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The Kinetic Chain Revisited: New Concepts on Throwing Mechanics and Injury

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Abstract

The overhead throwing motion is a complex activity that is achieved through activation of the kinetic chain. The kinetic chain refers to the linkage of multiple segments of the body that allows for transfer of forces and motion. The lower extremities and core provide a base of support, generating energy that is transferred eventually through the throwing arm and hand, resulting in release of the ball. The kinetic chain requires optimal anatomy, physiology, and mechanics and is involved in all 6 phases of overhead throwing: windup, stride, arm cocking, acceleration, deceleration, and follow-through. Breaks or deficits in the kinetic chain can lead to injury or decreased performance. Through an understanding of the mechanics and pathomechanics seen in each phase of throwing, the clinician can better evaluate and screen for potential kinetic chain deficits in the overhead throwing athlete. The purpose of this article is to review the biomechanics of the overhead throwing motion, the role of the kinetic chain in throwing, and the clinical evaluation and management of abnormal throwing mechanics and related injuries.

Introduction

The overhead throwing motion is a complex activity that involves the entire body to achieve accuracy and velocity [1,2]. This activity is accomplished through activation of the *kinetic chain*, which refers to the mechanical linkages of body segments that allows for the sequential transfer of forces and motions when performing a task such as throwing [3,4]. The kinetic chain has been studied with regard to its role in the normal overhead throwing motion and its impact on injury and decreased performance [1-6]. The throwing motion is a fluid, continuous movement that starts with the lower extremities and core, which provides a base of support and helps generate kinetic energy that translates through the throwing arm, eventually culminating with the ball release from the hands and fingers. An efficient and effective throwing motion requires optimized anatomy, physiology, and mechanics in all of the segments of the kinetic chain. Accordingly, deficits or "breaks" in the kinetic chain can lead to injury or impaired throwing performance. Several studies have investigated shoulder injuries in the overhead throwing athlete, addressing the biomechanics and role of the kinetic chain in injury and training principles for the overhead throwing athlete [6-9].

The purpose of this article is to review the biomechanics of the overhead throwing motion, the role of the kinetic chain in throwing, and the clinical evaluation and management of abnormal throwing mechanics and related injuries. The goal is also to provide the clinician with a structured evaluation and screening tool that assesses potential deficits in the kinetic chain as it pertains to throwing motion.

Background

Throwing and the Kinetic Chain

The overhead throwing motion traditionally has been divided into 6 phases that primarily focus on upper extremity function: windup, stride, arm cocking, acceleration, deceleration, and follow-through (Figure 1) [2,5,10]. The kinetic chain temporarily links multiple body segments during the phases of throwing motion, including the feet, which provide contact with the ground, maximize the ground reaction force, and create a stable proximal base for distal arm mobility [4]. In addition, maximizing force development in the large muscles of the core and legs produces more than 51%-55% of the kinetic energy that is transferred to the hand [3,5]. The thoracolumbar fascia is involved in the kinetic

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Figure 1. Six phases of throwing. (A) Windup. (B) Stride. (C) Arm cocking. (D) Acceleration. (E) Deceleration. (F) Follow-through.

chain during throwing activities and connects the lower limbs through the gluteus maximus muscle to the upper limbs through the latissimus dorsi. It covers the deep back and trunk muscles, including multifidi, and has attachments to the internal oblique and transversus abdominis muscles [4,11].

An efficient kinetic chain requires optimal anatomy, physiology (that includes muscle flexibility, strength, and task-specific motor patterns), and mechanics throughout all of the body segments involved [3]. Breakdown in the kinetic chain from factors such as variation in motor control, inadequate muscle strength, flexibility and endurance, joint injury, and improper muscle activation patterns can lead to impaired function, performance, and injury [5,6]. A "catch-up" phenomenon has been described in which breaks in the kinetic chain alter forces in distal segments, leading to pain and possible injury [3,12].

For the disabled throwing shoulder, common sites of pathologic deficits include the core, legs, and the shoulder, which includes the scapula [3]. The scapula plays a pivotal role in the throwing motion. Scapular movements during throwing include retraction, upward rotation, posterior tilt, and controlled internal and external rotation. These scapular movements assist with glenohumeral stability [1,3,13]. The shoulder serves as a funnel to transmit forces from the core and trunk to the hand. To maximize shoulder function in the kinetic chain, optimum glenohumeral kinematics must be present to create concavity/compression and stabilize the joint throughout the entire range of motion. Some of the requirements for functional stability include the alignment of the humerus and glenoid within $\pm 30^{\circ}$ angulation, a stable scapular base, coordinated contraction of rotator cuff and other shoulder musculature, and labral integrity [3,5]. The arm and hand provide a rapidly moving delivery mechanism of force to the ball [3,13].

In assessing the kinetic chain as it pertains to the baseball pitching motion, 8 nodes or key progressive positions and motions have been described to achieve the overhead throwing task most efficiently. These