has been shown that differences will occur in the kinetic and kinematic parameters between novice and elite pitchers(Sabick, Torry, Lawton, & Hawkins, 2004). It has also been shown that there is an increase in the lower extremity and upper extremity muscle activation in the novice pitching group when compared to the elite pitching group(Aguinaldo, Buttermore, & Chambers, 2007; Sabick et al., 2004). Pitching performance has been investigated with kinematics of the fastball and muscle activation of the stretch pitching delivery. Little research has been performed on the curveball pitch and the comparison of kinematics and muscle activation between the fastball and curveball, therefore it was the aim and the goal of this research study to shed light on the muscle activation and kinematics associated with the different pitch types.

METHODS: Participants were chosen based on their status as baseball pitchers. Participants were only considered if they were between the ages of 18-30, had no current pain that might hinder their ability to play baseball and had not had any injuries in the previous three months. The age, body height and body mass of each pitcher was recorded. There were nine right-handed pitchers and three left-handed pitcher who participated in this research study. The pitchers had an average age of 22.33±4.54yrs, height of 1.742±0.13m and mass of 89.02±10.98kg. Bipolar electrodes were placed on the stride leg biceps femoris, stride leg medial gastrocnemius, ipsilateral (pitching arm) lower trapezius, ipsilateral upper trapezius, ipsilateral triceps brachii and ipsilateral biceps brachii. A ground electrode was placed over the patella. Prior to electrode placement, the skin was shaved and cleansed to decrease electrical impedance. After the placement of the electrodes, muscle specific tests were conducted to find the Maximal Voluntary Isometric Contraction of each of the muscles (MVIC). Each MVIC test consisted of one familiarization test followed by three actual trials. Electrode placement and MVIC tests were based on SENIAM guidelines (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Prior to performing the pitching analysis of the fastball and curveball, each participant was fitted with a standardized running shoe. The upper body of each participant was marked with twenty-four lightweight retro-reflective markers, the lower body was marked with twenty-one markers, rigid body clusters of 5 markers were placed on the right thigh and shank, rigid body clusters of 4 markers were placed on the left thigh and shank as well as right and left forearm. Motion capture of the pitch was completed using six Eagle and four Raptor Motion Analysis (Santa Rosa, California, USA) cameras recording at 200 Hz. A static image of each participant was taken in anatomical neutral to identify the anatomical locations of the markers. Each participant threw from a pitching mound into a net placed inside the laboratory. A ten-pitch warm-up period allowed the participants to become familiarized to the laboratory setting. Participants were then instructed to complete ten pitches for data collection. Five pitches were fastballs while the other five pitches were curveballs, each pitch was randomized as to the order thrown. Each pitch was broken into four events: foot contact (FC), maximal external rotation (MER), ball release (BR) and maximal internal rotation (MIR). The stride phase starts when the lead leg extends to a maximum height and the ball is removed from the pitching glove. The stride phase ends when the lead leg is in contact with the rubber mound (FC). The cocking phase is between foot contact with the mound and maximal external rotation of the throwing shoulder (MER). Marker trajectory data were tracked using Cortex software (Santa Rosa, California, USA). Data processing including filtering and calculating joint/segment angles, were done using Visual 3D software (C-Motion, Germantown, Maryland, USA). Raw marker trajectory data were filtered using a fourth order low-pass Butterworth filter with a cut-off frequency of 13 Hz. An X-Y-Z (sagittal-frontal-transverse) Cardan sequence were used to quantify joint angles, in which the distal segment was expressed relative to the proximal segment. Elbow flexion-extension, elbow angular velocity, shoulder rotation, pelvis rotation, biceps brachii, triceps brachii, upper trapezius, lower trapezius, biceps femoris and gastrocnemius muscle activity were compared using a repeated measure analysis with a Sidak confidence level adjustment. A Mauchly's Test of Sphericity was completed for both muscle activation and kinematic variables. If significance was found a Greenhouse-Geisser test was performed to test the within-participant and determine significance. A pairwise analysis was performed to establish between which pitch type the significance was occurring if significance was found with the Greenhouse-Geisser test. All statistical analysis was performed using SPSS statistical software (SPSS Inc) with a significance level of $p \leq 0.05$.

RESULTS: One pairwise comparison was significant ($p \leq .01$) for the biceps brachii mean muscle activity. Two pairwise comparisons were significant ($p \leq .01$) for the triceps brachii mean muscle activity. Three pairwise comparisons were significant ($p \leq .01$) for the upper trapezius mean muscle activity, lower trapezius mean muscle activity, and gastrocnemius mean muscle activity. Four pairwise comparison were significant ($p \leq .01$) for the biceps femoris mean muscle activity (refer to Figure:2). One pairwise comparisons was significant ($p \leq .01$) for elbow flexion-extension and shoulder rotation. Two pairwise comparisons were significant ($p \leq .01$) for pelvis rotation (refer to Figure:1 & Figure:2). The biceps brachii from the stretch fastball had a significant increase for ball release when compared to the curveball. For the triceps brachii the stretch fastball had a significant increase in muscle activity at foot contact and ball release. The upper trapezius had a significant increase in muscle activity for the stretch fastball at foot contact, maximal external rotation, and ball release. A significant increase in muscle activity was also seen at foot contact, maximal external rotation, and ball release for the lower trapezius. The biceps femoris showed a significant increase in the muscle activity for the stretch fastball at foot contact, maximal external rotation, ball release, and maximal internal rotation. Finally, a significant increase in the gastrocnemius for the stretch fastball at foot contact, maximal external rotation, and ball release when compared to the curveball. The stretch curveball has a significant increase in elbow flexion-extension, shoulder rotation, and pelvis rotation at maximal external rotation compared to the fastball. There was also a significant increase seen in pelvis rotation for the fastball at maximal internal rotation and ball release.

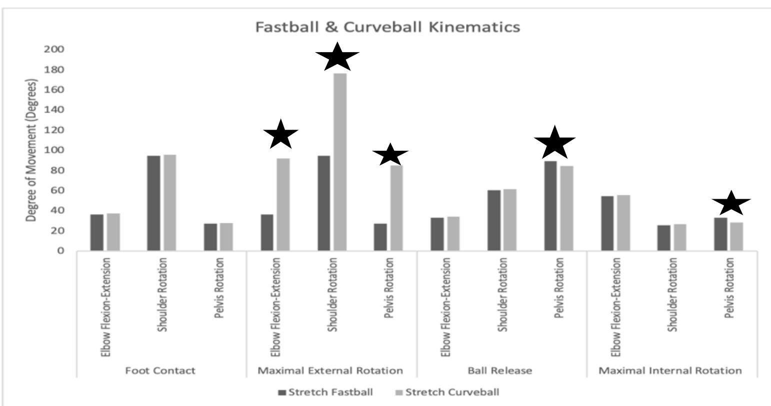

Figure 1: Stretch fastball and stretch curveball kinematic variables: elbow flexion-extension, shoulder rotation & pelvis rotation. Star indicates significant difference (p<.01)

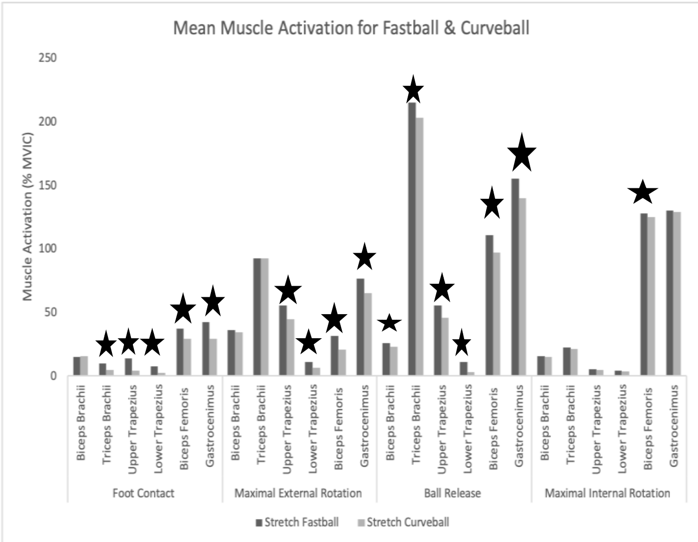

Figure 2: Stretch fastball and stretch curveball mean muscle activation: biceps brachii, triceps brachii, upper trapezius, lower trapezius, biceps femoris & gastrocnemius. Star indicates significant difference (p<.01)

DISCUSSION: The purpose of this study was to compare the muscle activation and kinematics between a fastball and curveball when pitched from the stretch. It was hypothesized that the stretch fastball would have an increase in the muscle activation as well as have an increase in the range of motion for the kinematic variables (shoulder rotation, pelvis rotation, elbow flexion-extension) when compared to the stretch curveball. For the mean muscle activation of the biceps brachii, the stretch fastball had a significant increase for ball release when compared to the curveball. For the triceps brachii the stretch fastball had a significant increase in muscle activity at maximal external rotation and ball release. The upper trapezius had a significant increase in muscle activity for the stretch fastball at foot contact, maximal external rotation, and ball release. A significant increase in muscle activity was also seen at foot contact, maximal external rotation, and ball release for the lower trapezius. The biceps femoris showed a significant increase in the muscle activity for the stretch fastball at foot contact, maximal external rotation, ball release, and maximal internal rotation. Finally, a significant increase in the gastrocnemius for the stretch fastball at foot contact, maximal external rotation, and ball release when compared to the curveball. The stretch curveball has a significant increase in elbow flexion-extension, shoulder rotation, and pelvis rotation at maximal external rotation compared to the fastball. There was also a significant increase seen in pelvis rotation for the fastball at maximal internal rotation and at ball release. In agreement with Werner et al., (Werner et al., 1993) the biceps brachii muscle activation was increased for a fastball pitched from the stretch when compared to a fastball pitched from the wind-up. This muscle activity finding by Werner et al.(Werner et al., 1993) was in support of the biceps brachii muscle activity and triceps brachii muscle activity seen in this current study. The findings from this study are in agreement with the results from Jobe et al. that the triceps muscle activity can be observed to be over 200% of the MVIC amount whereas the biceps activity stays relatively close to a peak value of 33-36% of the MVIC(Jobe, Tibone, Perry, & Moynes, 1983). Having sufficient muscle strength is crucial in maintaining proper pitching mechanics. Campbell et al. reported that over the course of the entire pitch cycle there was a fluctuation of muscle for the gastrocnemius and biceps femoris having very similar outcomes as what was seen in the mean and peak muscle activity for the biceps femoris and gastrocnemius muscle activity in this study(Campbell, Stodden, & Nixon, 2010).

CONCLUSION: There are significant differences in kinematic parameters of elbow flexion-extension, shoulder rotation, and pelvis rotation for the stretch curveball when compared to the stretch fastball (refer to Figure: 2). The stretch curveball had an increase in elbow flexion-extension, shoulder rotation, and pelvis rotation at maximal external rotation while only an increase in pelvis rotation at maximal internal rotation. There was a significant increase seen in the mean muscle activity of the triceps brachii, upper trapezius, lower trapezius, biceps femoris and gastrocnemius at foot contact and maximal external rotation for the stretch fastball. There was also a significant increase seen in the mean muscle activity of the biceps brachii, triceps brachii, upper trapezius, lower trapezius, biceps femoris and gastrocnemius at ball release for the stretch fastball and at maximal internal rotation a significant increase was seen in the biceps femoris stretch fastball. Depending on the type of pitch type thrown there will be differences seen in the kinematic parameters and the muscle activation of both the upper extremity muscles and the lower extremity muscles. The implication of the increase in muscle activity and the greater than MVIC values, indicate that the lower extremity muscles are beneficial in incorporating into the pitching literature as well as play a role in the dynamic muscle strength needed to complete a pitch from a specific delivery. This outcome of having an increase in muscle activity during the stretch fastball when compared to a curveball indicates that pitching a fastball from the stretch increases the activation of the muscles and can therefore lead to muscle injury, which would have to be investigated further.

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