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THE INFLUENCE OF HUMERAL ELEVATION ON SHOULDER KINETICS IN CATCHERS THROWING FROM THEIR KNEES

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SUMMARY

Understanding throwing kinematics and kinetics of catchers is paramount for developing injury prevention protocols. It is believed that catchers rush their throwing mechanics when they throw to second base from their knees. The purpose of this study was to examine the influence of humeral elevation on shoulder kinetics, specifically shoulder moments and compressive forces in catchers throwing to second base from their knees. Maximum humeral elevation was obtained at MER and was 75.6°. A significant negative correlation between humeral elevation and shoulder moment ($r = -0.5$, $p = 0.02$) at MIR was present.

INTRODUCTION

The kinetic chain is composed of the body's segments that operate interdependently of each other to produce a desired movement. The kinetic chain functions to transfer forces sequentially, in a proximal to distal manner, to allow for optimal performance in dynamic activities such as striking and throwing. Proximal to distal sequencing, during throwing, occurs when forces are transferred from the lower extremity (the most proximal link) through the hips and trunk to the shoulder, elbow, and wrist (the most distal link).

The mechanics of catchers throwing to second base is beginning to be reported in the literature. Fortenbaugh et al [5] found catchers throwing to second base had a shorter stride length, open foot position, closed foot angle, and reduced pelvis-trunk separation at foot contact as well as excessive elbow flexion during arm cocking and less forward trunk tilt at ball release than pitchers' throwing long toss. An additional study examined the kinematic and kinetics of two different age groups of catchers [12]. This study revealed that pelvis-trunk separation was less than those reported by Fortenbaugh et al [5]. The group of younger catchers displayed greater upper extremity segmental velocity and pelvis rotation earlier in the throwing motion than those values displayed by the older catchers. The authors postulated that early pelvic rotation may lead to kinetic chain dysfunction ultimately leading to greater upper extremity segmental velocities due to the upper extremity compensating for lost energy.

When attempting to throw out a stealing base runner the catcher may throw from a squatted position or their knees. Pitch location is the most common factor that determines which type of throw the catcher will have to make. The catcher's ultimate goal is to attempt to throw out a runner progressing to second base and it is believed that throwing from the knees allows for the fastest release of the ball.

The lower extremity (legs, hip, trunk) plays a critical role in force production and transfer during dynamic movements. It has been previously determined that the lower extremity generates 54% of total force during a tennis serve emphasizing the importance of the proximal segments during dynamic movement [6]. When a catcher throws from their knees they eliminate a major portion of their kinetic chain force production, the lower extremity. The absence of the lower extremity may alter efficient kinetic chain sequencing. An altered kinetic chain may cause glenohumeral joint to adapt and become a force producer versus a funnel to transfer the forces. The purpose of this study was to examine the influence of humeral elevation on shoulder kinetics, specifically shoulder moments and compressive forces in catchers throwing to second base from their knees.

METHODS

Twenty-two baseball and softball catchers (14.04 ± 4.05 years; 162.54 ± 18.91 cm; 62.21 ± 22.08 kg) participated. Participants were selected based on criteria that included coach recommendation, multiple years of catching experience, and freedom from injury within the past six months. Informed consent was obtained prior to testing.

The MotionMonitor^{TM} (Innovative Sports Training, Chicago, IL) synched with electromagnetic tracking system (Flock of Birds Ascension Technologies Inc., Burlington, VT) was used to collect data. Participants had a series of 10 electromagnetic sensors (Flock of Birds Ascension Technologies Inc., Burlington, VT) attached at the following locations: (1) the medial aspect of the torso at C7; (2) medial aspect of the pelvis at S1; (3-4) bilateral distal/posterior aspect of the upper arm; (5-6) bilateral distal/posterior aspect of the forearm; (7-8) bilateral distal/posterior aspect of lower leg; and (9-10) bilateral distal/posterior aspect upper leg [9-10,12]. All kinematic data were sampled at a frequency of 100 HZ. The collection rate for these data describing the position and orientation of electromagnetic sensors was set at 144 Hz. Raw data were independently filtered along each global axis using a 4th order Butterworth filter with a cutoff frequency of 13.4 Hz. Raw data regarding sensor orientation and position were transformed to locally based coordinate systems for each of the respective body segments. Euler angle decomposition sequences were used to describe both the position and orientation. ISB standards and conventions were used to define trunk and shoulder movements. The catching surface was positioned so that the participant's knees would land on top of a 40 x 60 cm Bertec force plate (Bertec Corp, Columbus, Ohio) that was anchored into the floor. Force plate data were sampled at a frequency of 1000 Hz.

Following the attachment of the electromagnetic sensors and subsequent digitization, participants were given an unlimited time to warm-up in their gear (helmet, chest protector, and shin guards). Once the participants deemed themselves warm, testing began. In order to best simulate a game experience, the participant received a pitch from a pitcher and then threw the ball to a position player on second base. Data were collected for five accurate throws. An accurate throw to second base was one in which the position player did not have to move off the base when receiving the throw.

The throwing motion was broken down into the events of knee contact (KC), maximum shoulder external rotation (MER), ball release (BR), and maximum shoulder internal rotation (MIR) (Figure 1). Knee contact was defined as the point in the throwing motion where the participants' knees landed on the force plate as they dropped down to their knees to initiate the throw. Descriptive statistics and Pearson Product Moment Correlation Coefficients were calculated to identify relationships between humeral elevation and shoulder moment and compressive force. Type I error rate was set *a priori* at $p \leq 0.05$ and each event of throwing was analyzed independently.

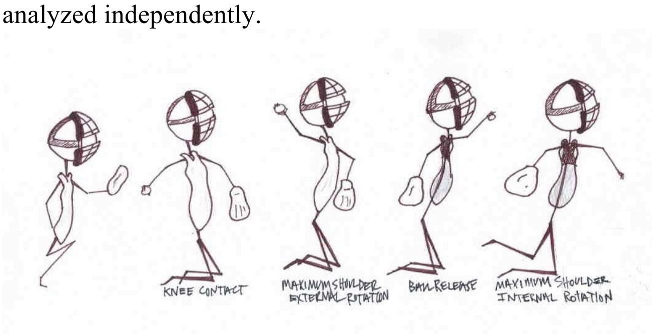

Figure 1: Events of the throwing motion from the knees.

RESULTS AND DISCUSSION

Shoulder kinematic and kinetic data are presented in Table 1. Maximum humeral elevation was obtained at MER, however the average value was only 75.6°. Shoulder moment and compressive force displayed the greatest values at BR. Significant relationships between humeral elevation and shoulder compressive force were observed during MER ($r = -0.5$, $p = 0.02$), BR ($r = 0.5$, $p = 0.009$), and MIR ($r = -0.5$, $p = 0.01$). A significant negative correlation between humeral elevation and shoulder moment ($r = -0.5$, $p = 0.02$) at MIR was also present.

Pitching literature has reported that decreased humeral elevation is a predictor for injury [1]. The ideal position of the humerus, for reducing joint torques and maximizing functional stability, has been reported as 90° [4,7-8]. Matsuo et al [7] performed simulations analyzing pitching kinematics and kinetics and suggests that a narrow range of shoulder abduction centering around 90° with slight lateral trunk tilt maximizes wrist and ball velocity. These data help provide valuable insight into the level of humeral elevation that other position players should strive for during throwing. The current study revealed that humeral elevation was 75.6°, which is not only lower than the recommended position for maximizing joint stability but also less than what has been observed in catchers throwing from their stance. Humeral elevation angles above 90°, until the point of maximum shoulder internal rotation, have been observed in catchers throwing from their stance [12]. The difference in humeral elevation between throwing from the stance and the knees may indicate that catchers rush the throw to second base when throwing from their knees. In attempt to release the ball as quickly as possible they may not take the time to reach an adequate level of elevation.

Shoulder compressive force and moment both peaked at the point of BR whereas pitching and throwing from the stance produced the greatest kinetics at MIR [2-3,12]. Significant correlations existed between shoulder compressive force and humeral elevation throughout a majority of the throwing motion. The static and dynamic stabilizers of the glenohumeral joint act to provide a compressive force that resists shoulder distraction during throwing. Increased stress that may be placed on these structures while throwing from the knees may ultimately lead injury.

CONCLUSIONS

It is evident by the presented data that when catchers throw to second from their knees, relationships exist between humeral elevation and shoulder moment and compressive force. Catchers appear to abbreviate their throwing motion from the knees to accommodate for lack of force production from the lower extremity. Large shoulder moment and compressive forces may be the result of the shoulder compensating for decreased proximal-distal force transfer. Over time, large shoulder moment and compressive force may lead to rotator cuff, glenoid labrum, or biceps tendon injury in catchers.

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Table 1: Means and standard deviations at each event of the throw.

	FC	MER	BR	MIR

Humeral Elevation (°)	-49.3±62.3	-75.6±73.8	-70.1±64.4	-56.8±53.9
Shoulder Compressive Force (N)	15.2±53.2	326.8±488.4	-803.2±553.0	487.0±339.2
Shoulder Moment (N)	11.6±11.7	106.9±81.5	203.6±161.1	134.0±100.0
Elbow Moment (N)	3.4±3.4	47.4±41.2	40.5±40.4	29.5±24.0