Elbow anatomy, biomechanics and clinical examination

Neil R Marshall

Matthew R Randell

Alex J Nicholls

Abstract

The elbow joint is a complex articulation vital for upper limb function, combining stability with a wide range of motion in multiple planes. The joint consists of the three articulations: the ulno-humeral, radio-humeral and proximal radio-ulnar joints. These articulations are supported by several soft tissue stabilizers, which form the medial and lateral collateral ligaments, in addition to the joint capsule and annular ligament. The elbow joint is controlled by four main muscle groups: flexors, extensors, supinators and pronators. Numerous important structures cross the elbow joint: the brachial artery supplying the forearm, wrist and hand, and branches of the brachial plexus, principally the median, radial and ulnar nerves. The biomechanics of the elbow allow not only for flexion and extension of the elbow joint, but also supination and pronation of the forearm. The stability of the elbow joint whilst performing these movements is provided by the static and dynamic elbow stabilizers. The elbow joint is commonly assessed in OSCE examinations, and is assessed systematically through look, feel, move, and special tests.

Keywords Anatomy; arm; elbow; forearm; humerus; pronation; radius; supination; ulna

Anatomy

Bony anatomy

The elbow joint is formed by the distal humerus, proximal radius and ulna, which form part of the static elbow stabilizers. Three separate articulations occur within the elbow: the humero-ulnar, humero-radial, and proximal radio-ulnar joints, which allow for flexion and extension of the elbow, as well as pronation and supination of the forearm.

The humero-ulnar articulation, between the trochlea of the humerus, and trochlear notch of the ulnar act as a simple hinge allowing for approximately 145° of flexion and extension of the elbow.

The humero-radial articulation between the capitellum of the humerus, and head of the radius act as a ball and socket joint allowing both forearm rotational movement and flexion of the elbow.

The proximal radio-ulnar articulation between the head of the radius and radial notch of the ulna act as a pivot joint, allowing for 85° of forearm supination and 75° of forearm pronation.

The bony anatomy provides static stability to the elbow, and the key anatomical parts are demonstrated in Figure 1.

Ligamentous anatomy

The elbow joint's static stability is also provided by the ligamentous support from the medial collateral ligament (MCL) and lateral collateral ligament (LCL).

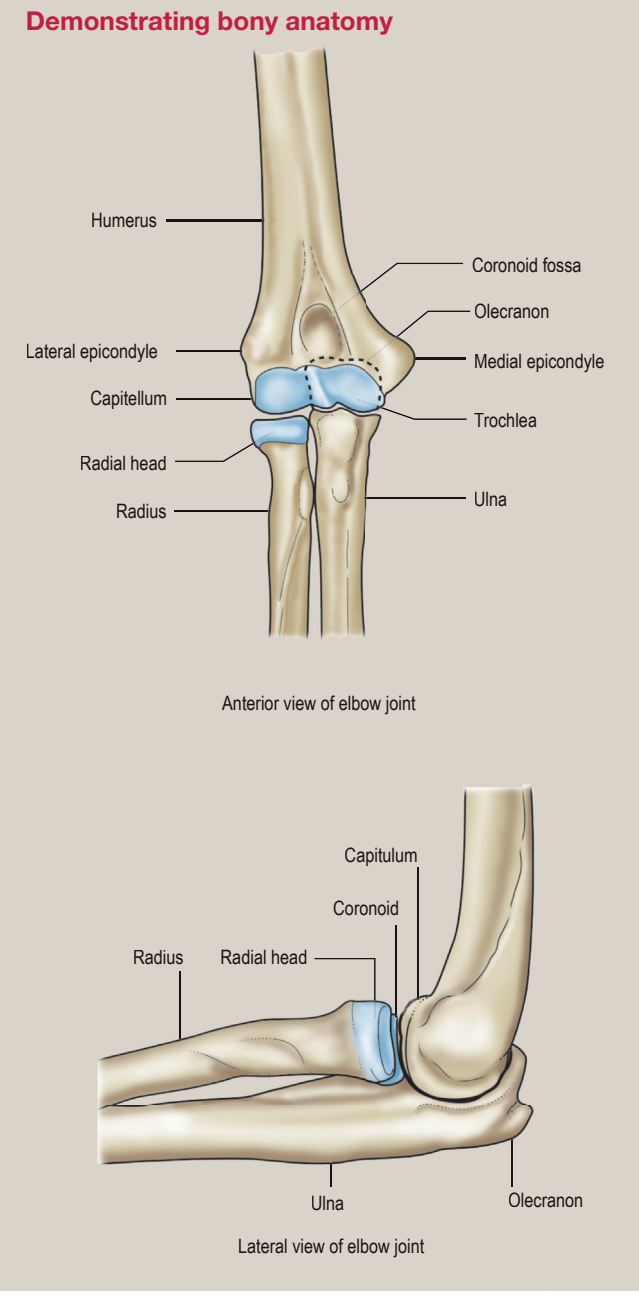

Figure 1

Neil R Marshall ***BSc(hons) BMBS MRCS*** *is an Orthopaedic Registrar at Hampshire Hospitals NHS Foundation Trust, UK. Conflicts of interest: none declared.*

Matthew R Randell ***BAppSc GradDipCom MBBS*** *is an Orthopaedic Registrar at Hampshire Hospitals NHS Foundation Trust, UK. Conflicts of interest: none declared.*

Alex J Nicholls ***BMedSc MBChB MSc FRCS(Tr&Orth)*** *is an Orthopaedic Consultant specializing in Hand Surgery at Hampshire Hospitals NHS Foundation Trust, UK. Conflicts of interest: none declared.*

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008

The MCL, formed of the anterior oblique ligament, posterior oblique ligament and transverse ligament, provides stability and resistance to valgus stress.

The lateral ligament complex is formed of the radial collateral ligament, annular ligament, lateral ulnar collateral ligament, and accessory lateral collateral ligament, providing resistance to varus stress. The annular ligament also provides stability to the radial head, whilst allowing it to rotate. The ligamentous anatomy is demonstrated in Figure 2.

Muscles and tendons

There are several muscles which act upon the elbow joint; they can be grouped into: flexors, extensors, pronators, and supinators. These act as dynamic stabilizers of the elbow joint. These muscles, their origins and insertions, action and nerve supply are summarized in Table 1.

Flexors: the flexors include the biceps brachii, brachialis and brachioradialis.

Biceps brachii originates from the supraglenoid tubercle and coracoid process of the scapula, and inserts into the radial tuberosity, acting to not only flex the forearm, but also as a forearm supinator.

Brachialis originates from the anterior surface of the distal half of the humerus and inserts into the ulnar tuberosity and is the primary flexor of the elbow joint.

Brachioradialis originates from the lateral supracondylar ridge of the humerus, just above the lateral epicondyle, and inserts into the styloid process of the distal radius. Brachioradialis assists not only in elbow flexion but also in supination and pronation of the forearm.

Extensors: the extensor muscles of the elbow joint include the triceps brachii and anconeus.

The triceps brachii is formed from three origins: the long head originating from the infra-glenoid tubercle of the scapula, the lateral head originating from the posterior surface of the humerus, above the spiral groove, and the medial head which also arises from the posterior surface of the humerus, but inferior to the spiral groove. The three heads form the triceps tendon and insert into the olecranon and is the primary extensor of the elbow joint.

Anconeus originates from the lateral epicondyle of the humerus, inserting into the lateral aspect of the olecranon and proximal posterior ulna. Anconeus' main action is to stabilize the elbow joint when in extension.

Pronators: the two pronator muscles acting upon the forearm, and therefore also on the elbow joint, are the pronator teres and pronator quadratus.

Pronator teres arises from both the medial epicondyle of the humerus, and coronoid process of the ulnar, and inserts into the lateral surface of the midshaft of the radius. Pronator teres primarily acts as a pronator of the forearm and provides weak flexion.

Pronator quadratus arises from the distal aspect of the anterior surface of the ulna and inserts into the distal anterior surface of the radius. Pronator quadratus acts primarily to pronate the forearm, but also acts as a stabilizer of the distal radio-ulnar joint.

Supinators: the supinator muscle originates from the lateral epicondyle of the humerus, radial collateral ligament, and supinator crest of the ulna, and inserts into the lateral, posterior and anterior surface of the proximal radius. Supinator acts to supinate the forearm, particularly with the elbow extended.

Biceps brachii also contributes to supination through its insertion into the radial tuberosity.

Nerves

Three main nerves traverse the elbow joint: the median, ulnar and radial nerves.

The medial nerve (C5–T1), a continuation of the medial and lateral cords of the brachial plexus, descends anterior to the

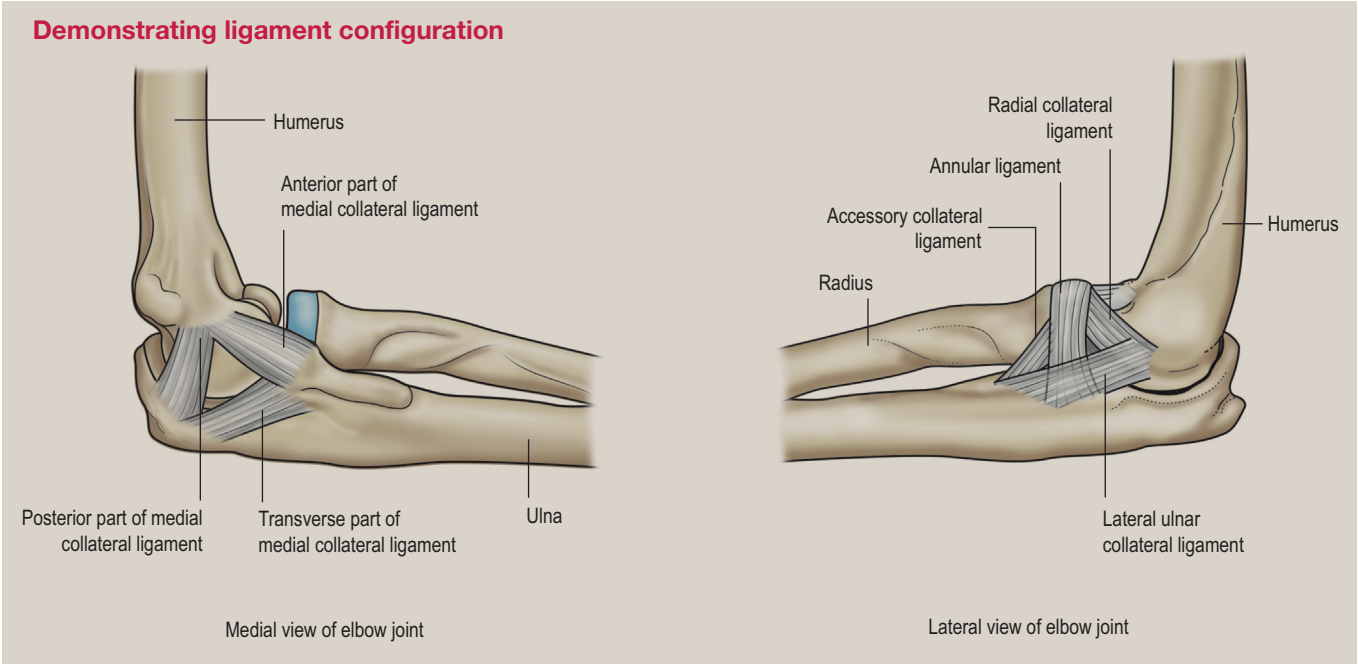

Figure 2

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008

Summarizing the muscles affecting the elbow joint, their origins and insertions, action and nerve supply

Name	Origin	Insertion	Action	Nerve Supply
Flexors				
Biceps brachii	Long head: supraglenoid tubercle of scapula Short head: coracoid process of scapula	Radial tuberosity	Forearm flexion and supination	Musculocutaneous nerve (C5—C6)
Brachialis	Anterior surface of the distal half of the humerus	Ulnar tuberosity	Elbow flexion	Musculocutaneous nerve (C5—C6)
Brachioradialis	Lateral supracondylar ridge of the humerus	Styloid process of the radius	Elbow flexion Forearm pronation and supination	Radial nerve (C5—C7)
Extensors				
Triceps brachii	Long head: infraglenoid tubercle of the scapula Lateral head: posterior surface of the humerus, above the radial (spiral) groove Medial head: posterior surface of the humerus, below the radial (spiral) groove	Olecranon process of the ulna	Extension of the elbow joint: the triceps brachii is the primary extensor of the elbow Extension and adduction of the shoulder (long head only)	Radial nerve (C6—C8)
Anconeus	Lateral epicondyle of the humerus	Lateral aspect of the olecranon	Stabilizing the elbow joint in extension	Radial nerve (C7—C8)
Pronators				
Pronator teres	Medial epicondyle of the humerus Coronoid process of the ulna	Lateral surface of the midshaft of the radius	Pronation of the forearm, weak elbow flexion	Medial nerve (C6—C7)
Pronator Quadratus	Distal anterior surface of the ulna	Distal anterior surface of the radius	Pronation of the forearm, stabilization of distal radio-ulnar joint	Median nerve (anterior interosseous branch) C8—T1
Supinators				
Supinator	Lateral epicondyle of the humerus Radial collateral ligament Supinator crest of the ulna	Lateral, posterior, and anterior surfaces of the proximal third of the radius	Supination of the forearm	Radial nerve (posterior interosseous branch) C6—C7

Table 1

humerus in the arm, crossing from lateral to medial to the brachial artery at the antecubital fossa. In the forearm the nerve passes between the two heads of pronator teres to continue to the carpal tunnel and into the hand.

The radial nerve (C5—T1), a continuation of the posterior cord of the brachial plexus, descends posteriorly to the proximal humerus, before rotating via the radial groove, to the anterior aspect of the lateral epicondyle and into the cubital fossa. The radial nerve then divides into a deep branch which supplies the muscles in the posterior forearm compartment, and a superficial branch which supplies sensation to the hand.

The ulnar nerve (C8—T1), a continuation of the medial cord of the brachial plexus, descends via the medial aspect of the arm, entering the posterior compartment midway down the humerus. The ulnar nerve traverses the elbow through the cubital tunnel between the medial epicondyle and olecranon. The ulnar nerve then forms three main branches: the muscular branch, palmar cutaneous branch and dorsal cutaneous branch.

Blood supply

The blood supply to the arm is provided by the brachial artery, continuation of the axillary artery. The brachial artery divides into the brachial artery proper and profunda brachii. The

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008

brachial artery proper bifurcates into the radial and ulnar arteries on the cubital fossa.

The radial artery continues along the posterolateral aspect of the forearm, terminating in the deep and superficial palmar arches.

The ulnar artery continues along the anteromedial aspect of the forearm, terminating in the deep and superficial palmar arches.

Biomechanics

Range of motion

The elbow's configuration allows for two primary movements: flexion extension and pronation—supination.

Flexion and extension of the elbow joint occurs at the humeroulnar and humeroradial joints. The normal range of motion is from 0° (full extension) to 145° (full flexion). Most functional activities only require a range of motion from 30° to 130°.

Pronation and supination of the forearm occurs at the humeroradial joint and proximal radio-ulnar joint. The motion of supination allows the radius to rotate anteriorly to stationary ulna, crossing in the mid forearm. This motion is possible through the rotation in the radio-capitate joint, allowing the range of motion in the radial head, and the distal radio-ulnar joint. The normal range of motion is 85° of supination from neutral, and 80° of pronation.

The range of motion provided by the elbow joint is summarized in Figure 3.

Joint stability

Stability of the elbow joint is provided by two main components: static stabilizers and dynamic stabilizers.

Static stabilizers include the osseous stabilizers of the radio-humeral joint and ulno-humeral joint and the soft tissue stabilizers of the MCL, lateral ligament complex and anterior capsule.

Dynamic stabilizers include the muscles which cross the elbow joint, principally biceps brachii and triceps.

Static stabilizers: amongst the static stabilizers, the ulno-humeral joint acts as the primary stabilizer during the application of varus stress, through the articulation of the olecranon with the trochlea. Within the ulno-humeral joint the coronoid process of the ulna provides stability when posterior stress is applied to the elbow in flexion. The coronoid demonstrates a reasonable amount of redundancy, enabling it to continue to provide stability even when up to 50% is deficient.

In extension the tip of the olecranon engages with the olecranon fossa to increase stability.

The radio-humeral joint acts as a secondary stabilizer to valgus stress, in the absence of an effective MCL.

The static soft tissue stabilizers are the MCL, lateral ligament complex, and anterior capsule.

The MCL provides stability when the elbow is placed under valgus stress, acting in conjunction with the radiocapitellar and ulnohumeral joints.

The lateral ligament complex contributes to both preventing posterolateral instability, and varus stress when the elbow is flexed.

The anterior capsule principally provides stability when the elbow undergoes varus stress in extension, as well as when the elbow undergoes valgus stress, distraction and hyperextension.

Dynamic stabilizers: the dynamic stabilizers of the elbow consist of the muscles crossing the elbow joint: extensors, flexors, pronators and supinators.

Each muscle acting across the joint provides dynamic stability whilst contracting, through compressing the joint.

Carrying angle

The carrying angle of the elbow refers to the natural valgus angulation of the forearm to arm. The angulation is formed by the trochlea axis, which is approximately 6° deviated from the perpendicular of the humeral shaft axis.

The angle is measured in extension and varies from 11° in men to 14° in women.

Clinical examination

Clinical examination of the elbow follows the routine orthopaedic examination rigmarole: look, feel, move, and special tests.

Look

Commence with a general inspection as follows.

Observe the patient's posture and arm position.

Assess the joint for any obvious deformities, skin changes (including scars), swelling, or bruising.

Whilst observing from the front, rear and side assess for evidence of muscle atrophy or asymmetry.

Whilst assessing the patient from the front, and with the elbows extended assess the carrying angle.

Finally complete the initial inspection by assessing for any aids such as splints, braces or slings.

Feel

Initially assess the temperature of both joints.

Palpate the bony landmarks of the medial and lateral eipicondyles, radial head, radiocapitellar joint and olecranon.

With the patient's elbow flexed to 90° palpate the biceps tenon on the anterior aspect of the joint, assessing for pain and congruency.

With the patient's elbow extended palpate the triceps insertion to the olecranon, assessing for pain and congruency.

Move

Initially assess the active movements of the elbow, commencing with the 'normal' side.

Ask the patient to flex and extend the elbow, assessing the range of motion between 0° (full extension) and 145° (full flexion).

Move on to assess the patient's pronation and supination. With their arms adducted, and with the elbow joint at 90°, ask them to start with their palm perpendicular to the floor.

To assess supination ask them to rotate their palm to face the ceiling, from 0° to 90°.

To assess pronation ask them to rotate their palm to face the floor, from 0° to 85°.

Next assess the passive range of movements, repeating the active movement steps, assessing the range of movement, crepitus and any discomfort.

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008

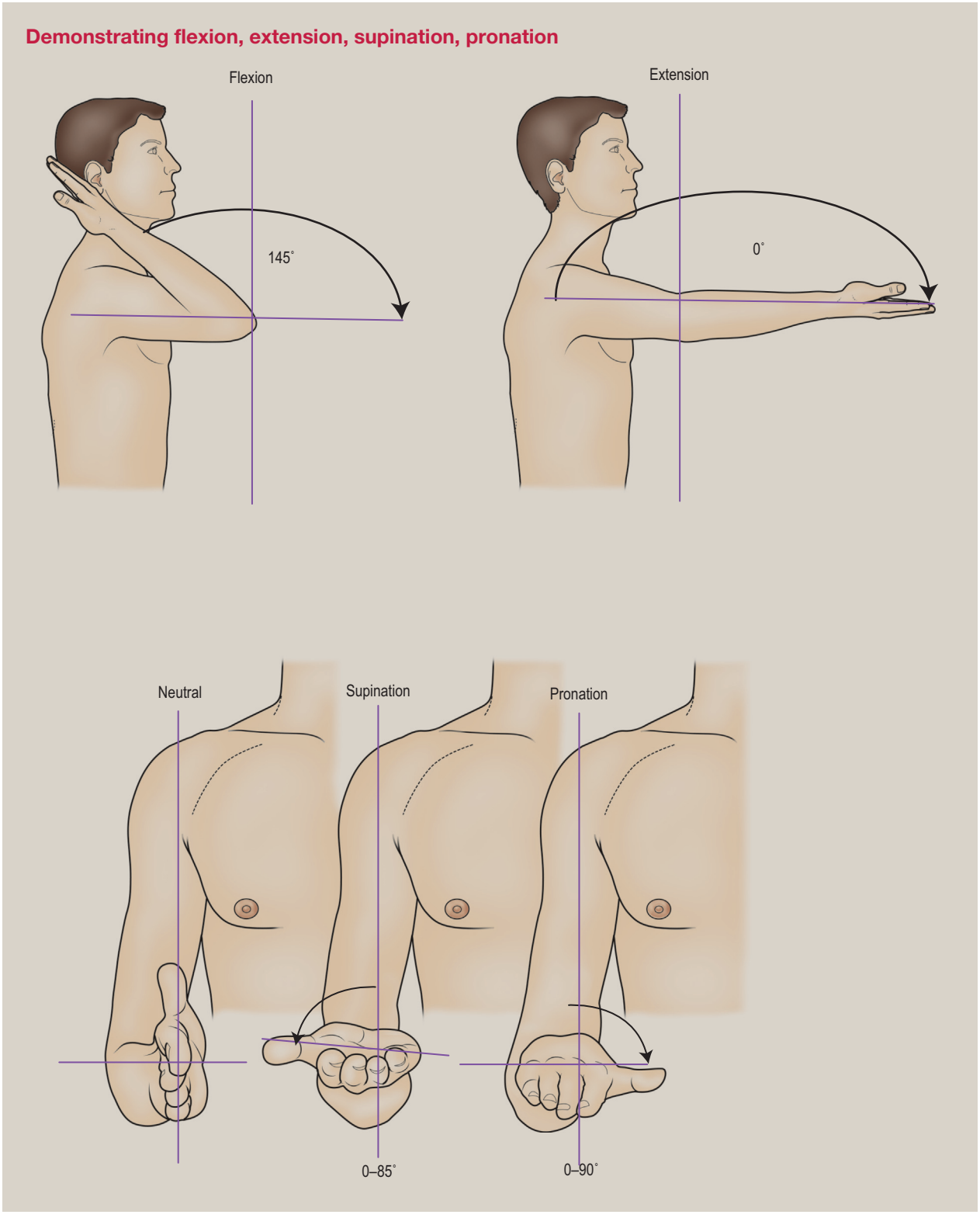

Figure 3

Special tests

Valgus stress test: with the elbow flexed at 20–30°, stabilize the humerus with one hand, with the other hand grasp the patient's forearm proximal to the wrist.

Gently pull the forearm away from the midline, whilst pulling the humerus towards the midline.

Assess for laxity, instability or gapping at the medial joint line.

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008

Varus stress test: with the elbow flexed at 20–30°, stabilize the humerus with one hand, with the other hand grasp the patient's forearm proximal to the wrist.

Gently pull the forearm towards the midline, whilst pulling the humerus away from the midline.

Assess for laxity, instability or gapping at the lateral joint line.

Complete examination

To complete the examination explain that you would check the neurovascular status of the arm, and examine the joint above and below. ◆

FURTHER READING

Douglas G, Nicol F, Robertson C. Macleod's clinical examination E-book. Elsevier Health Sciences, 2013.

Ellis H, Mahadevan V. Clinical anatomy: applied anatomy for students and junior doctors. John Wiley & Sons, 2018.

Ramachandran M, ed. Basic orthopaedic sciences. CRC Press, 2018.

Practice points

- The elbow joint enables forearm pronation and supination, in addition to flexion and extension
- These complex movements are enabled by the bony articulations, ligamentous stabilizers, and musculature
- The elbow joint is crossed by important neurovascular structures which supply the forearm and hand
- The key biomechanics of the elbow are a balance between allowing the movements required for upper limb function, and providing adequate stability to prevent joint dislocation
- The elbow examination is a commonly assessed OSCE station, requiring candidates to follow the standard joint assessment of: look, feel, move and special tests

Please cite this article as: Marshall NR et al., Elbow anatomy, biomechanics and clinical examination, Surgery, https://doi.org/10.1016/j.mpsur.2024.12.008