Anatomy, surgical approaches and biomechanics of the elbow

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Abstract

The elbow is a complex, trochoginglymoid joint consisting of three articulations with close relationships to the surrounding soft tissue envelope. It facilitates positioning of the hand in space, acts as a fulcrum for the forearm lever and as a load-carrying joint. In this article, we consider the anatomy of the elbow including the osteology, the surrounding muscles and the neurovascular structures. Surgery around the elbow may be required in the management of degenerative, inflammatory and traumatic conditions – the choice of surgical approach depends on the pathology. We aim to familiarize the reader with a number of surgical approaches to the elbow including posterior, medial, lateral and anterior approaches. We consider the indications for each and the possible pitfalls. This article provides an introduction to the biomechanics of the elbow, in particular an understanding how both the mobility and the stability required for recreational and professional activities is achieved. Elbow biomechanics can be considered in terms of motion, stability and force transmission. An understanding of the anatomy and biomechanics of the elbow has guided the design and development of both replacement prostheses and other surgical implants.

Keywords anatomy; biomechanics; elbow; radiocapitellar; surgical approach; ulnohumeral

Introduction

The elbow is a hinge joint, which acts as a fulcrum for the forearm and plays a key role in positioning the hand in space. Adequate elbow function is essential for independent living: from self-feeding to personal hygiene. It is a surgically complex and technically demanding joint, with close relations to surrounding neurovascular structures and key ligamentous stabilizers.

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Anatomy of the elbow

Osteoarticular anatomy

The elbow joint is a trochoginglymoid joint. It has two degrees of freedom, capable of flexion–extension and supination–pronation. It is comprised of three separate articulations: the humeroulnar, radiocapitellar and proximal radioulnar joints. These three together articulate the humerus, radius and ulna.

The humerus: the humeral shaft transitions distally to medial and lateral columns, each forming a condyle terminating in an epicondyle. These two columns support the trochlea and the capitellum. The medial condyle is connected to the spool-shaped trochlea, which articulates with the greater sigmoid notch of the proximal ulna. The lateral condyle is connected to the hemispherical capitellum, which articulates with the concave surface of the radial head. The trochlear groove separates the two articular surfaces where the capitellum and trochlea join (Figure 1). The trochlear-capitellar articular surface is internally rotated approximately 5 to 7 degrees in relation to the trans-epicondylar axis.[1] In addition, the medial ridge of the trochlea is more prominent distally than the lateral ridge creating 6–8 degrees of physiological cubito valgus.[2] In the sagittal plane, the articular surface of the humerus protrudes approximately 30 degrees anterior to the long axis of the humerus. Appreciation of this alignment is paramount when the joint axis is to be surgically reproduced.

On the anterior surface of the humerus, proximal to the articular surface, lie the coronoid and radial fossae. These accommodate the coronoid process and radial head when the elbow is fully flexed. Similarly, on the posterior humerus, the olecranon fossa accommodates the olecranon process of the ulna during full extension of the elbow. A sulcus posterior to the medial epicondyle permits the passage of the ulna nerve (Figure 2).

The ulna: the main articulation of the proximal ulna is the greater sigmoid notch. It is formed predominantly by the olecranon, with an anterior extension of the joint from the coronoid process (Figure 3). Its elliptical shape and longitudinal ridge ensure a fully congruent and stable articulation with the trochlea, forming the humeroulnar joint. It is angled approximately 30 degrees posterior to the long axis of the ulna to match the anterior angulation of the distal humerus. On the lateral aspect of the coronoid process, distal to the greater sigmoid notch, is the lesser sigmoid notch. This articulates with the radial head, forming the proximal radioulnar joint (Figure 4). Distal to the lesser sigmoid notch is the supinator crest. This provides the origin of the supinator muscle and the insertion of the lateral ulnar collateral ligament. On the medial coronoid lies an important bony prominence – the sublime tubercle. This is the site of insertion for the anterior bundle of the anterior medial collateral ligament. This ligament is fundamental in maintaining humeroulnar joint congruency and valgus stability of the elbow.

The radius: the surface of the radial head that articulates with the capitellum is concave in shape and is covered in articular cartilage both over its proximal end and around 280 degrees of its

BIOMECHANICS OF THE ELBOW IN THE THROWING ATHLETE

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The biomechanics of the elbow have been examined during the baseball pitch, the football pass, the tennis serve, the javelin throw, and the underhand softball pitch. Primary emphasis has been placed on the baseball pitch, because most throwing injuries occur during this motion. The baseball pitch is divided into six phases. They are wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through. Low muscle activity and low elbow joint forces and torques occur during the wind-up and stride phases. The wind-up and stride position the body in preparation for the highly dynamic movements that follow. High muscle activity and high elbow joint forces and torques are generated during the arm cocking, arm acceleration, and arm deceleration phases. Consequently, hard and soft tissue injuries about the elbow occur during these highly dynamic phases of the pitch. Overall, elbow joint forces and torques are greatest during the arm cocking and arm deceleration phases of the pitch. The follow-through phase consummates the pitching motion and positions the athlete in a good, balanced position ready to resume play. Similarly to the wind-up and stride, low muscle activity and low elbow joint forces and torques occur during the follow-through phase.
KEY WORDS: kinematics, kinetics, electromyography, throwing, throwing injuries

Before discussing injuries and treatment of the elbow in the throwing athlete, it is vital to understand the biomechanics of the elbow joint. Biomechanics is a function of kinematics, kinetics, and electromyography. Kinematics describes how something is moving without stating the causes behind the motion. Specifically, it quantifies linear and angular displacement, velocity, and acceleration–the effects of the motion. Elbow kinematics during throwing include elbow flexion angles, elbow angular velocities, and elbow angular accelerations. High speed videography or cinematography is often used to collect kinematic data.

Kinetics explains why an object moves the way it does; it quantifies both the forces and torques that cause the motion. Elbow kinetics includes the forces and torques about the elbow causing elbow motion to occur. Inverse dynamics equations are often used in conjunction with videographic or cinematographic data to estimate the net force or torque acting about the elbow.

Electromyography is used to quantify muscle activity. Surface electrodes are often used to detect muscle activity from larger surface muscles, whereas indwelling electrodes are often used to detect muscle activity from smaller deep muscles.

In this report, the biomechanics of the elbow in the throwing athlete are examined. Both the overhand and underhand throwing motion will be discussed, including the baseball pitch, the football pass, the tennis serve, the javelin throw, and the underhand softball pitch. Most of the emphasis will be given to the baseball pitch, because more injuries result from baseball pitching than from other throwing motions.

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BIOMECHANICS OF THE ELBOW DURING BASEBALL PITCHING

One of the most demanding activities on the elbow in sports is the baseball pitch. The prevalence of overuse injury to the elbow caused by pitching is well documented.[1-7] Most of these overuse throwing injuries occur because of repetitive trauma to the elbow. An understanding and application of proper pitching biomechanics not only helps maximize performance, but also helps minimize injuries that are often caused by faulty pitching biomechanics.

Although the baseball pitch is one continuous motion, it is helpful to divide the motion into phases. Werner et al[8] separated the pitch into six phases. They are: wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through. A description of the biomechanics of the elbow during each phase is provided below.

Wind-Up

The objective of the wind-up phase is to put the pitcher in a good starting position. The wind-up starts when the pitcher initiates the movement (Fig 1A) and is completed when the front knee has reached its maximum height (Fig 1B). The time from when the stance foot pivots to when the knee has achieved maximum height and the pitcher is in a balanced position is typically 0.5 to 1.0 second. Minimal elbow kinetics and muscle activity are present during this phase.[3,8-10] The elbow is flexed througout the phase, and elbow flexion is maintained by isometric contractions of the elbow flexors (Table 1).[10-12]

Stride

The stride phase begins at the end of the wind-up, when the lead leg begins to fall and move toward the target and the two arms separate from each other (Figs 1D and 1E).