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Descriptive analysis of kinematics and kinetics of catchers throwing to second base from their knees

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ABSTRACT

In order to decrease the amount of time that it takes the catcher to throw the ball, a catcher may chose to throw from the knees. Upper extremity kinematics may play a significant role in the kinetics about the elbow observed in catchers throwing from the knees. If relationships between kinematics and kinetics exist then the development of training and coaching instruction may help in reduced upper extremity injury risk. Twenty-two baseball and softball catchers (14.36 ± 3.86 years; 165.11 ± 17.54 cm; 65.67 ± 20.60 kg) volunteered. The catchers exhibited a less trunk rotation (5.6 ± 16.2°), greater elbow flexion (87.9 ± 21.4°) and decreased humeral elevation (71.1 ± 12.3°) at the event of maximum shoulder external rotation as compared to what has previously reported in catchers. These variables are important, as they have previously been established as potential injury risk factors in pitchers, however it is not yet clear the role these variables play in catchers' risk of injury. A positive relationship between elbow varus torque during the deceleration phase and elbow flexion at MIR was observed ($r = 0.609$; $p = 0.003$). Throwing from the knees reduces a catcher's ability to utilize the proximal kinetic chain and this may help to explain why their kinematics and kinetics differ from what has previously been presented in the literature.

1. Introduction

The literature has yet to describe the mechanics of a catcher throwing to second base from the knees, however catchers throwing from the squat have been examined briefly (Fortenbaugh et al., 2010; Plummer and Oliver, 2013a,b; Sakurai et al., 1994). Fortenbaugh et al. (2010) found catchers throwing to second base had a shorter stride length, open foot position, closed foot angle, and reduced pelvis-trunk separation angle 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 the same distance. Though the stresses about the shoulder and elbow were similar, the catchers had significantly less ball velocity. Thus leading the authors to suggest that catchers have a less efficient throwing motion than other position players. In addition, Plummer and Oliver (2013a) examined the kinematics and kinetics of catchers throwing to second base and reported pelvis-trunk separation to be less than those reported by Fortenbaugh et al. (2010). Additionally, greater upper extremity segmental velocity and early pelvis rotation was displayed by the younger catchers (Plummer and Oliver, 2013a). Thus it was speculated that increased upper extremity segmental velocity and early pelvis rotation may increase the risk of injury in youth catchers due to altered kinetic chain sequencing. Though injury prevention is of great concern in baseball pitchers, the limited data concerning the position of catcher's has not allowed for further investigation into the catcher's injury susceptibility.

When attempting to throw out a stealing base runner the catcher may throw from a squatted position or from the knees. Many times the method in which the catcher chooses to utilize is dictated by where the pitch is located. It is the catcher's ultimate goal to catch the pitch, transfer the ball from glove to throwing hand, and release the ball as quickly as possible in attempt to beat a runner progressing to second base. Base runners are often taught to steal when a pitch is in the dirt. A pitched ball in the dirt results in the catcher having to drop to the knees to block the ball, grasp the ball, and then perform the throw to second base. Consequently allowing the runner more time to successfully steal the base. In order to decrease the amount of time that it takes the catcher to throw the ball, a catcher may chose to throw from the knees. And as a result the catcher may then rush and or alter their mechanics thus possibly resulting in greater stress being placed on the upper extremity, specifically the elbow.

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The human body is depicted as a kinetic chain in that segments function interdependently of each other to produce a desired movement. Proper sequencing during the overhead throwing motion is essential to limit the forces acting about the shoulder and elbow that may lead to injury (Burkhart et al., 2003; Plummer and Oliver, 2013a). The dynamic movement of the overhead throwing motion relies on the interaction of a series of structural and functional components of the neuromuscular system. The interaction of these components must allow for adequate pelvic and scapular stability and mobility for efficient shoulder movement. Therefore dynamic movement efficiency is dependent upon postural stability, strength, flexibility, and movement patterns of the entire kinetic chain (Sewick et al., 2012). The majority of force generation in overhead throwing is produced, in the lower extremity, through the legs and trunk and then funneled through the glenohumeral joint and on to the ball (Kibler, 1995, 1998). Sequential functioning of the lower extremity and trunk allow for the maximum force transfer to the upper extremity in throwing, and the lack of lower extremity force generation leads to injury within the shoulder as the body attempt to create the force in the upper extremity (Burkhart et al., 2003). In attempt to maximize ball speed when throwing, the movement should start with the more proximal segments (hips, pelvis and trunk) and progress to the more distal segments (shoulder, elbow, and wrist) (Bunn, 1972; Putnam, 1993).

Kibler has determined that the lower extremity (legs, hip, trunk) generates 54% of total energy during a tennis serve, thus emphasizing the importance of the proximal segments during dynamic movement (Kibler, 1995). When a catcher throws from the knees, the major force producer of the kinetic chain, the lower extremity, is altered. Therefore the force that is typically generated from foot contact is now eliminated. It is hypothesized that the alteration of the lower extremity, as when a catcher throws from the knees, could result in a disruption of kinetic chain sequencing and eventually contribute to injury. To the authors' knowledge there are currently no data concerning injury susceptibility in catchers. Therefore it was the primary purpose of this study to quantitatively describe the kinematics and kinetics of catchers throwing from the knees. After quantifying the mechanics of catcher's throwing from their knees, we additionally sought to examine the relationship between elbow kinetics and upper extremity kinematics of catchers throwing from the knees. It was hypothesized that catchers throwing from the knees would display decreased humeral elevation and increased elbow kinetics compared to the recommended kinematics and kinetics reported in the literature.

2. Methods

2.1. Participants

Twenty-two baseball and softball catchers (14.36 ± 3.86 years; 165.11 ± 17.54 cm; 65.67 ± 20.60 kg) volunteered. Thirteen participants were male baseball players and nine were female softball players. Baseball and softball participants were chosen because previous research has examined both genders combined because the throwing motions of baseball and softball catchers are similar (Plummer and Oliver, 2013a,b). Participants had 7.26 ± 5.00 years of experience playing either baseball or softball and had at least one year of experience playing the position of catcher competitively. Participant selection criteria included coach recommendation, years of catching experience, and freedom from injury within the past six months (Oliver and Keeley, 2010a,b; Plummer and Oliver, 2013a,b). Coach recommendation was sought to ensure that the catchers were experienced playing the position and that the catchers do throw from the knees during game situations. While freedom from injury within the past six months was one of the criteria for selection none of the participants reported that they had ever suffered an injury to their throwing arm. They also did not report any pain or stiffness in their upper extremity following extensive throwing sessions. Testing was conducted in a gym inside the University's Sports Medicine and Movement Laboratory. The University's Institutional Review Board approved all testing protocols. Prior to data collection all testing procedures were explained to each participant and their parent(s)/legal guardian(s) and informed consent and participant assent was obtained.

2.2. Procedures

The MotionMonitor™ (Innovative Sports Training, Chicago, IL) synced with electromagnetic tracking system (Track Star, Ascension Technologies Inc., Burlington, VT) was used to collect data. The electromagnetic tracking system has been validated for tracking humeral movements, producing trial-by trial interclass correlation coefficients for axial humerus rotation in both loaded and non-loaded condition in excess of 0.96 (Ludwig and Cook, 2000). With electromagnetic tracking systems, field distortion has been shown to be the cause of error in excess of 5° at a distance of 2 m from an extended range transmitter (Day et al., 2000), but increases in instrumental sensitivity have reduced this error to near 10° prior to system calibration and 2° following system calibration (Day et al., 2000; Ludwig and Cook, 2000; Meskers et al., 1999, 1998). Thus prior to data collection, the current system was calibrated using previously established techniques. Following calibration, magnitude of error in determining the position and orientation of the electromagnetic sensors within the calibrated world axes system was less than 0.01 m and 3° respectively.

Participants had a series of 11 electromagnetic sensors [Track Star, Ascension Technologies Inc., Burlington, VT] attached at the following locations: (1) seventh cervical vertebra (C7) spinous process; (2) pelvis at sacral vertebrae 1 (S1); (3) deltoid tuberosity of the throwing arm humerus; (4) throwing arm wrist, between the radial and ulnar styloid processes; (5) acromioclavicular joint of the throwing arm (6–7) bilateral shank centered between the head of the fibula and lateral malleolus; (8–9) bilateral lateral aspect of the femur (Oliver, 2013; Oliver and Keeley, 2010a,b; Wu et al., 2002, 2005) and (10–11) bilateral third metatarsal of the foot. Student researchers who were trained in the application techniques applied the sensors. Sensors were affixed to the skin using PowerFlex cohesive tape (Andover Healthcare, Inc., Salisbury, MA) to ensure the sensors remained secure throughout testing. Following the application of the sensors, an additional sensor was attached to a stylus and used for digitization following previously established guidelines (Oliver, 2013; Oliver and Keeley, 2010a,b; Wu et al., 2002, 2005). Participants stood in anatomical position during digitization to guarantee accurate bony landmark identification. The medial and lateral aspect of each joint was digitized and the midpoint of the two points was calculated to determine the joint center (Oliver, 2013; Oliver and Keeley, 2010a,b; Plummer and Oliver, 2013a,b; Wu et al., 2002, 2005). A link segment model was developed through digitization of joint centers for the ankle, knee, hip, shoulder, thoracic vertebrae 12 (T12) to lumbar vertebrae 1 (L1), and C7 to thoracic vertebrae 1 (T1). The spinal column was defined as the digitized space between the associated spinous processes, whereas the ankle and knee were defined as the midpoints of the digitized medial and lateral malleoli, medial and lateral femoral condyles, respectively. The shoulder and hip joint centers were estimated using the rotation method. This method of calculating a joint center has been reported for the as providing accurate positional data (Huang et al., 2010; Veeger, 2000). The shoulder joint center was calculated from the rotation between the humerus relative to the scapula and the hip joint center was from the rotation