Handbook of Clinical Examination in Orthopedics

An Illustrated Guide

Sarvdeep S. Dhatt
Sharad Prabhakar
Editors

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About the Editors

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General Principles of Orthopedic Examination

S. S. Dhatt and Siddhartha Sharma

A focussed examination is the key to correct orthopaedic diagnosis. It should be remembered that diagnostic tests and imaging techniques should aid and not replace clinical diagnosis. The clinician needs to obtain a precise history of the patient's complaints and examine the patient as a whole, rather than just focus on the anatomical area of involvement. This chapter provides a brief outline of the orthopedic clinical examination. The reader is encouraged to develop his or her own scheme of examination and ensure all essential parts are covered.

Consent, Rapport and Other Important Aspects

Please remember that the patient has the right to refuse examination. Therefore, the clinician must obtain consent from the patient before beginning examination. A verbal consent suffices for physical examination. Also, it is extremely important to clean your hands before and after examining each patient as this reduces the spread of infections. Many orthopedic tests can be frightening for the patient and even painful, so it is best to establish a good rapport with the patient before conducting the examination. Furthermore, it is of utmost importance to ensure that a female hospital staff member or the patient's relative accompanies a female patient if she has to be examined by a male doctor.

Analysis of Gait and Walking Aids

The gait is the first thing that you may notice as the patient walks into your clinic. Does the patient use any walking aid for support? Is he or she able to bear

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weight on both feet equally while walking (bipedal gait)? Is there an abnormality of gait?

Analysis of Footwear

It is all too easy to forget to examine the patient's footwear. Footwear may be the cause of the patient's problems, or may hint to the diagnosis. Look for abnormal shoe wear patterns, which are discussed in the chapter on foot and ankle examination. Does the shoe have any modifications? Observe if the shoe has been provided with an overall raise (to compensate for limb length discrepancy), medial raise (for valgus foot), and lateral raise (for varus foot). Are there any insoles or modifications of the sole?

General Physical Examination

A quick but focussed general physical examination is invaluable and its importance cannot be overemphasized. Loss of eyebrows and typical facies in patient presenting with ulnar neuritis, along with skin lesions is typical of leprosy. 'Moon' facies, protuberant abdomen, skin striae etc. may well reveal chronic steroid intake as the aetiology of avascular necrosis of the hip in a patient with hip pain. Similarly, nicotine stains on the teeth and nails and atrophy of the nails indicate that the patient has been a chronic smoker and that his leg pain may be a result of vascular claudication due to Buerger's disease. Bruising over the body, cigarette burn marks and other 'accidental' burn marks in a young child who presents with a history of multiple fractures may hint towards child abuse. It is often helpful to revisit the general physical examination after examining the joint, in light of the aetiological possibilities.

Systemic Examination

It is necessary to examine all other body systems in addition to the musculoskeletal system. The reader is encouraged to develop a routine of conducting a quick and precise evaluation of the nervous system, cardiovascular and respiratory systems, gastrointestinal system and the urogenital system. Excellent textbooks of medicine are available that cover these examination and the reader is encouraged to refer to these texts for details.

Examination of the Musculoskeletal System

In general, it is advisable to follow the *'look-feel-move'* scheme of examination for the musculoskeletal system.

(a) Inspection (Look)
It is essential to expose the joint to be examined adequately or else you may miss important information. Inspection should be done from the front, the sides and the back in each case. In lower limbs, it is important to conduct inspection in supine as well as standing positions. Many abnormalities will reveal themselves only on standing; for example, pelvic tilt or equinus posturing to compensate for limb shortening and flexible flatfoot. Inspection of each joint is detailed in the chapters that follow.

(b) Palpation (Feel)
Ensure that your hands are not cold before you touch the patient. Palpation should always begin with assessment of joint warmth, as subsequent examination may raise the skin temperature and make comparison difficult. This is followed by assessment of tenderness. Palpation of each joint is discussed in detail in the respective chapters.

(c) Movements
The examiner should check for active as well as passive movements at the joint being examined. First, the patient is asked to perform a particular movement (for e.g. flexion of the hip) as much as he can. From this position, the examiner tries to elicit more movement to know the amount of passive movement possible. This should always be compared with the normal side. The 'arc of movement' is the sum of movements in any plane, taking into account the deformities in that plane, if any. For example, if the patient has 10° of flexion deformity of the hip and further flexion is possible up to 70°, the arc of movement is 60° (10–70°). Movements of individual joints are discussed in detail in the respective chapter.

(d) Assessment of motor power, sensations, vascular status and regional lymph nodes
It is imperative to test for motor power and sensations of the muscles around the joint. Motor power should be documented according to the MRC (medical research council) grade. This is discussed in greater detail in the chapter on examination of the spine. The peripheral pulsations should be felt and compared with the other side. The regional lymph nodes must be examined in every case. Details are presented in the respective chapters.

(e) Special tests
Every joint or anatomical area has some unique clinical tests for diagnosis of different pathologies. One or more of such 'special' tests may be necessary, depending on the differential diagnoses in mind. Special tests relevant to each joint are presented in the respective chapters.

(f) Examination of neighbouring joints
As a rule, it is mandatory to examine the joints adjacent to the pathological joint being evaluated. Not only may the primary pathology affect multiple joint (for example, a cold abscess presenting in the hip may have its origin in the lumbar spine, rheumatoid arthritis may result in flexion deformities of the hip and knee); many times the aetiology of a joint problem may very well originate from the adjacent joint (for example, pain in the knee may actually be referred pain from the hip and pain in the leg may originate from lumbar intervertebral disc prolapse).

Examination of the Peripheral Nervous System

S. Prabhakar, S. S. Dhatt, and A. Hooda

This chapter reviews the anatomy of the peripheral nervous system and some of the more common focal neuropathies.

The Brachial Plexus

Anatomy

The brachial plexus arises from the anterior primary rami of C5–T1. The posterior primary rami leave the spinal nerves just after they exit to innervate the paraspinal muscles.

The C5 and C6 roots join to form the upper trunk. The suprascapular nerve branches off the upper trunk to the supraspinatus and infraspinatus branches off the upper trunk, making them the most proximal muscles innervated by the plexus. The C7 anterior primary ramus continues as the middle trunk. The C8 and T1 rami join to form the lower trunk.

The three trunks then split into anterior and posterior divisions, from which the three cords are derived and are named for their anatomical relationships to the axillary artery. All the posterior divisions form the posterior cord. It is smaller than the other cords and contains little contribution from T1. It divides into two major terminal branches: the radial and axillary nerves.

The anterior divisions form the medial and lateral cords. The anterior divisions of the upper and middle trunk combine to form the lateral cord, which lies lateral to the artery and terminates in two major branches: the musculocutaneous nerve and the lateral head of the median nerve. The lateral head of the median is

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predominantly sensory and carries all the median sensory functions and the motor innervation to the pronator teres and flexor carpi radialis.

The anterior division of the lower trunk continues as the medial cord which divides into two major branches: the medial head of the median nerve and the ulnar nerve. The medial head of the median nerve carries all of the other motor functions, but has no cutaneous sensory component. After giving off the medial head to the median nerve, the medial cord continues as the ulnar nerve. As a rough guide, the posterior cord supplies the extensor muscles and the lateral and medial cords the flexor muscles.

The Phrenic Nerve (C3–C5)

The phrenic nerve arises from the phrenic nucleus at C3–C5. The fibers arise from root level. Unilateral diaphragmatic paralysis causes few or no symptoms. With bilateral paralysis there is dyspnea on exertion, a scaphoid abdomen that does not protrude on expiration, absence of Litten's sign, increased excursion of the costal margins, retraction of the epigastrum on inspiration, overactivity of the accessory respiratory muscles, and difficulty in coughing, sneezing or sniffing.

The Long Thoracic Nerve (C5–C7)

This nerve arises from the C5–C7 roots and supplies the serratus anterior muscle. It may be injured by pressure from carrying heavy objects or packs on the shoulder (*backpack/rucksack palsy*), or by penetrating trauma. Paralysis of the serratus anterior muscle causes winging of the scapula.

The Dorsal Scapular Nerve (C5)

The dorsal scapular nerve arises directly from the C5 nerve root to innervate the rhomboid muscles. It is of importance in distinguishing between C5 radiculopathy and upper trunk brachial plexopathy using EMG testing.

The Suprascapular Nerve (C5–C6)

This nerve is derived from C5 to C6 and arises from the upper trunk. It runs through the suprascapular notch, beneath the suprascapular ligament and innervates the supraspinatus muscle. It then runs into the spinoglenoid notch to reach the infraspinous fossa and innervates the infraspinatus. The nerve may be entrapped at the suprascapular notch, causing pain and weakness of both the supraspinatus and infraspinatus muscles or at the spinoglenoid notch, causing weakness of only the infraspinatus muscle.

The Axillary Nerve (C5–C6)

The axillary nerve is a terminal branch of the posterior cord of the brachial plexus with the root value of C5–C6. With the posterior humeral circumflex artery it passes through the quadrangular space, and then divides into anterior and posterior branches. The anterior branch supplies the anterior part of the deltoid muscle; the posterior branch supplies the posterior part of the deltoid and the teres minor muscles, and sends sensory twigs to a small circular area of skin over the deltoid muscle. Injury to the nerve results in weakness and wasting of the deltoid with a small patch of sensory loss over the shoulder (*Regimental badge sign*).

Preservation of dorsal scapular and suprascapular nerve function help distinguish axillary neuropathy from C5 radiculopathy and upper trunk plexopathy. The assessment of suprascapular nerve function however requires an EMG as both the deltoid and supraspinatus carry out shoulder abduction and both the teres minor and infraspinatus muscles are external rotators.

The Musculocutaneous Nerve (C5–C7)

This nerve is is a terminal branch of the lateral cord with a root value of c5-C7. It passes into the arm and supplies the coracobrachialis muscle,. The nerve then traverses a foramen in the muscle, after which it descends and innervates the biceps and most of the medial part of the brachialis. At the elbow it pierces the deep fascia just lateral to the biceps tendon and continues as the lateral cutaneous nerve of the forearm to supply sensation to the lateral aspect of the forearm from the elbow to the thumb. The musculocutaneous may be injured by excessively vigorous elbow flexion (*Weightlifter's palsy*). On examination, there is weakness of elbow flexion with the forearm supinated and marked weakness of supination. The midprone forearm can still be flexed by the brachioradialis. There is a small area of sensory loss on the lateral surface of the forearm. The biceps reflex is absent or decreased.

The Median Nerve (C5–T1)

The lateral division of the median nerve is a terminal branch of the lateral cord of the brachial plexus, the other being the musculocutaneous nerve. The medial cord of the brachial plexus also divides into two terminal branches; the medial division of the median nerve and the ulnar nerve. The medial and lateral divisions of the median nerve join to form a single trunk, which passes through the upper arm down to the elbow. There are no branches in the arm.

At the elbow, branches are given off to the pronator teres and flexor carpi radialis muscles. The main trunk passes through the two heads of the pronator teres muscle and beneath an aponeurosis connecting the two heads of the flexor digitorum superficialis (*the sublimis bridge*). Just distal to the pronator teres the nerve gives off the anterior interosseus nerve (AIN), which runs along the interosseus membrane.

It innervates the lateral half of the flexor digitorum profundus (FDP), the flexor pollicis longus (FPL), and the pronator quadratus muscles. The AIN has no cutaneous sensory component. The main trunk of the median nerve continues down the forearm, giving off branches to the palmaris longus and flexor digitorum superficialis (FDS) muscles.

The median nerve crosses into the hand through the carpal tunnel. The roof of the carpal tunnel is formed by the transverse carpal ligament. Lying with the median nerve in the canal are the eight deep and superficial finger flexor tendons and the tendon of the flexor pollicis longus, surrounded by a synovial sheath.

After exiting the carpal tunnel, the median nerve gives off its recurrent thenar motor branch, which innervates the abductor pollicis brevis, opponens pollicis and lateral head of the flexor pollicis brevis. The nerve ends by giving off terminal motor branches to innervate the first and second lumbricals, and then dividing into common digital sensory branches that carry sensory fibers from the palmar surfaces of the thumb, index and middle fingers, palmar aspect of the radial half of the ring finger, and the dorsal aspect of the middle and distal phalanges of the index and middle fingers and radial half of the ring finger.

In *carpal tunnel syndrome (CTS)*, sensation over the thenar eminence is spared. This is because the palmar cutaneous branch of the median nerve arises from the main trunk 5–8 cm proximal to the wrist crease and provides sensation to the thenar eminence. It does not traverse the carpal tunnel. Thus, loss of sensation over the thenar eminence is not part of carpal tunnel syndrome and suggests a lesion proximal to the wrist.

Entrapment of the median nerve beneath the transverse carpal ligament is often brought on or exacerbated by excessive hand, wrist or finger movements. Other causes include mass lesions narrowing the passageway such as a ganglion, osteophytes, lipoma, aneurysm etc. Systemic conditions include rheumatoid arthritis, diabetes mellitus, chronic renal insufficiency, hypothyroidism, amyloidosis, myeloma, and pregnancy.

CTS produces a characteristic clinical picture of hand pain, numbness and paresthesias, which are exacerbated at night. The patient may also suffer from proximal pain in the forearm. Findings on examination vary with the severity of carpal tunnel syndrome. The earliest sensory loss occurs over the volar tip of the middle finger. Patients with more advanced disease have weakness of the thenar muscles. Patients with severe involvement demonstrate thenar atrophy and dense sensory loss.

Tinel's sign is positive. However only the presence of a disproportionately active Tinel's sign over the clinically suspect nerve is of any localizing value. *Phalen's test* is reproduction of paresthesias in the median nerve distribution by forceful flexion of the wrist for 60 s. The *reverse Phalen's (prayer) test* is similar but with the wrist in hyperextension. In the *Carpal compression test* the examiner applies firm thumb pressure over the median nerve at the wrist crease, seeking to reproduce the patient's symptoms. The *"flick" sign*, in which the patients flick the wrist to demonstrate what they do to "restore the circulation" at night is also indicative of carpal tunnel syndrome. Less commonly *"reverse Tinel's sign"* with paresthesias radiating retrograde up the forearm may be present. (Figs. 3, 4, 5, 6, 8 and 9)

CTS often needs to be distinguished from C6 cervical radiculopathy. Neck and shoulder pain, weakness in C6 innervated muscles, reflex changes, sensory loss restricted to the thumb, the absence of nocturnal paresthesias, and reproduction of the paresthesias with root compression maneuvers all favor cervical radiculopathy. Differential diagnosis include proximal median neuropathy, neurogenic thoracic outlet syndrome, and upper brachial plexopathy.

Proximal Median Neuropathy

A complete proximal median nerve injury causes paralysis of flexion of the wrist and radial fingers, forearm pronation, and thumb abduction, opposition and flexion. Finger flexion at the metacarpophalangeal (MCP) joints may be partially preserved due to preserved function of the interossei. Loss of ability to flex the distal phalanx of the index finger is distinctive. This is demonstrated as the "*Pointing Index sign*" on clasping the fingers of both the hands. The thumb lies adducted and extended "*Ape hand*". There is no substitution for palmar abduction, and comparison of this movement on both sides is required. The thumb cannot be opposed to the tip of the little finger or abducted at right angles to the palm and the terminal phalanx cannot be flexed (Figs. 1, 2 and 7).

The sensory changes involve the lateral side of the palm, including the thenar region (palmar cutaneous nerve distribution), the index and middle fingers, and the lateral half of the ring finger. On the dorsum of the hand the distal and middle phalanges of the index and middle fingers and sometimes part of the thumb and lateral half of the ring finger are involved. Median nerve paralysis is often accompanied by vasomotor and trophic changes and by reflex sympathetic dystrophy.

The median nerve may be entrapped by the *ligament of Struthers*, a fibrous band running from the distal lateral humeral supracondylar spur to the medial epicondyle. In the *pronator teres syndrome* the median nerve is entrapped at the point where it passes through the two heads of the pronator teres; it may affect the main trunk, causing both motor and sensory involvement (*Seyffrath's syndrome*). Often only the anterior interosseus nerve is affected (*Kiloh-Nevin syndrome*) causing inability to flex the distal phalanx of either the thumb or index finger. The patient cannot make a circle by touching the tip of the thumb to the tip of the index finger and makes a triangle instead by touching the fingerpads (*pinch sign*). Depending on the individual anatomy and the origin of the branch to the pronator teres, the pronator teres may or may not be involved in a pronator syndrome. There are no sensory changes in anterior interosseus nerve plasy.

The Ulnar Nerve (C8, T1)

The ulnar nerve arises as a continuation of the medial cord of the brachial plexus. As it exits from the thorax, it passes into the arm lying medial to the brachial artery. At the level of the insertion of the coracobrachialis, the ulnar nerve leaves the

Fig. 1 Ape hand deformity

Fig. 2 Ape hand deformity lateral view

common neurovascular bundle and pierces the medial intermuscular septum to enter the posterior compartment of the arm. The point of the ulnar nerve's penetration of the medial intermuscular septum and the nearby deep fascia binding the nerve in the triceps groove are sometimes referred to as the *arcade of Struthers*, a potential entrapment site. The ulnar nerve then traverses the elbow in the ulnar groove and passes beneath the humero-ulnar aponeurotic arch. This is a dense aponeurosis joining the humeral and ulnar heads of origin of the flexor carpi ulnaris (FCU) muscle. Compression at this site is sometimes referred to as the "*cubital tunnel syndrome*".

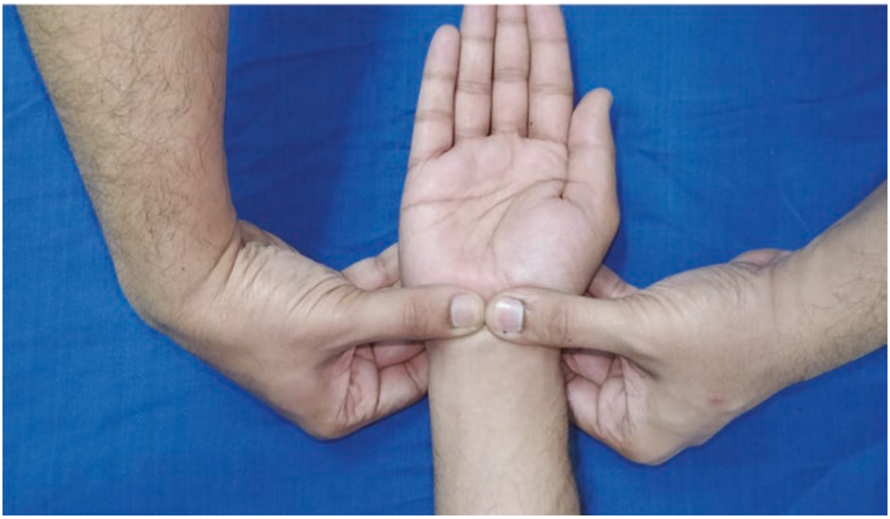

Fig. 3 Carpal compression test

Fig. 4 Phalens test

Fig. 5 Pinch sign (normal person)

Fig. 6 Pinch sign (abnormal)

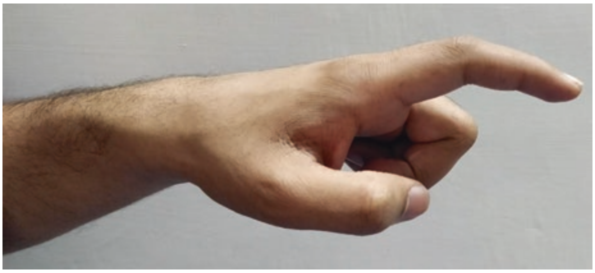

Fig. 7 Pointing index sign

Fig. 8 Reverse Phalens test

The nerve runs through the belly of the FCU and then exits through the deep flexor-pronator aponeurosis. It gives off the palmar ulnar cutaneous branch supplying the skin over the hypothenar region and a large dorsal ulnar cutaneous nerve which provides sensation to the dorso-ulnar aspect of the hand, as well as the small and the ring fingers. The ulnar nerve enters the hand through Guyon's canal.

As it emerges from beneath the volar carpal ligament, the ulnar nerve gives a branch to the palmaris brevis, and then branches into the superficial terminal sensory division and the deep palmar division. The deep branch exits Guyon's canal,

Fig. 9 Tinel's test

Fig. 10 Finger drop

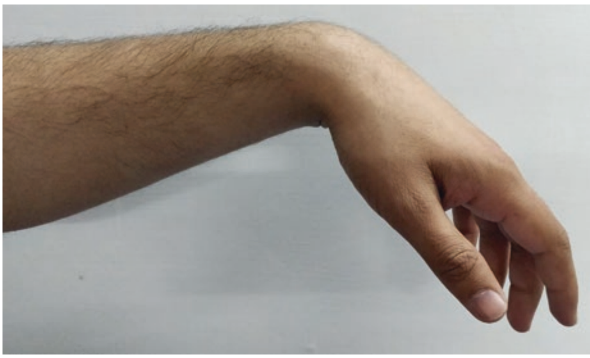

Fig. 11 Wrist drop

arches laterally beneath the flexor tendons, innervating the interossei and breaking up into terminal branches on reaching the adductor pollicis and the first dorsal interosseous. The deep head of the flexor pollicis brevis is also supplied.

Ulnar Neuropathy at the Elbow

The initial symptoms are intermittent numbness and tingling in the ulnar nerve distribution, weakness of grasp and pinch, or a loss of dexterity. Later intrinsic muscle atrophy becomes obvious. An early symptom is loss of control of the small finger, which causes the finger to get caught when the patient is trying to place the hand in a pocket (Not to be confused with Dupuytren's contracture), and examination shows an abducted posture of the small finger (*Wartenberg's sign*). This is due to weakness of the third palmar interosseous muscle. Inability to cross the flexed middle finger dorsally over the index finger or index over the long finger due to interossei dysfunction is called *Crossed Finger test*. Inability to abduct the fingers (*Egawa's test*) and adduct the fingers (*Card test*) is also due to interossei dysfunction. If the patient is unable to abduct the middle finger either radially or ulnarly while keeping the hand flat on a surface, this is called *Pitres-Testut sign*. The flattened palmar metacarpal arch and loss of hypothenar elevation is called *Masse's sign*. Loss of extrinsic muscle power to the ulnar innervated portion of FDP with the patient being unable to flex the DIP's of ring and little finger is known as *Pollock's sign* (Figs. 12, 13, 14, and 15).

The lumbricals flex the MCP joints and extend the interphalangeal (IP) joints. The lumbricals for the ring and small fingers are normally supplied by the ulnar

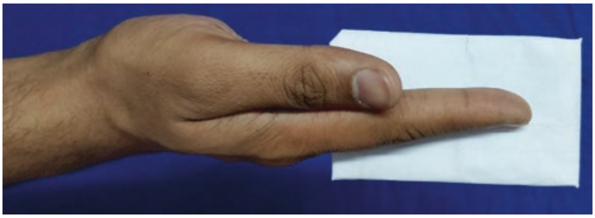

Fig. 12 Card test superior view

Fig. 13 Card test side view

Fig. 14 Card test

Fig. 15 Normal ulnar nerve showing resistance

nerve, and those for the index and middle fingers by the median. In ulnar lesions, unopposed extensor pull at the fourth and fifth MCP joints and unopposed flexor tone at the IP joints produce the *ulnar claw hand deformity*. Clawing varies with the level of the lesion; a “low” (distal) ulnar lesion with preserved function of the FDP induces more clawing than a “high” (proximal) ulnar lesion, where the accompanying FDP paralysis diminishes the deforming force on the distal phalanx. Clawing of the ulnar 2 digits is also known as *Duchenne’s sign*. Pressure or downward force over the proximal phalanges corrects most of the clawing. This is known as *Bouvier’s manouever*. This is because if hyperextension prevented by dorsal pressure, the Extensor Digitorum Communis can extend the PIP and DIP joints. The deformity of clawing is made worse by an unconscious effort to extend the fingers by tenodesing the extensor tendons with palmar flexion of the wrist (*Andre-Thomas sign*).

Froment’s sign is a test which may also be performed to check Ulnar nerve function. This is performed by asking the patient to hold a piece of paper between their thumb and index finger; this will check the function of the adductor pollicis. In Ulnar nerve palsy the interphalangeal joint of the thumb will flex to compensate. In addition to overt weakness of the pinch, the examiner also notes that the thumb flexes at the interphalangeal joint because the flexor pollicis longus activates in an attempt to compensate for the weakness. If, while performing the test, MCP of thumb hyperextends, the hyperextension is noted as positive *Jeanne's sign* (Figs. 16, 17, 18, 19, 20, 21, 22, 23, and 24).

The term *benediction hand* is sometimes used to refer to an ulnar claw hand with the hand at rest, and sometimes to a high median neuropathy when the patient is attempting to make a fist. The hand posture is somewhat similar in that the ring and small fingers are flexed and the index and middle fingers are not.

Non-ulnar innervated hand and forearm muscles should also be assessed in ulnar neuropathy because weakness of non-ulnar muscles is seen in conditions involving the C8 root or the lower brachial plexus. The distal two phalanges of the little finger are the autonomous zone of the ulnar nerve for sensory testing. Check vibratory perception and light touch with Semmes-Weinstein monofilaments.

Fig. 16 Cross finger test

Fig. 17 Duchennes sign

Fig. 18 Egawas test

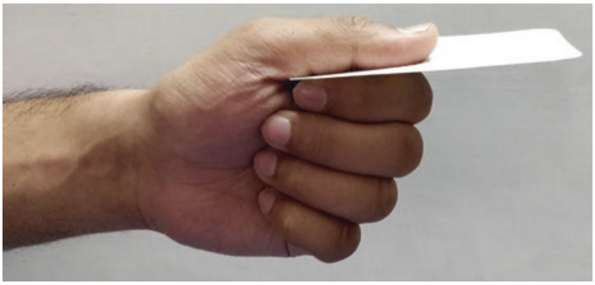

Fig. 19 Froment sign normal

Anomalous innervation may render the tests falsely negative. The *Martin-Gruber communication* between the ulnar nerve and either the median or anterior interosseous nerve in the forearm is present in 10–30%. It carries motor fibres from the median nerve to the ulnar nerve and on to hand intrinsics. In such patients, lesions of the ulnar nerve produce atypical intrinsic dysfunction because of innervation from the median nerve. Another one called the *Riche-Cannieu anastomosis* is a connection between the deep branch of the ulnar nerve and the recurrent branch of the median nerve in the hand. Hence the median nerve may innervate all lumbricals

Fig. 20 Froments sign abnormal

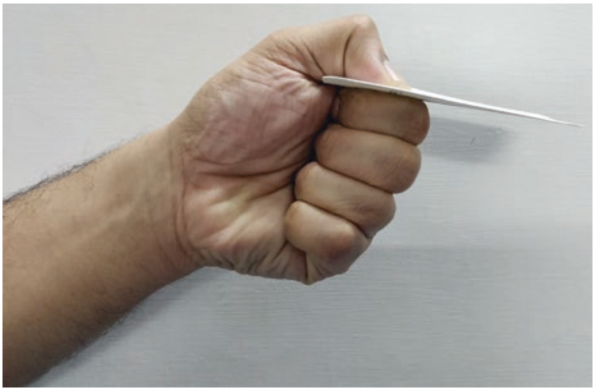

Fig. 21 Jeanne's sign

(so there would be almost no clawing of the digits). Similarly, an atypical ulnar to median nerve communication in the forearm is termed as a *Marinacci communication* but is less common.

The Radial Nerve (C5–T1)

The radial nerve arises as a continuation of the posterior cord of the brachial plexus. It supplies the long head of the triceps before entering the spiral groove. Branches to the medial and lateral heads of the triceps arise in the groove. The nerve pierces the lateral intermuscular septum to reach the anterior compartment and descends giving off a branch to the brachioradialis muscle and the extensor carpi radialis longus and brevis. The main trunk terminates by dividing into the posterior interosseus nerve (PIN) and the superficial radial nerve. The superficial radial nerve supplies the radial aspect of the dorsum of the hand and the radial three and one-half digits.

The PIN supplies the supinator muscle, and then passes over the fibrous edge of the extensor carpi radialis brevis and through a slit in the supinator muscle

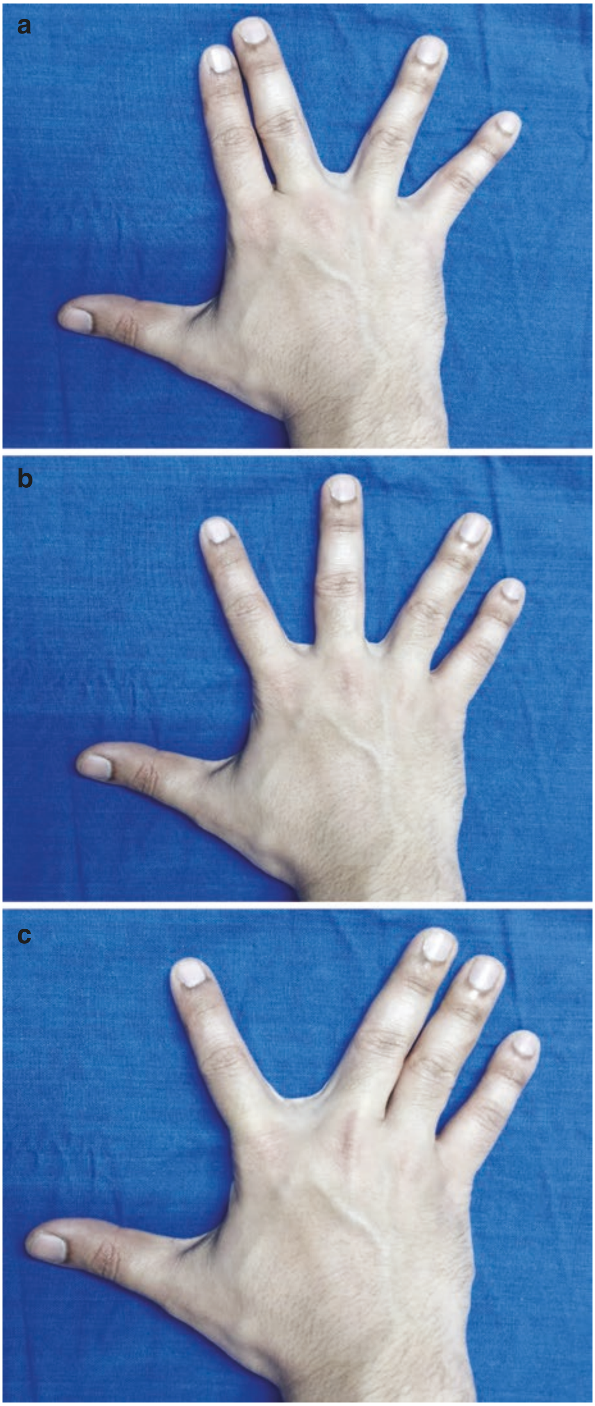

Fig. 22 Pitres testut sign (**a**–**c**)

Fig. 23 Pollock sign

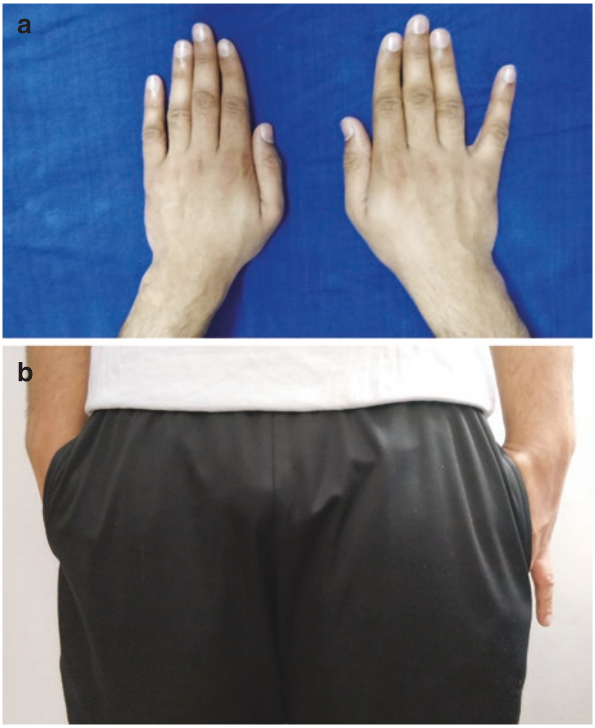

Fig. 24 Wartenberg sign (**a**, **b**)

(*the arcade of Frohse*), a potential site of compression. It continues along the interosseus membrane supplying the extensor muscles of the fingers and thumb and the abductor pollicis longus. It has no cutaneous sensory component.

Acute compression of the radial nerve in the spiral groove results from sustained compression over a period of several hours during sleep or in an alcohol-induced state (*"Saturday night" or "bridegroom's" palsy*). Weakness involves all muscles distal to the triceps. Radial nerve injury can also occur in the axilla by a crutch (*Crutch palsy*), or by shoulder dislocation, fractures of the humerus or radius, or penetrating wounds. The most prominent finding in radial nerve injury is wrist drop. There is weakness of finger extension at the MCP joints. Extension of the interphalangeal joints is preserved because this movement is carried out by the lumbricals and interossei. If the lesion is above the branch to the brachioradialis, there is weakness of flexion of the midprone forearm. The sensory involved area is usually limited to the dorsum of the thumb (Figs. 10 and 11).

A PIN palsy causes weakness of finger extension (finger drop) without wrist drop. The wrist deviates radially on extension because of paralysis or weakness of the PIN innervated extensor carpi ulnaris with preservation of the main trunk innervated extensor carpi radialis longus. A PIN lesion causes no sensory changes.

Neuropathy of the superficial radial nerve will cause pain and alterations of sensation in its distribution; it may be injured by tight bands around the wrist (*handcuff neuropathy*).

Nerves of the Lower-Extremity

The Lumbosacral Plexus

The nerves innervating the lower extremity and hip region arise from the lumbosacral plexus. The lumbar portion of the plexus originates from the anterior primary rami of L1–L4. It lies in or just posterior to the psoas muscle. The L4 and L5 roots give rise to the lumbosacral trunk, which joins the lumbar plexus to the sacral plexus. Roots from S1 to S3 join the lumbosacral trunk to complete the plexus; the sacral portion lies along the posterolateral wall of the pelvis, between the piriformis muscle and the major vessels. The major motor nerves arising from the lumbosacral plexus are the femoral, obturator, sciatic, common peroneal, tibial, superior gluteal, inferior gluteal, and pudendal.

The Femoral Nerve (L2–L4)

The femoral nerve is the largest branch of the lumbar plexus. It arises from the posterior divisions of the anterior primary rami of the L2–L4 roots. Leaving the cover of the psoas, it runs between the psoas and the iliacus muscle and exits from the pelvis beneath the inguinal ligament, lateral to the femoral vessels. Its motor branches innervate the psoas, iliacus, sartorius, pectineus, and quadriceps muscles. Its sensory branches, the intermediate (anterior) and medial femoral cutaneous nerves, innervate the anterior thigh. The femoral nerve terminates as a large sensory branch, the saphenous nerve, which supplies the medial aspect of the leg and the foot.

The femoral nerve may be involved in pelvic tumors, psoas abscesses or hematomas, fractures of the pelvis and proximal femur, aneurysms of the femoral artery, and penetrating wounds. Injury to the Femoral nerve causes impairment of knee extension due to quadriceps weakness. Walking forward and climbing stairs is difficult, although the patient may walk backward easily. The patient may walk holding the knee stiff or with a hand over the knee, and if the knee bends the patient may fall. Involvement within the pelvis or abdomen may also affect the function of the psoas major, causing weakness of hip flexion. Femoral nerve lesions impair the patellar reflex and cause sensory loss over the anterior and medial aspects of the thigh and the medial aspect of the leg.

The Obturator Nerve (L2–L4)

This nerve arises from the lumbar plexus from the anterior divisions of the anterior primary rami of L2–L4. It supplies the adductor muscles of the thigh, the gracilis, and the obturator externus, and sensations to a small area on the medial aspect of the thigh. Injuries are uncommon, but when they occur there is weakness of adduction and external rotation of the thigh, with a small area of anesthesia over the inner surface of the thigh.

The Lateral Femoral Cutaneous Nerve (L2–L3)

The lateral femoral cutaneous is a sensory nerve formed by the posterior divisions of the L2–L3 anterior primary rami. It transmits sensation from the skin of the anterolateral aspect of the thigh. Pain, paresthesias, and sensory loss in the distribution of the nerve is known as *meralgia paresthetica*. The nerve probably becomes entrapped where it passes under or through the inguinal ligament just medial to the anterior superior iliac spine, or where it pierces the fascia lata. Precipitating causes include weight gain, pregnancy, ascites, trauma such as during bone graft harvesting from the iliac crest, pressure by a belt or due to diabetes mellitus.

The Sciatic Nerve (L4–S3)

The sciatic nerve usually exits the pelvis beneath the piriformis muscle, but may pierce it or rarely passes above it. The nerve courses in close proximity to the posterior aspect of the hip joint and then enters the thigh. In its course through the thigh it innervates the hamstring muscles, and also part of the adductor magnus.

From its beginnings the sciatic nerve is made up of two divisions: the peroneal (lateral) and the tibial (medial). The tibial division arises from the anterior divisions of the lumbosacral plexus, and the peroneal from the posterior divisions. The peroneal and tibial divisions run together in a common sheath, forming the sciatic nerve, until the level of the popliteal fossa where they divide. The only hamstring muscle innervated by the peroneal division is the short head of the biceps femoris; all other hamstring muscles are innervated by the tibial division.

After the bifurcation in the popliteal fossa, the peroneal nerve moves laterally and winds around the fibular head, and then descends toward the foot. The tibial nerve descends in the midline down the posterior aspect of the leg to supply the gastrosoleus. In its proximal course it gives off a sural communicating branch, which joins another branch from the common peroneal nerve to form the sural nerve. The sural then runs distally and pierces the deep fascia to emerge into a superficial position about 15 cm proximal to the lateral malleolus, and then curves around and beneath the lateral malleolus to supply the skin of the lateral aspect of the foot and toes.

The tibial nerve passes beneath the medial malleolus, under the flexor retinaculum and ends by dividing into the medial and lateral plantar nerves. It innervates the abductors and short flexors of the toes and supplies sensation to the skin of the sole.

Injury to the main trunk of the sciatic nerve may result in weakness of both the common peroneal and tibial innervated muscles, but often the deficit involves predominantly the peroneal component. The sciatic nerve may be injured in pelvic fractures, posterior hip dislocations, intragluteal injections, or penetrating wounds. Hamstring muscle weakness is indicative of the lesion involves the main trunk of the sciatic nerve. When the deficit is limited to the peroneal division, the only way to prove the lesion involves the sciatic nerve rather than the peroneal is to demonstrate abnormality in the short head of the biceps femoris by needle EMG.

With complete sciatic lesions sensory loss involves all but the anteromedial aspect of the leg (saphenous distribution). Knee flexion is greatly impaired, the only muscles participating in this movement being the sartorius and gracilis. Flexion and extension of the ankle and toe joints, and inversion and eversion of the foot are lost. The patient cannot stand on either heel or toes. Trophic disturbances and neuropathic pain are common.

Common Peroneal Nerve (L4–S2)

The peroneal nerve at the fibular head is superficial, covered only by skin and subcutaneous tissue, making it exceptionally vulnerable to external compression. The nerve is also tethered at its point of passage through the peroneus longus muscle, making it susceptible to stretch as well. Significant peroneal neuropathy causes a foot drop. Habitual leg crossing is a classical cause of common peroneal neuropathy at the fibular head. Occasionally a skin dimple marks the precise site of compression. This type of palsy is particularly common in slender patients, or those who have recently lost weight (*slimmer's palsy*). Prolonged squatting is another common cause.

The most common differential diagnosis is L5 radiculopathy in the patient with foot drop. The presence of back and leg pain, weakness of foot inversion, positive root stretch signs, and depression of the medial hamstring reflex favor radiculopathy. The absence of pain, weakness limited to ankle eversion and foot/toe dorsiflexion, and preservation of the medial hamstring reflex favor common peroneal neuropathy.

The Tibial Nerve (L4–S3)

The tibial nerve is the larger of the two terminal branches of the sciatic nerve. It is formed by a fusion of all five of the anterior divisions of the sacral plexus (L4–S2 or S3). It supplies the long head of the biceps femoris, and the semimembranosus, semitendinosus, gastrocnemius, popliteus, soleus, plantaris, tibialis posterior, and flexors digitorum and hallucis longus muscles and, through the medial and lateral plantar nerves, the plantar flexors of the toes and the small muscles of the foot. Through the sural nerve it transmits sensation from the posterolateral aspects of the leg and ankle and the lateral aspects of the heel and foot. Calcaneal nerves supply sensation to the posterior and medial aspects and plantar surface of the heel; the medial and lateral plantar nerves supply the plantar surface of the foot. If the tibial nerve is injured, there is weakness distal to the lesion, with sensory loss over the plantar and lateral aspects of the foot, the heel, and the posterolateral aspects of the leg and ankle. Trophic changes and pain are common. The Achilles reflex is lost. Tibial nerve injuries are relatively infrequent because of its deep location and protected course, but it may be involved in lesions in or below the popliteal space. Compression by the flexor retinaculum behind the medial malleolus (lancinate ligament) may cause burning pain and sensory loss in the toes and sole of the foot and paresis or paralysis of the small muscles of the foot (*tarsal tunnel syndrome*).

Suggested Readings

1. Anto C, Aradhya P. Clinical diagnosis of peripheral nerve compression in the upper extremity. Orthop Clin N Am. 1996;27:227–36.
2. Boome RS, Kaye IC. Obstetric traction injuries of the brachial plexus: natural history, indications for surgical repair, and results. J Bone Joint Surg (Br). 1988;70:57l–6.
3. Chan RK. Splinting for peripheral nerve injury in upper limb. Hand Surg. 2002;7(2):251–9.
4. Kuschner SH, Ebramzadeh E, Johnson D, Brien WW, Sherman R. Tinel's sign and Phalen's test in carpal tunnel syndrome. Orthopedics. 1992;15(11):1297–302.
5. Werner RA, Bir C, Armstrong TJ. Reverse Phalen's maneuver as an aid in diagnosing carpal tunnel syndrome. Arch Phys Med Rehabil. 1994;75(7):783–6.
6. Laha RK, Lunsford LD, Dujovny M. Lacertus fibrosus compression of the median nerve: case report. J Neurosurg. 1978;48(5):838–41.
7. Pryse-Phillips WE. Validation of a diagnostic sign in carpal tunnel syndrome. J Neurol Neurosurg Psychiatry. 1984;47(8):870–2.
8. Durkan JA. A new diagnostic test for carpal tunnel syndrome. J Bone Joint Surg Am. 1991;73(4):535–8.
9. Bowden RE, Napier JR. The assessment of hand function after peripheral nerve injuries. J Bone Joint Surg. 1961;43(3):481–92.

10. Goldman SB, Brininger TL, Schrader JW, Koceja DM. A review of clinical tests and signs for the assessment of ulnar neuropathy. J Hand Ther. 2009;22(3):209–20.
11. Massy-Westropp N, Grimmer K, Bain G. A systematic review of the clinical diagnostic tests for carpal tunnel syndrome. J Hand Surg. 2000;25(1):120–7.
12. Katirji MB, Wilbourn AJ. Common peroneal mononeuropathy: a clinical and electrophysiologic study of 116 lesions. Neurology. 1988;38:1723–8.
13. Parziale JR, Hudgins TH, Fishman LM. The piriformis syndrome. Am J Orthop. 1996;25(12):819–23.
14. Sayson SC, Ducey JP, Maybrey JB, et al. Sciatic entrapment neuropathy associated with an anomalous piriformis muscle. Pain. 1994;59(1):149–52.
15. Beltran LS, Bencardino J, Ghazikhanian V, Beltran J. Entrapment neuropathies III: lower limb. Semin Musculoskelet Radiol. 2010;14(5):501–11.
16. Campbell WW. Diagnosis and management of common compression and entrapment neuropathies. Neurol Clin. 1997;15:549–67.
17. Campbell WW. DeJong's the neurologic examination. 6th ed. Philadelphia: Lippincott Williams & Wilkins; 2005.
18. Shapiro BE, Preston DC. Entrapment and compressive neuropathies. Med Clin N Am. 2003;87:663–96.
19. Stewart JD. Focal peripheral neuropathies. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2000.

The Cervical Spine

S. S. Dhatt, S. Siva Swaminathan, and Karthick S. R

Anatomy

The cervical spine consists of 7 cervical vertebrae, intervertebral discs beginning at the C2–C3 interspace, a complex network of supporting ligaments, and neurovascular structures. The cervical vertebrae are smaller than their thoracic or lumbar counterparts and the transverse processes possess a foramen transversarium for the passage of the vertebral artery (Note that the vertebral artery passes through the transverse process of C1–C6 and not through C7).

The first two cervical vertebrae have exceptional anatomic features.

The first cervical vertebra is called the *atlas* because it supports the head. Distinct from all other vertebrae, the atlas has no body and no spinous process; it is a ring-like structure with anterior and posterior arches. It has a lateral mass on each side [1]. The superior surfaces of the lateral masses articulate with the occipital condyles, forming the atlanto-occipital joint. Functionally, this joint allows 50% of neck flexion and extension (nodding movement takes place at atlanto-occipital joint).

The second cervical vertebra, the *axis*, forms the surface on which the atlas pivots to allow lateral rotation of the head. The axis has a peglike odontoid process also called dens is the cranial extension of the body of the axis into the ring of the atlas; it is the most characteristic feature of C2 (Fig. 1). The dens articulates with the posterior aspect of the anterior ring of C1 and is stabilized by the transverse ligament. This articulation provides stability as the atlas pivots during rotation. Half of neck rotation occurs at this atlanto-axial joint (movement for saying "no" takes place at atlanto-axial joint). There is no intervertebral disc at either the atlanto-occipital or the C1–C2 joints, predisposing them to inflammatory arthritis [2].

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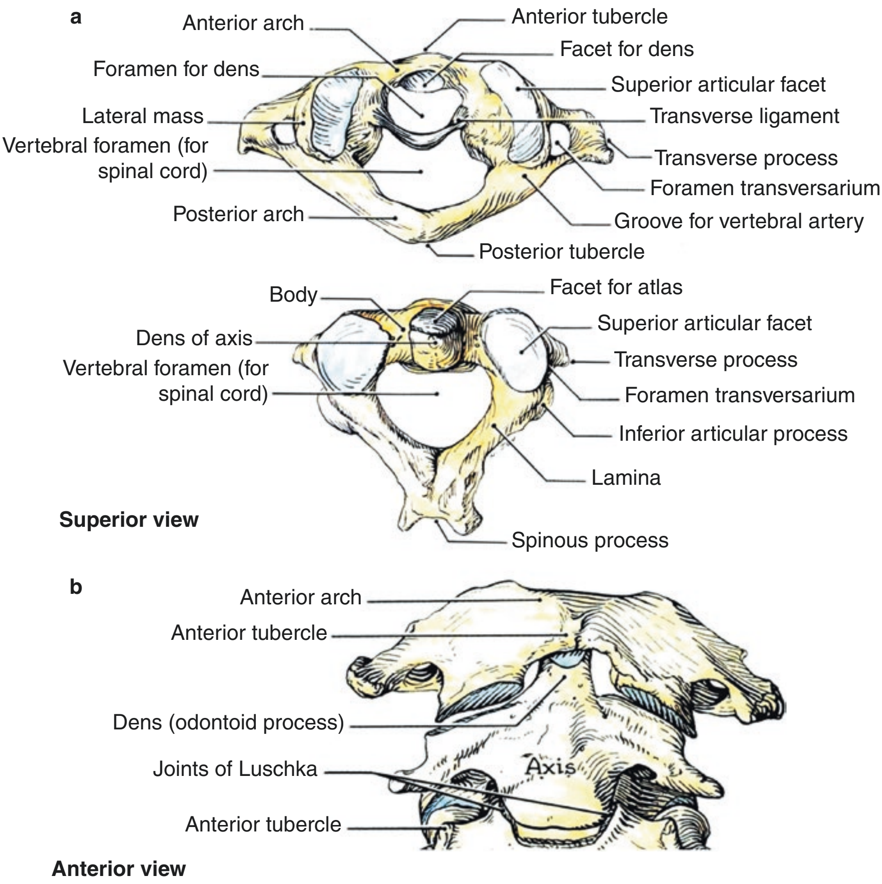

Fig. 1 (**a**, **b**) Cervical vertebra one and two: atlas and axis. (**a**) Superior view (**b**) anterior view

There are 14 facet (apophyseal) joints in the cervical spine. The upper four facet joints in the two upper thoracic vertebrae are often included in the examination of the cervical spine. The uncovertebral joints or Joints of Luschka (Fig. 2) are unique to the cervical spine. The uncus gives a "saddle" form to the upper aspect of the cervical vertebra, which is more pronounced posterolaterally. Extending from the uncus is a "joint" that appears to form because of a weakness in the annulus fibrosus. The portion of the vertebra above, which "articulates" or conforms to the uncus, is called the echancrure, or notch.

Although there are seven cervical vertebrae, there are eight cervical nerve roots. This difference occurs because there is a nerve root exiting between the occiput and C1 that is designated the C1 nerve root. In the cervical spine, each nerve root is named for the vertebra below it. *As* an example, C5 nerve root exists between the C4 and C5 vertebrae (Fig. 3). In the rest of the spine, each nerve root is named for the vertebra above; the L4 nerve root, for example, exists between the L4 and L5

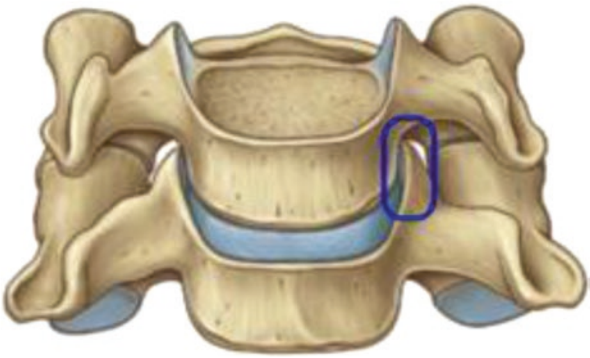

Fig. 2 Joints of Luschka

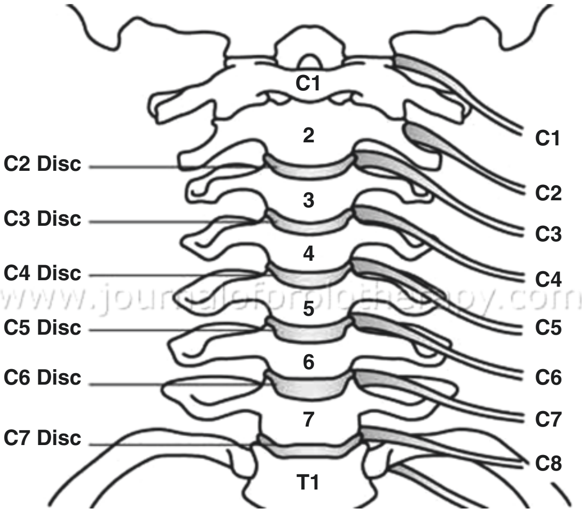

Fig. 3 Cervical spine nerve root anatomy

vertebrae. The switch in naming of the nerve roots from the one below to the one above is made between the C7 and T1 vertebrae. The nerve root between these two vertebrae is called C8, accounting for the fact that there are eight cervical nerve roots and only seven cervical vertebrae.

Patient History

Age

Age may be important because some disorders do not occur or do typically occur at a certain period of life. Torticollis in a baby is probably congenital whereas acute torticollis in a 5-year old child is more likely to be caused by contraction of the sternomastoid muscle after, for example, glandular swelling or abscess formation. And sudden torticollis during adolescence is probably the result of disc protrusion.

Spondylosis is often seen in patients older than 30 or 40 years. 60% of those older than 45 years and 85% of those older than 65 years have spondylosis [3]. Radicular pain in a young person can be due to a neurofibroma,while in the elderly its usually due to compression by a osteophyte or invasion of spine by secondary deposits.

Pain

Pain is the most common symptom. Its localisation may give an idea about the site of the lesion.

Onset

Where???

Pain of cervical origin often starts at the cervical spine but frequently spreads to another region, so that the cervical origin may pass unnoticed.

Interscapular onset is typical of lower cervical disc lesions which compress the dura.

Pain that starts in the region of arm in a young patient may be due to neurofibroma.

When???

Pain of cervical origin usually occurs in discrete attacks especially when a disc lesion is responsible. So patient may give a waxing and waning history.

How???

The origin may be spontaneous, either acute or chronic or due to an injury. In the latter, details about the type of injury should be sought afer (e.g., fall or whiplish).

Localization

Pain that spreads and expands over a larger area is typical of an expanding lesion and should always arouse suspicion. On the other hand, pain that shifts from scapular region to the upper limb is highly indicative of a cervical disc lesion. The fragment of disc substance first displaces postero-centrally and compresses the duramater, which results in central, bilateral or unilateral scapular pain; it then moves laterally and impinges on the dural investment of a nerve root. The scapular pain disappears and is replaced by a radicular pain down the upper limb.

Headache

If headache is of cervical spine origin, patient will usually mention an association between symptoms and certain posture or movements (Table 1).

Cervical radiculopathy or injury to the nerve roots in the cervical spine, presents primarily with unilateral motor and sensory symptoms in the upper limb, with muscle weakness (myotome), sensory alteration (dermatome), reflex hypoactivity and sometimes focal activity being the primary signs [4, 5].

Table 1 Signs of headache having a cervical origin

1. Occipital or suboccipital component to headache
2. Neck movement alters headache
3. Painful limitation of neck movements
4. Abnormal head or neck posture
5. Suboccipital or nuchal tenderness
6. Sensory abnormalities in occipital and suboccipital areas

Cervical Myelopathy or injury to the spinal cord itself, is more likely to present with spastic weakness, parasthesia, and possible incoordination in one or both lower limbs, as well as proprioceptive or sphincter dysfunction [6].

Pain in the trapezioscapular region is the most common pain reference for cervical lesions. Majority of pain in the trapezius or scapular area have a cervical origin and must be considered as a multisegmental reference of a discodural conflict.

Duration

Most of the benign cervical disorders are having intermittent pain. If pain progressively worsens, then the presence of an irreversible lesion such as metastases should be considered, particularly in the elderly. Root pain caused by a disc protrusion lasts for a variable but limited period and then ceases as spontaneous remission takes place.

Paraesthesia

Patients most often complain of numbness, tingling or 'pins and needle' sensations in the extremities of cervical spine lesions. The moment the patient mention such symptoms, the examiner should carefully examine how proximal they are because the point of compression always lies proximal to that of the paraesthesia.

Spinal Cord

External pressure on the spinal cord is characterized by painless paraesthesia in the upper and/or lower limbs felt distally and in a multisegmental distribution. The paraesthesia comes and goes in a wholly irregular way, most marked by day. Neck flexion usually increases the symptoms, or Lhermitte's sign (Fig. 4) may be present: an electric shock sensation in the trunk and/or upper limbs following forceful passive flexion of the cervical spine.

Nerve Root

When a nerve root is affected paraesthesia with pins and needle sensations may occur in the corresponding dermatome level. Pins and needles can come and go in an erratic fashion and usually do not last for more than an hour at a time.

Fig. 4 Lhermitte's sign

Inspection

For a proper observation, a patient should be suitably undressed. The examiner should make it point to see the patient when he/she enters the examination rooms and when the patient undresses. This can give vital information regarding the patient's condition.

Ideally patient must be in a standing posture when examination is done.

Examination should be done while standing in front, back and by the side of the patient (Fig. 5).

Head and Neck Posture

The head should be in midline with the chin above the manubrium. In torticollis the head may be tilted towards the side of the lesion with the chin pointing the opposite direction. Normal neck shows a slight lordotic curve. In whiplash injuries, there may be loss of lordosis with the head fixed in flexion.

Short neck may be seen in a person with Klippel-Feil syndrome [7] due to fusion of cervical vertebra and in a girl with Turner's syndrome [8] one may notice webbing of neck.

Shoulder Level

Usually the shoulder on the dominant side will be slightly lower than the non-dominant side. In a child with sprengel's shoulder the affected side is usually at a higher level.

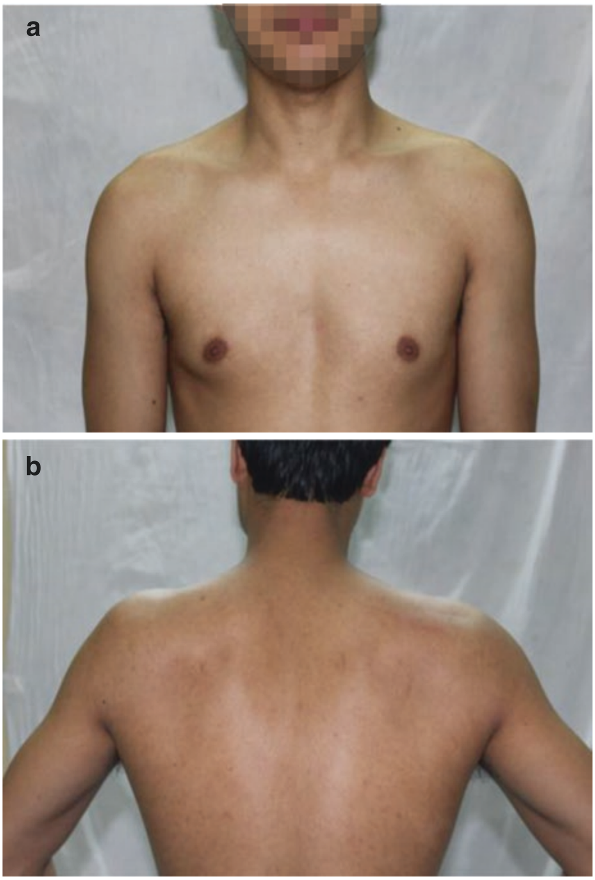

Fig. 5 (**a**) Cervical spine. Inspection infront. (**b**) Cervical spine. Inspection from back

Muscle Wasting or Asymmetry

The scapular and deltoid regions should be surveyed to rule out muscle wasting (e.g., deltoid wasting in axillary nerve palsy). A tight and prominent sternomastoid muscle may be seen in torticollis.

Palpation

Spinous Processes

Palpation of cervical spine begins at the inion, located at the base of the skull. The palpation should proceed distally to identify each spine process, the most prominent being that of C7. Tenderness at a particular level may indicate a localized injury to the region.

Normally all the spinous process should be aligned in a perfectly linear fashion and regularly spaced. An acute lateral shift of a spinous process may be due to unilateral facet joint dislocation or fracture.

Posterior Cervical Musculature

The main muscle in this region is the trapezius. Localized mass or spasm may indicate a hematoma or injury to the muscle itself. Tenderness at the base of the skull, deep to the trapezius may be due to occipital neuritis (greater occipital nerve) or C1–C2 instability in rheumatoid patients.

Anterior Aspect

Three prominent structures are to be identified in the anterior aspect of the neck mainly to orient the examiner to the corresponding vertebral level of spinal pathology.

The hyoid bone lies just caudal to the angle of mandible and it lies at the level of C3 vertebral body.

Inferior to the hyoid bone is the thyroid cartilage or the Adam's apple which lies at the level of C4–C5 vertebral bodies.

Lying inferior to the thyroid cartilage at the level of C6 vertebral body is a mobile ring called the cricoids cartilage (Fig. 6).

Movements

With the patient seated active movements of the cervical spine are tested first. The examiner must look for differences in range of motion (ROM) and patient's willingness to do the movements. The range of motion usually decreases with age, except rotation at C1–C2, which increases with age [9, 10].

Fig. 6 Palpation of cricoid cartilage

Active Movements

Flexion: The maximum ROM is 80–90° (Fig. 7). In rheumatoid arthritis patients with C1–C2 instability, one can notice a posterior bulge of the spinous process of C2 when the patient is flexing his neck.

Extension: Normal ROM is 70° (Fig. 8).

Rotation: Normal rotation is 70–90° to the left and right (Fig. 9).

Lateral flexion: Side or lateral flexion is approximately 20–45° to the right and left (Fig. 10).

Passive Movements

The movements done actively previously are done passively. Pain, limitation and the end-feel are assessed while doing passive movements.

Fig. 7 Cervical spine: flexion

Fig. 8 Cervical spine: extension

Fig. 9 Cervical spine rotation-right

Fig. 10 Cervical spine right lateral flexion

Normal end-feel is capsular. Muscle spasm, bone-to-bone, crisp, empty, soggy and elastic rebound are some of the abnormal end-feels.

Resisted Movements

Lateral Rotation

The sternocleidomastoids function as rotators as well as flexors of cervical spine. They are supplied by spinal accessory nerve.

To test a given sternocleidomastoid muscle, the examiner places the palm of one hand on the opposide side of the patient's head or face and instructs the patient to attempt to rotate the head to that side as strongly as possibly. The tension in the sternomastoid being tested should be quite visible and can be palpated as well (Fig. 11).

Fig. 11 Assessing right lateral rotation strength

Fig. 12 Assessing flexion strength

Flexion

The principal flexors are the sternocleidomastoids. To test flexors, the examiner places a resisting palm against the patient's forehead with the other hand stabilising the patient's thorax (Fig. 12).The patient is asked to flex the neck against resistance and the contraction of sternocleidomastoids should be visible.

Extension

The main extensors are the posterior intrinsic neck muscles and the upper portion of trapezius (Fig. 13). The examiner places a resisting hand on the patient's occiput and asks the patient to extend the neck against resistance.

Motor Examination

C5 Nerve Root

C5 nerve root is best assessed by testing deltoid function. The examiner makes the patient to sit in an upright position and asks him to abduct the arm with the elbows

Fig. 13 Assessing extension strength

Fig. 14 Assessing C5 motor function (deltoid strength)

flexed. The examiner exerts downward pressure on the elbow while the patient tries to resist with a pure abduction force (Fig. 14). In a normal patient, the examiner is unable to overcome the patient's abduction power.

C6 Nerve Root

C6 nerve root can be assessed by testing for biceps brachii and wrist extensors. To test the biceps, the examiner asks the patient to flex the elbow to 90° (in supination). With one hand the examiner supports the patient's elbow and with the other hand he holds the patient's wrist and tries to extend the elbow while the patient tries to flex (Fig. 15). In a normal patient, the examiner will find it difficult to extend the elbow.

To test the wrist extensors, the patient is asked to keep his elbows flexed, and the examiner applies a downward pressure on a dorsiflexed wrist (Fig. 16).

Fig. 15 Assessing C6 motor function (biceps)

Fig. 16 Assessing C6 motor function (wrist extensors)

C7 Nerve Root

C7 nerve root can be assessed by testing the wrist flexors, long finger extensors and triceps brachii.

To test the wrist flexors, the examiner first asks the patient to make a fist and then asks the patient to flex the wrist while he tries to extend it (Figs. 17, 18, and 19).

To test the long finger extensors, the examiner stabilises the patient's wrist in one hand and asks the patient to extend the fingers while he applies downward pressure to flex to metacarpo-phalangeal joint.

To test for triceps, the patient is asked to flex to elbow to 90°. Now with one hand the examiner stabilises the elbow and with the other hand grasping the wrist, the examiner tries to flex to elbow while the patient tries to extend it.

C8 Nerve Root

This is assessed by testing for long finger flexors. The examiner places his index and middle finger in the patient's palm and asks the patient to squeeze his hand (Figs. 20 and 21).

Fig. 17 Assessing C7 motor function (wrist flexors)

Fig. 18 Assessing C7 motor function (long finger extensors)

Fig. 19 Assessing C7 motor function (triceps)

An alternative method is for the examiner to place his flexed fingers against the patient’s palm and ask the patient to make a tight fist. This causes the examiner’s and the patient’s fingers to be hooked together in a reciprocal manner. The examiner then instructs the patient not to allow the fist to be pulled open while he attempts to do so.

Fig. 20 Assessing C8 motor function (long finger flexors)

Fig. 21 Assessing C8 motor function (alternative technique)

T1 Nerve Root

T1 nerve root is assessed by testing the interossei muscles which play a vital part in finger abduction and adduction (Figs. 22, 23, and 24).

To test for finger abduction, the patient is asked to keep his hands on a table and spread his fingers as far apart as possible. Now the examiner grasps the patient's fingers between his index finger and thumb and tries to push them back together while the patient tries to spread them apart.

To test for finger adduction, the examiner places a card between the spread index and long fingers of the patient. Now the patient is asked to squeeze the two fingers together while the examiner tries to pull the card out. Normally the card can be pulled out by the examiner but with some difficulty.

To test the first dorsal interossei, the patient's hand is kept on a table and the examiner places the index finger of his hand against the radial aspect of the patient's index finger. Now the patient is asked to press his index finger against that of the examiner's while the examiner tries to bring the patient's finger medially. The muscle can be seen contracting and can be palpated as well.

Fig. 22 Assessing T1 motor function (finger abduction)

Fig. 23 Assessing T1 motor function (finger adduction)

Fig. 24 Assessing T1 motor function (first dorsal interosseous)

Reflex Examination

The reflexes are tested and it is observed whether they are normal, diminished, absent or inverted. It should be noted that the reflexes is always compared with the other side when in doubt.

Biceps Reflex (C5)

The patient's elbow is at right angle with his forearm resting on the examiner's forearm. With the examiner's thumb over the biceps tendon in the antecubital fossa, hammer is tapped on the thumb. The examiner will be able to see the contraction of the biceps muscle (Fig. 25).

Brachioradialis Reflex (C6)

With the patient's elbow at 90° flexion and his midprone forearm in a relaxed position over that of the examiner's hand, the examiner taps the radial aspect of the forearm 4–8 cm proximal to the radial styloid. The examiner is usually able to see the contractions of brachioradialis muscle (Fig. 26).

Triceps Reflex (C7)

With the patient in 90° shoulder abduction and 90° elbow flexion, and with the examiner supporting the patient's arm, the examiner strikes the triceps tendon just proximal to olecranon, which results in visible contraction of triceps and extension of the elbow (Figs. 27 and 28).

Fig. 25 Biceps reflex (C5)

Fig. 26 Brachioradialis reflex (C6)

Fig. 27 Triceps reflex (C7)

Fig. 28 Triceps reflex (alternative technique)

Plantar Reflex

The patient is asked to sit comfortably in a chair with his feet dangling. The examiner grasps the patient foot in one hand and ṣtroking the sole of the patient's foot, starting at the lateral aspect of the heel and moving along the lateral border of the foot to the base of the fifth metatarsal and then curves towards the base of the great toe at the medial aspect of the foot. The normal reaction, as described by Strümpell, is flexion of the toes and withdrawal of the foot. The pathological reflex—Babinski's sign—is a slow extension of the big toe, combined with fanning of the other toes and flexion of knee and hip. The presence of Babinski's sign in adults indicates an upper motor neuron lesion (Figs. 29, 30, and 31).

Hoffmann's Sign

The hand is supported and pronated so that wrist and fingers fall into slight flexion. The middle finger is firmly grasped and partially extended. The terminal phalanx of the patient's middle finger is flicked downwards. In states of hypertonia, the thumb flexes and adducts and the other fingers flex (Fig. 32).

Fig. 29 Eliciting plantar reflex

Fig. 30 Normal plantar reflex response

Fig. 31 Babinski's sign

Fig. 32 Hoffmann's sign

Grading of Reflexes

Grade 0: Absent
Grade 1: Present
Grade 2: Brisk
Grade 3: Very brisk
Grade 4: Clonus

Clonus

Clonus is a state of exaggerated deep tendon reflex where repetitive contractions of the muscle being tested occurs after a single stimulus.

Ankle Clonus

With the patient lying supine,the examiner flexes the hip and knee to 90°. With one hand supporting the leg, and the other holding the forefoot of the patient, the examiner gives a dorsiflexion stimulus at the ankle.In cases of upper motor neuron lesions, repeated plantar flexion movements can be seen (Fig. 33).

Fig. 33 Eliciting ankle clonus

Fig. 34 Eliciting patellar clonus

Patellar Clonus

With the patient lying supine with hip in neutral and knee in extension, the examiner holds the superior pole of patella with his fingers and gives a single stimulus by pushing the patella distally. In upper motor neuron lesions, there will be repeated pulling of patella upwards by the quadriceps tendon (Fig. 34).

Sensory Examination

Sensations and the corresponding tracts

1. Pain (superficial and deep)—lateral spinothalamic tract.
2. Temperature-lateral spinothalamic
3. Touch-anterior spinothalamic tract, posterior column
4. Proprioception-posterior column
5. Vibration sense-posterior column
6. Two point discrimination-posterior column

7. Stereognosis-posterior column
8. Graphaesthesia- posterior column

Pain

All sensory testing should be done with the patient's eyes closed. Superficial pain can be tested using a sharp pin and it should be noted that the examiner should always move from the area of impaired sensation to the normal site.

Deep pain can be tested by squeezing muscles of calf and tendo-achilles. Deep pain is increased in subacute combined degeneration of cord, infective polyneuritis. In syringomyelia and tabes dorsalis sensation of deep pain is decreased (Figs. 35, 36, and 37).

Temperature

Test tubes containing hot (110 °F) and cold (45 °F) can be used to test temperature sensation (Fig. 38).

Sensory Examination

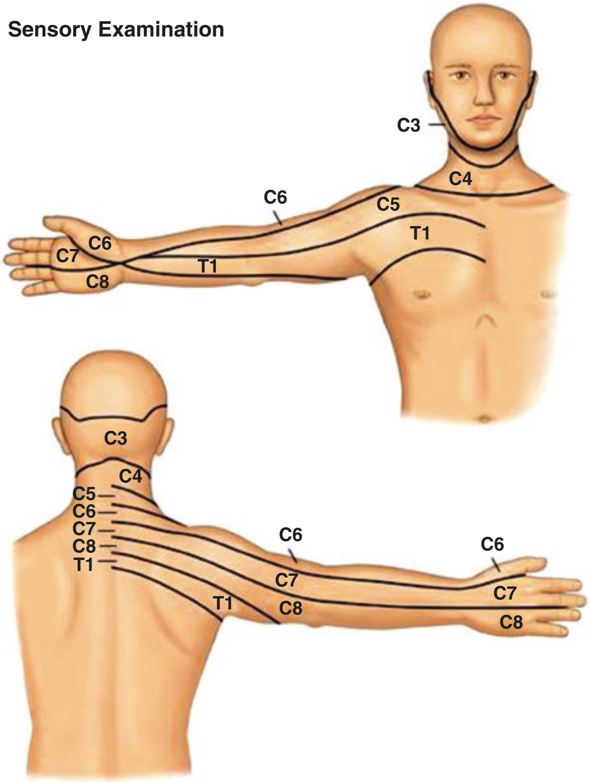

Fig. 35 Cervical dermatomes

Fig. 36 Testing for superficial pain

Fig. 37 (**a**, **b**) Testing for deep pain

Touch

Cotton wool is shaped to a point and the skin is touched lightly in dermatome areas, tell the patient to shut his eyes and to say "yes" if he feels anything. Dermatomal mapping done. Fine hair brush can also be used to test. Do not stroke hairy areas.

Vibration Sense

Vibration sense can be tested using a tuning fork of 256 Hz over bony prominences such as olecranon, humeral epicondyles, radial styloid, medial malleolus. The examiner places the base of the tuning fork after striking on the bony prominence and ask the patient to report when the vibration stops. The examiner then suddenly stop the vibration with the free hand. Normally the patient identifies the cessation of vibration quite readily (Fig. 39).

Proprioception

The patient is instructed to close his or her eyes and the examiner grasps one of the patient's fingers or toes. The examiner then alternately flexes and extends the digit several times, randomly stopping in flexion or extension. The patient should be able to identify whether the digit ends the manoeuver in extension or flexion (Fig. 40).

Fig. 38 Testing for temperature

Fig. 39 Testing for vibration sense

Fig. 40 Testing for proprioception

Two Point Discrimination

A person with normal sensation will be able to distinguish two points 5 mm apart on the fingertips. The points are initially apart and are approximated till the patient starts making mistakes.

Stereognosis

It is the ability to recognize an object purely from the feel of its size and shape with the eyes closed. When other forms of sensation are normal, presence of astereognosis should indicate a parietal lobe lesion.

Graphaesthesia

It is the ability to recognize letters, shapes written on the skin with a blunt object.

References

1. Gray H. Osteology. In: Goss CM, editor. Gray's anatomy. 29th ed. Philadelphia: Lea & Febiger; 1973. p. 95–286.
2. Nakano K. Neck pain. In: Ruddy S, Harris EJ, Sledge C, editors. Textbook of rheumatology. 6th ed. Philadelphia: Saunders; 2001. p. 458.
3. Magee DJ. Orthopedic physical assessment. 4th ed. Philadelphia: Saunders; 2002.
4. Malanga GA. The diagnosis and treatment of cervical radiculopathy. Med Sci Sports Exerc. 1997;29:S236–45.
5. Levine MJ, Albert TJ, Smith MD. Cervical radiculopathy diagnosis and nonoperative management. J Am Acad Orthop Surg. 1996;4:305–16.
6. Tsairis P, Jordan B. Neurological evaluation of cervical spinal disorders. In: Camins MB, O'Leary PF, editors. Disorders of the cervical spine. Baltimore: Williams & Wilkins; 1992.

7. Samartzis DD, Herman J, Lubicky JP. Classification of congenitally fused cervical patterns in Klippel–Feil patients: epidemiology and role in the development of cervical spine-related symptoms. Spine. 2006;31(21):E798–804.
8. McCarthy K, Bondy CA. Turner syndrome in childhood and adolescence. Expert Rev Endocrinol Metab. 2008;3(6):771–5.
9. Youdas JW, Garrett TR, Suman VJ, Bogard CL, Hallman HO, Carey JR. Normal range of motion of the cervical spine: an initial goniometric study. Phys Ther. 1992;72:770–80.
10. Dvorak J, Antinnes JA, Panjabi M, Loustalot D, Bonomo M. Age and gender related normal motion of the cervical spine. Spine. 1992;17:S393–8.

Shoulder Examination

S. Prabhakar and Kevin Syam

Shoulder examination comprises of examining the shoulder girdle as a whole which consists of

1. The sternoclavicular joint—a saddle type of joint between the medial end of the clavicle, the manubrium sterni and the first rib
2. The acromioclavicular joint—a plane synovial joint between the acromion process and the lateral end of the clavicle
3. The glenohumeral joint—a multiaxial synovial joint
4. The scapulothoracic articulation—comprising of the body of the scapula and the muscles over the posterior chest wall.

Because of this complexity, the examination of the shoulder girdle seems to be a difficult task. But a systematic approach to the assessment and a thorough knowledge of the anatomy would help a lot in the easy understanding of the pathology that the patient is suffering from.

Clinical Anatomy

The glenohumeral joint is a ball and socket joint that depends primarily on the muscles and ligaments rather than bones for its support, stability, and integrity [1] (Fig. 1). The fibrocartilaginous labrum surrounds and deepens the glenoid cavity of the scapula to about 50% [2]. The glenoid has a 5° superior inclination and an

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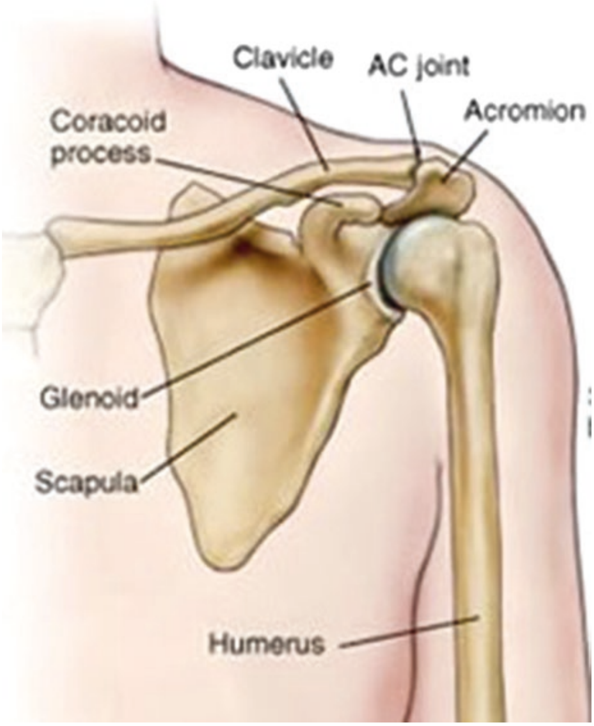


Fig. 1 Anatomy of the shoulder joint

average 5–7° of retroversion (Fig. 2). The angle between the humeral neck and shaft is about 130° and the humeral head is retroverted 30–40° [3]. The soft tissue comprises of the glenohumeral ligaments, coracohumeral ligaments, glenoid labrum and the rotator cuff muscles.

History

An idea of what the patient is suffering from is obtained from a good clinical history. Most commonly, they complain of pain, especially on movement, restricted motion, and/or shoulder instability. The patients age is important as various pathologies have predominant age groups like instability issues are more common in the 1920s, rotator cuff pathologies in the age group of 30–50 years and frozen shoulder in patients who are 45 years+. If there was a traumatic incident that initiated the complaints, the details regarding the injury should be taken including whether the patient was able to move his arm immediately after the injury and the treatment he or she received for the same. When the patient is complaining of pain, the onset, character, severity, any radiation, aggravating and relieving factors should all be probed into. If the patients tell that the pain had started after throwing something, then the possibility of SLAP lesion should be kept in mind. It should never be forgotten that cervical pathologies

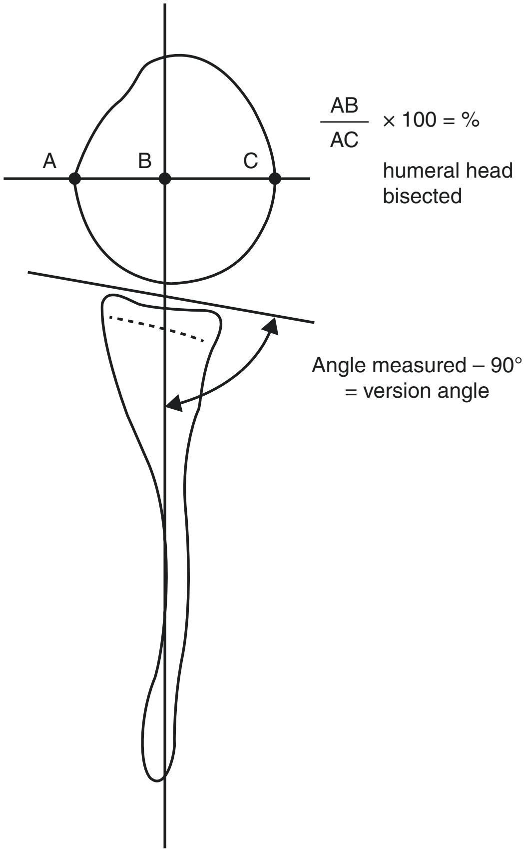


Fig. 2 Figure depicting the version of the glenoid

and thoracic outlet syndrome can have radiating pain in the shoulder with shooting character. Similarly one can have referred pain in the right shoulder from cholecystitis and in the left shoulder due to myocardial infarction. Such shoulder pain mimickers should always be there in the examiners mind and should be ruled out whenever found appropriate. In case of instability, the attitude of the limb that produces the instability, the number of episodes that the patient has suffered from and the how the joint is reduced should be enquired about. Last but not the least, the patients hand dominance, occupation (functional demand) and functional disability should be noted so that the patient's problems can be properly addressed.

Examination

Before starting a local examination a general examination should be conducted. The presence of generalised laxity should be looked for using Beighton scoring system [4]. Scores greater than 4 or more indicates generalised laxities and such patients may have multidirectional shoulder instabilities and exaggerated range of motion.

Attitude

The moment patient walks into your out/inpatient department, a diagnosis can be made from looking at the attitude of the limb. Examples include, the patient supporting his arm away from his body with loss of deltoid contour suggest an *anterior dislocation* of the shoulder Fig. 3, keeping the arm fully abducted by the side of his/her ear could be due to an inferior shoulder dislocation (*luxation erecta*) Fig. 4, arm lying flail by the side of the body and internally rotated with elbow extended, forearm pronated and the wrist and fingers partially palmar flexed (police tip attitude) suggests that it could be case of *Erb's palsy* Fig. 5.

Inspection (To Look)

The patient should be adequately exposed and a female attender should be there with the examiner while examining a female patient.

From the Front

Ensure that the head and neck are in the midline of the body and observe their relation to the shoulders. Asymmetry may be found in case of congenital torticollis, scoliosis etc. Look for the presence of any *step deformities*. Such a deformity may be seen in an acromioclavicular dislocation, with the distal end of the clavicle lying

Fig. 3 Attitude of anterior dislocation of shoulder with the affected arm held away from the body

Fig. 4 Attitude of inferior dislocation of right shoulder

Fig. 5 Attitude of the right upper limb with Erb's palsy (police man tip deformity)

superior to the acromion process or in a sternoclavicular dislocation. The deformity at the acromioclavicular joint may be accentuated by asking the patient to horizontally adduct the arm or to medially rotate the shoulder and bring the hand up the back as high as possible. Look at the bony contour of the clavicle. Any asymmetry may suggest an old malunited or Non-union of the clavicle. Fullness in the anterior axillary fold region with loss of deltoid contour would suggest an anterior shoulder dislocation. Wasting of the deltoid will also be seen in deltoid paralysis, tuberculosis of the shoulder joint, chronic inflammatory and rotator cuff pathologies Fig. 6.

From the Side

Again look for the deltoid contour and presence of any sulcus below the acromion process. This is known as the sulcus sign and is exaggerated when traction is applied to the arm. Causative factor could be multidirectional instability or loss muscle control due to nerve injury or a stroke, leading to inferior subluxation of the glenohumeral joint Fig. 7.

From the Back

The examiner again should note bony and soft-tissue contours and body alignment. Atrophy of the upper trapezius may indicate spinal accessory nerve palsy; whereas atrophy of supraspinatus and/or infraspinatus may indicate supraspinous nerve palsy. The spines of the scapulae are at the level of the third (T3) thoracic vertebra and extend to the T7 or T9 spinous process of the thoracic vertebrae Fig. 8. A high riding scapula will be seen in *Sprengel's deformity*. An associated short neck and low hair line would suggest *Klippel-Feil syndrome*. The examiner should next look for the presence of winging of the scapula, a condition in which the medial border moves away from the posterior chest wall. *Dynamic winging* (i.e., winging with movement) may be caused by injury to the long thoracic nerve affecting serratus anterior, injury to the spinal accessory nerve leading to trapezius palsy, rhomboid weakness, multidirectional instability, voluntary action, or a painful shoulder resulting in splinting of the glenohumeral joint, which in turn causes reverse scapulohumeral rhythm [5]. The two common causes -long thoracic nerve palsy and spinal accessory nerve palsy-cause different positioning of

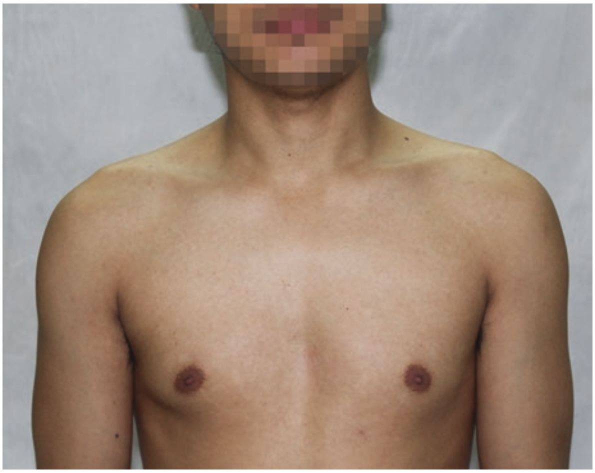


Fig. 6 Inspection from the front

the scapula and different winging patterns. Spinal accessory nerve palsy causes the scapula to depress and move laterally, with the inferior angle rotated laterally and this occurs before 90° abduction and there is little winging on forward flexion [6]. Long thoracic nerve palsy causes the scapula to elevate and move medially, with the inferior angle rotating medially and this occurs on abduction and forward flexion [7, 8]. The splinting of the glenohumeral joint seen in painful shoulder pathologies lead to reverse origin-insertion of the 'rotator cuff muscles so that instead of the humerus, the scapula starts to move. Commonly the scapular control muscles are weak in such scenarios and cannot counteract this action, resulting in dynamic winging. *Static winging* is usually caused by a structural deformity of the scapula, clavicle, spine, or ribs [9] Fig. 9.

Fig. 7 Inspection from the side

Fig. 8 Inspection from the back

Fig. 9 Winging of the left scapula

Fig. 10 Palpation of the sternoclavicular joint

Palpation (To Feel)

With patient in sitting position and the examiner standing behind, start the palpation from the *sternoclavicular joint* Fig. 10. Look for local raise of temperature and tenderness at this site. Mild step deformities could be made out during palpation. Palpate the adjacent suprasternal notch, sternocleidomastoid muscle and the first rib. Now run your fingers on both the sides along *the clavicle* feeling for any tenderness or bumps Fig. 11. At the deepest portion of the concavity move your finger approximately 1 in. distally and press laterally and deeply to feel for the *coracoid process* Fig. 12. Continue along the clavicle till the *acromioclavicular joint*. Identification of this joint can be made easier by simultaneous asking the patient to flex and extend the shoulder around which would produce movement at the AC joint too. The examiner then palpates the

Fig. 11 Palpation of the clavicle

Fig. 12 Palpation of the coracoid process

lateral tip of the acromion process and then moves inferiorly to the *greater tuberosity* of the humerus Fig. 13. Externally rotate the humerus and feel the *long head of the biceps in the bicipital groove* slipping under the fingers, followed by the *lesser tuberosity of the humerus and the subscapularis tendon*. By rotating the humerus alternately internally and externally, the smooth progression over the three structures is normally noted (*de Anquin test*). The patient is then asked to further internally rotate the humerus so that the forearm rests behind the back, and the examiner palpates 2 cm inferior to the anterior aspect of the acromion process for the *supraspinatus tendon*. The shoulder is then passively abducted between 80–90° to form a notch by the acromion and spine of the scapula with the clavicle. Here, the examiner feels for the musculotendinous junction of the supraspinatus muscle. Now place the fingers over the

Fig. 13 Palpation of the greater tuberosity of the humerus

Fig. 14 Palpation of the humeral head

anterior *humeral head* and the thumb over the posterior humeral head, slide them medially Fig. 14. As the humeral head is larger than the glenoid, the fingers and thumb will dip in as they approach the glenohumeral joint which should be slightly greater anteriorly. If there is no dipping anteriorly or posteriorly, it means the humeral head is sitting further posteriorly or anteriorly than it should be. The *joint line* can be determined by rotating the humerus while palpating.

From the acromion process, move along *the spine of the scapula*, noting any tenderness or abnormality Fig. 15. Continue on to the *medial border of the scapula* and then follow the outline of the scapula Fig. 16. Along the medial border and spine of the scapula, one can palpate the trapezius muscle and the rhomboids. Moving down the medial border, we reach the *inferior angle of the scapula* where we could palpate for the lattismus dorsi. Against the *lateral border of the scapula* and along the ribs, the serratus anterior can be palpated. Near *the glenoid*, long head of triceps and teres minor may be palpated. After the borders have been palpated, the *body of the scapula* (supraspinatus and infraspinatus muscles) may be palpated for tenderness, atrophy, or spasm and in the midline, the examiner may palpate the *cervical and thoracic spinous processes*, followed by palpation of the trapezius muscle.

The *axilla* should also palpated for by the examiner standing in front of the patient with patients shoulder abducted slightly to 15–20° and feel for any lymph

Fig. 15 Palpation of the scapular spine

Fig. 16 Palpation of the medial border of the scapula

nodes, pectoralis major of the anterior fold, lattismus dorsi of the posterior fold of the axilla and humeral head tenderness. Also palpate for the costochondral junctions for tenderness (Teitz syndrome/ costochondritis) Fig. 17.

Movements (To Move)

Movements of the shoulder joint need to be assessed actively and passively. This is because patient may have reduced movement in the joint due to pain, weakness, tendon injuries and bony or soft tissue blockade to motion. In the scenarios with pain, weakness and cuff injury the patient will have reduced active movements, but on testing the movements passively, one would see that the arc of motion is fairly preserved in some cases. Additionally, the character of the blockade to motion can be assessed passively, with a soft and elastic end point suggesting soft tissue contractures and a firm end point pointing to a bony blockade. If the patient is able to perform full active movements, there is no requirement for passive testing of movements.

The following movements need to be tested.

Fig. 17 Palpation of the axilla

Fig. 18 Painful arc syndrome producing pain in the right shoulder on abducting

Abduction (Normal Range 170–180°)

The principle abductors of the shoulder joint are the middle portion of the deltoid and the supraspinatus. The secondary abductors are the anterior and posterior portions of the deltoid and serratus anterior.

Normally, the abduction at the shoulder happens via the scapulohumeral rhythm which comprises of movement of the humerus, scapula and the clavicle. This is divided into 3 phases as follows

Phase 1	Humerus 30° abduction
	Scapula minimal movement (setting phase)
	Clavicle 0–5° elevation
Phase 2	Humerus 40° abduction
	20° of scapular rotation, with minimal protraction or elevation, making a total of 60° of abduction in this phase (2:1 ratio)
	Clavicle 15° elevation
Phase 3	Humerus 60° abduction and 90° external rotation to clear the greater tuberosity from the acromion process
	Scapula 30° rotation (2:1 ratio)
	Clavicle 30–50° posterior rotation and up to 15° elevation

Pathologies noted during abduction include

Fig. 19 Terminal pain on abducting to beyond 160° suggestive of acromioclavicular pathology

(a) *Painful arc*:

As the patient abducts the shoulder, the examiner should note whether a painful arc is present. This may be caused by the impingement of the inflamed or tender structures under the acromion process and the coracoacromial ligament. Initially till 45–60°, the structures are not pinched and hence the patient would be able to abduct with little difficulty. As the patient abducts further (60–120°), the structures impinge and he/she is often unable to abduct fully because of pain Fig. 18. If full abduction is possible, the pain diminishes after approximately 120° as the pinched soft tissues have passed under the acromion process. A second painful arc may be seen during the same abduction movement, which occurs towards the terminal 10–20° of abduction, and is caused by pathology in the acromioclavicular joint Fig. 19.

(b) *Shoulder shrug sign/ shoulder hike*:

The patient elevates the whole shoulder or the scapula when asked to abduct the arm Fig. 20. The magnitude of shrug can be defined as the angle between the arm and the horizontal point at which the shrug movement started. This could be seen in patients with adhesive capsulitis, rotator cuff tears or weakness etc. this is also referred to as the reverse scapulohumeral rhythm, as the scapula moves more than the humerus.

While testing the passive abduction motion, the examiner stands behind the seated or standing patient and stabilizes the scapula either by keeping one hand palm downwards over the spine of scapula, acromion and the clavicle from the back and with the other hand holds the arm just above the elbow Figs. 21a, b or by holding at the inferior angle Fig. 22. The arm is passively taken through abduction and the isolated glenohumeral movement can be assessed.

Adduction (Normal Range 50–75°)

The Pectoralis major and the Lattisimus dorsi are the primary adductors, whereas the Teres major and the Anterior portion of the deltoid are the secondary adductors of the shoulder joint. To accomplish this movement, the patient first flexes the arm to 90° and then moves the arm across the front of the body Fig. 23. The examiner

Fig. 20 Shoulder shrug sign in the right shoulder on attempted active abduction by the patient (reverse scapulohumeral rhythm)

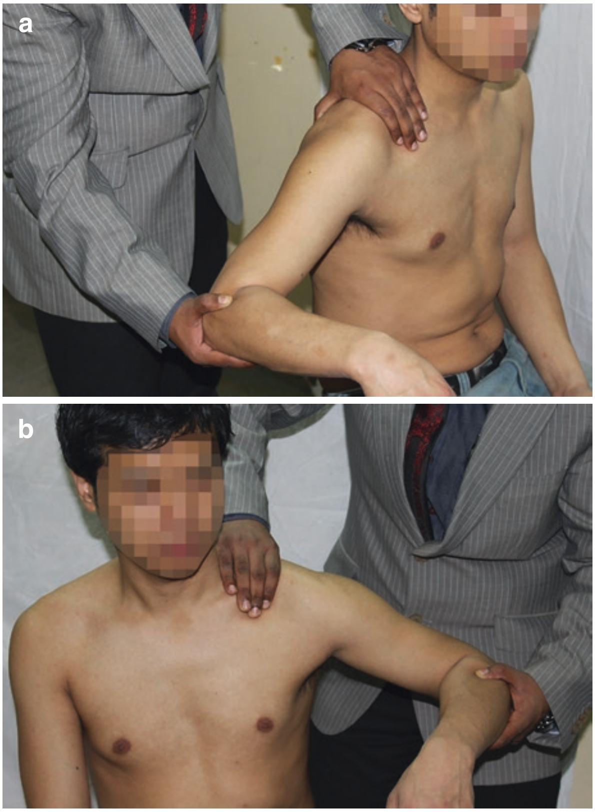


Fig. 21 (**a**) Testing passive abduction of the right shoulder as viewed from the side. Note the position of the examiners hand over the clavicle and scapula. (**b**) passive abduction of the left shoulder as viewed from the front

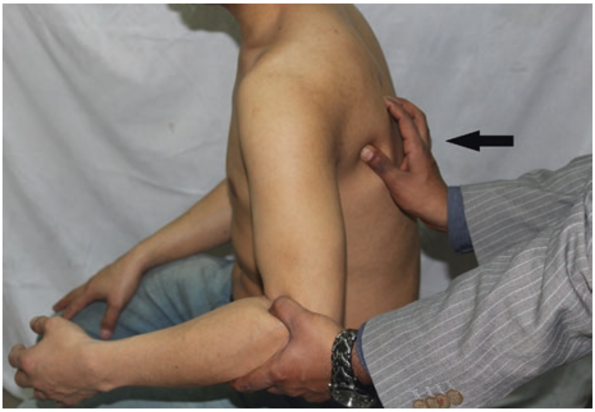


Fig. 22 Passive abduction of the shoulder with the examiner stabilizing the scapula by holding the inferior angle of the scapula

Fig. 23 Active adduction movement of the right shoulder joint

should watch the relative amount of scapular movement. If movement is limited in the glenohumeral joint, greater scapular movement will be seen. On testing the passive adduction movement after stabilising the scapula with the palm on the acromion and spine of scapula from behind and keeping the elbow flexed, terminally the patient may show pain in the front of the shoulder. This is known as the *Cross Body Adduction test* and this signifies pathology of the acromioclavicular joint Fig. 24.

Forward Flexion (Normal Range 160–180°)

The primary flexors include anterior portion of the deltoid muscle and coracobrachialis. The secondary flexors include pectoralis major and the biceps muscles. To passively test flexion, stand behind the patient and stabilize the scapula by keeping the palm on the acromion and hold the arm above the elbow using the other hand Fig. 25.

Fig. 24 Cross body adduction test. Patient wincing with pain suggestive of acromioclavicular pathology

Fig. 25 Passive forward flexion of the right shoulder joint

Extension (Normal Range 50–60°)

Extension of the shoulder is mainly produced by the latissimus dorsi, teres major and posterior portion of the deltoid and secondarily by teres minor and triceps long head. Stay behind the patient with one hand on the acromion to stabilize the scapula and with the other hand hold the arm above the elbow and extend the shoulder passively Fig. 26.

External Rotation (Normal Range 80–90°)

The primary external rotators include the Infraspinatus and the Teres minor. The secondary external rotator is the posterior portion of the deltoid muscle. The examiner moves to the front of the patient and asks the patient to flex both his forearms and the examiner stabilises both elbows into the waist to prevent the patient from substituting with adduction. The patient is now asked to rotate his arms outwards Fig. 27.

Fig. 26 Passive extension of the right shoulder joint

Fig. 27 Active external rotation of both the shoulder joints. Note how the examiner stabilizes the elbow against the waist region

This can be passively tested one side at a time by continuing the stabilization of the elbow into the waist and holding the forearm with the other hand and moving it outwards Fig. 28. Individual muscle tests will be dealt with in the special tests section.

Internal Rotation (Normal Range 60–100°)

The Subscapularis, Pectoralis major, Lattisimus dorsi and the Teres major are the principle internal rotators and the anterior portion of the Deltoid is the secondary internal rotator. Maintain the position as described for testing external rotation, the patient is asked to rotate his arms inward Fig. 29. If he/she is able to bring up to his abdomen, ask him/her to take the forearm behind his back Fig. 30. For testing passive internal rotation, assume the position as described for testing passive external rotation and then move rotate the arm inward Fig. 31. Once the abdomen is reached the forearm can be taken to the back.

A quick method to test all the above mentioned movements of the shoulder is to perform the *Apley's Scratch test*. Ask the patient to reach behind his/her head and touch the superior medial angle of the opposite scapula. This tests the abduction and external rotation movements. Next instruct the patient to reach in front of his/her head and touch the opposite acromion to determine internal rotation and adduction. To further test this combination of movements, make the patient reach behind his/her back to touch the inferior angle of the opposite scapula Fig. 32a–c

Fig. 28 Passive testing of the external rotation of the right shoulder joint

Fig. 29 Active internal rotation of both the shoulder joints with the elbows stabilized

Fig. 30 Patient actively taking his forearm behind the back-testing active internal rotation

Fig. 31 Passive internal rotation of the right shoulder joint

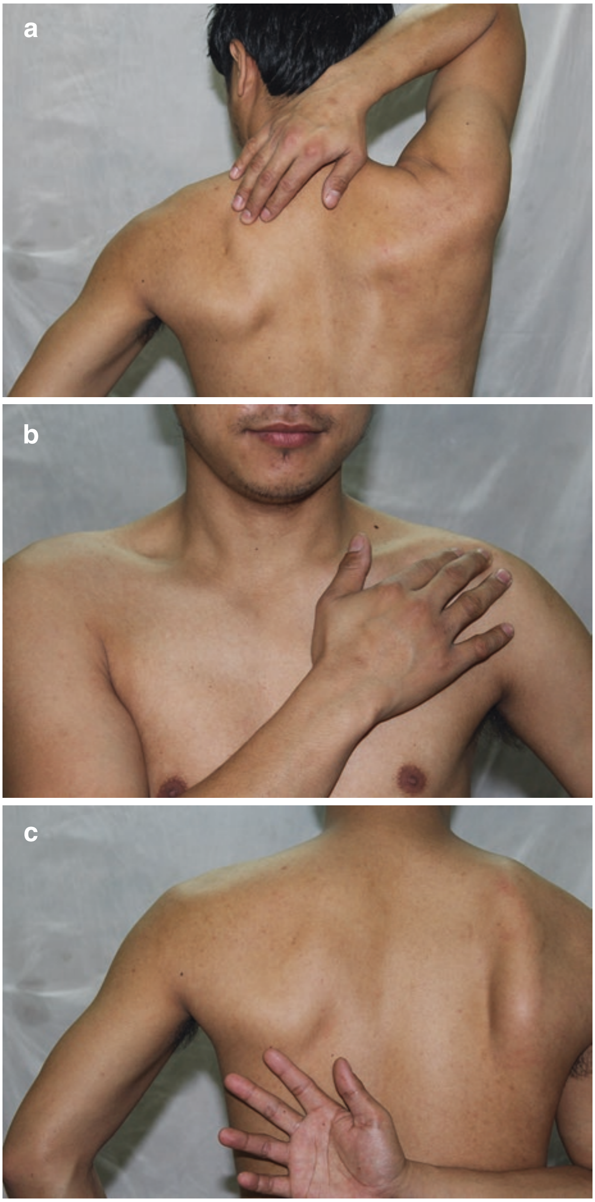


Fig. 32 (**a**) Apley's scratch test-testing abduction and external rotation by touching the superior angle of the opposite scapula. (**b**) Apley's scratch test-testing adduction and internal rotation by touching the opposite acromion. (**c**) Apley's scratch test-further testing adduction and internal rotation by touching the inferior angle of the opposite scapula

Scapular Elevation (Shoulder Shrug)

The primary elevators are the Trapezius and Levator scapulae. The secondary elevators include the Rhomboids. Stand behind the patient and ask the patient to shrug Fig. 33. Note the scapular elevation and the contraction of the muscles and look for any abnormal winging suggestive of muscle weakness.

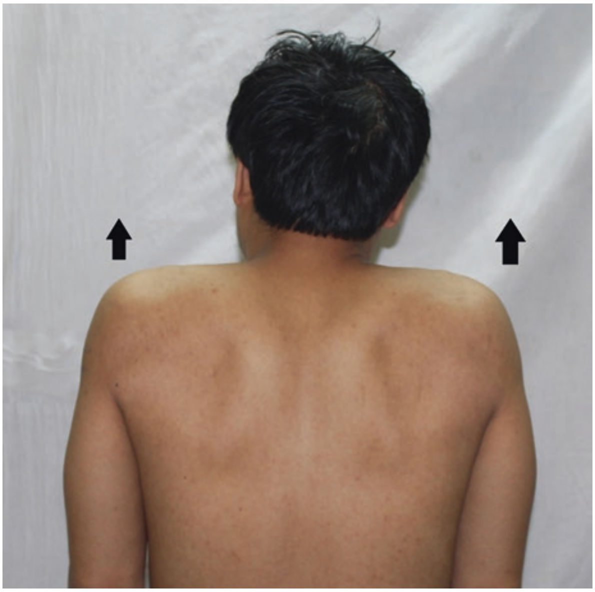


Fig. 33 Scapular elevation

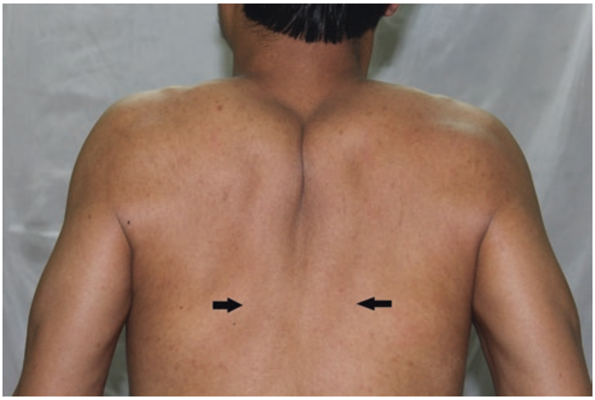


Fig. 34 Scapular retraction

Scapular Retraction and Protraction

The Rhomboids are the primary retractors and the trapezius is the secondary retractor. Stand behind the patient and instruct him/her to throw both his/her shoulder to the back into position of attention Fig. 34.

Protraction of the scapula is enabled by the Serratus anterior muscle. Stand behind the patient and ask him/her to flex the shoulder to 90° and flex the elbow so that his/her hand touches the opposite shoulder. Place one hand over the patient's spine to prevent substitution by trunk rotation. Now instruct the patient to reach further behind the opposite shoulder and look at the protraction of the scapula Fig. 35.

During protraction and retraction, feel for any crepitus suggestive of *snapping scapula syndrome* by keeping a hand over the scapular body.

Fig. 35 Scapular protraction. The examiner holds the patient's trunk to prevent trunk rotation to substitute for scapular protraction

Measurements

The length of the arm is measured from the angle of the acromion (the point where the spine of scapula bends forward to become the acromion process) to the lateral epicondyle of the humerus Fig. 36. Circumferential measurement of the arm should also be done to document muscle wasting.

Special Test

Special tests need to be done to confirm certain findings which have been assumed from clinical history and examination. They can be categorized into various groups.

Instability Tests

Anterior Atraumatic Instability Tests

Load and Shift Test [10, 11]

Sitting Position

Keep the forearm of the test side on the thigh. The examiner stands or sits behind the patient and the shoulder is stabilized with one hand over the clavicle and scapula. The other hand of the examiner grasps the head of the humerus with the thumb

Fig. 36 Arm length measurement from the angle of acromion to the tip of the lateral epicondyle

over the posterior humeral head and the fingers over the anterior humeral head. The humerus is then carefully pushed anteriorly or posteriorly in the glenoid if necessary to seat it properly in the glenoid fossa. This is the load portion of the test Fig. 37a. The examiner then tries to translate the humeral head anteriorly or posteriorly, and the amount of translation and end feel are noted. This is the shift portion of the test Fig. 37b, c.

Supine Position

In order to test the anterior translation, the patients arm is taken to 45–60° abduction in the plane of the scapula in neutral rotation by the examiner by holding the forearm near the wrist. With the other hand, hold the patient's upper arm near the deltoid insertion with the thumb anterior and the fingers posterior feeling the movement of the humeral head in the glenoid while applying an anterior or anteroinferior translation force (with the fingers) or a posterior translation force (with the thumb) while the hand holding the forearm transfers an axial load to the humerus Fig. 38a–c.

The anterior glenohumeral translation is graded as follows.

Normal laxity	Mild translation (0–25%)
Grade I	Humeral head riding up to the rim (25–50%)
Grade II	Head riding over the rim but reduces spontaneously (>50%)
Grade III	Head riding over the rim and remains dislocated

For posterior translation, translation of 50% of the diameter of the humeral head is considered normal [12].

In addition to the translation and the pain that may be produced, the most important aspect of the test is reproduction of the patient's symptoms with the manoeuvre.

Modifications of Load and Shift Test

(a) *Prone Anterior Instability Test* [13]. With the patient in *prone* position, the examiner abducts the patient's arm to 90° and externally rotates to 90° with one hand at the elbow. Maintaining this position the examiner places his other hand over the humeral head and pushes it anteriorly Fig. 39. A positive test is indicated by reproduction of the patient's symptoms.

(b) *Andrews' Anterior Instability Test* [13]. The patient lies in *supine* position with the shoulder abducted 130° and externally rotated to 90° by controlling from the elbow. The examiner uses the other hand to grasp the humeral head and lift it forward Fig. 40. Reproduction of the patient's symptoms is considered as a positive test.

(c) *Anterior Drawer Test of the Shoulder* [14]. In *supine* position, the examiner places the hand of the affected shoulder in his axilla, holding the patient's hand with the arm. The shoulder is abducted between 80° and 120°, forward flexed up to 20°, and externally rotated up to 30°. The patient's scapula is stabilized with the opposite hand by pushing the spine of the scapula forward with the index and middle fingers and by giving counter pressure on the patient's coracoid process using the thumb. Using the arm that is holding the patient's hand, the examiner places his or her hand around the patient's relaxed upper arm and draws the humerus forward Fig. 41. Associated translation and presence of click are noted.

(d) Anterior Instability Test of Leffert [15]. The examiner stands behind the seated patient and places his near hand over the shoulder so that the index finger is over the head of the humerus anteriorly and the middle finger is over the coracoid process. The thumb is placed over the posterior humeral head. The other hand grasps the patient's wrist and abducts and externally rotates the arm Fig. 42. On movement, if the finger palpating the anterior humeral head moves forward, the test is said to be positive for anterior instability. Normally, the two fingers remain in the same plane.

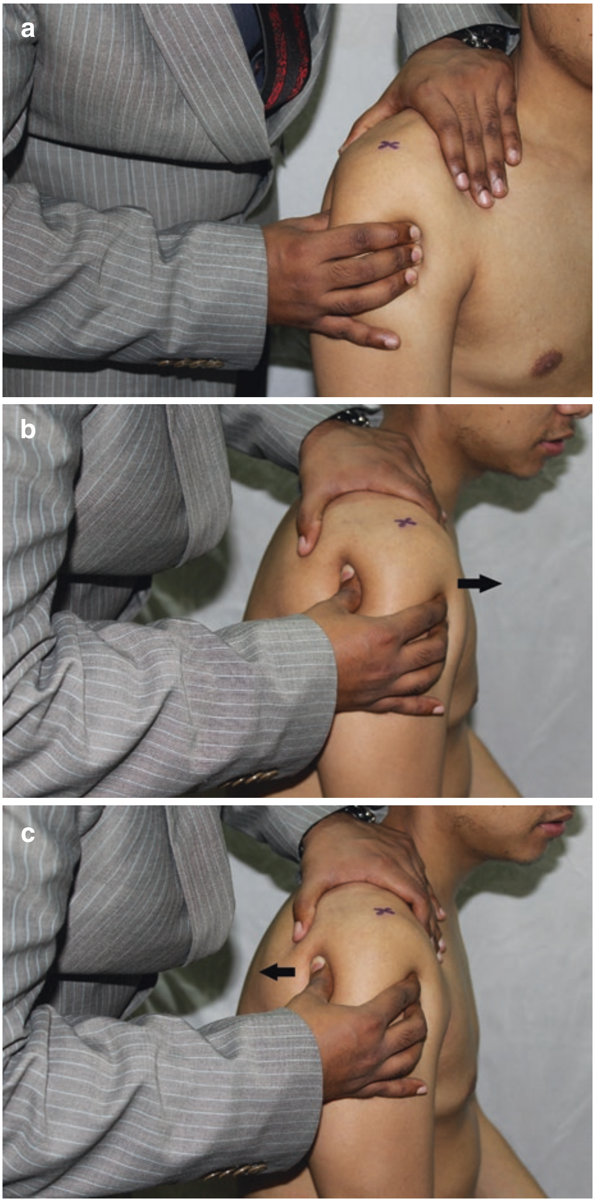


Fig. 37 (**a**) Load part of the load and shift test in sitting position. The humeral head is medially forced into the glenoid. (**b**) Shift part of the load and shift test in sitting position. The humeral head is being translated anteriorly. (**c**) Shift part of the load and shift test in sitting position. The humeral head is being translated posteriorly

Tests for Anterior Traumatic Instability

Apprehension Test

With the patient in supine position the examiner abducts the arm to 90° and slowly externally rotates the shoulder Fig. 43. A positive test is indicated by a look or feeling of apprehension and resistance to further motion.

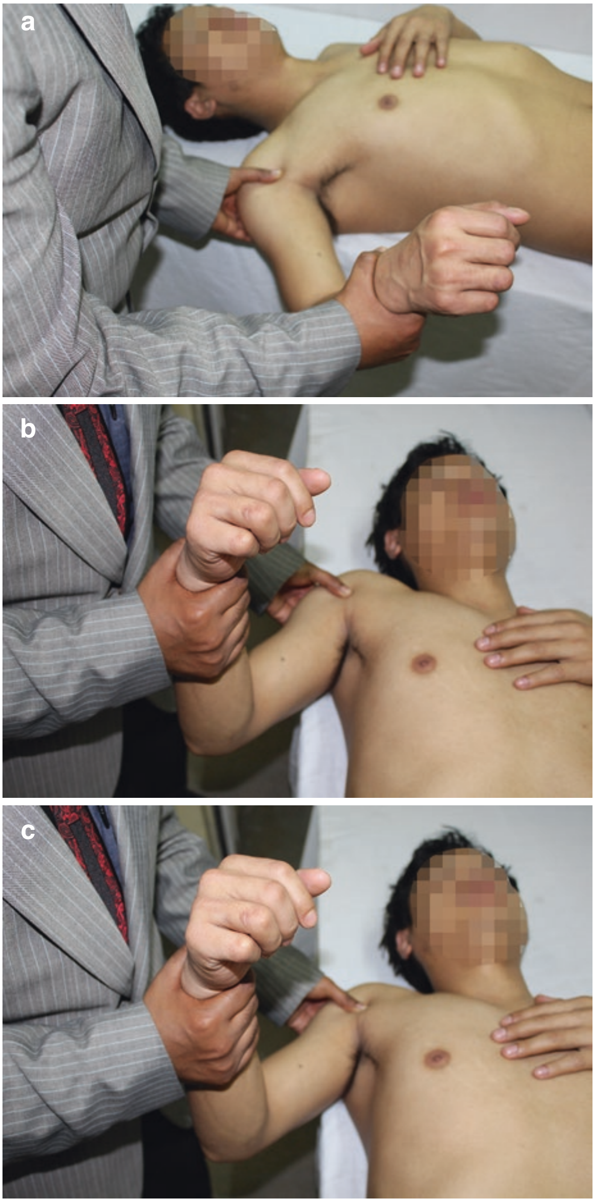


Fig. 38 (**a**) Position for load and shift test in supine position. (**b**) Supine position load and shift test. The fingers of the left hand of the examiner pushing the humeral head anteriorly from behind and the thumb feeling for the translation. (**c**) supine position load and shift test. The thumb of the left hand of the examiner is used to push the humeral head posteriorly

Fig. 39 Prone anterior instability test. With one hand examiner pushes the humeral head anteriorly

Fig. 40 Andrew's anterior instability test. The humeral head is grasped and lifted forwards

Fig. 41 Anterior drawer test. Note the thumb giving counter pressure over the coracoid process

Fig. 42 Anterior instability test of Leffert. The thumb is placed over the posterior aspect of the humeral head, the index finger over the anterior aspect of the humeral head and the middle finger over the coracoid process

Fig. 43 Apprehension test

Fulcrum Test

The apprehension test is converted into the fulcrum test by placing a hand under the glenohumeral joint to act as a fulcrum Fig. 44.

Relocation Test/Fowler Sign/Jobe Relocation Test [11]

Once the patient shows apprehension as described above, the examiner applies a posterior directed force from the front of the shoulder Fig. 45. This reduces or completely abolishes the apprehension of the patient. If there was no apprehension to start with and only pain was present, reduction in pain is also considered as a positive result.

Anterior Release Test [16]

The force that was relocating the head is suddenly withdrawn leading to reappearance of apprehension and pain Fig. 46.

Fig. 44 Fulcrum test. The hand kept in the posterior aspect of the shoulder acts as the fulcrum

Fig. 45 Relocation test

It can be seen clearly that the above tests are to be done as a continuum.
Apprehension → Relocation → Anterior release

Rockwood Test for Anterior Instability [17]
The examiner stands behind the seated patient. With the arm at the patient's side, the examiner externally rotates the shoulder Fig. 47a. The arm is abducted to 45° Fig. 47b and again passively externally rotated. The same procedure is repeated at 90° Fig. 47c and 120° Fig. 47d. These different positions are performed because the stabilizers of the shoulder vary as the angle of abduction changes. The presence of apprehension signifies a positive test.

Rowe Test for Anterior Instability [18]
The test is similar to the fulcrum test except that the fulcrum is provided by keeping a clenched fist against the back of the humeral head. The patient keeps his hand behind his head and the examiner extends the arm slightly while pushing from the back with the fist Fig. 48.

Fig. 46 Anterior release test

Posterior Instability Tests

Load and Shift Test

As described earlier.

Posterior Apprehension Test [19, 20]

The test can be performed in supine or sitting position. The examiner stabilizes the scapula with one hand (when done in sitting position) and elevates the patient's shoulder in the plane of the scapula to 90° with the other. The examiner then applies a posterior force on the patient's elbow and horizontally adducts and internally rotates the shoulder Fig. 49a, b. A positive result is indicated by apprehension and resistance to further motion or the reproduction of the patient's symptoms.

Posterior Drawer Test [14, 21]

The examiner stands at the level of the shoulder of the patient who is in supine position. The patient's proximal forearm is held with one hand, and the patient's elbow is flexed to 120° and the shoulder to between 80° and 120° of abduction and between 20° and 30° of forward flexion. The scapula is stabilized by placing the index and middle fingers on the spine of the scapula and the thumb on the coracoid process. The arm is internally rotated and flexed to between 60° and 80° and at the same time the thumb is taken off the coracoid process and the head of the humerus is pushed posteriorly Fig. 50. The head of the humerus is felt by the index finger of the same hand. A translation greater than 50% of the humeral diameter is considered as positive.

Fig. 47 (**a**) Rockwood test for anterior instability. External rotation of the arm by the side of the body. (**b**) Rockwood test for anterior instability. External rotation of the arm at 45° abduction. (**c**) Rockwood test for anterior instability. External rotation of the arm at 90° abduction. (**d**) Rockwood test for anterior instability. External rotation of the arm at 120° abduction

Fig. 48 Rowe test for anterior instability

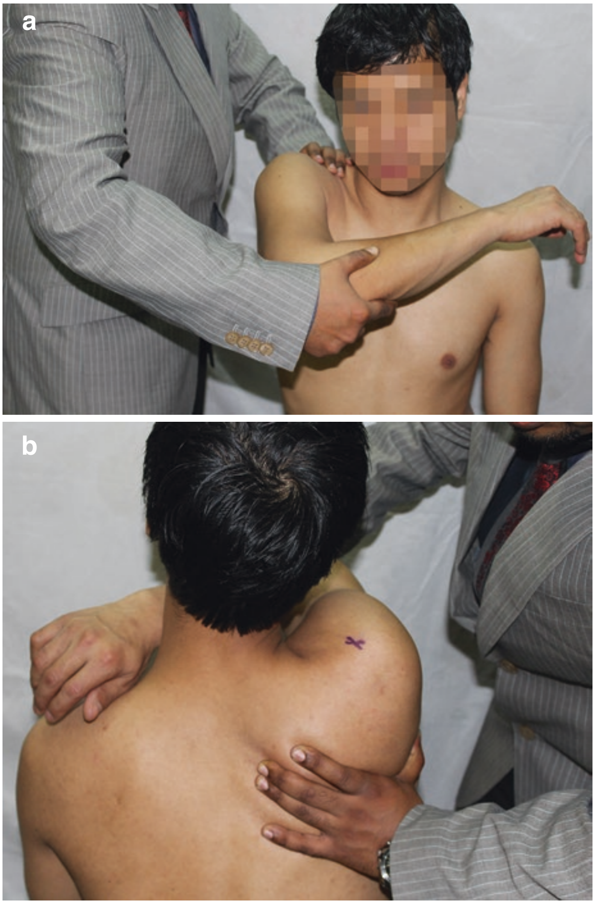


Fig. 49 (**a**) Position for the posterior apprehension test as viewed from front. (**b**) Posterior apprehension test. Posterior view. Axial force applied along the humerus from the elbow

Jerk Test [22]

The patient is seated with the arm internally rotated and forward flexed to 90°. The examiner axially loads the humerus in a proximal direction by grasping at the elbow. While maintaining the axial loading, the arm is horizontally adducted across the body Fig. 51. The production of a sudden jerk or clunk as the humeral head slides off the back of the glenoid is regarded as a positive test. When the arm is returned to the original 90° abducted position, a second jerk of reduction of the head may be felt.

Circumduction Test [23]

With the patient standing and the examiner standings behind him/her, grasps the patient's forearm with the hand. The examiner begins to circumduct the shoulder by extending the patient's arm while maintaining slight abduction Fig. 52a. As the

Fig. 50 Posterior drawer test

Fig. 51 Jerk test. A sudden jerk or clunk produced on adducting the axially loaded arm is considered as a positive result

Fig. 52 (**a**) Circumduction test. The arm is being extended. (**b**) Circumduction test. The arm is being taken to overhead position. (**c**) Circumduction test. Forward flexed arm. (**d**) Circumduction test. The arm is adducted. The examiner looks for any posterior subluxation of the joint

Fig. 52 (continued)

circumduction continues, the arm is brought over the top Fig. 52b and into the flexed Fig. 52c and adducted position Fig. 52d. In this motion, it is vulnerable to posterior subluxation if there is posterior instability. If the examiner palpates the posterior aspect of the patient's shoulder as the arm moves downward in forward flexion and adduction, the humeral head will be felt to sublux posteriorly in a positive test.

Push-Pull Test [22]

The patient lies supine. The examiner holds the patient's arm at the wrist (in supine position) and abducts to 90° and forward flexes to 30°. The other hand is placed over the humerus close to the humeral head. The examiner then pulls up on the arm at the wrist while pushing down on the humerus with the other hand Fig. 53. The degree of translation of the humeral head is noted.

Tests for Inferior and Mutidirectional Instability

Sulcus Sign [14, 22, 24]

With the patient standing, the arm by the side, the patient's forearm is held firmly and the arm is pulled distally. The presence of a sulcus below the acromion process indicates inferior instability Fig. 54.

The sulcus sign with a sensation of subluxation is more clinically significant.

The sulcus sign is graded by measuring from the inferior margin of the acromion to the humeral head.

+1 sulcus	Distance of less than 1 cm
+2sulcus	1–2 cm
+3 sulcus	more than 2 cm

Fig. 53 Push-Pull test. The examiner pulls up on the arm at the wrist while pushing down on the humerus with the other hand

Fig. 54 Picture depicting the sulcus test. The examiner pointing at the likely site of development of sulcus in case of inferior instability

Feagin Test [17]

It is a modification of the sulcus sign test with the arm abducted to 90° and is supported on the examiner's shoulders. This test can be done either in sitting or in standing position. The examiner's hands are clasped together over the patient's humerus, between the upper and middle thirds. The examiner pushes the humerus down and forward Fig. 55. A sulcus may be seen as described before.

If both the sulcus sign and Feagin test are positive, it is a greater indication of multidirectional instability.

Tests for Anteriorly Dislocated Shoulder

Hamilton Ruler Test (Fig. 56)

Normally, a straight ruler cannot be made to touch both the acromion process and the lateral epicondyle of the humerus simultaneously as the greater tuberosity pushes the ruler away. In case of an anterior dislocation, this would become possible.

Callaway's Test

Increase in vertical circumference of the dislocated shoulder in comparison with the other normal shoulder is known as the Callaway's test.

Duga's Test

In case of dislocation, the patient will be unable to touch the contralateral shoulder while the arm is kept in contact by the side of the chest.

Fig. 55 Feagin test. The examiner pushes the head of humerus anteriorly and inferiorly and the presence of sulcus is noted

Fig. 56 Depicting a normal Hamilton ruler test. In case of anteriorly dislocated shoulder, the ruler would simultaneously touch the acromion and the lateral epicondyle

Tests for Scapular Instability

The scapula must be stabilized by its muscles to act as a firm base for the glenohumeral muscles in order for the muscles of the glenohumeral joint to work in a normal coordinated fashion.

Lateral Scapular Slide Test [24, 25]

The patient sits or stands with the arm at the side. The examiner measures the distance from T2 spinous process to the superior angle of the scapula or from the base of the spine of the scapula to the spinous process of T3 or from the inferior angle of the scapula to the spinous process of T7–T9 Fig. 57a. The patient is then asked to hold the arm at various positions: 45° abduction Fig. 57b 90° abduction with internal rotation Fig. 57c, 120° abduction Fig. 57d and 150° abduction Fig. 57e. In each of these positions the distance measured should not vary more than 1–1.5 cm from the original measure 50,159. However, there may be increased distances above 90° as the scapula rotates during scapulohumeral rhythm.

The test may also be performed by providing resistance at 45° and greater abduction. This is known as the *Scapular Load test* to see how the scapula stabilizes under dynamic load.

Wall Pushup Test [26, 27]

The patient is asked to do a wall push up 15–20 times, standing at an, arm's length from a wall Fig. 58.

Any weakness of the scapular muscles or winging will usually show up with 5–10 push ups. For younger people, a normal pushup on the floor will show similar scapular changes.

Closed Kinetic All Upper Extremity Stability Test [28]

Two markers (e.g., tape) are placed 91 cm (36 in.) apart on the floor. Patients assume the pushup position with one hand on each marker. When the examiner gives the go signal, the subject moves one hand to touch the other and returns it to the original position and then does the same with the other hand, repeating the motions for 15 s Fig. 59. The number of touches or crossovers in the allotted time is counted. The test is repeated three times and the average is the test score.

Scapular Isometric Pinch or Squeeze Test [26]

The patient is in a standing position and is asked to actively retract the scapulae together and to hold the position. Normally, one can hold the contractions for 15–20 s with no pain or obvious muscle weakness. If pain occurs in less than 15 s, the scapular retractors are weak.

Scapular Assistance Test [26–28]

This test is used to evaluate scapular and acromial involvement in patients with impingement symptoms. The patient is in a standing position and the examiner stands behind the patient and places the fingers of one hand over the clavicle with the heel of the hand over the spine of the scapula to stabilize the clavicle and scapula

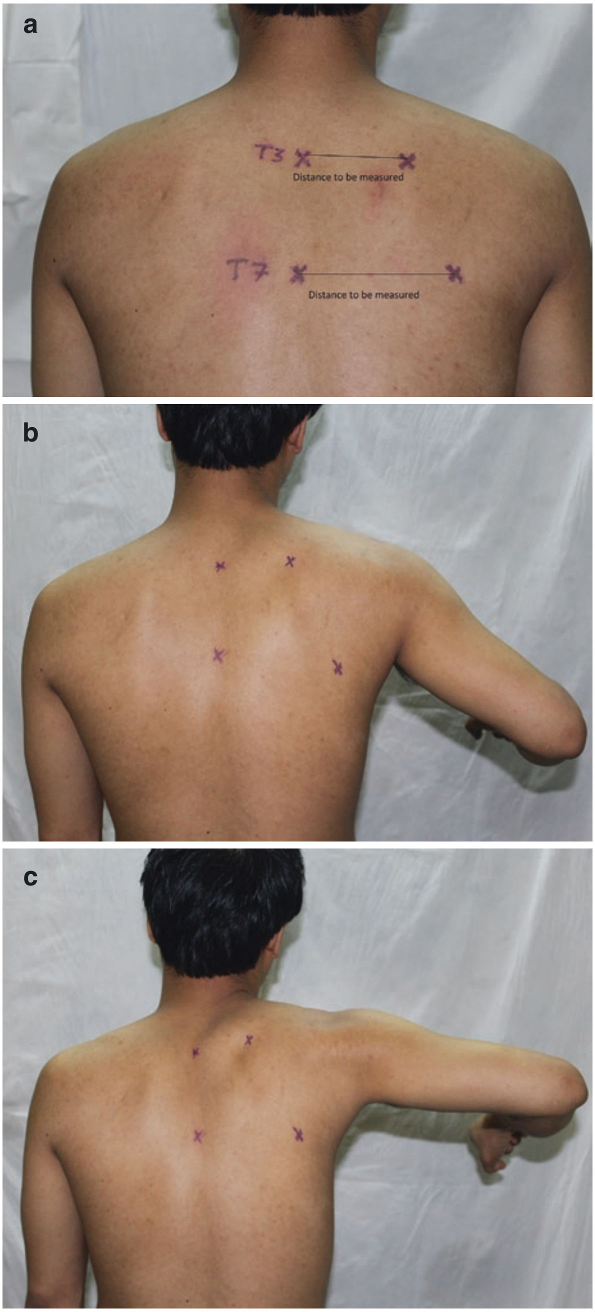
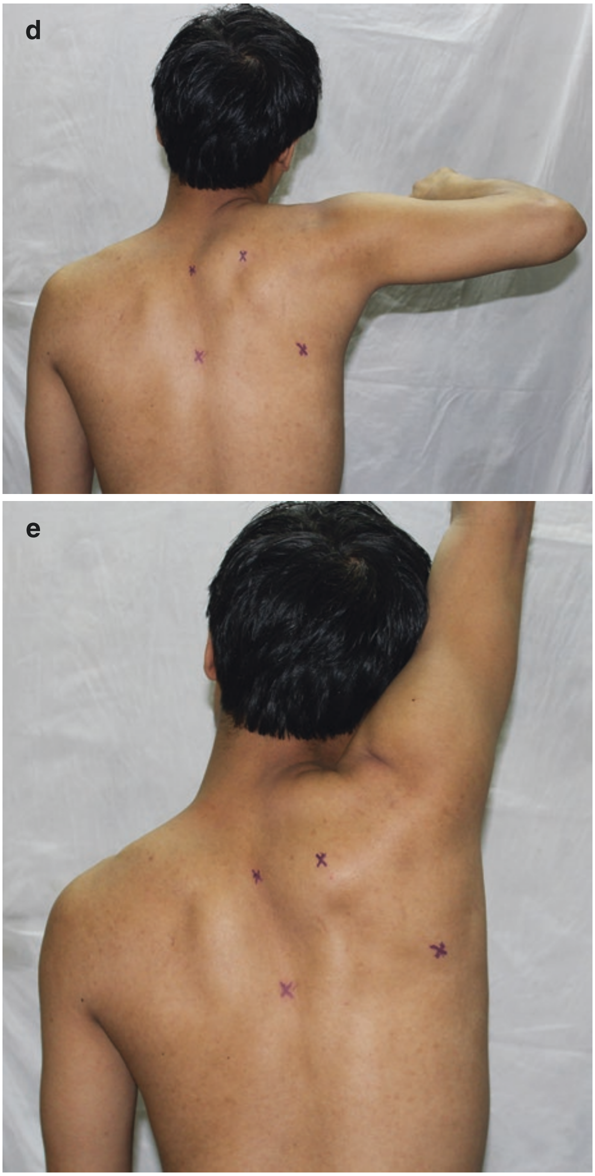


Fig. 57 (**a**) Lateral scapular slide. Picture depicting the various landmarks for measurement. (**b**) Lateral scapular slide test. 45° abduction and the distance between the medial border of the scapula and the corresponding spinous process is measured. (**c**) Lateral scapular slide at 90° abduction. (**d**) Lateral scapular slide at 120° abduction. (**e**) Lateral scapular slide at 150° abduction

Fig. 57 (continued)



and holds the scapula retracted. The other hand holds the inferior angle of the scapula. As the patient actively abducts or forward flexes the arm, the examiner stabilizes and pushes the inferior medial border of the scapula up and medially while keeping the scapula retracted Fig. 60. Decreased pain as when compared with impingement test would indicate the scapular muscles are weak.

Fig. 58 Wall push up test. Note the dynamic winging of the right scapula

Fig. 59 Close kinetic all upper extremity test

Fig. 60 Scapular assistance test. The examiner pushes the inferior and medial border of the scapula upwards and medially while the patient is actively abducting

Impingement Tests

The basis of these tests is to compress the affected structure (like the rotator cuff, biceps tendon) between the head of humerus and the coracoacromial arch.

Neer's Impingement Sign and Test [29]

The test is designed to detect involvement of the supraspinatus tendon mainly and sometimes of the biceps tendon. The patient in sitting position, the arm is passively fully elevated in the scapular plane with the arm internally rotated by the examiner. The scapular rotation has to be prevented by the examiner Fig. 61. This compresses the greater tuberosity against the anteroinferior border of the acromion. Pain produced by this maneuver reflects a positive test result (*Neer's impingement sign*). Patients with other shoulder conditions like instability, partial shoulder stiffness etc. may also produce pain during this test. But the pain due to these other causes is not relieved by the injection of 10 ml of 1.0% xylocaine beneath the anterior acromion. This is known as the *impingement test*.

Hawkins-Kennedy Impingement Test [30]

With the patient standing, the examiner forward flexes the arm to 90° and then internally rotates the shoulder Fig. 62. This compresses the supraspinatus tendon against the coracoacromial ligament and coracoid process. Pain indicates a positive test for supraspinatus paratenonitis/tendinosis.

Fig. 61 Neer's impingement sign

Fig. 62 Hawkin's-Kennedy impingement test

Fig. 63 Yocum's test

The Yocum Test [31]

With the patient sitting/standing the hand of the patient is placed on the opposite shoulder and the elbow of the tested side is passively raised Fig. 63. Presence of pain indicates a positive test result.

Reverse Impingement Sign (Impingement Relief Test) [32]

This test is done when the patient has a positive painful arc or pain on external rotation. The patient in supine/standing positions, the examiner pushes the head of the humerus inferiorly as the arm is abducted or externally rotated Fig. 64. Corso [33] also added a posteroinferior glide of the humeral head during forward flexion just before the ROM where pain occurred on active movement Fig. 65. The reduction in pain with the humeral head depressed was suggestive of a positive test for impingement under acromion.

Fig. 64 Impingement relief test. The examiner pushes the head of the humerus inferiorly as the arm is abducted or externally rotated

Fig. 65 Corso's modification of impingement relief test where the humeral head is given a postero-inferior glide while forward flexing

Posterior Internal Impingement Test [34–37]

This type of impingement is primarily found in athletes involved with overhead activities were the impingement occurs between the rotator cuff and the posterosuperior edge of the glenoid when the arm is abducted, extended and laterally rotated. The test is performed with the patient in supine lying position. The examiner passively abducts the shoulder to 90°, with 15–20° of forward flexion and maximum external rotation Fig. 66. The test is considered positive if pain is localized to the back of the shoulder.

Fig. 66 Posterior internal impingent test

Fig. 67 Yergason's test for bicipital tendinitis

Tests for Musculo-Tendinous Pathologies and Integrity

Biceps Tendon

Yergason's Test [38]
This tests ability of the transverse humeral ligament to hold the biceps tendon in the bicipital groove. Flex the patient's elbow to 90° and stabilized it against the waist area and pronate the forearm. Now ask the patient to supinate the forearm along with external rotating the arm, while the examiner resists these movements Fig. 67.

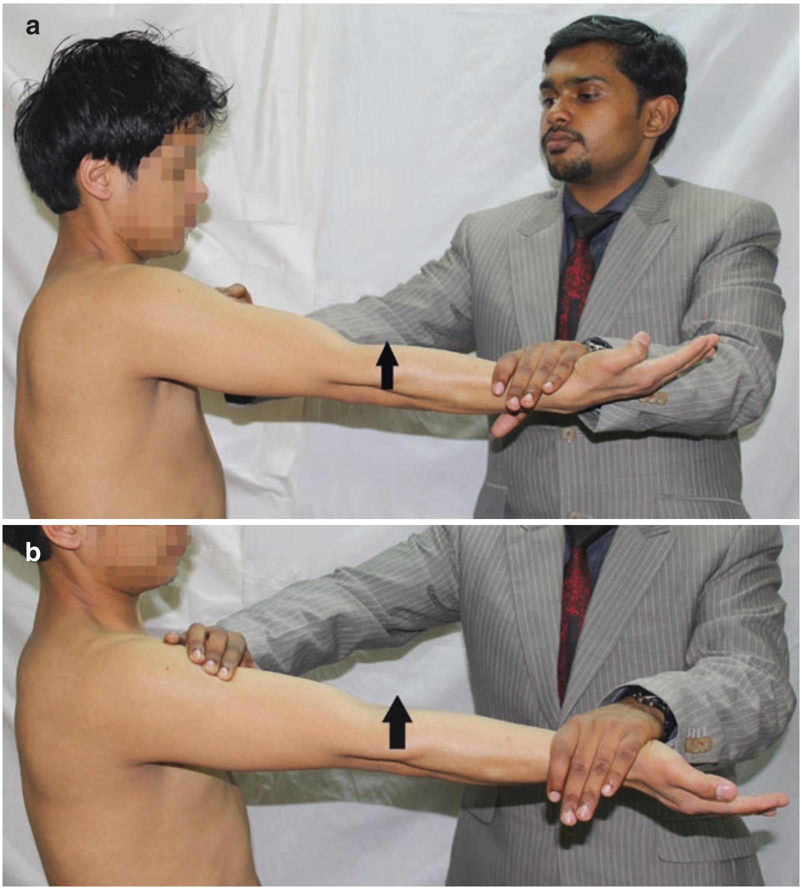


Fig. 68 (**a**) Speed's test. Resisted forward flexion in supination an the bicipital groove is palpated. (**b**) Speed's test. Resisted forward flexion in pronation. Less pain as in comparison to supinated forward flexion

Palpate the biceps tendon in the bicipital groove 7–8 cm below the glenohumeral joint during the manoeuvre with the other hand and feel for any popping out of the tendon. This will happen if the transverse humeral ligament is torn. Tenderness alone without pop-out sensation may be indicative of bicipital paratenonitis/tendinosis.

Speed's Test (Biceps or Straight-Arm Test) [39]

Speed's test is more effective than Yergason's test as the bone moves over more of the tendon during the Speed's test. Resisted shoulder forward flexion with fully extended elbow is done initially in supinated position Fig. 68a and next with forearm in pronation Fig. 68b. Simultaneously, the examiner palpates the bicipital groove region with the other hand. The test is said to be positive, when there is tenderness in the bicipital groove especially with the arm supinated. This test may give false positive result in

Fig. 69 Ludington's test. Patient contracting his right biceps muscle and the examiner palpates for the biceps tendon in the groove

Fig. 70 Lippman's test. Here the examiner moves the long head of the biceps muscle sideways in the bicipital groove

cases with SLAP lesions. If profound weakness is found on resisted supination, a second- or third-degree sprain of the biceps tendon should be suspected.

Ludington's Test [40]

The patient is instructed to clasp both hands on top of or behind the head. In this position the biceps tendon is in maximum relaxation. The patient is then asked to alternately contract and relax both the biceps muscles, while the examiner palpates for the biceps tendons Fig. 69. A positive result indicates rupture of the long head of biceps tendon which means that the examiner would be able to feel the contracting tendon on the unaffected side only.

Gilchrest's Sign [41, 42]

In standing position, the patient is instructed to lift a 2- to 3-kg weight over the head.

The arm is then externally rotated fully and lowered to the side. A positive test is indicated by discomfort or pain in the bicipital groove which would indicate para-tendinitis/tendinosis.

Lippman's Test [43]
The examiner with one hand passively flexes the arm to 90° and with the other hand, he palpates the biceps tendon and moves the tendon from side to side in the groove Fig. 70. A sharp pain indicates a positive test.

Heuter's Sign [42]
Normally, when the elbow is flexed against resistance with the forearm pronated, some supination occurs as the biceps attempts to help the brachialis muscle flex the elbow. This supination movement is called Heuter's sign. The absence of this sign suggests biceps tendon disruption.

Popeye Sign
Popeye muscle is seen with the disruption of the normal biceps muscle attachment leads to its retraction distally (down the arm). The subsequent appearance is that of a bulge in the mid-arm.

Supraspinatus and Rotator Cuff Complex

Supraspinatus ("Empty Can" or Jobe) Test [44]
The patient's arms are abducted to 90° without any rotation, and resistance to abduction is applied by the examiner Fig. 71a. The shoulders are then internally rotated and brought forward into the plane of the scapula with the patient's thumbs pointing towards the floor Fig. 71b. This is known as empty can position. Resistance to abduction is again provided while the examiner looks for weakness or pain, reflecting a positive test result which would indicate a tear of the supraspinatus tendon or muscle or neuropathy of the suprascapular nerve.

Drop-Arm (Codman's) Test [45]
The examiner passively abducts the patient's shoulder to 90° Fig. 72a and then instructs him/her to slowly lower the arm to the side Fig. 72b. A positive test is indicated if the patient is unable to return the arm slowly or has severe pain when attempting to do so. This would suggest a tear in the rotator cuff complex.

Abrasion Sign [46]
The patient is seated and asked to abduct the arm to 90° with the elbow flexed to 90°. The patient then rotates the arm internally Fig. 73a and externally at the shoulder Fig. 73b. The presence of a palpable crepitus over the joint is a sign that the rotator cuff tendons are frayed and are abrading against the under surfaces of the acromion process and the coracoacromial ligament.

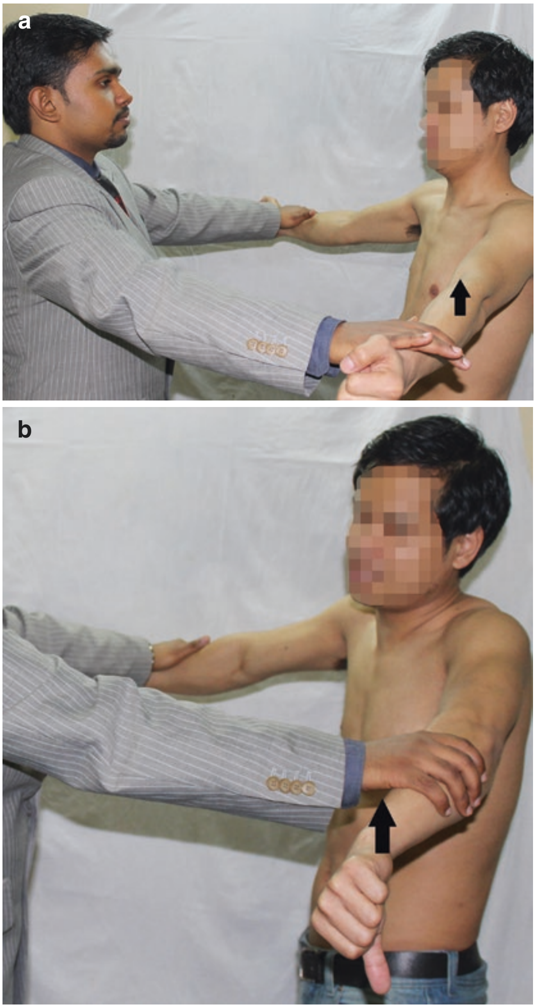


Fig. 71 (**a**) Jobe's empty can test. Patients arm is in abduction and neutral rotation. (**b**) Jobe's empty can test. Patients shoulder is in internal rotation with the thumb facing the floor

Subscapularis Muscle

Lift-Off Sign [39, 47]

With the patient standing, he/she is asked to place the dorsum of the hand on the back against the mid lumbar spine. The patient is instructed to lift the hand away from the back Fig. 74a. Inability to do so indicates a lesion of the subscapularis muscle. If the patient is able to take the hand away from the back, the examiner applies resistance towards the back to test the strength of the subscapularis by comparing with the normal side Fig. 74b. With a torn subscapularis tendon, passive (and active) external rotations will be more.

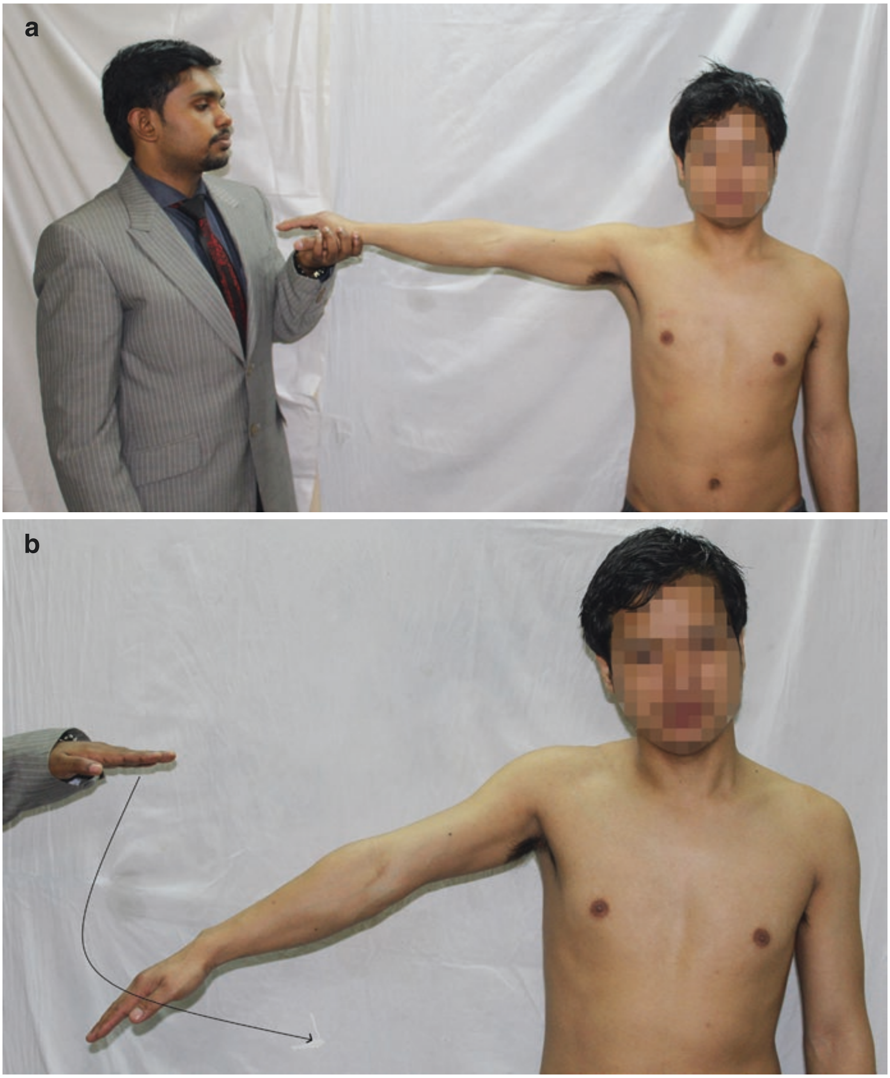


Fig. 72 (**a**) Drop arm test. Patients shoulder passively abducted to 90°. (**b**) Drop arm test. Patient tries to lower the arm slowly

Modified Lift Off Test/Subscapularis or Internal Rotation Spring Back or Lag Test [48, 49]

With the hand of the patient positioned as in lift off test, the examiner passively internal rotates as far fully and instructs the patient to hold the position Fig. 75. When there is subscapularis weakness or any sprain, the patient would be unable to hold the position. A small lag between maximum passive internal rotation and active

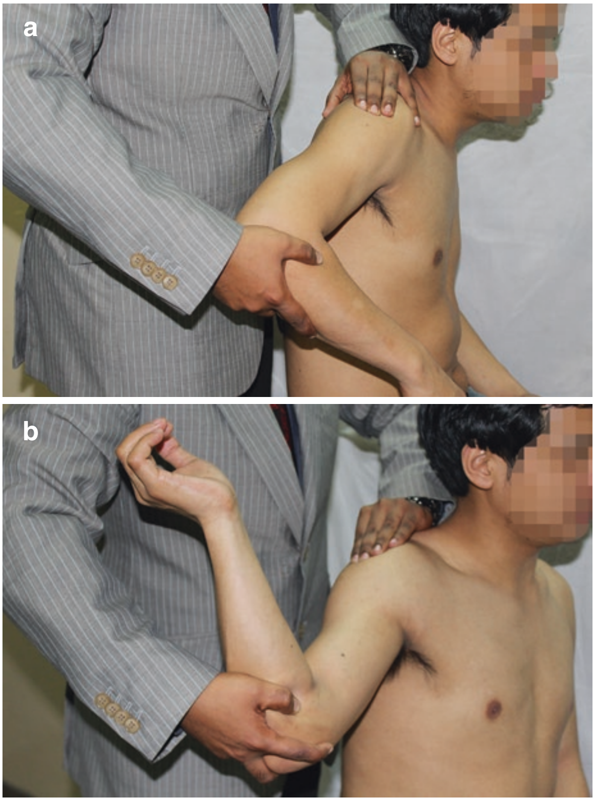


Fig. 73 (**a**) Abrasion sign. Patients shoulder passively internally rotated while feeling for crepitus. (**b**) Abrasion sign. Patients shoulder passively externally rotated while feeling for crepitus

internal rotation implies a partial tear (1°, 2°) of subscapularis [47]. Medial border winging of the scapula during the test may indicate that the rhomboids are affected [50]. Stefko et al. [51] reported that maximum isolation of the subscapularis was achieved by placing the hand against the posteroinferior border of the scapula and then attempting the lift off. In the other positions for lift off, teres major, latissimus dorsi, posterior deltoid, or rhomboids may compensate for a weak subscapularis.

Abdominal Compression (Belly-Press) Test [47, 52]

This test is utilised when the patient cannot internally rotate the shoulder adequately to take it behind the back. With the patient standing, the examiner places a hand on the abdomen and asks the patient to push the examiner's hand into the stomach using his/her hand. While pushing, normally the patient would attempt to bring the elbow forward to the scapular plane by internally rotating the shoulder Fig. 76. If the patient is unable to maintain the pressure on the examiner's hand by moving the elbow forward or extends the shoulder, the test is positive for a tear of the subscapularis muscle.

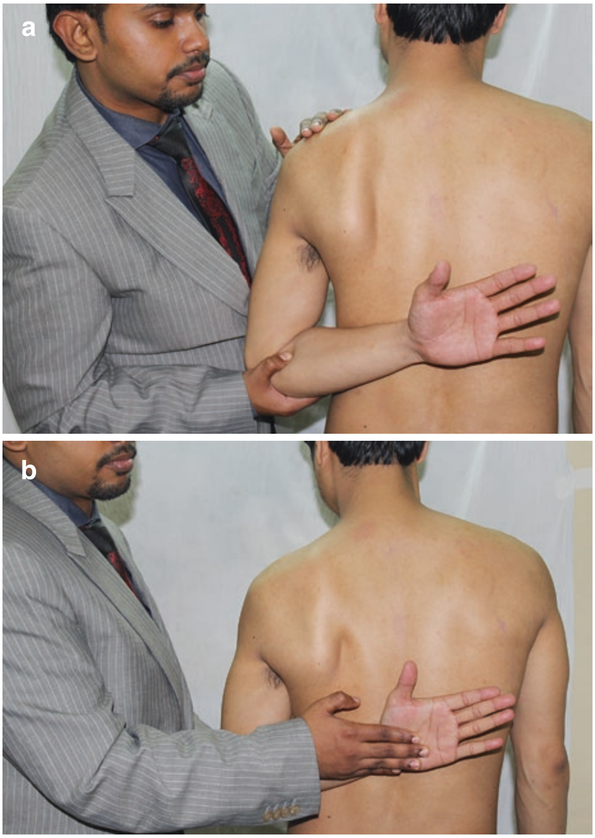


Fig. 74 (**a**) Lift off test. (**b**) Resisted lift off test

Fig. 75 Internal rotation lag test/modified Lift off test. The patients arm maximally internal rotated behind his back and asked to hold the position

Fig. 76 Belly press test

Infraspinatus and Teres Minor Muscles

External Rotation Lag Sign/Infraspinatus Spring Back Test [53]

The patient is seated or in standing position with the arm by the side and the elbow flexed to 90°. The examiner passively abducts the arm to 90° in the scapular plane and externally rotates the shoulder to end range and instructs the patient to hold it Fig. 77. For a positive test, the patient cannot hold the position and the hand springs back towards midline indicating infraspinatus and teres minor weakness Fig. 78. If performed with the arm in 20° abduction in the plane of the scapula or by the side with the elbow at 90°, then it is the supraspinatus and infraspinatus that are being tested together Fig. 79. The spring back forward motion of the arm has also been called the drop sign as the arm "drops" back to 0° of rotation [50]. If the patient is able to hold the position, the muscle strength of infraspinatus can be graded against resistance.

Infraspinatus Test

The patient stands with the arm at the side with the elbow at 90° and the humerus internally rotated to 45°. The examiner then applies an internal rotating force that the patient is asked to resist Fig. 80. Pain or inability to resist, indicates a positive test for an infraspinatus strain.

Teres Minor Test

The patient is made to lie in prone position and is asked to place the hand on the opposite posterior iliac crest. The patient is then instructed to extend and adduct the arm against resistance Fig. 81. Pain and/or weakness indicate a positive test for teres minor strain.

Fig. 77 External rotation lag sign. Patients shoulder maximally external rotated at 90° of abduction

Fig. 78 External rotation lag sign. Patient unable to hold the position

Fig. 79 Testing supraspinatus and infraspinatus together

Fig. 80 Infraspinatus test

Fig. 81 Teres minor test

Hornblower's (Signe de Clairon) Sign [49, 53, 54]
This test is designed to test the strength of teres minor. The patient is in a standing position, arm by the side of the body, with the elbow flexed to 90°. The examiner abducts the patient's arm to 90° in the plane of the scapula. The patient is asked to externally rotate the shoulder against resistance Fig. 82a. Inability to do so indicates a positive test result. A second way to do the test is to ask the patient to standing with the arms by the side and then to bring the hands to the mouth. With a massive posterior rotator cuff tear, the patient is unable to do this without abducting the arm first Fig. 82b. This abduction with hands to the mouth is called Hornblower's sign.

Trapezius
The patient is seated and is asked to place the hands together over the head and to maintain the posture. The examiner stands behind the patient and pushes the elbows forward. Look for the contraction of the three parts of the trapezius Fig. 83a, b. To separately test the *upper trapezius*, e1evate the shoulder with the arm slightly abducted or simultaneously resist shoulder abduction and head side flexion [55]

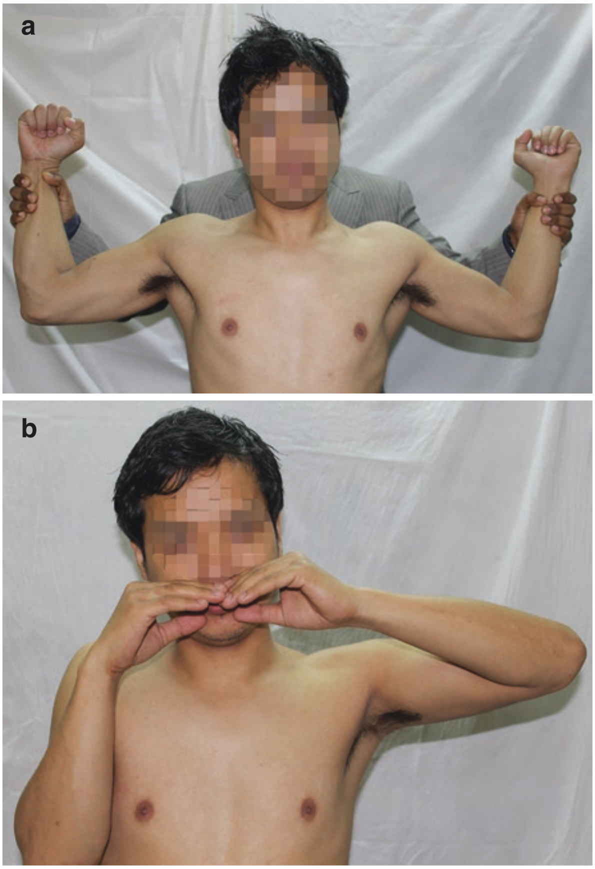


Fig. 82 (**a**) Hornblower's sign. (**b**) Right shoulder showing Hornblower's sign-alternative method

Fig. 83 (**a**) Testing for the whole trapezius muscle as viewed from the back. (**b**) Trapezius muscle testing as viewed from the front.

Fig. 84. If the shoulder is elevated with the arm by the side, levator scapulae and rhomboids are more likely to be involved. *Middle trapezius* can be tested with the patient in a prone position with the arm *abducted to 90°* and externally rotated. Then resistance is applied to horizontal extension of the arm, while watching for retraction of the scapula and feeling for the contractions Fig. 85. If scapular protraction occurs, the middle fibres of trapezius are weak. To test the *lower trapezius*, the patient again in prone lying position with *arm abducted to 120°* and the shoulder externally rotated. The examiner applies resistance to diagonal extension and watches for scapular retraction and feels for the contraction of the muscle fibres Fig. 86. If scapular protraction occurs, the lower trapezius is weak [55].

Serratus Anterior [56]

With the patient standing, forward flex the arm to 90° and apply a backward force to the arm, instructing the patient to maintain the position Fig. 87a, b. If serratus anterior is weak or paralyzed, the medial border of the scapula will wing. A similar finding may be accomplished by doing a wall or floor pushup.

Fig. 84 Testing of the upper trapezius fibres

Fig. 85 Testing of the middle trapezius fibres

Fig. 86 Testing of the lower trapezius fibres

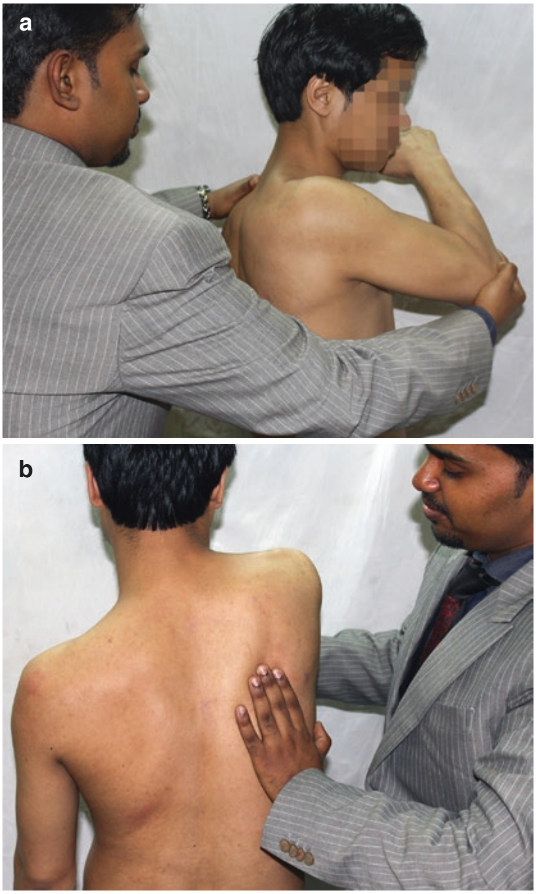


Fig. 87 (**a**) Testing of the serratus anterior muscle as viewed from the side. The examiner feels for the muscle contractions. (**b**) Testing of the serratus anterior muscle as viewed from the back

Rhomboid [53, 56]

The patient in prone or sitting position, with the test arm behind the body so the hand is on the opposite side (opposite back pocket), the examiner places the index finger along and under the medial border of the scapula by asking the patient to push the shoulder forward slightly against resistance to relax the trapezius Fig. 88a. The patient is then asked to raise the forearm and hand away from the body. If the rhomboids are normal, the finger is pushed away from under the scapula Fig. 88b.

Latissimus Dorsi [23]

The patient is in a standing position with the arms elevated in the plane of the scapula to 160°. Against resistance of the examiner, the patient is asked to internally rotate and extend the arm downward as if climbing a ladder. Feel for the contracting muscle Fig. 89.

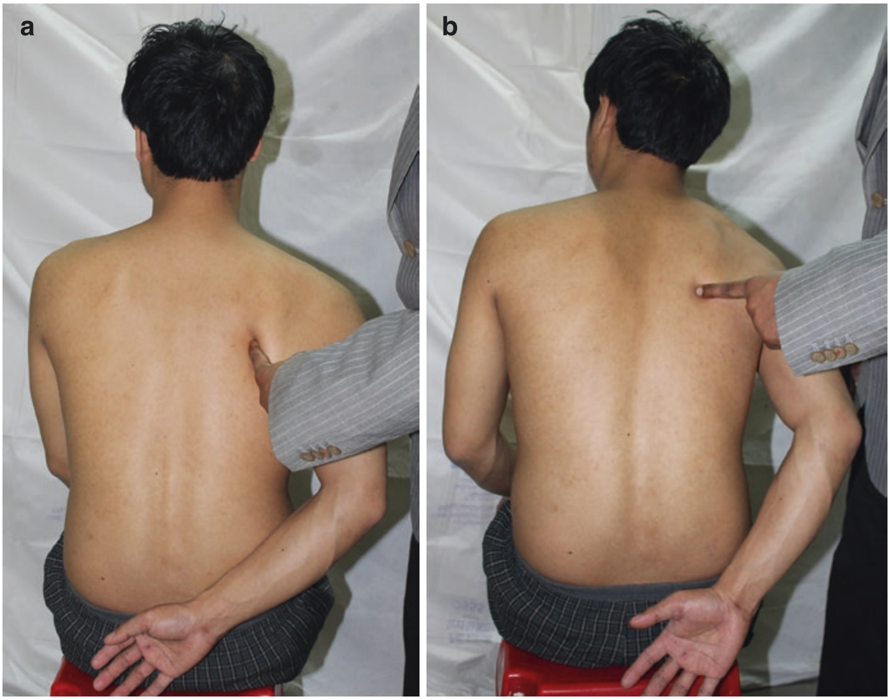


Fig. 88 (**a**) Test for the rhomboids muscle. The examiner insinuates his index finger under the medial border of the scapula. (**b**) The examiners index finger being pushed out by the contracting rhomboids muscle

Fig. 89 Latissimus dorsi testing

Tests for the Labrum

Snyder and colleagues l48 have divided the SLAP lesions Fig. 90 into four types:

Type I	Superior labrum markedly frayed but attachments intact
Type II	Superior labrum has small tear and there is instability of the labral-biceps complex (most common)
Type III	Bucket-handle tear of labrum that may displace into joint; labral biceps attachment intact
Type IV	Bucket-handle tears of labrum that extends to biceps tendon, allowing tendon to sublux into joint

Clunk Test [57]

The patient lies in supine position and the examiner places one hand on the back of the shoulder over the humeral head and the other hand holds the humerus above the elbow. The examiner fully abducts the arm over the patient's head. The examiner then pushes anteriorly with the hand over the humeral while the other hand rotates the humerus into external rotation Fig. 91. A clunk or grinding sound indicates a positive test and is indicative of a tear of the labrum.

Kibler's Anterior Slide Test [58, 59]

The patient is seated with the hands on the waist, thumbs pointing posterior. The examiner stands behind the patient and stabilizes the scapula. With the other hand, the examiner applies an anterosuperior force at the elbow Fig. 92. If the labrum is torn the humeral head slides over the labrum with a pop and the patient complains of anterosuperior pain.

Fig. 90 Picture depicting a SLAP lesion

Fig. 91 Clunk test

Fig. 92 Kibler's anterior slide test

Active Compression Test of O'Brien [34, 60]

The patient is in the standing position with the arm forward flexed to 90°, elbow fully Extended and the arm is then horizontally adducted 10–15° and internally rotated with thumb facing downward. The examiner stands behind the patient and applies a downward eccentric force to the arm while the patient is instructed to hold the position Fig. 93a. Now the forearm is supinated and the downward eccentric force is repeated Fig. 93b. If pain or painful clicking is produced *inside* the shoulder (not over the acromioclavicular joint) in the first part of the test and eliminated or decreased in the second part, the test is considered positive for labral abnormalities.

Snyder's Biceps Tension Test [61]

The patient standing abducts and externally rotates the arm to 90° with the elbow extended and forearm supinated. The examiner then applies an eccentric adduction force to the arm Fig. 94. Reproduction of the patient's symptoms is a

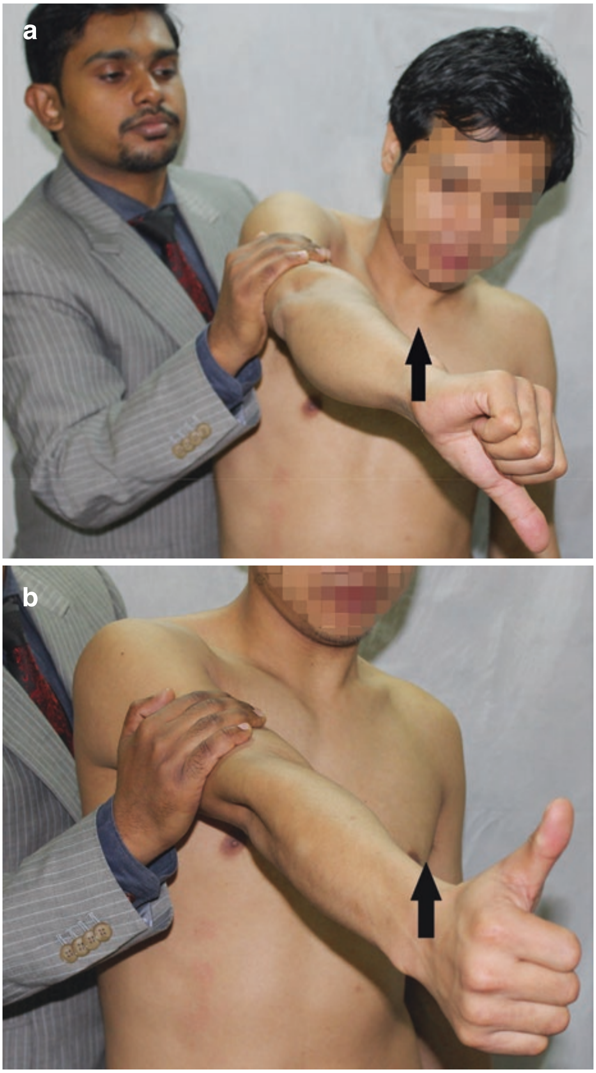


Fig. 93 (**a**) Active compression test of O'Brien with the patients thumb facing downwards. (**b**) Active compression test of O'Brien with the patients thumb facing upwards

positive test. The examiner should also do Speed's test (already discussed) to rule out biceps pathology.

Kim's Biceps Load Test [62]

This test is designed to test for *SLAP lesions in patients with recurrent anterior dislocation*. The patient in the supine position with the shoulder abducted to 90° and externally rotated passively by the examiner sitting by his/her side, with the elbow flexed to 90° and the forearm supinated Fig. 95a. When the apprehension appears, the examiner stops the external rotation and holds the position. The patient is then

Fig. 94 Snyder's biceps tension test

Fig. 95 (**a**) Kim's biceps load test. Starting position for the test. (**b**) Kim's biceps load test. Patient asked to flex his elbow against resistance

asked to flex the elbow against resistance Fig. 95b. If the apprehension remains the same or the shoulder becomes more painful, the test is considered positive.

Kim's Biceps Load Test II [63]

This was described to assess SLAP lesions in patients without recurrent dislocation. The difference in this test is that, the patient's arm is abducted to 120° rather than to 90° as in previous test Fig. 96a, b. The test is considered positive if patient complains of more pain during resisted flexion in the external rotated position as compared with the pain before doing resisted flexion.

SLAP Prehension Test [64]

The patient is in the sitting or standing position. The arm is abducted to 90° with the elbow extended and the forearm pronated with thumb facing downwards. The

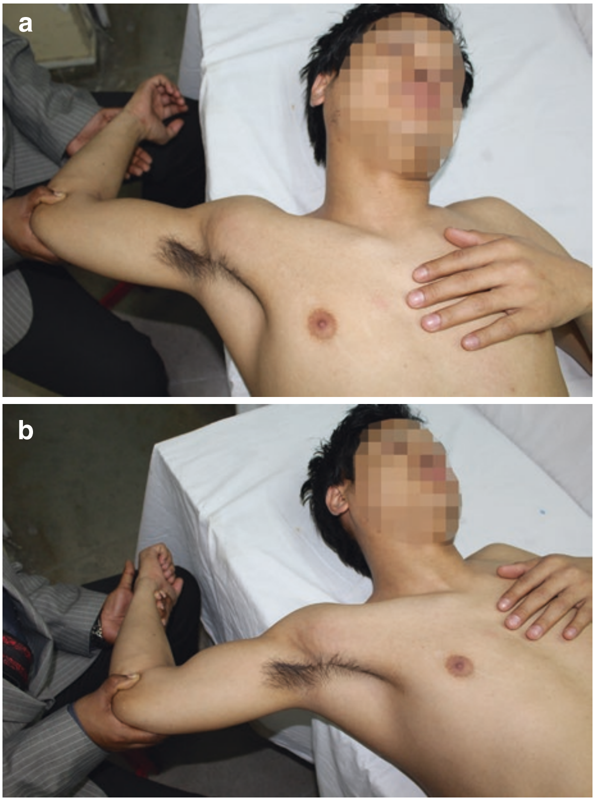


Fig. 96 (**a**) Kim's biceps load test II. Starting position for the test. Note the 120° of abduction at the shoulder. (**b**) Kim's biceps load test II. Patient flexing his elbow against resistance

patient is then instructed to horizontally adduct the arm Fig. 97a. The test is repeated with the forearm supinated Fig. 97b. If pain is felt in the bicipital groove in the first case is lessened or absent in the second case the test is considered positive for a SLAP lesion.

Labral Crank Test of Liu [65]

The patient is in the supine or sitting position. The examiner elevates the arm to 160° in the scapular plane. In this position, an axial load is applied to the humerus with one hand of the examiner while the other hand rotates the humerus internally Fig. 98a and externally Fig. 98b. A positive test is indicated by pain on rotation with or without a click or reproduction of the patient's symptoms.

Pain Provocation Test of Mimori [66]

The patient is seated and the arm is abducted to between 90° and 100° and the arm is externally rotated by the examiner by holding at the wrist. The forearm is taken into maximum supination, Fig. 99a and then full pronation Fig. 99b. If pain is provoked only in the pronated position or if the pain is more severe in the pronated

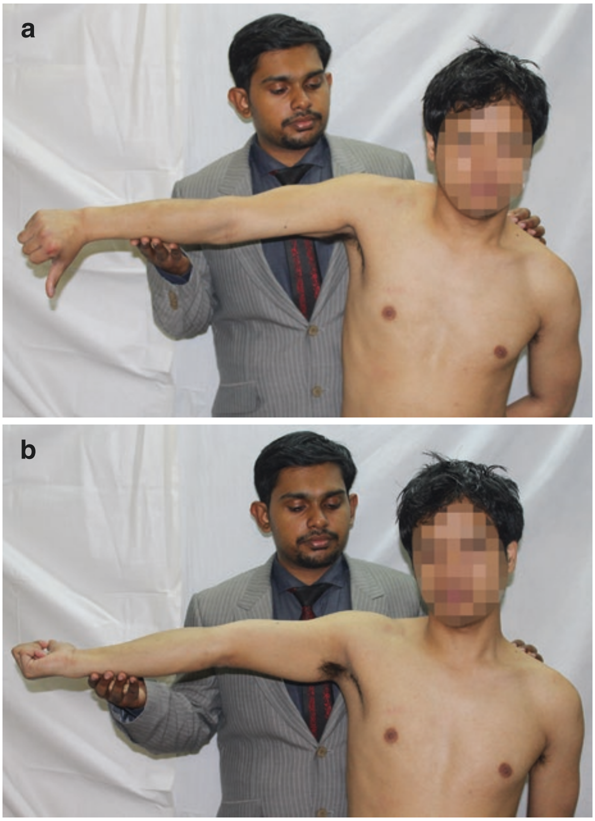


Fig. 97 (**a**) Slap prehension test with forearm pronated. (**b**) Slap prehension test with forearm supinated

Fig. 98 (**a**) Labral crank test of Liu in internal rotation. (**b**) Labral crank test of Liu in external rotation

position, the test is considered positive for a SLAP tear. Biceps pathology should be ruled out with Speed's test.

Snyder's Compression Rotation Test [67]

This test is analogous to Mcmurray's test in the knees. The patient lies in supine position. The examiner grasps the arm and flexes the elbow with the arm abducted to about 20°. The examiner then pushes or compresses the humerus into the glenoid by pushing up on the elbow while simultaneously rotating the humerus internally Fig. 100a and externally Fig. 100b. If a snapping or catching sensation is felt, the test is positive for a labral tear.

Tests for A.C. Joint

Acromioclavicular Shear Test [41]

With the patient in sitting position, the examiner cups his or her hands over the deltoid muscle, with one hand on the clavicle and one hand on the spine of the scapula.

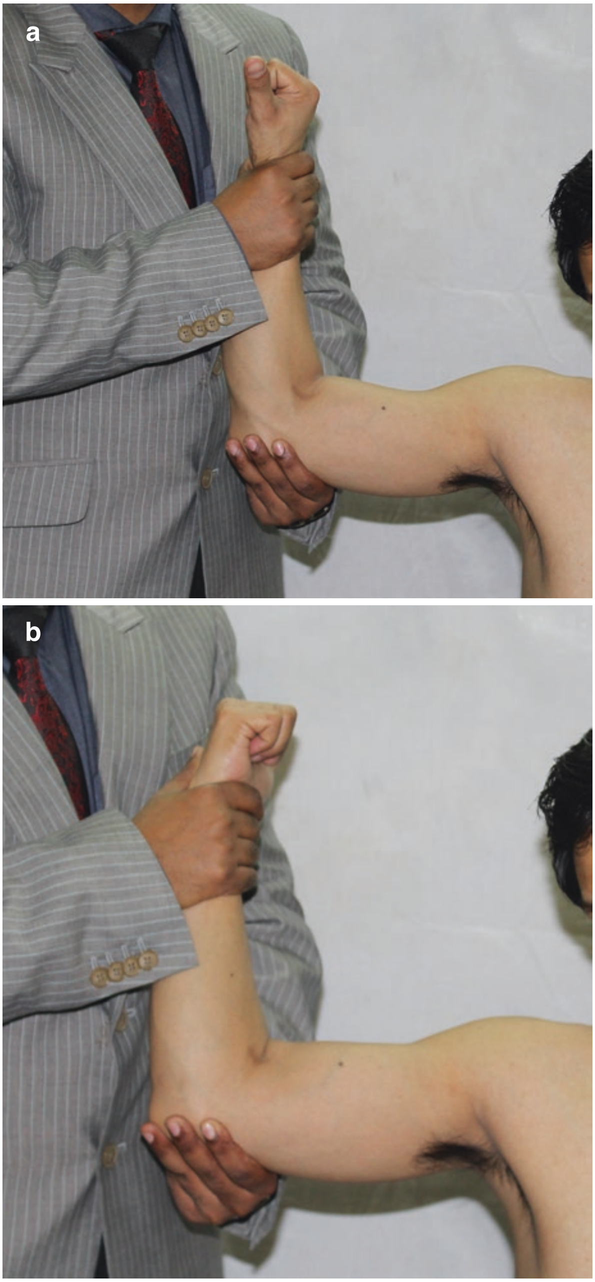


Fig. 99 (**a**) Pain provocation test of Mimori with patients forearm maximally pronated. (**b**) Pain provocation test of Mimori with patients forearm maximally supinated

Fig. 100 (**a**) Snyder's compression rotation test with humerus internally rotated. (**b**) Snyder's compression rotation test with humerus externally rotated

The examiner then squeezes the heels of the hands together Fig. 101. Pain or abnormal movement at the acromioclavicular joint indicates a positive test and is suggestive of A.C joint pathology.

Acromioclavicular Crossover/Crossbody/or Horizontal Adduction Test [31, 68]

The patient stands/sits and reaches the hand across to the opposite shoulder. The test may also be performed passively by the examiner Fig. 24. If localized pain is felt over the acromioclavicular joint, the test is positive.

Tests for Ligaments

Crank Test of Liu

The crank test may also be used as a test for the different glenohumeral ligaments. When it is done with the arm by the side, primarily the superior glenohumeral ligament and capsule are being tested Fig. 102a. At 45–60° abduction, the middle glenohumeral

Fig. 101 Acromioclavicular shear test

ligament, the coracohumeral ligament, the inferior glenohumeral ligament (anterior band), and anterior capsule are being tested Fig. 102b. Over 90° abduction, the inferior glenohumeral ligament and anterior capsule are being tested Fig. 102c.

Posterior Inferior Glenohumeral Ligament Test [58]

The patient sits while the examiner forward flexes the arm to between 80° and 90° and then horizontally adducts the arm 40° with internal rotation. While doing the movement, the examiner palpates the posteroinferior region of the glenoid Fig. 103. If the humerus protrudes or pain is felt in the area, it indicates a lesion of the posterior portion of the inferior glenohumeral ligament. If horizontal adduction is restricted, it may also indicate a tight posterior capsule.

Coracoclavicular Ligament Test

The integrity of the conoid portion of the coracoclavicular ligament may be tested by placing the patient in a side lateral position on the unaffected side. The examiner stabilizes the clavicle while pulling the inferior angle of the scapula away from the chest wall Fig. 104a. The trapezoid portion of the ligament may be tested by pulling the medial border of the scapula away from the chest wall Fig. 104b. Pain in either case in the area of the ligament (anteriorly under the clavicle between the outer one-third and inner two-thirds) constitutes a positive test.

Miscellaneous Tests

Tests for Thoracic Outlet Syndrome

As pointed out earlier in the discussion, thoracic outlet syndrome is yet another cause of pain around the shoulder region. The various tests include

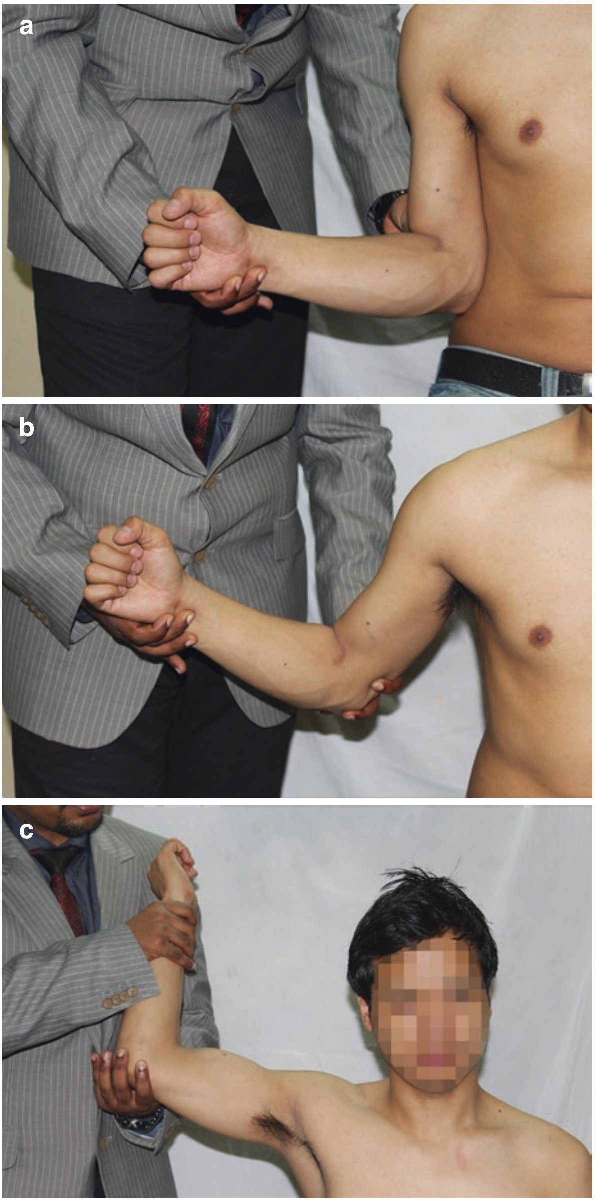


Fig. 102 (**a**) Crank test of Liu to test for the superior glenohumeral ligament. (**b**) Crank test of Liu to test for the middle and inferior glenohumeral ligaments and the coracohumeral ligament. (**c**) Crank test of Liu to test for the inferior glenohumeral ligament

Fig. 103 Posterior inferior glenohumeral test

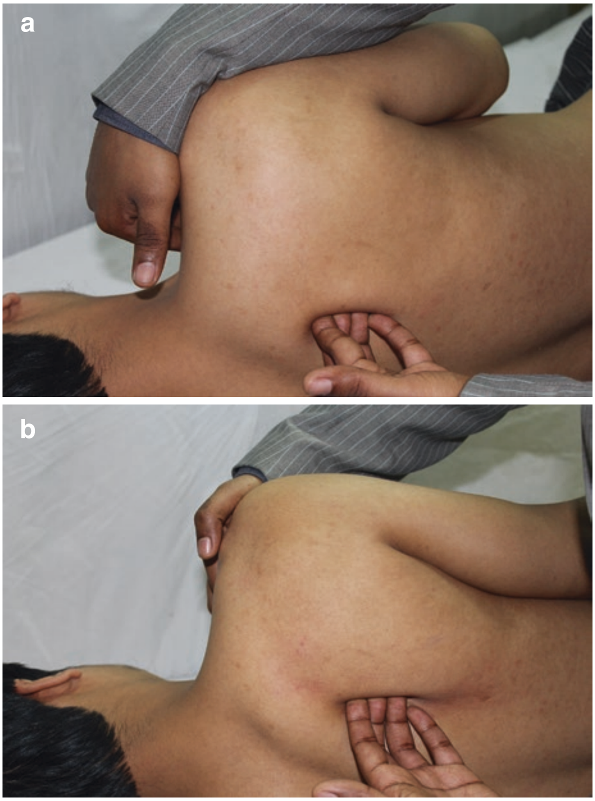


Fig. 104 (**a**) Test for the conoid portion of the coracoclavicular ligament. (**b**) Test for the trapezoid portion of the coracoclavicular ligament

Roos Test/Hands Up Test/Abduction and External Rotation Test/Elevated Arm Stress Test (EAST) [69]

The patient stands and abducts the arms to 90°, externally rotates the shoulder, and flexes the elbows to 90° Fig. 105. The patient then alternatively opens and closes the hands slowly for 3 min. If the patient is unable to keep the arms in the starting position for 3 min or suffer ischemic pain, heaviness or profound weakness of the arm, or nurnbness and tingling of the hand during the 3 min, the test is considered positive for thoracic outlet syndrome on the affected side.

Wright Test or Manoeuvre [70]

Here the arms are hyper abducted so that the hand is brought over the head with the shoulder externally rotated Fig. 106. The pulse is palpated for differences. The pulse disappearance indicates a positive test result for thoracic outlet syndrome.

Allen Manoeuvre

This is a modification of the Wright test. The examiner flexes the patient's elbow to 90° while the shoulder is extended horizontally and rotated externally. The patient is asked to rotate the head away from the test side. The examiner palpates the radial pulse, which becomes absent (disappears) when the head is rotated away from the test side Fig. 107.

Costoclavicular Syndrome/Military Brace Test

The examiner while palpating the radial pulse and draws the patient's shoulder down and back Fig. 108. A positive test is indicated by an absence of the pulse and implies possible thoracic outlet syndrome.

Fig. 105 Roos test

Fig. 106 Wright test

Fig. 107 Allen manoeuvre

Fig. 108 Military brace test

Provocative Elevation Test [22]
This test is a modification of the Roos test. The patient elevates both arms above the horizontal and is asked to rapidly open and close the hands 15 times. If fatigue, cramping, or tingling occurs during the test, the test is positive for vascular insufficiency and thoracic outlet syndrome.

Shoulder Girdle Passive Elevation [71]
The patient is seated and the examiner passively elevates the shoulder girdle up and forward into full elevation (a passive bilateral shoulder shrug) and the position is held for 30 or more seconds Fig. 109. Arterial relief is evidenced by stronger pulse, skin colour change (more pink), and increased hand temperature. Venous relief is shown by decreased cyanosis and venous engorgement. Neurological signs go from numbness to pins and needles or tingling as well as some pain as the ischemia to the nerve is released. This is referred to as a release phenomenon.

Adson Manoeuvre [72]
The examiner palpates the radial pulse. The patient's head is rotated to face the test shoulder and the patient is asked to extend the head while the examiner externally rotates and extend the patient's shoulder. The patient is instructed to take a deep breath and hold it Fig. 110. A disappearance of the pulse indicates a positive test.

Fig. 109 Shoulder girdle passive elevation test

Fig. 110 Adson manoeuvre

Fig. 111 Halstead manoeuvre

Halstead Manoeuvre

The examiner finds the radial pulse and applies a downward traction on the test extremity while the patient's neck is hyperextended and the head is rotated to the opposite side Fig. 111. Absence or disappearance of a pulse indicates a positive test for thoracic outlet syndrome.

The neurological examination of the various muscle groups and examination of cervical spine will be dealt in the appropriate section of this book.

References

1. Hess SA. Functional stability of the glenohumeral joint. Man Ther. 2000;5:63–71.
2. Tillman B, Petersen W. Clinical anatomy. In: Wulleer N, Mansat M, Fu F, editors. Shoulder surgery: an illustrated textbook. London: Martin Dunitz; 2001.
3. Warner JJ. The gross anatomy of the joint surfaces, ligaments, labrum and capsule. In: Matsen FA, Fu FH, Hawkins RI, editors. The shoulder: a balance of mobility and stability. Rosemont: American Academy of Orthopedic Surgeons; 1993.
4. Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. Ann Rheum Dis. 1973;32:413–8.
5. Butters KP. Nerve lesions of the shoulder. In: De Lee JC, Drez D, editors. Orthopedic sports medicine: principles and practice. Philadelphia: W. B. Saunders; 1994.
6. Schultz IS, Leonard JA. Long thoracic neuropathy from athletic activity. Arch Phys Med Rehabil. 1992;73:87–90.
7. Bowen M, Warren R. Ligamentous control of shoulder stability based on selective cutting and static translation. Clin Sports Med. 1991;10:757–82.
8. Duralde X. Surgical management of neurologic and vascular lesions in the athlete's shoulder. Sports Med Arthrosc Rev. 2000;8:289–304.

9. Fiddian NJ, King RI. The winged scapula. Clin Orthop Relat Res. 1984;(185):228–36.
10. Boublik M, Silliman JF. History and physical examination. In: Hawkins III ILJ, Misamore GW, editors. Shoulder injuries in the athlete. New York: Churchill Livingstone; 1996.
11. Hawkins RJ, Mohtadi NG. Clinical evaluation of shoulder instability. Clin J Sport Med. 1991;1:59–64.
12. Harryman DT, Sidles JA, Harris SL, Matsen FA. Laxity of the normal glenohumeral joint: a quantitative in vivo assessment. J Shoulder Elb Surg. 1992;1:66–76.
13. Andrews JA, Timmerman LA, Wilk KE. Baseball. In: Pettrone FA, editor. Athletic injuries of the shoulder. New York: McGraw-Hill; 1995.
14. Gerber C, Ganz R. Clinical assessment of instability of the shoulder. J Bone Joint Surg (Br). 1984;66:551–6.
15. Leffert RD, Gumley G. The relationship between dead arm syndrome and thoracic outlet syndrome. Clin Orthop Relat Res. 1987;(223):20–31.
16. Silliman JF, Hawkins RJ. Classification and physical diagnosis of instability of the shoulder. Clin Orthop Relat Res. 1993;(291):7–19.
17. Rockwood CA. Subluxations and dislocations about the shoulder. In: Rockwood CA, Green DP, editors. Fractures in adults. Philadelphia: J. B. Lippincott; 1984.
18. Rowe CR. Dislocations of the shoulder. In: Rowe CR, editor. The shoulder. Edinburgh: Churchill Livingstone; 1988.
19. Ramsey ML, Klimkiewicz JJ. Posterior instability: diagnosis and management. In: Iarmotti JP, Williams CR, editors. Disorders of the shoulder. Philadelphia: Lippincott Williams & Wilkins; 1999.
20. Pollack RG, Bigliani LU. Recurrent posterior shoulder instability: diagnosis and treatment. Clin Orthop Relat Res. 1993;(291):85–96.
21. McFarland EG, Campbell C, McDowell J. Posterior shoulder laxity in asymptomatic athletes. Am J Sports Med. 1996;24:468–71.
22. Matsen FA, Thomas SC, Rockwood CA. Glenohumeral instability. In: Rockwood CA, Matsen FA, editors. The shoulder. Philadelphia: W. B. Saunders; 1990.
23. Arcand MA, Reider B. Shoulder and upper arm. In: Reider B, editor. The orthopedic physical examination. Philadelphia: W. B. Salmders; 1999.
24. Kibler WB. Role of the scapula in the overhead throwing motion. Contemp Orthop. 1991;22:525–33.
25. Davies GJ, Dickoff-Hoffman S. Neuromuscular testing and rehabilitation of the shoulder complex. J Orthop Sports Phys Ther. 1993;18:449–58.
26. Kibler WB. Evaluation and diagnosis of scapulothoracic problems in the athlete. Sports Med Arthrosc Rev. 2000;8:192–202.
27. Kibler WB. The role of the scapula in athletic shoulder function. Am J Sports Med. 1998;26:325–37.
28. Goldbeck TG, Davies GJ. Test-retest reliability of the closed kinetic chain-upper extremity stability test: a clinical field test. J Sport Rehabil. 2000;9:35–43.
29. Neer CS, Welsh RP. The shoulder in sports. Orthop Clin N Am. 1977;8:583–91.
30. Hawkins RJ, Kennedy JC. Impingement syndrome in athletics. Am J Sports Med. 1980;8:151–63.
31. Rudert M, Wulker M. Clinical evaluation. In: Wulleer N, Mansat M, Fu F, editors. Shoulder surgery: an illustrated textbook. London: Martin Dunitz; 2001.
32. Kelley MJ. Evaluation of the shoulder. In: Kelley MJ, Clark WA, editors. Orthopedic therapy of the shoulder. Philadelphia: J. B. Lippincott; 1995.
33. Corso G. Impingement relief test: an adjunctive procedure to traditional assessment of shoulder impingement syndrome. J Orthop Sports Phys Ther. 1995;22:183–92.
34. Meister K. Injuries to the shoulder in the throwing athlete. Part II: evaluation/treatment. Am J Sports Med. 2000;28:587–601.
35. Jobe CM. Posterior superior glenoid impingement: expanded spectrum. Arthroscopy. 1995;11:530–6.
36. Jobe CM. Superior glenoid impingement. Clin Orthop Relat Res. 1996;330:98–107.

37. Giombini A, Rossi F, Pettrone FA, Dragoni S. Posterosuperior glenoid rim impingment as a cause of shoulder pain in top level waterpolo players. J Sports Med Phys Fitness. 1997;37:273–8.
38. Yergason RM. Supination sign. J Bone Joint Surg Am. 1931;13:160.
39. Khan KM, Cook JL, Taunton JE, Bonar F. Overuse tendinosis, not tendinitis. Part 1: a new paradigm for a difficult clinical problem. Phys Sportsmed. 2000;28:38–48.
40. Ludington NA. Rupture of the long head of the biceps flexor cubiti muscle. Ann Surg. 1923;77:358–63.
41. Davies GJ, Gould JA, Larson RL. Functional examination of the shoulder girdle. Phys Sportsmed. 1981;9:82–104.
42. Post M. Physical examination of the musculoskeletal system. Chicago: Year Book Medical; 1987.
43. Lippman RK. Frozen shoulder: periarthritis, bicipital tendinitis. Arch Surg. 1943;7:283–96.
44. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. Am J Sports Med. 1982;10:336–9.
45. Moseley HF. Disorders of the shoulder. Clin Symp. 1960;12:130.
46. Matsen FA, Lippitt SB, Sidles IA, Harlyman DT. Practical evaluation and management of the shoulder. Philadelphia: W. B. Saunders; 1994.
47. Gerber c, Krushell RJ. Isolated ruptures of the tendon of the subscapularis muscle. J Bone Joint Surg (Br). 1991;73:389–94.
48. Ticker JB, Warner JJ. Single-tendon tears of the rotator cuff. Evaluation and treatment of subscapularis tears. Orthop Clin N Am. 1997;28:99–116.
49. Arroyo JS, Flatow EL. Management of rotator cuff disease: intact and repairable cuff. In: Iannotti JP, Williams GR, editors. Disorders of the shoulder. Philadelphia: Lippincott Williams & Wilkins; 1999.
50. Hertel R, Ballmer FT, Lambert SM, Gerber CH. Lag signs in the diagnosis of rotator cuff rupture. J Shoulder Elb Surg. 1996;5:307–13.
51. Stefko JM, Jobe FW, Vanderwilde RS, Carden E, Pink M. Electromyographic and nerve block analysis of the subscapularis lift off test. J Shoulder Elb Surg. 1997;6:347–55.
52. Williams GR. Complications of rotator cuff surgery. In: Iannotti JP, Williams CR, editors. Disorders of the shoulder. Philadelphia: Lippincott Williams & Wilkins; 1999.
53. McClusky CM. Clasification and diagnosis of glenohumeral instability in athletes. Sports Med Arthosc Rev. 2000;8:158–69.
54. Walch G, Boulahia A, Calderone S, Robinson AH. The dropping and Hornblower's signs in evaluating rotator cuff tears. J Bone Joint Surg (Br). 1998;80:624–8.
55. Kendall HO, Kendall FP. Muscles-testing and function. Baltimore: Williams & Wilkins; 1999.
56. Brunnstrom S. Muscle testing around the shoulder girdle-a study of the function of shoulder blade fixators in 17 cases of shoulder paralysis. J Bone Joint Surg Am. 1941;23:263–72.
57. Andrews JR, Gillogly S. Physical examination of the shoulder in throwing athletes. In: Zarins B, Andrews JR, Carson WG, editors. Injuries to the throwing arm. Philadelphia: W. B. Saunders; 1985.
58. Kibler WB. Clinical examination of the shoulder. In: Pettrone FA, editor. Athletic injuries of the shoulder. New York: McGraw-Hill; 1995.
59. Kibler WB. Specificity and sensitivity of the anterior slide test in throwing athletes with superior glenoid labral tears. Arthroscopy. 1995;11:296–300.
60. O'Brien SJ, Pagnoni MJ, Fealy S, McGlynn SR, Wilson JB. The active compression test: a new and effective test for diagnosing labral tears and acromioclavicular joint abnormality. Am J Sports Med. 1998;26:610–3.
61. Snyder, S.J" R.P. Karzel, W. Del Pizzo, R.D. Ferkel, and M.J. Friedman: SLAP lesions of the shoulder. Arthroscopy 6:274–279, 1990.
62. Kim SH, Ha KI, Han KY. Biceps load test: a clinical test for superior labrum anterior and posterior lesions in shoulder with recurrent anterior dislocations. Am J Sports Med. 1999;27:300–3.
63. Kim SH, Ha KI, Ahn JH, et al. Biceps load test II: a clinical test for SLAP lesions of the shoulder. Arthroscopy. 2001;17:160–4.

64. Berg EE, Ciullo JV. A clinical test for superior glenoid labral or 'SLAP' lesions. Clin J Sport Med. 1998;8:121–3.
65. Liu SH, Henry MH, Nuccion SL. A prospective evaluation of a new physical examination in predicting glenoid labral tears. Am J Sports Med. 1996;24:721–5.
66. Mimori K, Mlmeta T, Nakagawa T, Shinomiya K. A new pain provocation test for superior labral tears of the sholuder. Am J Sports Med. 1999;27:137–42.
67. Guidi EJ, Suckerman JD. Glenoid labrallesions. In: Andrews JR, Wilk KE, editors. The athlete's shoulder. New York: Churchill Livingstone; 1994.
68. Buchberger DJ. Introduction of a new physical examination procedure for the differentiation of acromioclavicular joint lesions and subacromial impingement. J Manip Physiol Ther. 1999;22:316–21.
69. Roos DB. Congenital anomalies associated with thoracic outlet syndrome. Am J Surg. 1976;132:771–8.
70. Wright IS. The neurovascular syndrome produced by hyperabduction of the arms. Am Heart J. 1945;29:1–19.
71. Hawkins RJ, Bokor DJ. Clinical evaluation of shoulder problems. In: Rockwood CA, Matsen FA, editors. The shoulder. Philadelphia: W. B. Saunders; 1990.
72. Adson AW, Coffey JR. Cervical rib: a method of anterior approach for relief of symptoms by division of the scalenus anticus. Ann Surg. 1927;85:839–57.

Examination of Elbow

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Introduction

Elbow joint is trocho-ginglymoid joint between distal end of humerus, proximal ulna and radius. It consist of three articulation ulno-humeral, radio-humeral and proximal radio-ulnar joint. The trochoid (pivoting) components consist of the radio-humeral and proximalradioulnar joints, which allow for axial rotation of the forearm. The ginglymus (hinge) component is created by the ulnohumeral joint, allowing for flexion and extension

These complex articulation between three bones allows movement in a semi-saggital plane along with axial rotation of forearm. The movements are in a semisaggital plane, because with extension the distal part also moves laterally in the coronal plane while during flexion it moves near to midline. This happens because of the peculiar anatomy of articulating surfaces of humerus and ulna resulting in slight change in the sagittal plane than the sagittal plane of whole body.

Anatomy

The three bones articulating to form the elbow joint are the distal end of humerus, proximal ulna and radius. To understand the joint kinematics, an understanding of the basic anatomy of articulating ends and capsule-ligamentous complex is important.

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The Joints

Elbow is a compound synovial joint and is composed of three articulations: ulno-humeral, radio-humeral and superior radio-ulnar joints. All these articulations are covered in a single capsular cavity and their joint cavities are continuous. The capsule of the elbow joint is attached to the margins of the articular surfaces of capitullum and trochlea, but anteriorly and posteriorly its attachment is shifted proximally to also include the coronoid and olecranon fossae, respectively. Distally, capsule attaches to the margins of the trochlear notch of ulna at the edge of the articular cartilage, and to upper border of the annular ligament around radial head. Capsule does not attach to the radius. The synovial membrane lines the capsule and is attached to the articular margins of all the three bones. It covers the floor in the coronoid and olecranan fossae and also bridges the gap between ulnar radial notch and radial head. The quadrate ligament prevents herniation of the synovial membrane between the anterior and posterior free edges of the annular ligament.

Ulno-Humeral or Trochlear Joint

Uniaxial hinge joint
Axis of movement is not horizontal, but rather directed medially and downwards leading to the carrying angle
Resting position: 70° flexion, 10° supination
Capsular pattern: flexion more limited than extension
Closed packed position: extension, supination

Radio-Humeral Joint

Uniaxial hinge joint
Resting position: full extension, full supination
Capsular pattern: flexion more limited than extension
Closed packed position: 90° flexion, 5° supination

Superior Radio-Ulnar Joint

Uniaxial pivot joint
Annular ligament forms four-fifths of the joint, and keeps the radius head in proper position in relation to the ulna
Resting position: 35° supination, 70° flexion
Capsular pattern: equal limitation of supination and pronation
Closed packed position: 5° supination

Distal Humerus

The distal end of humerus embryologically develops from four separate ossification centers. The lateral epicondyle, capitellum, and trochlea unite by the age of 13 years to form a single epiphysis, which then fuses to the humeral shaft around age 16 [1]. The medial condylar remains open till the teenage and is extraarticular in location. The sequence of appearance of ossification centers is fairly constant and follows a sequence “CRITOE”: capitullum, radial head, internal or medial epicondyle, trochlea, and external or lateral epicondyle. The capitulum physis appears by 2 years of age and others follow one after another with a gap of 2 years aproximately [1].

Both the condyles extend upwards into supracondylar ridges which form the medial and lateral border of the thin and flat supracondylar area. The olecranon fossa separates the condyles from the supracondylar area in the center. Bone is wafer thin in this area which compromises the stable reduction in case of any fracture in the area. Thickening of supracondylar ridges is frequently seen in chronic cases of distal humerus fracture eg; supracondylar fracture, lateral condyle humerus fracture. The articulating end of distal humerus is directed anteriorly in relation to the long axis of humerus. The joint line of elbow istilted laterally because the medial flange of trochlea is 6 mm longer than the lateral flange, which causes the carrying angle of elbow. The radial head articulates with the capitulum.

Distal humerus has a olecranon fossa posteriorly which allows the olecranon process of ulna to engage in full extension, and two notches anteriorly one for seating the coronoid process of ulna above the trochlea and another above the capitellum for receiving radius head, respectively in deep flexion.

Proximal End of Ulna

Proximal end of ulna consist of the olecranon process posteriorly and coronoid process anteriorly which articulate with trochlea and forms the hinge type of synovial. Stability to the joint is provided by geometry and congruity of articulating surfaces, hence it allows movements in the saggital plane (flexion-extension) only with very limited movements in coronal plane.Proximal end of ulna has sigmoid notch on the lateral side which articulates with sides of radial head.

Proximal End of Radius

The articulation of radial head with capitulum moves antero-posteriorly with elbow flexion–extension, while its sideways articulation with ulna allows pronation-supination of forearm. Its stability is principally depends on capsule-ligamentous complex, particularly the annular ligament which attaches on both lips of the sigmoid notch in ulna and encircles the radial neck.

Capsuloligamentous Complex

Medial collateral ligament (MCL) provides stability against valgus stress in full extension and flexion. It consists of anterior, posterior and transverse component. The Anterior component fibers are attached to medial side of coronoid process and are taut in both flexion and extension. The Posterior band attaches to the medial side of olecranon process and is taut only in extension. MCL is the prime stabilizer against the valgus stress in flexion.

Lateral collateral ligament complex is the primary structure for postero-lateral instability, it consist of three components radial collateral ligament, lateral ulnar collateral ligament, annular ligament and accessory lateral collateral ligament. Radial collateral ligament is attached to annular ligament along the capsular attachment. Lateral ulnar collateral ligament attached to tubercle at crista supinatorius. Accessory lateral collateral ligament is attached to the inferior margin of annular ligament. Annular ligament is attached to the anterior and posterior margin of sigmoid notch.

Clinical Examination

Clinical examination steps for elbow are same as it is for anyorthopedics examination of a joint.

1. History
   (a) Pain: onset, duration, site of origin (bony or soft tissue), radiation, associated with fever or trauma
   (b) Swelling: Onset, duration, location, extent (localised or generalized), consistency, any associated symptoms
   (c) Limitation of movements
   (d) Deformity: onset (congenital/acquired), associated with trauma, fever or any swelling.
   (e) History of any massage or manipulation.
2. Inspection
   (a) Attitude,
   (b) Inspect from front, lateral aspect, medial aspect and from posterior aspect.
3. Palpation
   (a) Temperature
   (b) Tenderness
   (c) Bony landmarks
   (d) Three point relationship
   (e) Joint line
   (f) Distal neurovascular status
   (g) Draining lymph nodes
4. Movements
   (a) Flexion-extension, supination-pronation

5. Measurements
   (a) Linear, angular and circumferential measurements
6. Neurological examination
7. Special tests

The patient must be suitably undressed so that both arms are exposed to allow the examiner to compare the two sides. Examine both elbows together and in an identical position. Keep a look at the general body posture, especially shoulder and neck areas, for a possible referral of symptoms.

Inspection

Prerequisite

The normal elbow should be mirrored with that of the deformed one and then the assessment is done from the front, back and the sides.

Attitude

Observe the elbow and comment on how it appears in the anatomical position. The attitude may be either cubitus varus or valgus which in turn represents increase or decrease in carrying angle. The angle formed in between the long axis of the forearm and arm in a supine and extended position of the elbow is the carrying angle. It varies from 10 to 15° (more in females than in males).

1. Skin color—Obvious redness in case of infective condition and bruising in acute trauma.
2. Scar—from previous surgery or trauma
3. Discharging sinus or wound—chronic infective affection of the elbow or surrounding bone
4. Swelling—commonly it very obvious at triangle connecting the lateral epicondyle, tip of olecranon and head of radius.
5. Passive ROM—Elbow allows range of movement in saggital plane (flexion and Extension) at radio-capitellar and ulno-humeral joint from 0 to 140–150° or till the soft tissues of front of arm and forearm touches together. Some patient especially female may have hyperextension of −10° considered normal if it is equal on either side. As most of the muscles around the elbow crosses the wrist and small joints of hand as well, so the wrist and finger extension and flexion with elbow extended test for any contracture or shortening of common extensor tendons and common flexor tendon respectively.

   Radioulnar and radiocapitellar joint allows rotation of forearm in axial plane (supination-pronation). Normal range of movement in axial plane is about 90° of supination to 80° of pronation.

   Painful movement in saggital or axial plane indicates affection of the specific joint because it is contributed at different articulation.
6. Muscle contour of common extensor and flexors—In cases of chronic ulnar nerve deficit comparing the common flexor muscle contour on either side may so wasting because of wasting of flexor carpi ulnaris.

7. Deformity in saggital and coronal plane—flexion deformity or loss of extension is first to appear after any kind of affection of elbow joint. Hyperextension at considered deformity if it is unilateral and could be consequence to mal-union or flail elbow because of osseous defect.

From the Front

Look for any deformity, anatomical variations in cubital fossa, biceps and upper forearm bulge and also biceps tendon prominence.

From the Back

Look for any swellings, triceps bulge, olecranon and paraolecranon depression, anconeus triangle and upper end of ulna.

From the Lateral Side

Look for lateral epicondyle prominence and any abnormality in the brachioradialis and long extensors of the elbow.

From the Medial Side

Look for medial epicondylar prominence and the bulge of common flexors.

Palpation

Superficial Palpation

Feel for any local rise of temperature and superficial tenderness.

Deep Palpation

Following points are included

1. Confirm the inspection findings.
2. Palpate for swellings, sinuses and scars if present.
3. Feel for soft tissues around the elbow and assess for any abnormality.
4. Specially feel for any bony mass in the soft tissues.
5. Palpate for bony prominences like supracondylar ridges, three bony point relationship, medial and lateral epicondyles, olecranon process and head of radius.

Bony Landmarks to Palpate During Examination

Front of the elbow is covered with thick musculature, but rest all sides are subcutaneous and hence most of the articular definition and bony landmarks are easily palpable. The bony landmarks of interest while examining the elbow are the medial epicondyle, lateral epicondyle, olecranon and radial head.

Medial epicondyle is a prominent subcutaneous landmark which can become tender in cases medial epicondylitis. Over the backside of this is a cord like structure that can be rolled under the finger, it is the ulnar nerve.

Olecranon is the papable landmark at the point of elbow in flexed position. In cases of olecranon bursitis a localised tender swelling could be seen and palpated over it.

Head of radius can be palpated just distal to the lateral epicondyle and its identification facilitated by simultaneous supination and pronation movement of forearm while palpating the head. The procedure to palpate the head of radius is to first palpate the lateral epicondyle in a flexed elbow, and then slide the thumb downwards. The first depression that is felt is the radio-humeral joint line, and just distal to it is the radial head, which can be confirmed by rotating the forearm and feeling the corresponding movements of the radius head.

Lateral epicondyle is covered with a relativly thicker muscle bulk of extensor tendons' orogin and some time palpation is difficult specially in females and obese patient. Flexing the elbow to 90° facilitates its palpation. A gross method to locate the lateral epicondyle is to place middle finger over the head of radius (right hand of examiner for right elbow of patient) and the position of index finger beside it indirectly localises the lateral epicondyle in difficult cases. Tenderness over it could be seen in cases of lateral epicondylitis or acute trauma of lateral condyle or supracondylar area.

The three most prominent bony land marks of elbow; lateral and medial epicondyle, tip of olecranon are in straight line with elbow fully extended and in flexion form an isosceles triangle. It could be altered relative to opposite side in cases of elbow dislocation, olecranon fracture and lateral or medial condyle fractures.

Palpation of Supracondylar Ridges

Method: It will be easier with elbow semiflexed and in supinated position, hold the forearm in one hand and with the thumb and index finger of the other hand palpate for medial and lateral epicondyles and go upwards to feel the supracondylar ridges (note for any abnormality).

Palpation of Three Point Bony Relationship

In a normal elbow, it is palpated in 90° flexion. But in presence of deformity it should be measured in deformed position. It should always be compared with the opposite side for assessing and comparing the correlation. So while palpating the opposite normal elbow, keep it in an identical position as that of the deformed elbow.

Abnormal collections of fluid in the joint are specially felt in the anconeus triangle and finally feel for supratrochlear lymph nodes and thickening of ulnar nerve on medial side of the elbow.

Movements

It includes flexion, extension and rotation movements occurring at humeroulnar, humeroradial and superior radioulnar joints.

Method of Assessing the Movements

Flexion-Extension

It can be assessed in both sitting and standing position, better in sitting position. Ask the patient to sit on a stool and lean over the table with arm lying over the table from shoulder to elbow, make sure that forearm is fully supinated with wrist and fingers extended. After positioning, ask the patient to touch the table from the back of the hand without lifting the shoulder. This will be the zero extension position, now ask patient to bring the front of the upper forearm to the front of lower arm. This will show the flexion arc at the elbow. Always compare the movements with opposite side.

In standing position with arm by side of chest, forearm supinated and with an extended wrist and fingers and ask the patient to extend the elbow further which measures hyperextension of the elbow (10–15° of hyperextension is seen in some individuals). Then bring it back to neutral position and from there ask to approximate front of forearm and arm by stabilizing the elbow. This measures the flexion arc at elbow.

Rotational Movements

It can be measured in either standing or sitting position with arm vertical and side of the chest, elbow flexed to 90° with forearm in neutral position, wrist and fingers extended, ask the patient to rotate the forearm and palm towards the roof, this demonstrates the supination movement and the arc of movement is measured. Now, ask patient to bring the forearm to neutral position and rotate the forearm and palm towards the floor, this demonstrates the pronation movement and the arc of movement is measured.

The other method which helps measuring the arc of movement easily is same as the method described above but with a fisted hand and keeping a pen/stick in it, which acts as a guide to measure the arc of movement (Table 1).

Measurements

Linear Measurements

It includes the following measurements.

1. Arm length: The distance between posterolateral corner of acromion to lateral epicondyle of elbow.
2. Forearm length: The distance between lateral epicondyle of elbow to the tip of radial styloid.

Table 1 Showing normal active range of movements at the elbow complex

Movement	Range of motion
Flexion	0–140°
Extension	0–10°
Supination	0–90°
Pronation	0–80°

3. Inter-epicondylar distance.
4. Olecranon tip to medial epicondyle distance.
5. Olecranon tip to lateral epicondyle distance.

Circumferential Measurements

It includes the following measurements.

1. Arm girth.
2. Forearm girth.

Both are measured at the level of maximum muscular mass.

Measurement of Carrying Angle

Method: Draw the central axis of the arm by marking the two points, one is the centre of the inter-epicondylar line and the other is the centre of line drawn between anterior axillary fold and the lateral border of deltoid bulge. Then connect these two points to form a central axis of arm. The central axis of the forearm is drawn by connecting the mid-point of inter-epicondylar line to the mid-point of inter-styloid line at the wrist. The angle formed between these two axes is the carrying angle.

Deformity

Any painful intraarticular or periarticular lesion can lead to loss of terminal extension of the elbow which can eventually lead to a flexion deformity. Most of the time flexion deformity of the elbow is not of much concern cosmetically and functionally as the function arc starts from 30°. Any sagittal plane deformity can be measured by putting the center of goniometer on lateral epicondyle and keeping its arms along the arm and forearm of the patient.

In elbow, coronal plane deformities are more common and also of more cosmetic concern to the patient. A Valgus or varus deformity at elbow is named as cubitus valgus or varus, respectively. As already discussed about the relation of arm and forearm in the arc of movement, they are in valgus in extension and varus in flexion. It can be measured with a goniometer after marking the long axis of the arm and forearm on the front and putting the center of goniometer in the center of a line joining the two epicondyles anteriorly. The Normal elbow has a valgus of 5–10 ° in male and 10–15° in females, which is also named as the carrying angle. Because of the variation in angle with arc of movement, carrying angle has been defined in full extension only. Hence all the coronal plane deformity measurements are to be made in full extension of elbow, and hence consecutively if the patient has a flexion deformity of elbow the true coronal plane deformity cannot be measured.

Special Tests

Tests for Lateral Epicodylitis/Tennis Elbow

1. *Cozen's test/Resisted wrist extension*: The patient's elbow is stabilized by the examiner's hand. The patient is asked to pronate the forearm and do active wrist

extension and radial deviation of a fisted hand, while the examiner resists the extension. This causes severe pain at the lateral epicondyle which can be confirmed by asking the patient.

2. *Mill's test/passive wrist flexion*: fully extend the elbow and passively flex the wrist with hand fisted. This cause stretching of the extensor tendons and elicits pain.

   D/D: this test also similar pain in radial nerve compression around elbow. Hence in cases of persistent tennis elbow, electrodiagnostic tests should be done to rule out neurological causes of pain.
3. *Resisted Middle finger extension:* Patient is asked to extend the middle finger while the examiner applies pressure on the middle phalanx distal to proximal interphlangeal joint. This maneuvre puts stress on the extensor digitorum muscle and elicits pain on lateral epicondyle.
4. *Wringing test*: Ask the patient to wring a towel, pain will be felt at the lateral epicondylar region.
5. Other tests like-Chair test, Jug test, Stir-fry test and Broom test have been described in the literature.

Test for Medial Epicondylitis/Golfer's Elbow

Examiner extends the elbow and wrist of the patient, puts forearm in supination and extends the fingers. This maneuver elicits pain at the medial epicondyle due to stretching of the flexor tendons.

Instability Tests

1. *Valgus stress test*: keep the elbow in 30° flexion and stabilize the elbow with one hand such that examiners thumb palpates the medial collateral ligament at the medial joint line. Now give a valgus stress with the other hand at the forearm and simultaneously palpate for medial joint opening. The examiner should note the degree of opening, end point of opening (firm/mushy) and whether associated with pain. A positive test indicates tear of the medial collateral ligament.
2. *Moving valgus stress test:* Abduct the arm, flex the elbow to the maximum and with the valgus stress, examiner quickly extends the patient's elbow. Pain between 120° and 70° indicates the positive test and a partial tear of medial collateral ligament. This test can be done in both standing and supine position.
3. *Milking maneuver:* the patient sits with elbow flexed to 90°. The forearm is supinated to maximum. The examiner gives a valgus stress to elbow by pulling on the thumb. Pain indicates a partial tear of the medial collateral ligament.
4. *Varus instability test*: The examiner stabilizes the elbow with one hand and with other hand elbow is flexed to 20–30°, adduction and varus force is applied to the distal forearm to test the lateral collateral ligament. If excessive laxity is present when doing a test, it indicates injury to the ligament. In a normal person, the ligament can be felt as a taut structure.
5. *Posterolateral rotatory apprehension test*: Patient lies supine with the arm to be tested overhead, elbow is supinated and valgus stress is applied while the examiner flexes the elbow. This movement and stress will cause the patient to be

apprehensive that elbow will dislocate while reproducing the patient's symptoms. A positive test indicates posterolateral rotatory instability.

6. *Lateral pivot shift test:* the patient is made to lay supine with the arm abducted overhead, elbow extended and forearm supinated. the examiner now gives a valgus stress along with axial compression while simultaneously flexing the elbow and maintaining supination. This maneuver causes the radial head to sublux posterolaterally forming a dimple between the radial head and the capitellum. At about 40–70° flexion the radial head bounces back with a sudden clunk which can be palpated and also seen in thin patients. This subluxation of radial head and bouncing back represents a positive test indicative of posterolateral instability. This test, like the pivot shift test of the knee, relies on intact medial collateral ligament.
7. *Posterolateral rotary drawer test:* this test also indicates the tear of lateral collateral ligament and shows posterolateral instability of elbow. The patient lays supine with arm abducted overhead and elbow flexed 40–90°. The examiner pushes the radius and ulna posterolaterally to elicit any laxity.
8. *Stand up test:* this is a test for the posterior band of medial collateral ligament. The patient is seated on a chair without side rests, asked to pushup from chair with both forearms supinated.

Neurological Examination

Reflexes and Sensory Dermatomes Three reflexes are usually assessed around the elbow: biceps (C5–6), triceps (C7–8) and brachioradialis (C5–6). The sensory examination should involve the whole upper limb to differentiate any neurological problems arising from the cervical spine from local issues. Elbow also can be a site of referred pain from neck, shoulder or the wrist. Hence any these sites also need to be examined.

Peripheral nerve injuries around elbow The three major peripheral nerves of the upper limb cross the elbow joint and hence are susceptible to injury. Below we describe the main sites of their compression or injury around elbow and the tests to examine their integrity

Median Nerve (C6–8, T1) Median nerve crosses the elbow joint from the front in the cubital fossa, along with the brachial vessels. It can get injured in trauma, systemic disease or compression. One of the common sites of median nerve compression is just above the elbow, when it passes under the *ligament of struthers'*. Ligament of struthers' is an anomalous ligament present in about 1% of population, arising from an abnormal spur on shaft of humerus to the medial epicondyle. This condition is called as *humerus supracondylar process syndrome*. Pressure at this site leads to motor weakness in pronator teres and all the distal muscles supplied by median nerve, along with sensory loss in median nerve distribution of hand.

Another site of median nerve compression is between the heads of the pronator teres muscle, called as the *pronator syndrome*. As median nerve gives branches to pronator teres before entering the muscle, it is spared; other motor and sensory symptoms are similar to the supracondylar process syndrome. Although pronation is present, it becomes weak especially when the elbow is flexed to 90°.

The *anterior interosseous nerve (AIN)* is the terminal branch of median nerve and is pure motor branch. In *kiloh-nevin syndrome/AIN syndrome* the AIN is entrapped between the two heads of the pronator teres muscle, causing palsy of the deep anterior forearm compartment muscles and the characteristic *pinch deformity.* When a pinch is made with the index finger and thumb, it is tip to tip, but in cases of AIN palsy it is pulp to pulp. This happens due to the paralysis of long flexors of index finger and thumb.

Ulnar Nerve (C7–8, T1) Most likely site of ulnar nerve injuy around elbow is the *cubital tunnel* behind the medial epicondyle. In view of peculiar anatomy, the ulnar nerve stretch symptoms are elicited with elbow in flexion. The symptoms will be motor weakness of ulnar half of flexor digitorum profundus, flexor carpi ulnaris, hypothenar eminence, interosseii, medial two lumbricals and adductor policis. Paresthesia is present on medial side of forearm and hand.

Radial Nerve (C5–8, T1) Radial nerve divides into posterior interosseous nerve (PIN) and superficial radial nerve in front of the lateral epicondyle of humerus. The PIN turns backwards around the neck of radius and goes inside the supinator muscle. *Arcade/canal of frohse* is a fibrous band in the supiantor muscle occurring in 30% population and causes compression on the PIN. Another site of PIN compression is inside the supinator muscle known as the *radial tunnel syndrome*, its symptoms mimics the tennis elbow symptoms. PIN compression leads to motor weakness in extensor muscles of forearm causing wrist drop and finger drop, but no sensory deficit as PIN is a pure motor muscle. The superficial radial nerve can also get compressed under the tendon of brachioradialis, the condition is known as *cheiralgia paresthetica or Wartenberg's disease*. Symptoms include nocturnal pain along the dorsum of the wrist, thumb and web space.

Diagnostic Imaging

Plain Radiography

A routine radiographic evaluation of the elbow includes ananteroposterior (AP) and true lateral view [2, 3]. AP view is done with the elbow fully extended and forearm supinated, allowing good visualization of the medial and lateral epicondyles, radio-capitellar joint, and assessment of the carrying angle(normally between 11 and 13° of valgus) [4, 5]. The lateral view is done with the elbow in 90° of flexion and the forearm in neutral (thumb up) position. A true lateral radiograph shows the "teardrop" appearance formed by the thin bone between the coronoid fossa anteriorly and olecranon fossae posteriorly [4]. The ulnotrochlear joint, coronoid process, and olecranon process are well seen in this projection.

Radiographic checklist during examination of the elbow joint
1. Anterior humeral line passes through middle third of capitellum
2. Radiocapitellar line passes through capitellum on every radiographic view
3. Coronoid line should be smooth and concave
4. Check for abnormal fat pads:
• Elevated anterior fat pad or sail sign
• Visible posterior fat pad
• Displaced supinator fat plane
• Olecranon bursa
5. Ossification centers, "*CRITOE*":
Capitellum
Radial head
Internal or medial epicondyle
Trochlea
Olecranon
External or lateral epicondyle

Anteroposterior View Note the relation of epicondyles, trochlea, capitulum, radial head and tuberosity, coronoid and olecranon process. Look for any loose bodies, calcification, myositis ossificans, joint space narrowing or osteophytes. In pediatric patients, look for any abnormalities in the physis and epiphysis. Measure the Baumann's angle [6, 7]. i.e the angle formed between longitudinal axis of the humerus and the line along the lateral condylar physis (humero-capitellar angle).

Lateral View Note the relation of epicondyles, trochlea, capitulum, radial head and tuberosity, coronoid and olecranon process. Look for any loose bodies, calcification, myositis ossificans, joint space narrowing or osteophytes. Look for fat pad sign, which indicates elbow joint effusion due to fracture/inflammatory or infective process.

Axial View It is taken with the elbow flexed to 45°. Olecranon process and epicondyles are seen. It is useful in detecting osteophytes and loose bodies.

CT Scan and MRI

CT has a role in defining and in the management of intraarticular fractures of the elbow. It also helps in detecting undisplaced hair line fractures around the elbow.

MRI helps in detecting tendon ruptures, collateral ligament ruptures, cubital tunnel pathology, epicondylitis and osteochondritis dissecans. It is a non-invasive technique able to discriminate among bone marrow, cartilage, tendons, nerves and vessels without any need of contrast medium.

References

1. Peterson HA. Physeal injuries of the distal humerus. Orthopedics. 1992;15(7):799–808.
2. Miller TT. Imaging of elbow disorders. Orthop Clin N Am. 1999;30(1):21–36.
3. Potter HG. Imaging of posttraumatic and soft tissue dysfunction of the elbow. Clin Orthop Relat Res. 2000;370:9–18.
4. Sofka CM, Potter HG. Imaging of elbow injuries in the child and adult athlete. Radiol Clin N Am. 2002;40(2):251–65.
5. Cain EL Jr, Dugas JR, Wolf RS, Andrews JR. Elbow injuries in throwing athletes: a current concepts review. Am J Sports Med. 2003;31(4):621–35.
6. Camp J, Ishizue K, Gomez M, Gelberman R, Akeson W. Alteration of Baumann's angle by humeral position: implications for treatment of supracondylar humerus fractures. J Pediatr Orthop. 1993;13(4):521–5.
7. Omid R, Choi PD, Skaggs DL. Supracondylar humeral fractures in children. J Bone Joint Surg Am. 2008;90(5):1121–32.

Examination of the Wrist and Hand

Vishal Kumar and Avinash Kumar

Examination of the wrist Attitude: Look for the following attitudes:

- Palmarflexion of the wrist (wrist drop—specifically used for high radial nerve palsy)—radial nerve palsy, brachial palsy, Volkmann's ischemic contracture, infections around the wrist.
- Ulnar deviation of the wrist—Rheumatoid arthritis, congenital absence of the ulna (or any pathology causing loss of distal ulna: osteomyelitis, neglected trauma)
- Radial deviation of the wrist—Colles' fracture, congenital absence of radius
- Dinner fork deformity—Colles' fracture
- Manus valgus—Madelung deformity

Inspection: The things which you should note while inspecting wrist from different aspects are -

- *Dorsum*:
  – *Swelling*—Localized swelling is generally noted in cases like ganglion, rheumatoid nodule, tumour, tuberculosis, abscess or trauma. Dorsal ganglions become more prominent on palmarflexing the wrist. Small ganglions in radiocarpal area frequently present with vague wrist pain which can be seen better on palmarflexion of the wrist. *In the wrist and hand, joint effusion and synovial thickening is more marked on dorsal and radial aspects.* Generalized swelling can be seen in Sudeck's dystrophy with shiny skin, diffuse tenderness, pain and stiffness of the wrist and hand.

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  - *Skin*—any presence of erythema (trauma, Sudeck's dystrophy), vasomotor changes (Sudeck's dystrophy, nerve injuries), lacerations (may indicate some tendon injury), abrasions. Transverse lacerations at the level of wrist should increase your suspicion of extensor tendon injuries. The nature of the wound should be examined; whether they are red (fresh) or pale (old); whether the scar has healed or healing. If healed, is it normal, hypertrophic or keloid?
- *Volar*:
  - *Swelling*—localized swelling denotes ganglion, rheumatoid nodule, cyst, tumor, tuberculosis, abscess or trauma. If the swelling of the wrist is in continuation with that of the palm, it could be compound palmar ganglion seen in rheumatoid arthritis and also tuberculosis.
  - *Skin*—similarly skin should be looked for its colour, texture and vasomotor changes and scars.
  - Wasting of the thenar and hypothenar eminences should be looked for nerve palsies or neurological conditions like cervical spine pathologies or multiple sclerosis. Additionally wasting of the forearm should also be looked at.
- *Side*:
  - Look for any anterior or posterior subluxation of the wrist
  - Swelling—can be seen in cases of abscess or De Quervain's tenosynovitis.

Palpation:

- *Skin*—look for rise in temperature indicating infection. It can also be seen in Sudeck's dystrophy.
- *Fluctuation*—fluctuation of the swelling will give an idea of the cystic nature of the swelling. *Cross fluctuation should be elicited if swelling is present both in the wrist and palm suspecting compound palmar ganglion.*
- *Tenderness*:
  - *Diffuse*—diffuse tenderness is elicited in inflammatory pathologies like tuberculosis, rheumatoid arthritis, Sudeck's dystrophy.
  - *Anatomical snuff box*—seen classically in scaphoid fractures, also in wrist sprains, basilar joint arthritis/ instability. *Basilar joint is palpable distal to the pulsating dorsal branch of radial artery radial in the anatomical snuff box. It can be palpated after trading distal to proximal the first metacarpal and the first dip is the basilar joint in extended thumb. Trapezium can also be palpated. Basilar joint can also be palpated volarly just distal to scaphoid tubercle where trapezium is present.*
  - *Scaphoid tubercle*—tenderness at scaphoid tubercle palpable on volar aspect in a radially deviated wrist is more specific for scaphoid fractures or scapholunate instability. *The longitudinal axis of scaphoid becomes anteroposterior perpendicular to other carpal bones in a radially deviated wrist.*
  - *Dorsal surface of scaphoid*—presence of tenderness here is usually present in fractures not in sprains helping in distinguishing fractures from sprains.
  - *Scaphotrapeziotrapezoid (STT) joint*—it is palpable dorsally just ulnar to the junction of scaphoid and trapezium. Tenderness here indicates STT arthritis.

- *Dorsolateral border of distal forearm*—tenderness localized to the sheaths of abductor pollicis longus and extensor pollicis brevis indicate DeQuervain's tenosynovitis. Tendon sheath thickening can also be palpated over dorsolateral border of the radius in DeQuervain's tenosynovitis. Crepitus over the tendon sheaths can also be elicited.
- Tenderness in scapholunate joint can be elicited by slightly flexing the wrist and palpating a depression just distal to lister tubercle—seen in radioscaphoid arthritis.
- Tenderness for TFCC can be palpated just distal to ulnar styloid prominence.
- Distal to ulnar styloid dorsally in line with middle of ulnar head a depression corresponds to lunotriquetral joint and tenderness here indicates lunotriquetral arthritis or instability. *Further distally is triquetrum and more distally is dorsum of hamate and then carpometacarpal joint of fourth and fifth fingers.*
- *Ulnar snuff box*—tenderness located ulnopalmar to ECU tendon, between the triquetrum and ulna head, also called as "*ulnar fovea sign*", is seen in foveal disruption of TFCC (95% sensitive, 86.5% specific). It may also be seen in inflammatory synovitis of prestyloid recess or pathologies of meniscus homologue or ulnotriquetral ligament or lunotriquetral ligament.
- Pisiform can be palpated for any tenderness at the ulnar border at distal flexor crease or by tracing the flexor carpi ulnaris tendon.
- Distal and radial to the pisiform in line with the ring finger the bony prominence is the hook of hamate which should be looked for any tenderness.
- Ulnocarpal abutment syndrome—tenderness may be elicited at the proximal ulnar corner of lunate, distal surface of ulnar head and/or the proximal tip of the hamate.

Movements:

- *Dorsiflexion*—patient is asked to join his palms vertically with fingers pointing upwards like "*Namaste*" while raising the elbows to be horizontal. It is decreased in post colles' fracture or dorsal barton fracture. For objective measurement, goniometer can be used with the hinge at just distal to ulnar styloid. *Normally dorsiflexion of the wrist is 70–90°.*
- *Palmarflexion*—patient is asked to join his dorsum of the hands vertically with fingers pointing downwards bringing the forearms horizontal. For objective measurement, goniometer can be used with the hinge at just distal to ulnar styloid. *Normally palmarflexion of the wrist is 70–90°.*
- *Pronation*—ask the patient to hold a stick/pencil/pen in each hand making a fist and to pronate the wrist with both the elbows firmly by the sides. Measure the angle using a goniometer between the vertical line and the axis of the stick/pencil/pen. *Normally pronation of the wrist is 80–90°.*
- *Supination*—in a similar position, ask the patient to pronate and measure the angle. *Normally supination of the wrist is 80–90°.*

- *Radial deviation*—it is measured the angle between the axis of the middle metacarpal and that of the forearm with wrist radially deviated. *Normally radial deviation of the wrist is 15–20°.*
- *Ulnar deviation*—it is measured similarly with wrist ulnarly deviated.*normally ulnar deviation is 30–40°.*

Carpal tunnel syndrome:

- Wasting of the thenar muscles can be seen; of the muscles supplied by median nerve.
- *Phalen test*—acute flexion of the wrist for 60 s can produce paraesthesia in the median nerve supplied area of the hand. *Both the wrists should be exmined separately and using both together by joining the dorsum of the hands is not a good method.* Flexion of the wrist should be gravity assisted for better results.
- *Durkan compression test*—direct compression over the median nerve (which is present between the tendons of Palmaris longus and flexor carpi radialis or beneath the tendon of Palmaris longus at distal wrist flexion crease; in case of absent Palmaris longus, it can be located medial to the tendon of FCR) for 30 s with both of the thumbs or the bulb of the manometer will produce the symptoms of parasesthesia, numbness in the distribution of the median nerve which is lateral two thirds of the palm of the hand. *This test is most specific (90%) and sensitive (87%) test among other physical tests for carpal tunnel syndrome.*
- *Tinel sign*—extend the wrist and tap over the course of the median nerve *proximal to distal direction starting from the distal flexion crease at the wrist to 2–3 cm between the thenar and hypothenar eminences.* There is feeling of tingling, numbness and parasesthesia distal to the site of percussion in the distribution of median nerve.
- *Reverse phalen test (Prayer test)*—extending the wrist for 1 min may also produce symptoms of the CTS but the increase in pressure in the carpal tunnel is not so significant.
- *Moberg's two point discrimination test*—two point discriminator or paper clip or calipers are put over the two points in a longitudinal direction perpendicular to long axis of the finger from proximal to distal direction and the minimum distance at which the patient can recognize two points is determined. Normally it should be less than 6 mm.
- *Dellon's moving two point discrimination*—it is done similarly but the both the points are moved relative to each other. Normal discrimination distance recognition is 2–5 mm (slightly less than the static method).
- Extending the transverse carpal ligament using both the thumbs may also produce the symptoms of CTS. Extending and abducting the thumb may also produce the symptoms.
- *Square wrist sign*—the ratio of wrist thickness to the wrist width less than 0.7 is suggestive of CTS.
- Other less reliable tests are *flick maneuver* (flicking motion of the wrist and fingers as shaking off the thermometer), *closed fist sign* may also produce symptoms of CTS.

- Pressure of the carpal tunnel can also be increased by a blood pressure cuff inflating just above the systolic blood pressure of the patient for 1–2 min to reproduce the symptoms.
- Motor and sensory examination for the median nerve is also important in a case of CTS.

Distal Radioulnar Joint and TFCC Pathologies

- *Distal ulna ballottment test/DRUJ instability test/DRUJ shuck test*—one hand of the examiner stabilizes the ulna and using other hand he /she translates the radius and the carpus dorsally and volarly in neutral rotation and maximal supinated and pronated position. Upto 5 mm of translation is possible in neutral rotation but there should be no translation in extreme pronated and supinated position and also in the radially deviated position of the wrist owing to tightness of ulnocarpal ligament and ECU tendon.
- *Piano key sign*—patient's forearm is kept in pronation over a table and the distal ulnar head is pushed volarly by the examiner's finger and is released; the springing back of the distal ulna is suggestive of DRUJ instability. The movement of the distal ulna should be compared with the contralateral side if possible.
- *Table top test/dimple sign*—the patient is asked to press the table top with the pronated palm of the hand; there is undue prominence of the ulnar head and it displaces volarly forming a dimple on the dorsal surface. It is characteristic finding in the multidirectional instabilities of DRUJ.
- *Grind test*—it is eliciting pain by compressing the distal ulna and radius producing grinding motion, suggesting DRUJ arthrosis.
- *Supination Lift Test*—patient is seated with elbows flexed 90° and forearms supinated and is asked to lift the undersurface of the table, the patient has localized ulnar sided pain indicating dorsal TFCC tear.
- *Ulnar fovea sign*—as mentioned above
- *TFCC load/grind test*—examiner holds the wrist with one hand and the forearm with the another hand. The wrist is then axially loaded and is ulnarly deviated and moved from supination to pronation. Ulnar sided pain in area of TFCC / painful click in this rotation but not in neutral position or radial deviation indicates TFCC tear.
- *TFCC shear test (pisiform boost test/ulno-menisco-triquetral dorsal glide test)*—with one thumb of the examiner pisiform is pushed dorsally while the examiner's other thumb pushes the distal ulna volarly. Pain in this maneuver indicates pathology of meniscus homologue and TFCC. It can also be positive in ulnocarpal instability.
- *Press test*—patient lifts off from the chair using the hand over the arm of the chair pressing the wrist, the patient feels ulnar sided pain.
- *Waiter's test/ulnocarpal meniscoid test*—wrist is passively brought from extension to ulnar deviation and then to flexion while applying axial load to the ulnar carpus. Pain more so in supination indicates with the TFCC lesion.

Carpal Instability

- *Scapholunate Instability*
  - *Kirk-Watson test*—with the patient's elbow resting over the table, examiner holds the patient's wrist into full ulnar deviation and slight extension while holding the metacarpals while the thumb of his other hand presses the distal pole of the scaphoid palmarly. The wrist is then radially deviated and slightly palmarflexed while the thumb of the examiner presses the distal pole of scaphoid. A click is felt as scaphoid subluxes over distal radius and it returns back after releasing the pressure of the examiner's thumb. Also the patient should have pain both where the examiner is pressing and at the back of the wrist.
  - *Scapholunate ballottment*—the lunate is held with the thumb and index finger of one hand and the scaphoid is held with the thumb and index finger of the other hand. The scaphoid is pushed from volar to dorsal direction and positive ballottment indicates scapholunate injury.
- *Lunotriquetral instability*
  - Tenderness can be elicited at the lunotriquetral joint
  - *Reagan's test/Lunotriquetral Ballottment test*—in a pronated and slightly flexed wrist, after grasping lunate with one hand and triquetrum with the another, both the bones are displaced relative to each other (triquetrum is pushed in volar to dorsal direction), laxity/pain/crepitus indicates lunotriquetral laxity.
  - *Kleinman lunotriquetral shear/shuck test*—the thumb of examiner's one hand is kept over the pisiform palmarly while the fingers of the other hand rests over the dorsum of the proximal carpal row supporting the lunate and the thumb over the palm. With one thumb pisiform (which is directly palmar to triquetrum) is pushed dorsally and simultaneously with the other hand lunate is pushed palmarly applying a shear force across the lunotriquetral joint resulting in crepitation and pain. *This is the most sensitive test to diagnose lunotriquetral dislocation/injury.*
  - *Ulnar snuffbox compression test*—pain produced on radial pressure in the sulcus between ECU tendon and FCU tendon indicates lunotriquetral injury or triquetral chondromalacia.
  - *Murphy's sign*—ask the patient to make a fist and look for the knuckles/heads of the metacarpals. If the head of third metacarpal is at the level of that of second and the fourth, the sign is positive indicating lunate dislocation.
- *Midcarpal instability*
  - *Midcarpal shift test*—pressure is applied to the dorsum of the capitate as the wrist is moved from the radial to ulnar deviation. A clunk is felt as the lunate reduces from the palmarflexed position.
  - *Lichtman test*—patient's forearm is pronated. Distal forearm is held in one hand while the other hand holds the hand and is moved from radial to ulnar deviation while axially compressing the carpus to the radius. Clunk (jumping of the distal carpal row dorsally) and pain is indicative of midcarpal instability.

Dequervain's Tenosynovitis

- *Finkelstein's Test*—Patient makes a fist with thumb inside the fingers. Examiner stabilizes the forearm and deviates the wrist to the ulnar side; excruciating pain over the tendons of abductor pollicis longus and extensor pollicis brevis indicate the disease.

Differential diagnosis of wrist pain

Radial sided pain	Dorsal/central pain	Ulnar sided pain
• Scaphoid fracture	• Scapholunate advanced collapse (SLAC) wrist	• ECU tendinitis
• Scaphoid nonunion	• Scapholunate instability	• ECU subluxation
• Dequervain's tenosynovitis	• Keinbock's disease	• TFCC tear
• Basilar joint (trapeziometacarpal) arthritis	• Ganglion	• Lunotriquetral instability
• Basilar joint instability		• Triquetral avulsion fracture
• Scaphotrapeziotrapezoid (STT) arthritis		• Pisiform fracture
		• Hook of hamate fracture/nonunion
		• Ulnar impaction/abutment syndrome
		• DRUJ arthritis
		• Pisotriquetral arthritis

Examination of the Hand

Attitude: Look for these attitudes of the hand

- Flexion of the distal interphalangeal joint, extension of the proximal interphalangeal joint and flexion of metacarpophalangeal joint—swan neck deformity—seen in rheumatoid arthritis, mallet finger.
- Extension of the distal interphalangeal joint and flexion of the proximal interphalangeal joint and extension of metacarpophalangeal joint—boutonniere deformity—also seen in rheumatoid arthritis
- Flexion of the metacarpophalangeal joint and the proximal interphalangeal joint—Dupuytren's contracture, also associated with nodular thickening over the palm and fingers. In boutonniere deformity the metacarpophalangeal joint is extended.
- Flexion of the proximal and distal interphalangeal joints and extension of the metacarpophalangeal joint—claw hand—seen in leprosy, ulnar plus median nerve injury, Volkmann's ischemic contracture.

- *Ape thumb deformity*—wasting of the thenar eminence with the thumb falling back in the line with the other fingers—median nerve injury.
- *Bishop's hand/benediction hand deformity*—flexion of fourth and fifth fingers with hypothenar eminence wasting—seen in ulnar nerve injury.
- *Z deformity of the thumb*—the thumb is flexed at the metacarpophalangeal joint and hyperextended at the interphalangeal joint. It is seen in rheumatoid arthritis due to displacement of the extensor tendons or flexor pollicis longus.
- Flexion of the little finger, specially at the proximal interphalangeal joint—seen in congenital contracture of the little finger.
- Ulnar deviation at the metacarpophalangeal joints—seen in rheumatoid arthritis
- Flexion at the metacarpophalangeal joints with intact extension at the interphalangeal joints can be seein in extensor tendon injuries or in rheumatoid arthritis in which there is progressive rupture of extensor digitorum communis starting from that of little finger and progessing radially (known as *Vaughan Jackson lesion). Extension at interphalangeal joints are maintained by the intrinsic muscles.*
- Hyperextention of the finger—tendon injury of both the flexor tendons of the finger
- Hyperextension of DIP joint—flexor digitorum profundus avulsion or injury as in *jersey finger most commonly in the ring finger.*

Inspection:

- Look for the size and shape of the hand and fingers in comparison to the rest of the body of the patient:
  - short and stumpy fingers are seen in achondroplasia,
  - large and coarse hand in acromegaly,
  - proximal phalanges are long and thin in Marfan syndrome
  - 4^{th} finger is short in Turner syndrome
  - Short and bulbous fingertips are seen in hyperthyroidism
  - Little fingers are curved inwards in Down's syndrome and Hurler's syndrome.
  - Hypertrophied fingers are seen in Paget's disease, neurofibromatosis and local arteriovenous fistula.
- Swelling—localized discrete swellings can be
  - Seen in ganglions
  - Heberden's nodes (seen on dorsal aspect of distal interphalangeal joints),
  - Bouchard's nodes (seen on the dorsal aspect of proximal interphalangeal joint). *The last two are commonly seen in osteoarthritis and gastrectasis.*
  - Rheumatoid nodules over the knuckles or dorsum of PIP joint.
  - Fusiform swelling can be seen in collateral ligament injury at the interphalangeal joint or rheumatoid arthritis.
  - Nodular swellings are seen in Dupuytren's contracture. Nodular swelling in the line of ring and little finger is the early sign.
  - Single or multiple hard swelling on the fingers can be enchondromatosis.

- *Carpal bossing*—benign bony prominences over the dorsum of proximal ends of second and third metacarpals.
- swelling at the fingertip may be due to felon, herpes, epidermal inclusion cyst (nodular)

- There can be generalized swelling in cases of abscee in the synovial spaces of the palm or in compound palmar ganglion. Fluctuation in such cases should be elicited.
- Fingernails should be examined meticulously for the shape, deformity, nail plate, nail fold, disturbance of growth.
- The skin of the hand should be looked for any vasomotor changes, trophic ulcerations, erythema, lacerations.

Palpation:

- *Skin*—the local temperature should be checked. The skin should also be checked whether it is adherent to underlying fascia (as in Dupuytren's contracture). Fluctuations in case of swelling should be looked for.
- *Tenderness*—it should be looked for at the joints.
  - In trigger finger, a nodular swelling can be palpated at the metacarpophalangeal joint palmarly which is generally the thickening of the flexor tendon sheath at the flexor pulley. When the patient (adults) attempts to flex the finger, the tendon adheres and the finger is let go off with a click which can be palpated too.
  - Similar nodular swelling at metacarpophalangeal joint of the thumb can be palpated in infants and young children which is congenital trigger thumb due to involvement of flexor pollicis longus.
- The joints should be palpated for any step off or undue prominences as seen in mertacarpophalangeal joint dislocations or interphalangeal joint dislocations.

Movements:

- *Flexion of the fingers*—normally flexion of the finger involves first the flexion of the metacarpophalangeal joint (85–90°) followed by proximal interphalangeal joint (100–115°) and then that of distal interphalangeal joint (80–90°). *normally the finger tips should be tuck in inside the palm at the level of distal palmar crease*. If flexion of any one finger is restricted, the "tuck in" is prevented. Objectively this can be measured by the distance between the fingertips and the distal palmar crease.
- Extension at metacarpophalangeal joint is upto 30–45°, at proximal interphalangeal joint is 0° while at the distal interphalangeal joint is upto 20°.
- *Finger abduction* occurs at metacarpophalangeal joints upto 20–30°.
- *Finger adduction* also occurs at metacarpophalangeal joint and is 5–10°.
- Loss of flexion of the metacarpophalangeal joints can be seen in rheumatoid arthritis where there is progressive rupture of flexor tendons starting from the flexor pollicis longus and progressing ulnarward (*known as Mannifelt lesion*).

- *Bunnell-Littler test (Finochietto–Bunnell test)*—Loss of flexion at interphalangeal joint can be due to extensor tendon contractures (post traumatic) or intrinsic muscle contracture or due to joint capsule contracture. To differentiate the causes of this intrinsic tightness, this test is performed. The metacarpophalangeal joint is stabilized in extension and the proximal interphalangeal joint is tried to flex and the degree of flexion is noted. Then the metacarpophalangeal joint is flexed and again the degree of flexion of proximal interphalangeal joint is noted.

If the PIP flexion is increased, the pathology is intrinsic muscle contracture as the intrinsic get released on MCP flexion, if the PIP flexion is the same in both situations the pathology is joint capsule contracture while if the PIP flexion is decreased the pathology is extensor tendon contracture which is stretched further on MCP flexion.

- *Thumb flexion*—it occurs at interphalangeal joint (80–90°), metacarpophalangeal joint (20–90°) and carpometacarpal joint (45–50°). Ask the patient to bend the thumb across the palm as far as possible from the neutral position (point at which the dorsum of distal phalanx, proximal phalanx and first metacarpal form a straight line). Flexion is associated with the medial rotation of the thumb owing to saddle shape of carpometacarpal joint. Objectively it can measured using a goniometer between the axes of the index finger and the thumb with the hinge at the junction of these two axes. *Normally it is difficult to measure and is 80–90°.*
- *Extension of the thumb*—ask the patient to extend the thumb in the plane of the palm as far as possible as if hitchhiking. There is hyperextension upto 10° at both interphalangeal and metacarpophalangeal joints. This is associated with lateral rotation of the thumb. Objectively the extension can be measured using a goniometer with the hinge at the junction of axes of the thumb and the index finger and measuring the angle between the two axes. *Normally it is 70–80°.*
- *Thumb abduction*—Ask the patient to bring the thumb perpendicular to the plane of the palm as far from palm and the rest of hand in a supinated forearm and elbow in 90° flexion. *Abduction generally occurs at basilar joint or trapezio-metacarpal joint. Normally it is 60–80°.*
- *Thumb adduction*—Ask the patient to bring back the thumb to the palm in fully supinated forearm close to the index finger.
- *Opposition of the thumb*—it consists of thumb abduction, flexion of metacarpophalangeal joint, medial rotation (pronation) of thumb, radial deviation of proximal phalanx of thumb over metacarpal and motion of thumb towards the fingers. Ask the patient to touch the little finger or ring finger with the tip of the thumb. Patient should touch the tip of finger with both the fingernails parallel to each other. Though it is assessed qualitatively, it can be measured quantitatively by the distance between the thumb tip and the tip of little finger or metacarpophalangeal joint of little finger.

Ligamentous Injuries

- *Thumb Ulnar Collateral Ligament Laxity Test*—Stabilize the hand of the patient with one hand and with another hand extend the thumb of the patient; in extention give a valgus stress to the metacarpophalangeal joint of the thumb. If the valgus movement is more than 30–35°, it indicates complete tear of ulnar collateral ligament and accessory collateral ligament. If less than 30° valgus movement is there but more than the normal 15°, it indicates partial tear/laxity. For testing isolated ulnar collateral ligament laxity (*skier's or gamekeeper's thumb)*, 1st carpometacarpal joint is flexed to 30° and then valgus stress is applied at the metacarpophalangeal joint.
- *Haines–Zancolli Test*—This test is for tight retinacular (collateral) ligaments of PIP joints. The PIP joint is held in neutral position and then the DIP joint is flexed which is unable to be flexed until the PIP joint is flexed after which the DIP joint can be easily flexed.
- *Test for ulnar collateral ligament of metacarpophalangeal joint*—This ligament is relaxed in extension of MCP joint and is taut in flexion of MCP joint. Hold the pxoximal phalanx of two adjacent fingers with examiner's two hands and flex the MCP joint to 90°. Then separate both the fingers, normally there is little separation. If it is more than 15–20°, there is injury to the ligament and if the angle between the two fingers is more than 35°, there is complete rupture of ulnar collateral ligament.
- *Test for collateral ligament of interphalangeal joint*—the adjacent phalanges of the tested joint is stabilized by the examiners between his fingers and the joint is flexed for 30° and then the joint is tried to open up by deviating the distal stabilized phalanx towards the thumb, opening of more than 20° indicates the rupture of the ligament. More than 30° indicates complete rupture.

Tendon injuries

- Inspect the wounds present—whether they are fresh or old; whether they are transverse or longitudinal; what is the location of the wound—transverse laceration over phalanges (most likely flexor profundus), transverse wound on the radial/ulnar border of phalanx (flexor digitorum superficialis), if at distal transverse crease of palm (flexor digitorum superficialis/flexor profundus according to the depth of the wound superficial/deep)
- If both the flexor tendons are severed, the finger is in hyperextended attitude.
- On wrist flexion there is greater unopposed extension of the finger as normal tenodesis effect is lost.
- Gentle compression of the forearm muscles show concomitant flexion of the joints of uninvolved fingers but not of the injured finger.
- *Test for flexor digitoum profundus*—stabilize the PIP joint with examiner's fingers, support the middle phalanx too with the finger and then ask the patient to flex the DIP, he will be unable to do so in case of FDP injury.

- *Test for injury to both flexor digitorum superficialis and flexor digitorum profundus*—stabilize the metacarpophalangeal joint and ask the patient to flex the PIP and DIP joint, if both the joints cannot be flexed, both the tendons have been injured.
- *Test for isolated flexor digitotum superficialis injury*—hold all the fingers except the affected one in extension, which can be done by keeping the examiners fingers on the distal halanges of all the fingers (to neutralize the action of FDP on the PIP joint of the affected finger) and then asking the patient to flex the PIP joint of the affected finger; he will be unable to flex PIP joint in case of FDS injury.
- *Test for the isolated flexor digitorum superficialis tendon of the index finger*—the FDP of the index finger has an isolated action. For this the patient is requested to pinch and pull a sheet of paper with each hand using his index finger and the thumb. In normal hand, he will do so by relaxing FDP and using FDS resulting into hyperextension at DIP joint so that there is maximal pulp contact with the paper. In case of FDS injury, the DIP joint hyperflexes and the PIP joint is in extended position.
- *Test for flexor pollicis longus*—stabilize the metacarpophalangeal joint of the thumb and ask the patient to flex the interphalangeal joint; in case of injury he will be unable to do so.
- *Test for extensor digitorum communis*—on asking the patient to extend the fingers, the affected finger lags behind.
  - To assess the distal slips of the tendon, stabilize the middle phalanx and then ask the patient to extend the DIP joint, he will be unable to extend DIP joint.
  - To assess the middle slip, *Elson test* is performed, where the PIP joint is flexed to 90° at the edge of table and the patient is asked to extend the PIP joint, with a resistance from the examiner over the middle phalanx, normally PIP joint will be extended and DIP joint will be flail, but in case of middle slip injury, PIP joint will not be extended and DIP joint will be hyperextended and stiff.
  - *Boye's Test*—If the PIP joint is held passively extended, it is then possible for the normal individual to flex the terminal interphalangeal joint in isolation. However, if the central slip has been ruptured, there is increasing difficulty in performing this action. This test only becomes positive when the proximal part of the ruptured central slip has retracted and become adherent to the surrounding tissues.

Test of circulation of hand

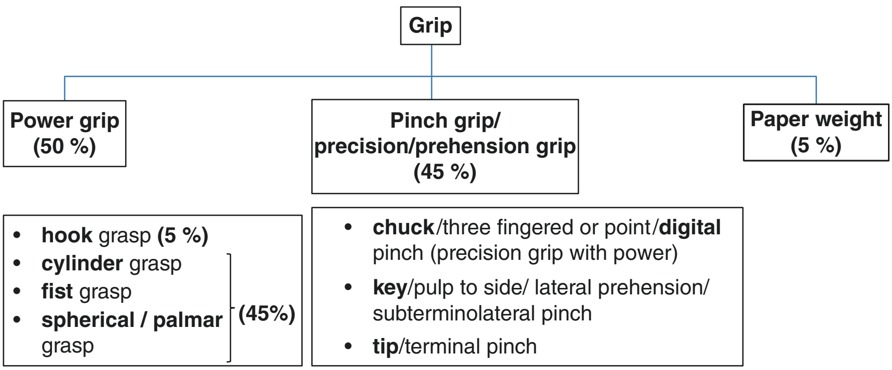
- *Capillary refilling*—note the color of the nailbed of the finger which should be healthy pink in color. Then compress the fingertip of the patient to empty most of the blood from the capillaries and then suddenly uncover the nailbed. The banched color of the nailbed should return to normal within 2 or 3 s.
- *Allen's test*—the elbow is kept flexed and the forearm is supinated. Examiner places his thumb over the patient's radial and ulnar arteries and ask the patient to clench his hand for successive three times. Then ask him to extend the fingers,

the hand shoulb be blanched, then the thumb over the radial artery is released and the return of skin color is noted which normally is within 3 s. This is again repeated with the release of ulnar artery next time. This also gives relative contribution of both the arteries to the circulation of the hand.

Infections

- Aggravation of pain at the end of nail may indicate paronychia
- Pain at the apex of the nail bed may be seen in apical infection or subungual exostoses
- Tender erythematous finger pulp may indicate pulp infection
- Fusiform swelling of the finger in a flexed attitude may indicate tendon sheath infection. *The four cardinal signs of Kanavel for flexor tendon sheath infection are fusiform swelling, tender volar surface of the finger, slightly flexed attitude of the finger and exacerbation of pain on passive extension of the finger.*
- Swelling of the dorsum of the hand and the web space with widely separated fingers indicate web space infection

Grips



Dorsal Spine Clinical Examination

S. S. Dhatt, S. Siva Swaminathan, Karthick S. R, and K. Pattabiraman

Clinical Anatomy

The thoracic spine is the most rigid part of the vertebral column because of the associated rib cage which in turn protects the heart and lungs. The thoracic spine, being one of the primary curves, exhibit a mild kyphosis (posterior curvature), the cervical and lumbar spine, being secondary curves, exhibit a slight lordosis (anterior curvature) (Figs. 1 and 2).

Thoracic pain can be difficult to diagnose. The most commonly involved area is the thoracolumbar junction. Pain can be from referred from chest or abdominal cavities or can be of muskuloskeletal in origin. Sudden onset pain in the thoracic spine is less common than mobile cervical and lumbar spine.

There are 12 vertebrae in the dorsal spine which diminish in size from T1 to T3 and then increases progressively in size till T12. These vertebrae are unique in having facets on the body and transverse process for articulation with the ribs. The spinous process of these vertebrae face obliquely downwards.

The *costovertebral joints* (Fig. 3) are the joints between the ribs and the vertebral bodies. There are 24 of these synovial joints in the dorsal spine. The *radiate ligament*, which joins the anterior aspect of the head of the rib radiating to the sides of the vertebral body and disc is the main ligament of these joints.

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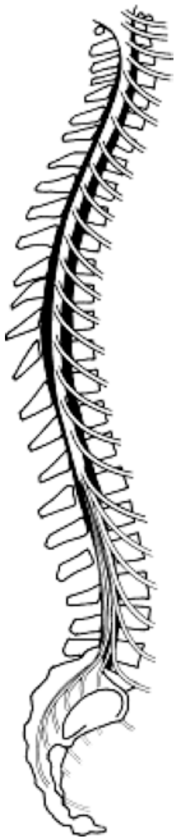


Fig. 1 Primary and secondary curves in the spine

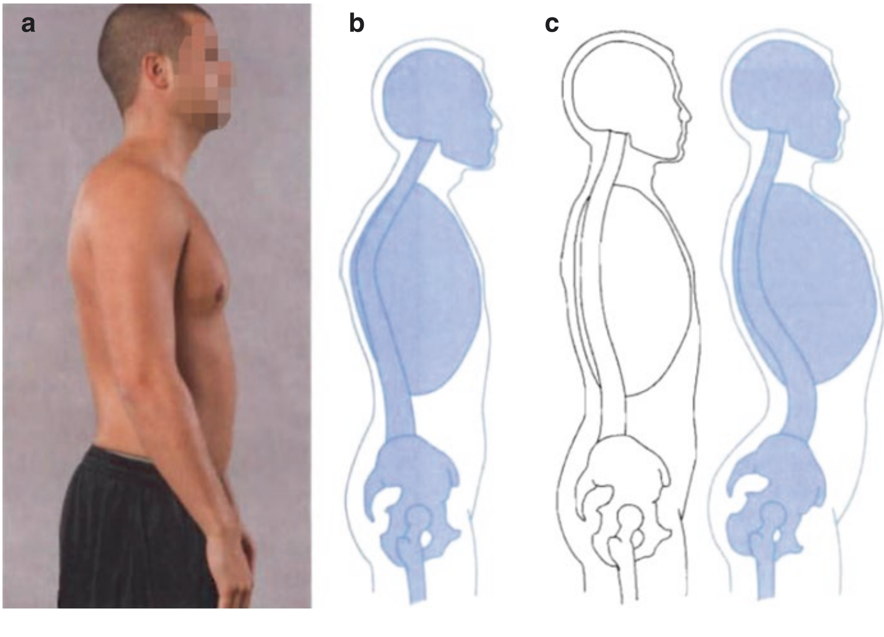


Fig. 2 (**a**) Normal curvature, (**b**) Kyphosis and (**c**) Lordosis

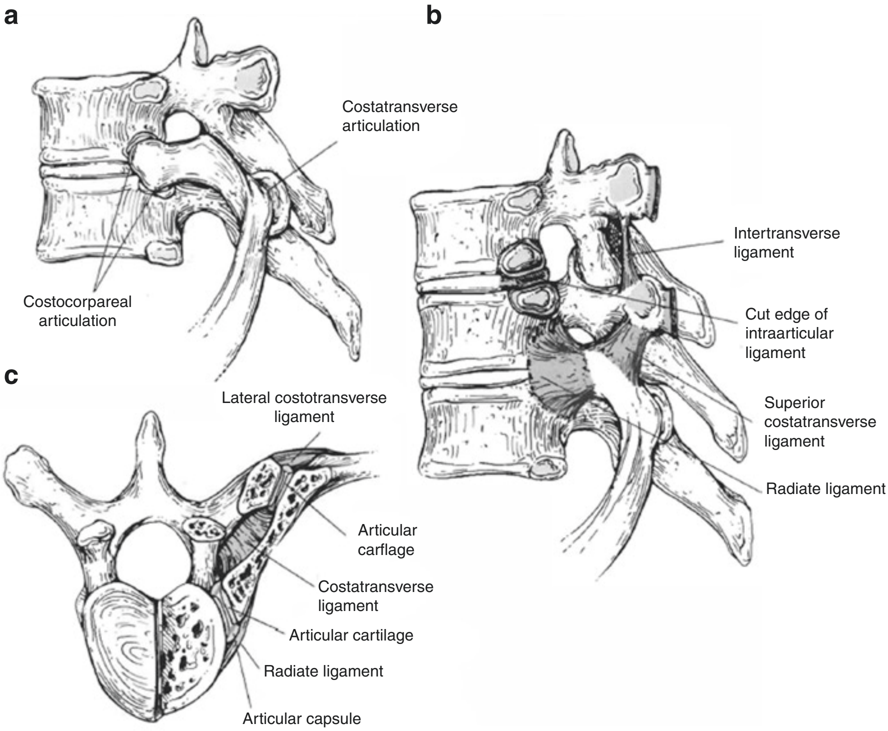


Fig. 3 Costovertebral articulations (from Cramer GD, Darby SA: Basic and clinical anatomy of spine, spinal cord and ANS. St. Louis, Mosby 1995)

Costotransverse joints are synovial joints between the ribs and the transverse processes of vertebrae. There are 10 costotransverse joints in the dorsal spine, the 11th and 12th rib being devoid of these joints since they do not articulate with transverse processes.

Costochondral joints lie between the ribs and costal cartilage. *Sternocostal joints* are found between sternum and costal cartilage. The facet or apophyseal joints are the main tri-joint complex along with the disc between the vertebrae. The superior facet of T1 is very much similar to that of a cervical vertebra. This is one another reason for naming T1 as a transitional vertebra.

The ribs, which help to stiffen the thoracic spine, articulate with the demifacets on vertebrae T2–T9. For T1 and T10, there is a whole facet for ribs 1 and 10, respectively. The first rib articulates with T1 only, the second rib articulates with Tl and T2, the third rib articulates with T2 and T3, and so on. Ribs 1–7 articulate with the sternum directly and are classified as *true ribs*. Ribs 8 through 10 join directly with the costal cartilage of the rib above and are classified as *false ribs*. Ribs 11 and 12 are classified as *floating ribs* because they do not attach to either the sternum or the costal cartilage at their distal ends. Ribs 11 and 12 articulate only with the bodies of the T11and Tl2 vertebrae, not with the transverse processes of the vertebrae nor with the costocartilage of the rib above (Fig. 4).

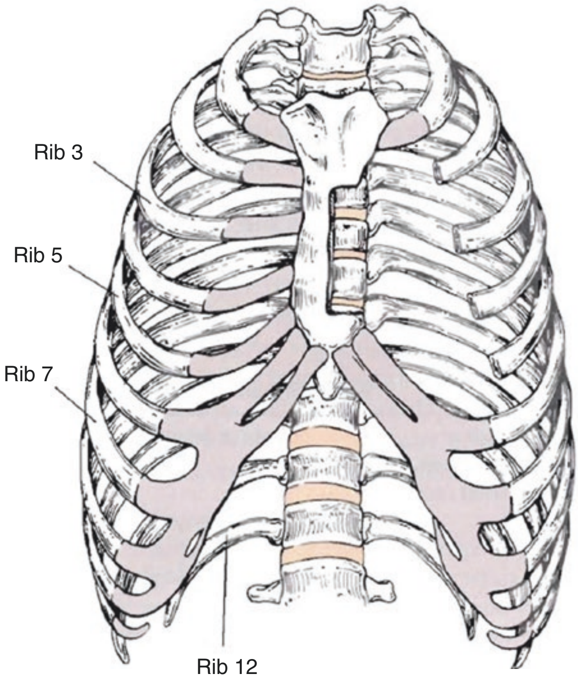


Fig. 4 Anterior view of the thoracic spine with rib cage

Clinical Examination

Inspection

The patient should be suitably undressed so that the body is exposed as much as possible. The patient is usually observed first standing and then sitting. Look at the spine from back and from side, and assess the thoracic curvature with the normal kyphosis.

It is important to observe total body posture from the head to toe and look for signs of trauma, blisters, scars, sinuses, skin discoloration (port wine patches, naevi), erythema, contusions, swelling, hairy patches, café-au-lait spots, fat pads, and other marks.

Posteriorly, the medial edge of the spine of the scapula should be level with the T3 spinous process, whereas the inferior angle of the scapula is level with the T7–T9 spinous process. The medial border of the scapula is parallel to the spine and approximately 5 cm lateral to the spinous processes.

Scoliosis

Scoliosis is deviation of spine in the coronal plane with concomitant rotation of the vertebrae in view of the buckling spinal columns (Fig. 5).

The examiner should note the following points while examining a patient with scoliosis:

- Facial asymmetry
- Evaluation of shoulder heights. The level should be placed across the shoulder at the top of the scapula. In the thoracic curves the shoulder is elevated on the convex side and in the lumbar curves the shoulder is elevated on the concave side (Fig. 6)
- The plumb line is measured by hanging a weight on a string from the C7 spinous process. It is a measure of balance of the curve.This line should pass through the

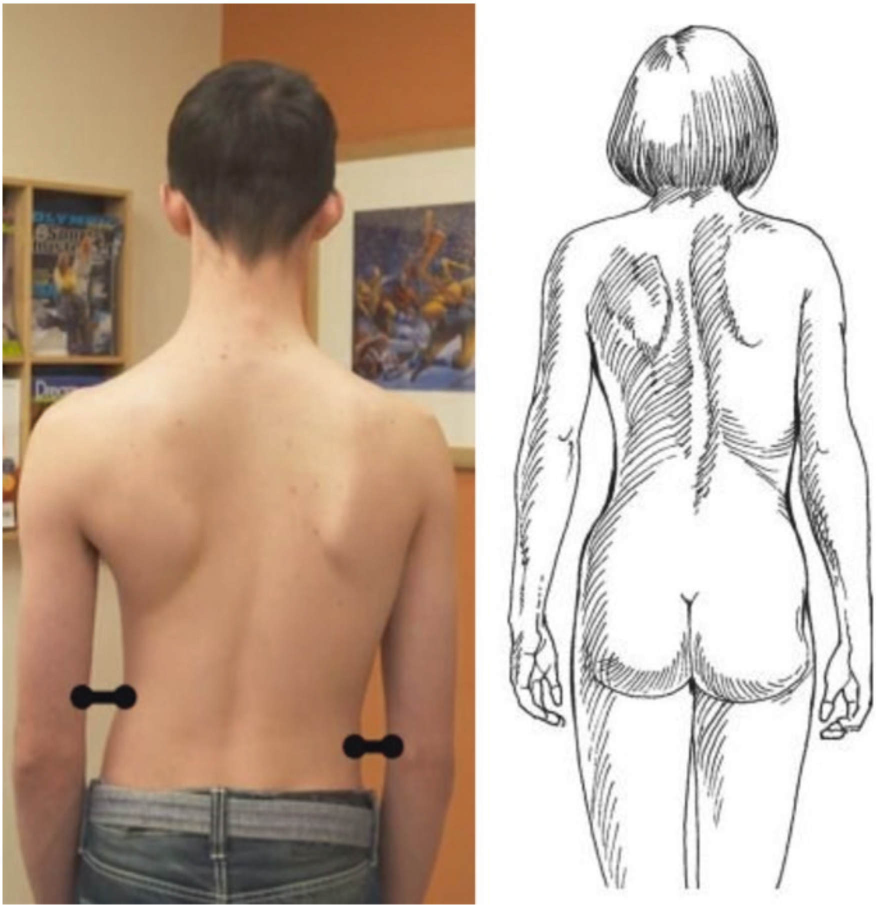


Fig. 5 Scoliosis is a coronal plane deformity with vertebral body rotation

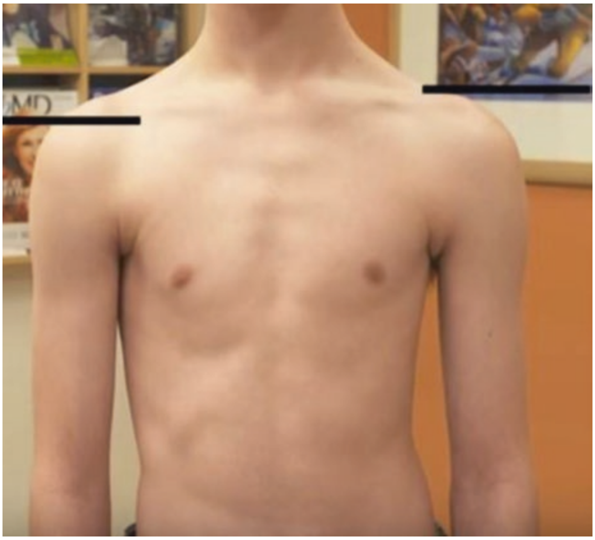


Fig. 6 Difference in shoulder heights in scoliosis

centre of the gluteal fold. Deviation to the right or left is measured in centimetres and recorded as coronal decompensation in either direction.

- The correctability/flexibility of the scoliosis curvature is tested by
  - Adam test. Persistence or disappearance of scoliosis on forward bending forward. The spinal rib hump can be clearly estimated by viewing the patient's back and comparing the elevated side (convexity) to the lower side. It is usually reported as centimetres of elevation compared to opposite side of centimetres of elevation.
  - Measurement of spinal flexibility with three-point bending i.e., pulling the curve from the convex side and noting the correction
  - Applying traction or relieving the weight of the body on the curve as seen by lifting the patient by the axilla or by the head
- Scoliosis may be structural or non-structural. Poor posture, hysteria, nerve root irritation, limb length discrepancy and hip contracture can cause non structural scoliosis. Wedge vertebra, hemivertebra (Fig. 7) can cause structural scoliosis. There is a structural change in bone and normal flexibility of spine is lost [1].
- Number of curvatures (primary and secondary curves).
- Side of convexity. In structural scoliosis vertebral bodies rotate into the convexity of the curve and become distorted [2] (Fig. 8). If the thoracic spine is involved, this rotation causes the ribs on the convex side of the curve to push posteriorly, causing a rib "hump" and narrowing the thoracic cage on the convex side. As the vertebral body rotates to the convex side of the curve, the spinous process deviates toward the concave side. The ribs on the concave side move anteriorly, causing a "hollow" and a widening of the thoracic cage on the concave side. There is crowding of the ribs with appearance of a transverse furrow on the concave side (Fig. 8).
- Upper and lower limits of curvature are noted
- Chest deformities. The involvement of thoracic spine results in a very poor cosmetic appearance of the ribs along with the spine.The deformity can vary from a

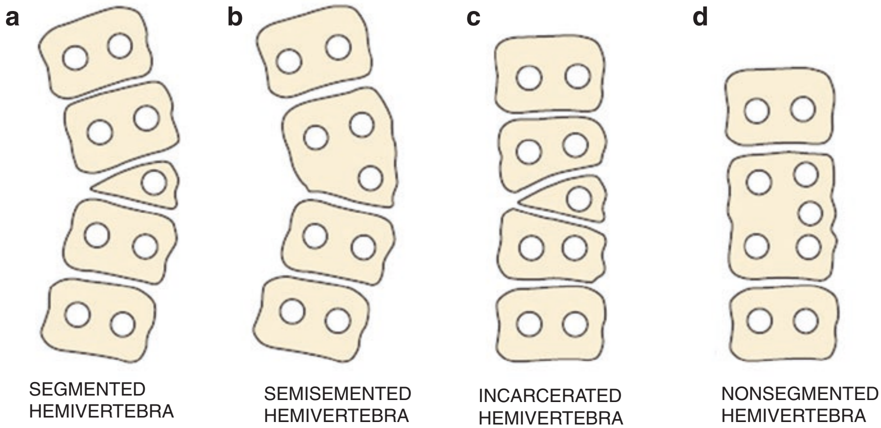
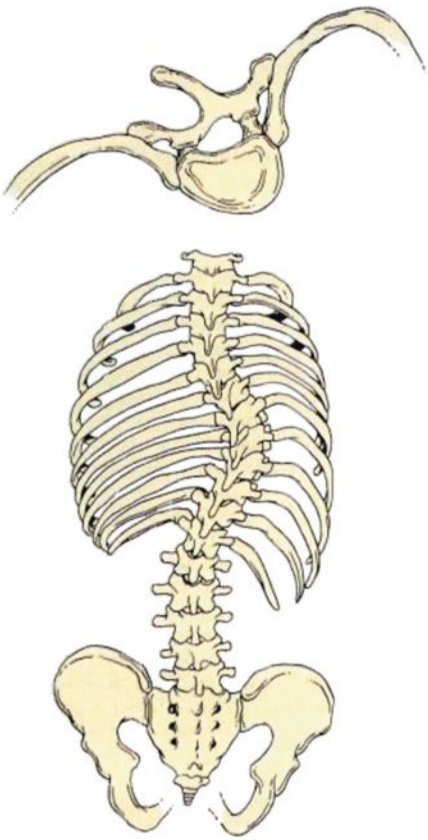


Fig. 7 Different types of hemivertebra

Fig. 8 Depicting vertebral body rotation in scoliotic spine



mild rib hump to a severe rotation of the vertebrae, causing a rib deformity called *Razorback spine* which can be assessed better when the patient bends forward.
- Level of the iliac crests are noted and approximation of the last rib to the iliac crest. The anterior and posterior iliac spines are higher on the concave side

Kyphosis

Kyphosis is deviation of spine in the lateral plane (Fig. 9).

The examiner must ensure that a kyphosis is actually present, remembering that a slight kyphosis, or posterior curvature, is normal and is found in every individual. If it becomes abnormally prominent (more than 45°), it is excessive kyphosis.

Types of Kyphosis

1. Round back is decreased pelvic inclination (20°) with a thoracolumbar or thoracic kyphosis (Fig. 10). Most forms of kyphosis seen show a decreased pelvic inclination. To compensate and maintain the body's centre of gravity, a structural kyphosis, usually caused by tight soft tissues from prolonged postural change or by a growth disturbance (e.g. Scheuermann's disease) results, causing a round back deformity. Dowager's hump (Fig. 11) results from postmenopausal osteoporosis. Because of the osteoporosis, anterior wedge fractures occur to several vertebrae, usually in the upper to middle thoracic spine, causing a structural scoliosis that also contributes to a decrease in height.
2. Gibbus is a localized, sharp, posterior angulation (Fig. 12). This kyphotic deformity is usually structural and often results from an anterior wedging of the body of one or two thoracic vertebrae. The wedging may be caused by a fracture, tumour, or bone disease. The pelvic inclination is usually normal (30°).
3. Flat back is decreased pelvic inclination (20°) with a mobile spine. This kyphotic deformity is similar to round back, except that the thoracic spine remains mobile and is able to compensate throughout its length for the altered centre of gravity caused by the decreased pelvic inclination. Therefore, although a kyphosis is or should be present, it does not have the appearance of an excessive kyphotic curve (Fig. 13).

Fig. 9 Kyphosis

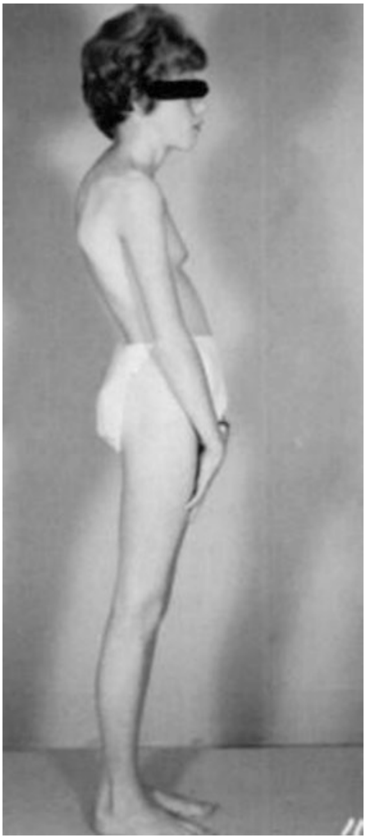


Fig. 10 Round back kyphosis

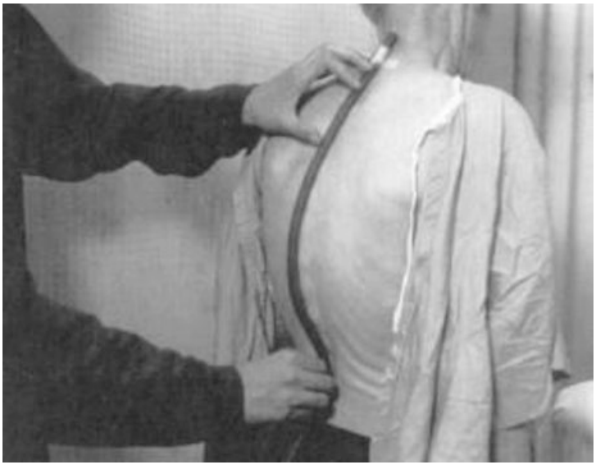


Fig. 11 Dowagers hump

Fig. 12 Gibbus

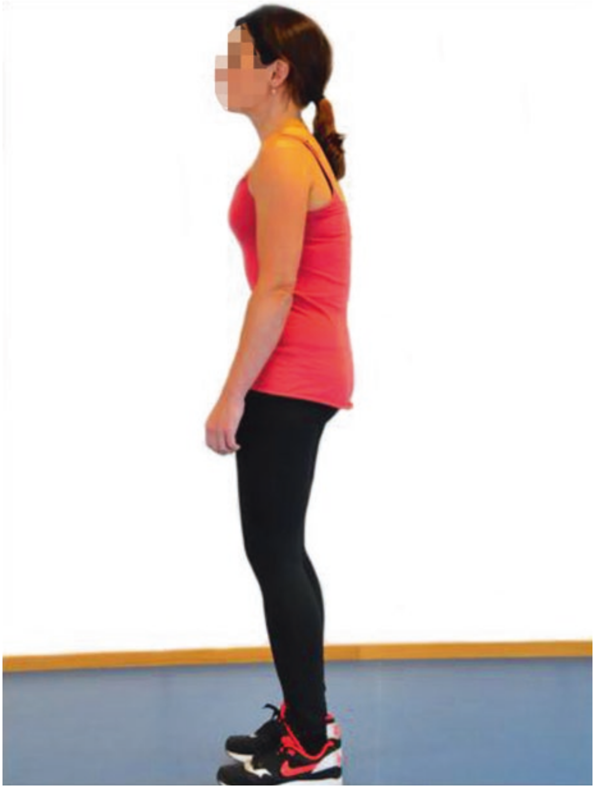


Fig. 13 Flat back

Chest Deformity

1. With a pigeon chest (pectus carinatum) deformity (Fig. 14), the sternum projects forward and downward, increasing the anteroposterior dimension of the chest. This congenital deformity impairs the effectiveness of breathing by restricting ventilation volume.
2. The funnel chest (pectus excavatum) is a congenital deformity that results from the sternum's being pushed posteriorly by an overgrowth of the ribs [3]. The antero-posterior dimension of the chest is decreased which affects ventilation (Fig. 15).
3. With the barrel chest deformity, the sternum projects forward and upward so that the antero-posterior diameter is increased. It is seen in pathological conditions such as emphysema.

Fig. 14 Pectus carinatum

Breathing

The examiner should also observe the patient's breathing pattern. Children tend to breathe abdominally, women tend to do upper thoracic breathing. Men tend to be upper and lower thoracic breathers. Elderly people are lower thoracic and abdominal breathers. The examiner should also note whether the patient is using his primary or accessory muscles of respiration while breathing.

Palpation

Palpation should with palpation of any warmth, tenderness over whole of the posterior aspect of spine.

Then the examiner should start palpating individual spinous processes and interspinous gaps. Any abnormality in the alignment of the spinous processes should be

Fig. 15 Pectus excavatum

noted. To avoid missing any minor deviations, the spinous processes can be marked using a skin marker.

Tenderness over the spinous processes can be elicited by

1. Direct pressure tenderness (Fig. 16)
2. Twist tenderness (Fig. 17)
3. Deep thrust tenderness (Fig. 18)

Paraspinal muscles should be palpated for wasting or spasm. The examiner then palpates for the presence of any cold abscess. The various sites of occurrence of cold abscess are:

1. In Cervical Spine—retropharyngeal abscess, mediastinum, posterior triangle of neck, axilla.
2. In Thorax—paravertebral abscess, pyothorax, post-renal abscess
3. Lumbar—post renal abscess, iliopsoas abscess, ischiorectal abscess, petit's triangle, in the front or back of thigh.

Fig. 16 Direct pressure tenderness

Fig. 17 Twist tenderness

Fig. 18 Deep thrust tenderness

Percussion

When the patient is seated or standing the thoracic spine is slightly flexed the spinous process are percussed using fingers or knee hammer. Localised pain indicates a fractured vertebrae, whereas radicular pain indicates disc pathology. Since it is a non-specific test, it is positive also in ligamentous sprains and spasm of paraspinal musculature.

Movements

The plane of the facet joint is at an angle of 60° to the horizontal. The facets are more vertically oriented than the cervical region. Hence the forward flexion is limited. Extension is limited due to the inferior articular process touching the subsequent lamina and the spinous process coming into contact with each other. Rotation is the main plane of movement possible in the thoracic spine (Fig. 3)

Active Movements

Forward Flexion

The amount of forward flexion possible in thoracic spine is 20–45° (Fig. 19). Because the range of motion at each vertebra is difficult to measure, the examiner can use a tape measure to derive an indication of overall movement (Fig. 13). The examiner first measures the length of the spine from the C7 spinous process to the T12 spinous process with the patient in the normal standing posture. The patient is then asked to bend forward, palpate the spinous process of T12 and L1. Place one

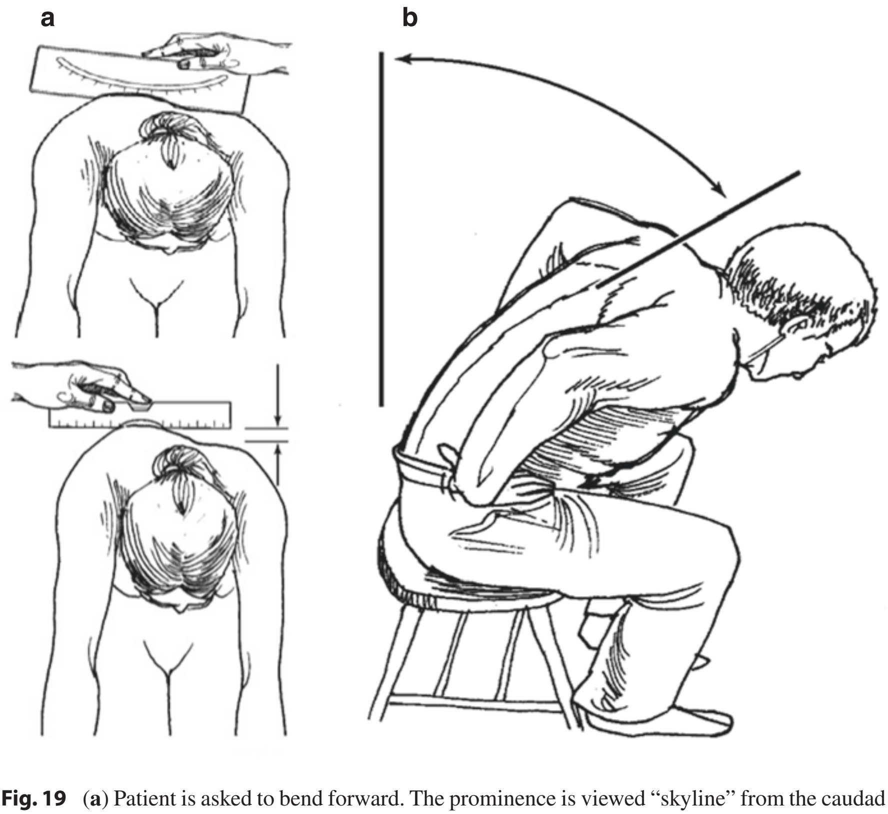


Fig. 19 (**a**) Patient is asked to bend forward. The prominence is viewed "skyline" from the caudad end. The difference in the height of the prominence on the either side of the spinous process is depicted directly in centimeters in the scoliometer or as a angular reading, (**b**) Forward bending with patient sitting to measure the thoracic flexion

hand on the back of the patient to detect the point at which the spinal extension moves into the lumbar vertebrae and the spine is again measured. A 2.7 cm (1.1 in.) difference in length is considered normal. Note is made of the ease with which the patient is able to carry out the movement.

While the patient is bending forward, the examiner observes the spine from the "skyline" view (Fig. 19a). The prominence is measured by a scoliometer giving an angular reading, or by measuring the height of the prominence directly and recorded in centimetres. If the patient has a non-structural scoliosis, it disappears during flexion while a structural scoliosis persists.

Extension

As with flexion, the examiner can use a tape measure and obtain the distance between the same two points (the C7 andT12 spinous processes). Again a 2.5 cm difference in tape measure length between standing and extension is considered normal. Palpate the spinous process of T12 and L1 and detect at which the spine extension moves into the lumbar vertebrae. McKenzie [3] advocates the examiner to place the hands on the lumbosacral region to add stability while performing the backward movement or to do extension while sitting or prone lying (sphinx position)" (Figs. 20 and 21).

Fig. 20 Evaluating extension of thoracic spine in the standing position

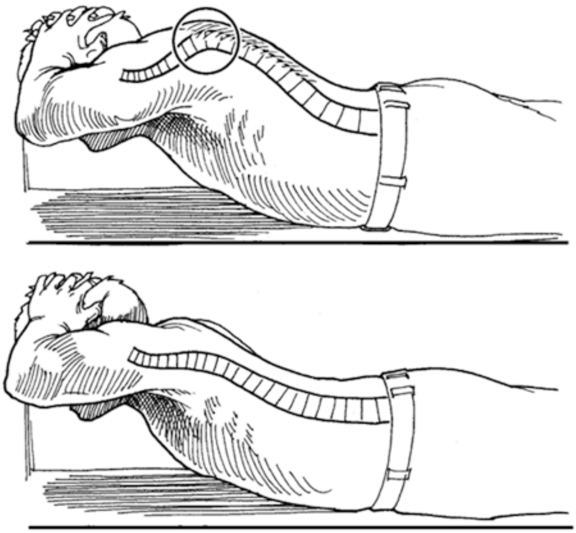


Fig. 21 Evaluation of extension of the thoracic spine in prone position

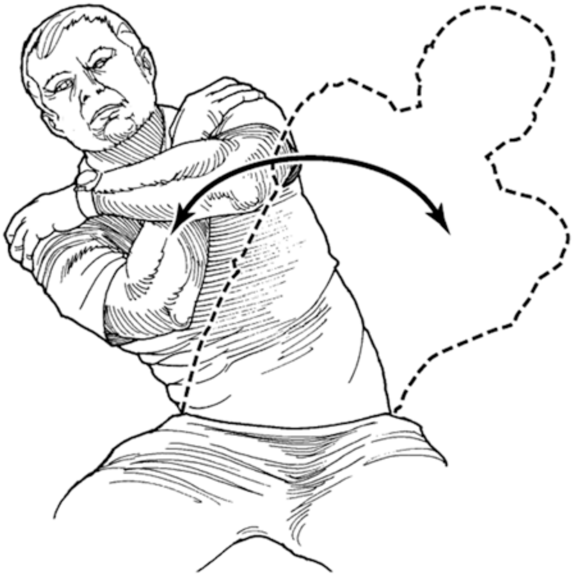


Fig. 22 Side or lateral flexion in thoracic spine

Side Flexion

Side (lateral) flexion is approximately 20–40° to the right and left in the thoracic spine. The patient is asked to run the hand down the side of the leg as far as possible without bending forward or backward. The examiner can then estimate the angle of side flexion or use a tape measure to determine the length from the fingertips to the floor and compare it with that of the other side (Fig. 22). Normally, the distances should be equal.

If, on side flexion, the ipsilateral paraspinal muscles tighten or their contracture is evident (Forrestier's bowstring sign), ankylosing spondylitis or pathology causing muscle spasm should be considered.

A wedge or block is placed under the patient's buttock on the side being tested. The elevation of the buttock will lock the lumbar spine in contralateral side bending and ipsilateral rotation. Instruct the patient to rotate as far as possible toward the side where the block was placed.

Rotation

Rotation in the thoracic spine is approximately 35–50°. The patient is asked to cross the arms in front or place the hands on opposite shoulders and then rotate to the right and left while the examiner looks at the amount of rotation, comparing both ways (Fig. 23). Again, the examiner must remember that movement in the lumbar spine and hips as well as in the thoracic spine is occurring. To eliminate or decrease the amount of hip movement, rotation may be done in sitting. To eliminate rotation of lumbar spine, a wedge is given under the ipsilateral buttock.

Chest Expansion

Costovertebral joint movement is usually determined by measuring chest expansion (Fig. 24). The examiner places the measuring tape around the chest at the level of the fourth intercostal space. The patient is asked to exhale as much as possible, and the examiner takes a measurement. The patient is then asked to inhale as much as possible and hold the breath while the second measurement is taken. The normal difference between inspiration and expiration is 3–7.5 cm (1–3 in.).

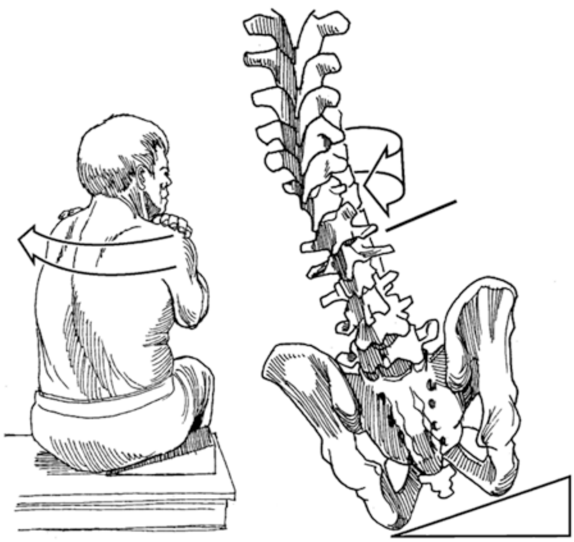


Fig. 23 Thoracic rotation to be examined in sitting posture with wedge on one side under the ischial tuberosity to prevent rotation at the lumbar level

Schober's Test

Limitation of forward flexion of spine can be assessed by Schober's test. The examiner asks the patient to stand erect. From the posterior aspect, a line is drawn connecting the two posterior superior iliac spines. From the midpoint of this line a point is marked 10 cm straight up in the midline (Fig. 25). Now the examiner asks the patient to bend forward with straight knees. In a normal person the measured distance should increase from 10 cm to atleast 15 cm. In a patient with Ankylosing spondylitis, forward flexion is limited and the measured distance does not increase by 5 cm.

Special Tests

Anghelescu Sign

When the patient in supine position tries to extend the thoracic spine sufficiently to raise it from the table, in the absence of thoracic spine pathology, the patient

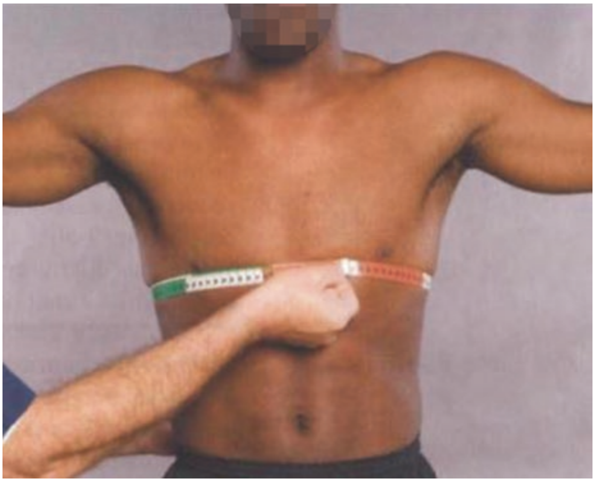


Fig. 24 Measurement of chest expansion at the level of fourth intercostal space

Fig. 25 Schober's test

will be able to rest on heel and shoulders (near opisthotonus posture). This sign is positive in tuberculosis lesions of thoracic spine where it cannot be done (Fig. 26).

Amoss Sign

When the patient in a side lying position on the examination table arises to a seated position a localised thoracic or thoracolumbar pain or stiffness or lack of mobility is elicited it is suggestive of chronic spondylitis like ankylosing spondylitis, ligaments sprain, intervertebral disc disease (Fig. 27).

Fig. 26 Anghelescu sign

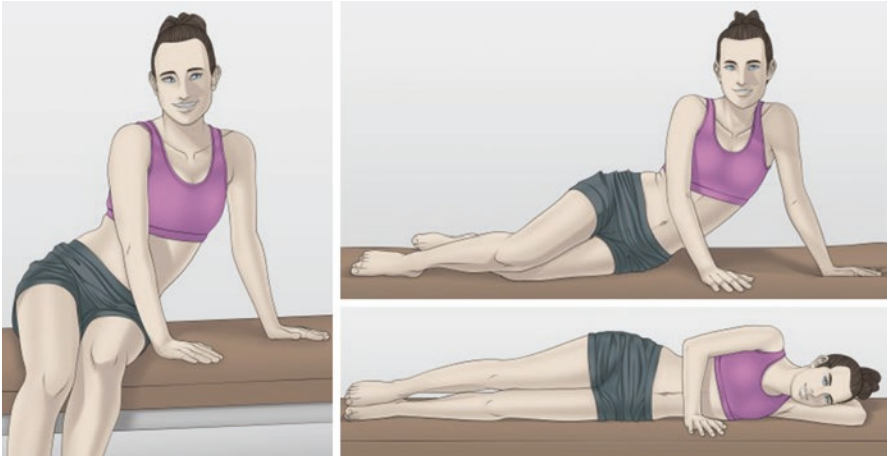


Fig. 27 Amoss sign

Beevor's Sign

The patient tries to sit up with arms folded across the trunk and the examiner presses down the patient's legs to the table. The umbilicus shifts to the side of stronger musculature. Superior shift implicates weakness of muscles innervated by lower thoracic spine whereas inferior shift implicates upper thoracic spine weakness at or below T7. As an alternative, the patient can perform a bilateral leg lift to test the lowermost fibres of abdominal musculature.

False positive test occurs when the abdominal musculature is extensively weak, the thorax may pull away from the pelvis and arching of back occurs causing tautness of the anterior abdominal muscles mimicking actual contraction of the muscles (Fig. 28).

First Thoracic Nerve Root Stretch Test

Pain resulting from stretch of the first thoracic nerve root tracks along the ulnar nerve is identified as T1 and T2 nerve root pain. When the affected arm is abducted to 90°, the elbow is flexed with pronation of forearm, the ulnar nerve and T1 nerve root are stretched and causes scapular pain on the ipsilateral side (Fig. 29).

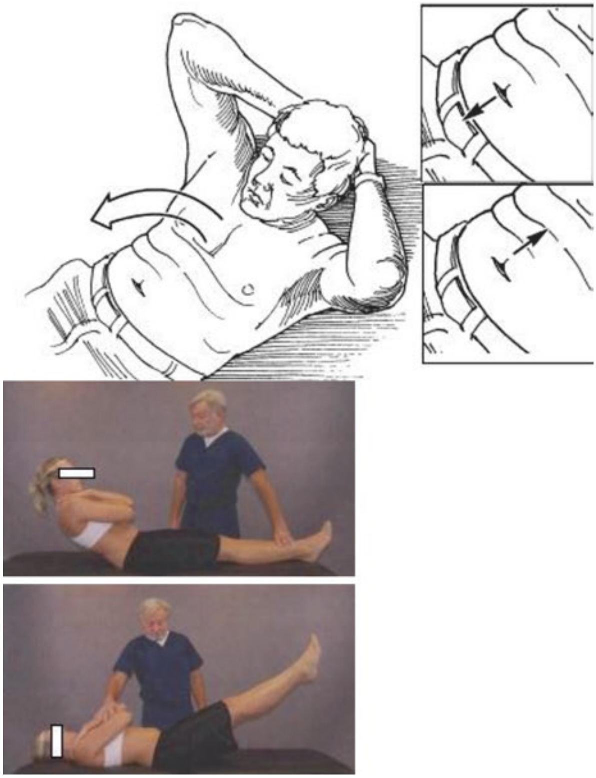


Fig. 28 Beevor's sign

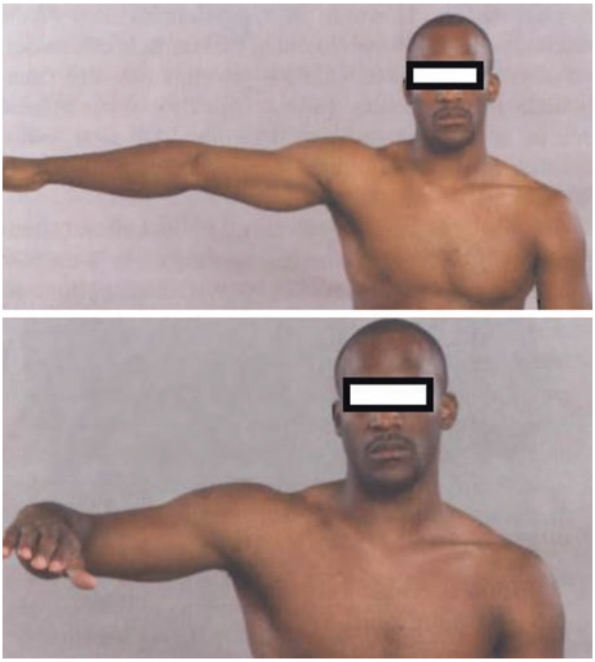


Fig. 29 First thoracic nerve root stretch test

Forrestier Bow Stringing Sign

Patient performs side bending and reveals ipsilateral tightening and contracture of the ipsilateral musculature, it suggests ankylosing spondylitis

Passive Scapular Approximation Test

When the examiner approximates the scapulae by pulling the shoulder tips backward, pain in the scapular area indicates a T1 or T2 nerve root involvement.

Slump Test

The patient sits on the examining table and is asked to "slump" so that the spine flexes and the shoulders sag forward while the examiner holds the chin and head erect. The patient is asked if any symptoms are produced. If no symptoms are produced, the examiner flexes the patient's neck and holds the head down and shoulders slumped to see if symptoms are produced. If no symptoms are produced, the examiner passively extends one of the patient's knees to see if symptoms are produced. If no symptoms are produced, the examiner then passively dorsiflexes the foot of the same leg to see if symptoms are produced. The process is repeated with the other leg. Symptoms of sciatic pain or reproduction of the patient's symptoms indicates a positive test, implicating impingement of the dura and spinal cord or nerve roots.

References

1. Keim HA. Scoliosis. Clin Symp. 1973;25:1–25.
2. Keim HA. The adolescent spine. New York: Springer; 1982.
3. McKenzie RA. The cervical and thoracic spine: mechanical diagnosis and therapy. Waikanae, New Zealand: Spinal; 1981.
4. Evans RC. Illustrated essentials in orthopaedic physical assessment. St. Louis: C. V. Mosby; 1994.

Examination of Lumbar Spine

S. S. Dhatt and S. Siva Swaminathan

Anatomy

The lumbosacral spine consists of 5 vertebrae in the lumbar spine, 5 vertebrae which are fused to form the sacrum and the coccyx which is a fusion of 3–5 vertebra. The lumbar spine also comprises of various supporting ligament which play an important role in the stability of spine.

Anterior Longitudinal Ligament

The anterior longitudinal ligament runs vertical along the anterior aspect of the vertebral bodies upto the sacrum. It is wide and attaches strongly to both the vertebra and the intervertebral discs (Fig. 1). It mainly prevents the spine from hyperextension.

Posterior Longitudinal Ligament

The posterior longitudinal ligament (Fig. 1) runs along the posterior aspect of the vertebral bodies. It is narrower and weaker than the anterior longitudinal ligament. It attaches mainly to the intervertebral discs. The posterior longitudinal ligament prevents hyperflexion of the spine.

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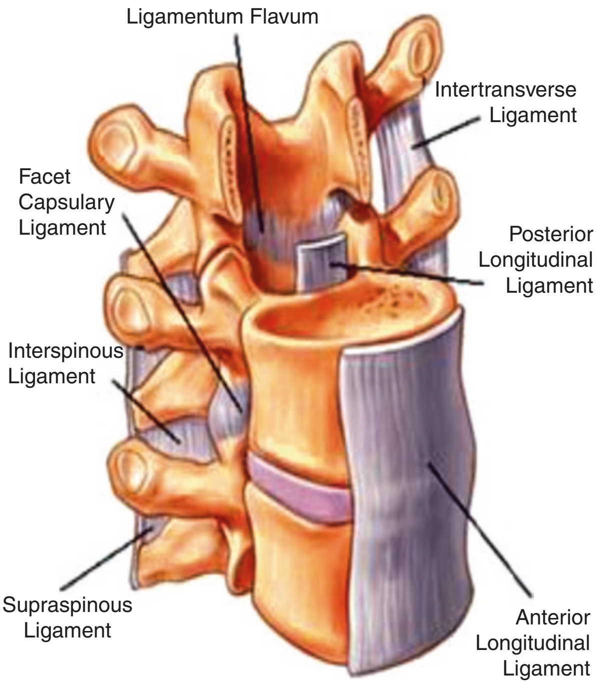


Fig. 1 Ligaments of spine

Ligamentum Flavum

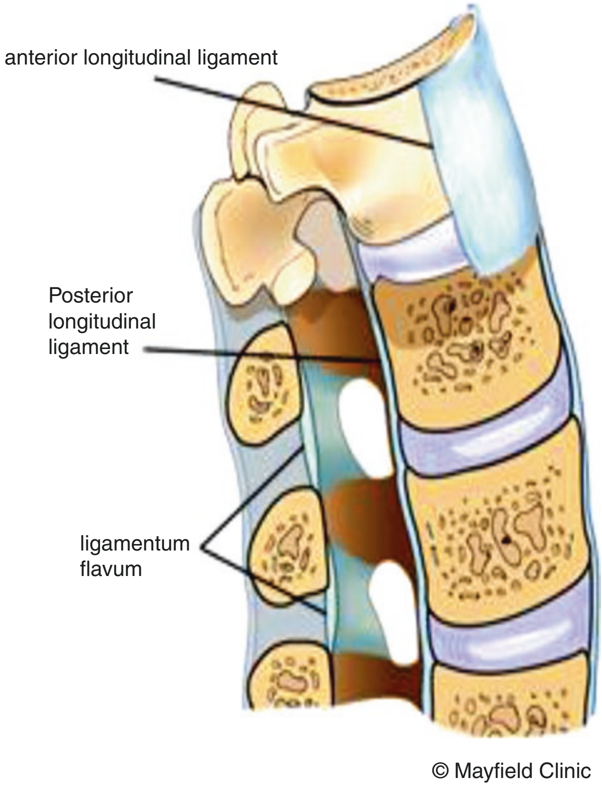
Ligamentum flavum is a very strong ligament that connects the lamina of the vertebrae (Fig. 2). It stabilises the spine to prevent excessive vertebral body motion. It forms the posterior wall of the spinal canal along with the lamina and it undergoes stretching in forward bending and recoils in erect position.

The intertransverse ligament connects the transverse processes, the interspinous ligament connects the spinous processes while the supraspinous ligament connects the apex of the spinous processes.

In addition to these ligament there is an important ligament unique to the lumbar spine and pelvis-iliolumbar ligament, which connects the transverse process of L5 to the posterior ilium [1].This ligament helps stabilize L5 with the ilium and helps prevent anterior displacement of ilium [2].

In the lumbar spine, the nerve roots exit through relatively large intervertebral foramina, and as in the thoracic spine, each one is named for the vertebra above it (in the cervical spine, the nerve roots are named for the vertebra below). For example, the L4 nerve root exits between the L4 and L5 vertebrae. Because of the course of the nerve root as it exits, the L4 disc (between L4 and L5) only rarely compress the L4 nerve root; it is more likely to compress the L5 nerve root.

Fig. 2 Ligaments of spine



Clinical Examination of Lumbar Spine

Inspection

The examiner should observe the patient from the moment he or she enters the consulting room, paying attention to how the patient walks into the room (any limp), how the patient sits down and gets up from the chair.

Inspection of the lumbar spine should be done from the posterior and lateral aspect (Fig. 3).

Posterior

Skin and Hair

A midline dimple or tufts of hair (Fig. 4) may suggest a variety of congenital, osseous or neurological disorders. 80% of all cases of spinal dysraphism have excess hair present in the midline. A lumbar lipoma or a hair patch may be associated with spina bifida or myelomeningocele. Large tan *cafe au lait spots* (Fig. 5) may be associated with neurofibromatosis.

Fig. 3 Inspection of lumbar spine. Posterior view

Fig. 4 Tuft of hair at lumbar region

Symmetry

From the posterior aspect, the shoulders and pelvis should be level and the soft tissue structures on both sides should be symmetrical. Both the angles of scapula and the iliac crest should be at the same level. Hip joints should not be adducted or abducted with feet parallel or toeing out slightly.

The paraspinal muscles (erector spinae or sacrospinalis) should be symmetrical on either side. In case of paraspinal muscle spasm, the muscles on the affected side usually stand out visibly.

Wasting of paraspinal muscles is rare but may indicate chronic inflammatory disease like ankylosing spondylitis or tuberculosis. It may also be seen after a previous spinal surgery due to denervation.

Pelvic Obliquity

The examiner should also verify that the patient's pelvis is level. An imaginary line drawn between the posterior superior iliac spines or the iliac crests should be parallel to the floor.

Pelvic obliquity may be due to spinal deformity like scoliosis or due to limb length discrepancy.

List

A list is an abrupt planar shift of the spine, above a certain point, to one side. This phenomenon typically occurs primarily in the lumbar spine. It is usually a reversible deformity related to pain and associated muscle spasm. A list may be caused by a herniated lumbar disc.

If the list is towards the painful side, this shows that the displacement of the herniated disc is medial, i.e., at the axilla of the nerve root.

If the list is away from the painful side, the disc protrusion lies lateral to the nerve root, which is drawn away by the deviation of the trunk.

Fig. 5 Cafe au lait spots

Scoliosis

Although scoliosis (Fig. 6) is usually considered a coronal deformity of the spine, it is really a helical abnormality involving abnormal vertebral rotation along the axis of the spine. Lumbar scoliosis may be primary or secondary. In primary scoliosis, an actual structural abnormality of the spine is present.

In secondary scoliosis, the curvature represents a compensatory adaptation of an otherwise normal spine to an extrinsic factor, such as muscle spasm or pelvic obliquity related to a leg length discrepancy.

Step-Off Deformity

This may be seen in severe degrees of spondylolisthesis. Commonly seen at the level of L5–S1. Step deformity occurs because the spinous process of one vertebra becomes prominent when either the vertebra above or the affected vertebra slips forward on the one below.

Lateral (Fig. 7)

The lumbar spine is normally lordotic, that is concave posteriorly. The normal lumbar lordosis, which averages about 60% is important in order to maintain healthy low back biomechanics.

Hyperlordosis

Also known as swayback is usually associated with flexion deformity at the hips.

Decreased Lordosis

This is usually a temporary deformity associated with muscle spasm. Ankylosing spondylitis may produce a more rigid decrease in lumbar lordosis.

Fig. 6 Scoliosis

Fig. 7 Inspection of lumbar spine. Lateral view

Flat Back Syndrome

The lumbar spine loses its normal lordosis completely and becomes a flat back.

Compression fractures that result in anterior wedging of the lumbar vertebral bodies can produce lumbar flatback syndrome (Fig. 8). Advanced degeneration of the lumbar intervertebral discs may also result in this same deformity.

Gibbus

Gibbus is a sharp, angular kyphotic deformity often noticed by the protruding spinous process at the apex of the deformity. Gibbus (Fig. 9) is classically associated with tuberculosis of the spine. Vertebral body collapse due to tumors, other infections, or fractures may also produce a gibbus.

Gait

Sciatica is most commonly caused by a herniated disc at the L5–S1 or the L4–L5 interspace compressing a nerve root that feeds into the sciatic nerve. Because knee extension and hip flexion place further tension on the painful sciatic nerve, the patient with sciatica may attempt to walk with the hip more extended and the knee

Fig. 8 Flatback

Fig. 9 Gibbus

more flexed than normal. In addition, the patient may display an *antalgic gait*, putting as little weight as possible on the affected side and then quickly transferring the weight to the unaffected side.

Palpation

Palpation of the lumbar spine is normally confined to the posterior aspect.

Muscles

Paraspinal muscles (Fig. 10) on either side of the spine are usually better felt by palpation than seen of inspection. If muscle spasm is suspected, the patient should be asked to bend toward the involved side while the examiner continues to palpate the paraspinous muscle in question. Normally, the paraspinous muscles on the side to which the patient is bending should soften and relax. If they remain firm, the impression of spasm is confirmed.

Trigger points and tender nodules in the paraspinal muscles may indicate fibromyalgia.

Spinous Processes

Firm palpation of the back can help in identifying individual spinous processes.

For orientation, the examiner should identify the top of each iliac crest (Fig. 11) and draw an imaginary line between the two. This line usually passes through the interspace between the L4 and the L5 spinous processes. The examiner can then identify the individual spinous processes by counting upward or downward from the L4–L5 interspace. Localized tenderness at a particular level may indicate pathology at that level.

In the presence of *spondylolisthesis,* palpation of the spinous processes may help confirm the examiner's visual impression of a step-off above the involved vertebra. The amount of slippage usually must be at least 50% of the diameter of the lumbar vertebral bodies before the step-off can be detected by physical examination.

Fig. 10 Palpation of paraspinal muscles

Fig. 11 Palpation of iliac crests

Fig. 12 Lumbar flexion

Movements

Flexion (80–90°)

With the patient standing, the examiner instructs the patient to bend straight forward at the waist as far as possible and attempt to touch the fingertips or the palms to the floor (Fig. 12). The amount of flexion present is estimated as the angle between the final position of the trunk and a vertical plane. The examiner can also measure the distance between the finger tips and the floor. In an average patient, the fingertips come to rest about 10cm from the floor.

Because lumbar flexion increases pressure on the intervertebral discs and places tension on sciatic nerve roots, herniation of L4–L5 and L5–S1 discs is frequently associated with painful, limited flexion of the lumbar spine.

Extension (20–30°)

To test for extension of the lumbar spine, the examiner asks the patient to lean backward as far as possible (Fig. 13). In order to stabilize the back, the patient can place both hands on the iliac crest while performing the test. The amount of extension is quantified by estimating the angle between the trunk and a vertical line.

Extension may be decreased in cases of lumbar canal stenosis, spondylolysis, tumors of posterior elements.

Lateral Bending (20–30°)

The examiner stabilises the patient's pelvis with a hand on each iliac crest and asks the standing patient to lean as far as possible to each side (Fig. 14). It may be estimated by drawing an imaginary line between the vertebra prominences and the sacrum and estimating the angle between this line and the vertical.

Fig. 13 Lumbar extension

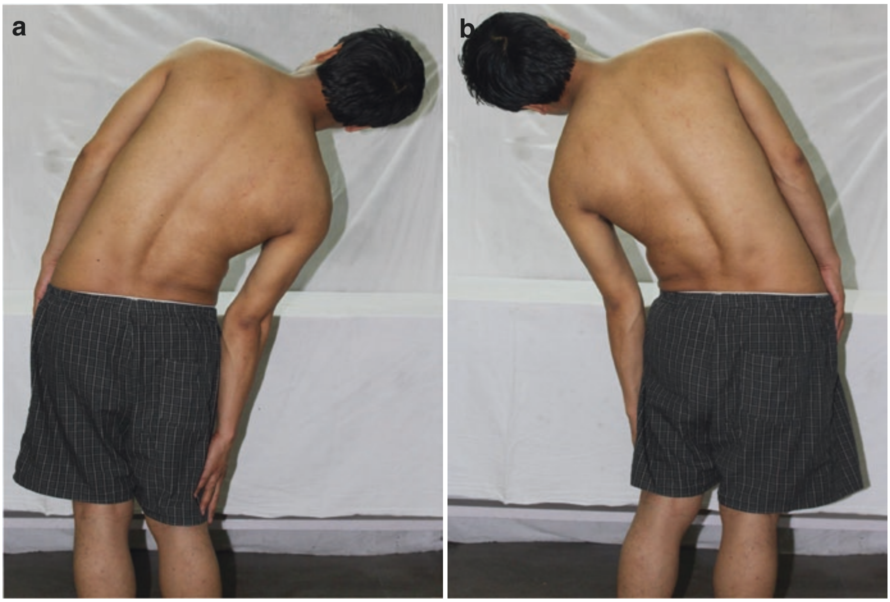


Fig. 14 (**a**) Lateral bending to the right. (**b**) Lateral bending to the left

The examiner should look for asymmetry between the two sides. Patients with herniated discs may avoid lateral bending toward the side of the herniation, as this causes the nerve root to further impinge on the herniated disc.

Rotation (30–40°)

The examiner holds the pelvis with a hand on each iliac crest and instructs the standing patient to rotate or twist in each direction as far as possible (Fig. 15). The normal range of rotation is 30–40° in each direction.

Motor Examination

L1, L2 Nerve Roots (Hip Flexion)

L1 and L2 nerve roots supply the iliopsoas muscle, the primary flexor of hip. To test the iliospoas, the patient is asked to sit by the side of the examination table with his knees flexed to 90°. The patient is now instructed to lift his thigh off the table (with the knee in flexion) while the examiner gives a downward pressure over the patient's knee with both hands (Fig. 16). In a normal patient, the examiner should be able to overcome the patient's effort with some difficulty.

Fig. 15 Lumbar spine rotation

Fig. 16 Assessing L1, L2 motor function (iliopsoas strength)

L3 Nerve Root (Knee Extension)

L3 nerve root is evaluated by testing the strength of quadriceps muscle. The patient is asked to sit by the edge of the examination table with the knee flexed to 90°. The examiner now gives a downward pressure on the patient's leg just above the ankle while the patient tries to extend his knee. In a normal patient, quadriceps muscle can be seen and felt contracting with the examiner being unable to initiate knee flexion (Fig. 17).

L4 Nerve Root (Ankle Dorsiflexion)

L4 nerve root is assessed by testing the strength of tibialis anterior muscle. With the patient seated by the side of the table with his knees at 90°, he is asked to maximally dorsiflex the ankle while the examiner tries to plantar flex the ankle. Comparison of both the sides can be done by testing both ankles simultaneously with the patient lying supine (Fig. 18). It can also be screened by asking the patient to walk on his heels with the toes held high off the floor (Fig. 19).

Fig. 17 Assessing L3 motor function (quadriceps strength)

Fig. 18 Assessing L4 motor function (tibialis anterior strength)

Fig. 19 Assessing L4 motor function (heel walking)

Fig. 20 Assessing L5 motor function (extensor hallucis longus)

L5 Nerve Root (Toe Extension, Hip Abduction)

L5 nerve root can be assessed by testing for long toe extensors (extensor hallucis longus and extensor digitorum longus) and hip abductor (gluteus medius).

With the patient lying supine on the examination table, the examiner instructs the patient to extend the great toe while he tries to flex the toe by applying pressure over the dorsal aspect of the distal phalanx of great toe. Both the legs are examined simultaneously and are compared to evaluate the strength of extensor hallucis longus (Fig. 20).

The extensor digitorum longus can be assessed by asking the patient to extend the toes as far as possible while the examiner tries to passively flex the toes with his fingers (Fig. 21).

Gluteus medius is evaluated by assessing the strength of hip abduction. With the patient lying in a lateral position on the examination table, the examiner instructs the patient to abduct his lower limb keeping the knee in extension while the examiner tries to push the thigh back towards the table (Fig. 22).

Fig. 21 Assessing L5 motor function (extensor digitorum longus)

Fig. 22 Assessing L5 motor function (gluteus medius)

S1 Nerve Root (Plantar Flexion, Ankle Eversion and Hip Extension)

Primarily plantar flexion is done by gastrosoleus complex, with assistance from toe flexors. Plantar flexion can be screened by asking the patient to toe walk (Fig. 23).

With the patient seated by the side of the table with his knees flexed, the examiner stabilizes the patient's ankle with one hand and instructs the patient to passively plantar flex the ankle (Fig. 24). The patient is told to maintain this position while the examiner attempts to force the ankle back into dorsiflexion by pressing upward on the patient's forefoot with the examiner's other hand.

The main evertors of the foot are peroneus longus and brevis. The examiner stabilises the patient's leg with one hand and asks the patient to rotate the foot outward. The examiner may have to passively place the patient's foot in eversion to communicate the desired position. The patient is then instructed to maintain the foot in the

Fig. 23 Assessing S1 motor function (toe walking)

Fig. 24 Assessing S1 motor function (gastrosoleus)

everted position while the examiner attempts to invert the foot by pressing inward on the lateral aspect of the foot (Fig. 25).

The gluteus maximus is the main extensor of the hip. To test it, the patient is asked to lie prone on the examination table and to flex the knee on the side being tested. The patient is then instructed to raise the thigh off the table. Finally, the examiner presses downward on the thigh with both hands while asking the patient to maintain the position of hip extension (Fig. 26). In a normal patient, the examiner is able to overcome the patient's effort with some difficulty.

Fig. 25 Assessing S1 motor function (peromeus longus and brevis)

Fig. 26 Assessing S1 motor function (gluteus maximus)

S2, S3 and S4 Nerve Roots

These nerve roots are the principal supply for the bladder and they also supply intrinsic muscles of the feet. The motor function of the sacral nerve roots is, therefore, usually tested by performing a rectal examination. When normal function is present, the examiner should note fairly firm resistance as the examining finger enters the rectum. The patient is then instructed to try to squeeze the examiner's finger, thus contracting the external anal sphincter. This should produce a strong, readily palpable feeling of constriction around the examiner's finger.

Sensory Examination

The approximate areas of sensory innervations from the lumbar and sacral nerve roots are shown in the figure (Fig. 27).

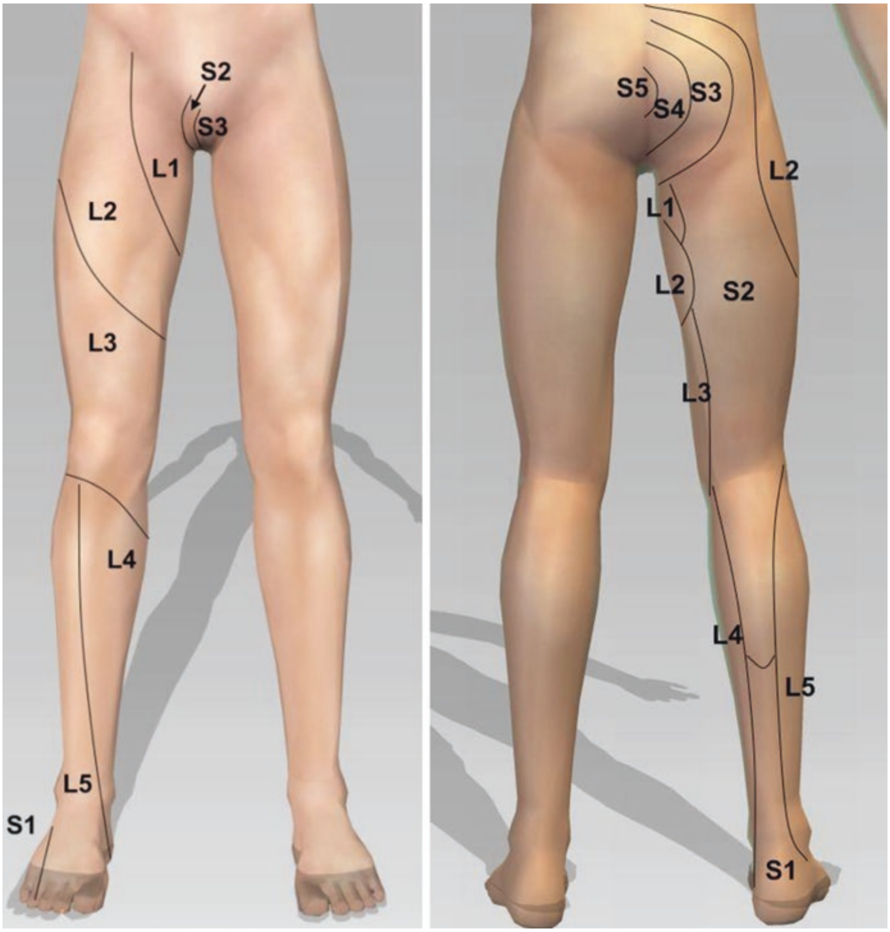


Fig. 27 Lumbo-sacral dermatomes

Reflex Examination

Cremasteric Reflex

The patient lies supine while the examiner strokes the inner side of the upper thigh with a pointed object. The test is negative if the scrotal sac on the tested side pulls up. Absence or reduction the reflex bilaterally suggests an upper motor neuron lesion. A unilateral absence suggests a lower motor neuron lesion between L1 and L2. Absences have increased significance if they are associated with exaggerated deep tendon reflexes [3] (Figs. 28, 29, 30, 31, 32, 33, and 34).

Fig. 28 Sensory evaluation of L1 dermatome

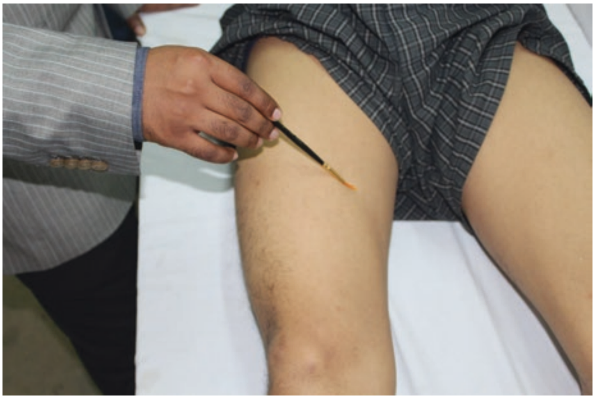


Fig. 29 Sensory evaluation of L2 dermatome

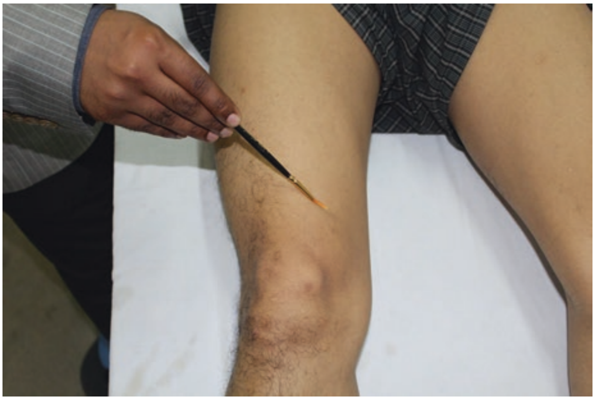


Fig. 30 Sensory evaluation of L3 dermatome

Fig. 31 Sensory evaluation of L4 dermatome

Fig. 32 Sensory evaluation of L5 dermatome

Abdominal Reflex

To test the superficial abdominal reflex, the examiner uses a pointed object to stroke each quadrant of the abdomen of the supine patient in a triangular fashion around the umbilicus (Fig. 35). Absence of the reflex (reflex movement of the skin) indicates an upper motor neuron lesion.

Anal Reflex

The examiner tests the superficial anal flex by touching the perianal skin with a pointed object. A normal result is shown by contraction of the anal sphincter muscles (S1–S4).

Fig. 33 Sensory evaluation of S1dermatome

Fig. 34 Sensory evaluation of S2 dermatome

Fig. 35 Abdominal reflex

Fig. 36 Patellar tendon reflex (L4 nerve root)

Fig. 37 Tibialis posterior reflex (L5 nerve root)

Patellar Tendon Reflex (L4)

The patellar tendon reflex is usually assessed with the patient seated on the side of the examination table with the knees flexed and the feet dangling. The examiner then sharply strikes the midportion of the patellar tendon with the flat side of a rubber reflex hammer. The examiner's other hand may rest lightly on the patient's quadriceps to feel for a muscle contraction (Fig. 36). In a normal patient, there is visible contraction of the quadriceps with extension of the knee.

Tibialis Posterior and Medial Hamstring Reflex (L5)

The tibialis posterior reflex is evaluated in the seated patient. The examiner holds the patient's foot in a small amount of eversion and dorsiflexion and strikes the posterior tibial tendon just below the medial malleolus. The examiner may also place a finger on the posterior tibial tendon and strike the finger instead of striking the tendon directly (Fig. 37). When the reflex is elicited, a slight plantar flexion inversion response is noted.

To elicit the medial hamstring reflex, the patient is placed in the prone position. The examiner passes one hand underneath the patient's leg and places the thumb of that hand on the semitendinosus tendon in the popliteal fossa. The patient's leg is allowed to rest on the examiner's forearm so that the patient's knee is somewhat flexed (Fig. 38). The examiner then strikes the thumb, which is pressing on the semitendinosus tendon, with the pointed end of the hammer. When the reflex is elicited, the examiner feels a contraction transmitted through the semitendinosus tendon or actually sees slight flexion of the knee take place.

Achilles' Tendon Reflex (S1)

With the patient by the side of the table with the legs dangling, the examiner gently dorsiflexes the foot to place the Achilles tendon under tension, and then strikes the Achilles tendon 3 cm above the calcaneum (Fig. 39). In a normal patient, this produces visible plantar flexion of the ankle and contaction of the gastrosoleus.

Undue briskness of the Patellar and Achilles tendon reflex should raise the suspicion of an upper motor lesion.

Nerve Tension Tests

The most important peripheral nerves deriving from the lumbar and the sacral nerve roots are the femoral and the sciatic nerves. The femoral nerve runs down the anteromedial aspect of the thigh and is formed by the L2, L3, and L4 nerve roots. The sciatic nerve runs down the posterior thigh and is formed by the L4, L5, S1, S2, and S3 nerve roots.

Fig. 38 Medial hamstring reflex (L5 nerve root)

Fig. 39 Achilles tendon reflex (S1 nerve root)

Straight Leg Raising Test (SLR) or Lasegue's Test

It is a passive test, and each leg is tested individually with the normal leg being tested first. With the patient in the supine position, the hip medially rotated and adducted, and the knee extended, the examiner flexes the hip until the patient complains of pain or tightness in the back or back of leg (Fig. 40) [4].

The angle formed by the lower limb and the examination table at the point of maximal elevation is noted, and the procedure is repeated with the opposite limb. In a normal patient, straight-leg raising of 70–90° should be possible and may be accompanied by a feeling of tightness in the posterior thigh. In the presence of sciatica, the angle of hip flexion is reduced and the patient reports shooting pain radiating down the posterior thigh and often into the lower leg along the distribution of the sciatic nerve. Straight-leg raising stretches the L5 and S1nerve roots 2–6 mm, but it puts little tension on the more proximal nerve roots. An abnormal straight-leg raising test, therefore, suggests a lesion of either the L5 or the S1 nerve root. Beyond 70° of hip flexion, deformation of the sciatic nerve occurs beyond the spine. Sciatic pain that is reproduced only with hip flexion beyond 70°, therefore, suggests the possibility of sciatic nerve compression outside the spinal canal (Fig. 41).

Fig. 40 Straight leg raising test

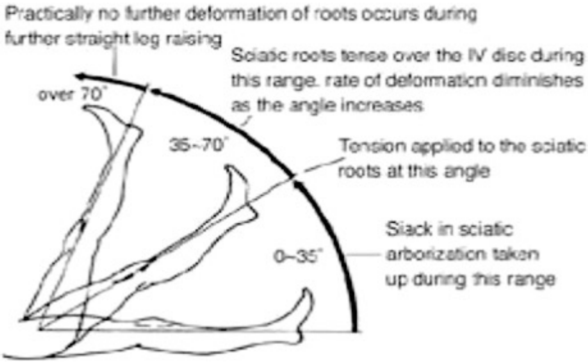


Fig. 41 Dynamics of straight leg raising test

Bragards Test

The examiner does the straight leg raising test until the patient starts complaining of pain in the posterior thigh. The examiner then slowly and carefully drops the leg back (extends it) slightly until the patient feels no pain or tightness. The patient is then asked to flex the neck so the chin is on the chest, or the examiner may dorsiflex the patient's foot, or both actions may be done simultaneously (Fig. 42). The neck flexion movement has also been called Hyndman's sign, Brudzinski's sign, Lidner's sign, and the Soto-Hall test. The ankle dorsiflexion movement has also been called the Bragard's test. Pain that increases with neck flexion, ankle dorsiflexion, or both indicates stretching of the dura mater of the spinal cord or a lesion within the spinal cord (e.g., disc herniation, tumor, meningitis).

Modified Straight Leg Raising Test

For patients who have difficulty lying supine, a modified straight leg raising test (Fig. 43) [5] has been suggested. The patient is in a side lying position with the test leg uppermost and the hip and knee at 90°. The lumbosacral spine is in neutral but may be

Fig. 42 Bragard's test

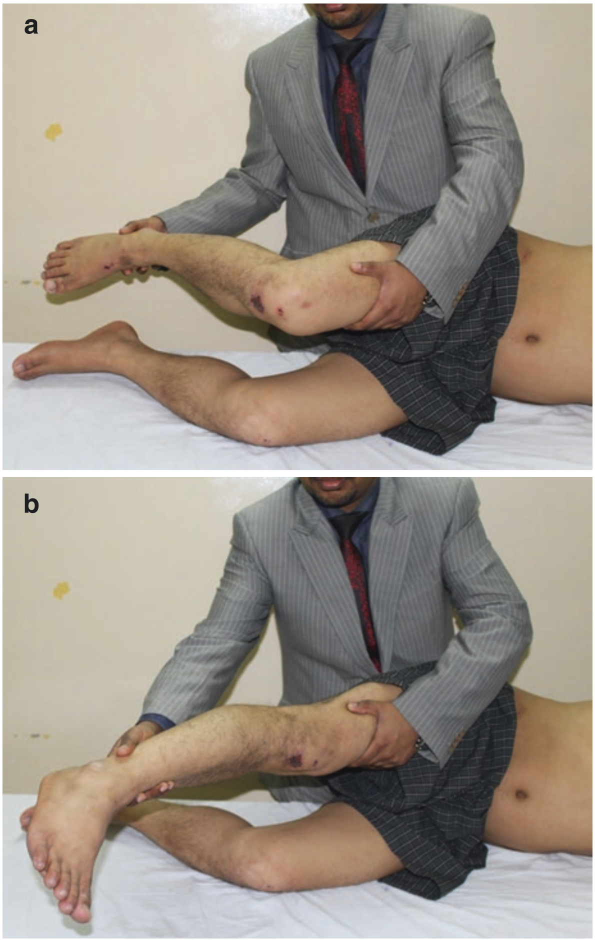


Fig. 43 (**a**, **b**) Modified straight leg raising test

positioned in slight flexion or extension if this is more comfortable for the patient. The examiner then passively extends the patient's knee, noting pain, resistance, and reproduction of the patient's symptoms for a positive test. The knee position (amount of flexion remaining) on the affected side is compared with that on the good side.

Crossed Straight-Leg Raising Test or Well Leg Raising Test of Fajersztajn or Cross Over Sign [6–8] (Fig. 44)

Performing the straight-leg raising test on the side opposite that of the sciatica is called the crossed straight-leg raising test. For example, if a patient complains of right-sided sciatica, the examiner performs a straight-leg raising test on the patient's left side. If this manuover reproduces or exacerbates the patient's right-sided sciatica, the result is extremely sensitive and specific for a herniated L5–S1 or L4–L5 lumbar disc. It is usually indicative of a large intervertebral disc protrusion usually medial to the nerve root. The crossed straight-leg raising test is less sensitive (0.29) but more specific (0.88) than the straight-leg raising test for confirming a compressed or irritated lumbar nerve root.

Bowstring Test or Cram Test or Popliteal Pressure Sign

MacNab described another confirmatory test for sciatic nerve tension known as the bowstring sign [9, 10]. To elicit the bowstring sign, the examiner again begins by performing the straight-leg raising test to the point of reproduction of the patient's radicular pain. The knee is then flexed 90°, which usually relieves the patient's symptoms. Digital pressure is then applied to the popliteal fossa over the posterior aspect of the sciatic nerve (Fig. 45). If this again reproduces the patient's radicular pain, the impression of sciatica is further confirmed.

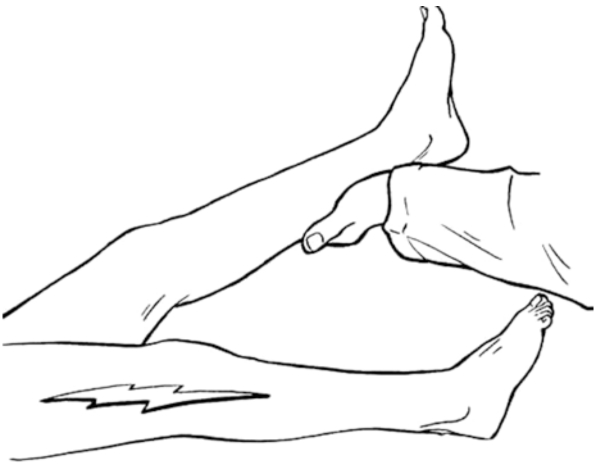


Fig. 44 Well leg raising test

Fig. 45 Bowstring test

Prone Knee Bending (Nachlas) Test

The patient lies prone while the examiner passively flexes the knee as far as possible so that the patient's heel rests against the buttock [11, 12]. The examiner should ensure that the patient's hip is not rotated. If the examiner is unable to flex the patient's knee past 90° because of a pathological condition in the hip, the test may be performed by passive extension of the hip while the knee is flexed as much as possible. Unilateral neurological pain in the lumbar area, buttock, and/or posterior thigh may indicate an L2 or L3 nerve root irritation.

Slump Test

The slump test [13–16] is really a variant of the straight-leg raising performed in the seated position. The slump test is a progressive series of maneuvers designed to place the sciatic nerve roots under increasing tension.

The patient begins the slump test, sitting on the side of the examination table with the back straight, looking straight ahead (Fig. 46). The patient is then encouraged to slump, allowing the thoracic and lumbar spines to collapse into flexion while still looking straight ahead (Fig. 47). The next step is to fully flex the cervical spine (Fig. 48). The patient is then instructed to extend one knee, thus performing a straight-leg raise (Fig. 49). The patient then dorsiflexes the foot on the same side (Fig. 50). The process is then repeated with the opposite lower extremity.

Reproduction of familiar radicular pain (at any stage of the test), as in the straight-leg raising, Lasegue, and crossed straight-leg raising tests, is highly suggestive of sciatic nerve root tension. Subsequent extension of the neck relaxes the spinal cord and may thus relieve nerve tension.

Fig. 46 Slump test

Fig. 47 Slump test: The patient slumps so that the dorsal and lumbar spine go into flexion

Fig. 48 Slump test: Flexion of cervical spine

Fig. 49 Slump test: Knee extension (straight leg raise)

Fig. 50 Slump test: Dorsiflexion of foot on the same side

Fig. 51 Femoral nerve stretch test

Femoral Nerve Stretch Test

As noted, the straight-leg raising test and its variants do not place significant tension on the nerve roots above L5. Although compression of the upper lumbar nerve roots is not common, it does occur. Herniations of the L3–L4 disc commonly compress the L4 nerve root. The femoral nerve stretch test is designed to assess compression of the L2, L3, or L4 nerve roots. To perform the femoral nerve stretch test, the patient is positioned prone on the examination table with the knee flexed to at least 90°. The patient's hip is then extended passively by lifting the thigh off the examination table (Fig. 51). In the normal patient, this induces only a mild feeling of tightness in the anterior thigh. When one of the nerve roots that contribute to the femoral nerve is compressed, this maneuver reproduces the patient's radicular pain in the anterior thigh.

Fig. 52 Valsalva maneuver

Valsalva Maneuver

The seated patient is asked to take a breath, hold it, and then bear down as if evacuating the bowels (Fig. 52). If pain increases, it is an indication of increased intrathecal pressure and therefore exacerbated pain that is due to pressure on the spinal cord or its nerve roots.

References

1. Fujiwana A, Tarnai K, Yoshida H, Kurihashi A, Saotome K, An HS, Lim T-H. Anatomy of the iliolumbar ligament. Clin Orthop Relat Res. 2000;380:167–72.
2. Aihara T, Takahashi K, Yamagata M, Moriya H, Shimada Y. Does the iliolumbar ligament prevent anterior displacement of the fifth lumbar vertebra with defects of the pars? J Bone Joint Surg (Br). 2000;82:846–50.
3. Hoppenfeld S. Physical examination of the spine and extremities. New York: Appleton-Century-Crofts; 1976.
4. Butler DA. Mobilisation of the nervous system. Melbourne: Churchill Livingstone; 1991.
5. Hall T, Hepburn M, Elvey RL. The effect of lumbosacral posture on a modification of the straight leg raise test. Physiotherapy. 1993;79:566–70.

6. Spengler DM. Low back pain: assessment ar1d management. Orlando, Florida: Grune & Stratton; 1982.
7. Scham SM, Taylor TKF. Tension signs in lumbar disc prolapse. Clin Orthop. 1971;75:195–204.
8. Woodhall R, Hayes GJ. The well-leg-raising test of Fajersztajn in the diagnosis of ruptured lumbar intervertebral disc. J Bone Joint Surg Am. 1950;32:786–92.
9. Macnab I. Backache. Baltimore: Williams & Wilkins; 1977.
10. Cram RH. A sign of sciatic nerve root pressure. J Bone Joint Surg (Br). 1953;35:192–5.
11. Herron LD, Pheasant HC. Prone knee-flexion provocative testing for lumbar disc protrusion. Spine. 1980;5:65–7.
12. Postacchini F, Cinotti G, Gumina S. The knee flexion test: a new test for lumbosacral root tension. J Bone Joint Surg (Br). 1993;75:834–5.
13. Maitland GD. The slump test: examination and treatment. Aust J Physiother. 1985;31:215–9.
14. Philip K, Lew P, Matyas TA. The inter-therapist reliability of the slump test. Aust J Physiother. 1989;35:89–94.
15. Maitland GD. Negative disc exploration: positive canal signs. Aust J Physiother. 1979;25:129–34.
16. Fidel C, Martin E, Dankaerts W, Allison G, Hall T. Cervical spine sensitizing maneuvers during the slump test. J Man Manip Ther. 1996;4:16–21.

Hip

Vishal Kumar and P. Gopinath

Applied Anatomy

The hip joint is a ball-and-socket that combines a wide range of motion (ROM) with considerable stability. The stability of the hip depends upon the deep placement of the femoral head into the acetabular socket, fibrocartilaginous acetabular labrum, the strong capsule and ligaments, and the powerful muscles surrounding the joint.

Attachments of the capsule: Proximal—edge of the acetabulum, acetabular labrum and transverse ligament. Distal—intertrochanteric line anteriorly and to the femoral neck about 1.5 cm proximal to the intertrochanteric crest posteriorly. Hence a large part of the neck is intracapsular.

The intracapsular space of the hip joint is smallest with the hip in extension and internal rotation. Also, this position produces maximum tension on the capsular iliofemoral ligament. Consequently, patients with inflammation of the hip joint often hold the extremity in the position of flexion and external rotation.

The normal femoral neck–shaft angle in an adult is 120–135°. In coxa vara the angle is less than 120°, and in coxa valga the angle is greater than 135°. The version of the femoral neck refers to the angle that the femoral neck makes in relation to the coronal plane of the rest of the femur. A normal femoral neck is anteverted about 80–150. When the femoral neck angles forward more than this, the patient is said to have increased femoral anteversion. If the femoral neck is angled less than normal, the patient is said to have decreased femoral anteversion or femoral retroversion.

Femoral head is placed in an offset position on the femoral shaft, through the femoral neck. This minimizes bony impingement. However, it requires a strong muscular support to stabilize the trunk over the hip joints.

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Applied Biomechanics

The Hip joint supports the weight of head, arms and trunk in all body postures. During the the stance phase, the femur is relatively fixed, and the motion of the hip joint is produced by movement of the pelvis on the femur.

When one leg is lifted off the ground, the tendency of the pelvis to fall towards the unsupported side is counteracted by the pull of abductor muscles of the weightbearing side. These abductor muscles work at a mechanical disadvantage since the distance from the abductor muscles to the femoral head is only about half the distance from the centre of gravity to the femoral head. The resultant joint reaction force is a combination of body weight and abductor muscular compression.

This forms the basis for understanding the trendelenberg test & Pathological gaits.

Surface Anatomy

The anterior most end of the iliac crest of the pelvis is the anterior superior iliac spine (ASIS). This can be palpated by tracing the illum anteriorly till you reach the first bony prominence. The iliac crest terminates posteriorly as the posterior superior iliac spine (PSIS), which may be felt in the depression seen just above the buttock. The sacroiliac joint is located just distal to PSIS. The ischial tuberosity is palpated in the lower part of the buttock. The gluteus maximus covers it in the upright posture, but can be identified when the hip is flexed.

The greater trochanter is felt as a big bony prominence on the lateral aspect of the proximal femur. This will be more prominently felt as the hip joint is adducted.

Introduction

The principal goals of a good history and physical examination are:

- To consider life-threatening or limb-threatening diagnoses, such as malignancy, vascular pathology, acute infection, and severe or progressive neurological conditions
- To determine of whether the source of the patient complaint is extra-articular in origin, or intra-articular
- To create of a manageable differential diagnosis, to which further workup, including diagnostic imaging can be applied.

History Taking

Pain

Hip joint pathology commonly causes pain in the groin region which may radiate down toward the anterior aspect of the knee. Occasionally, patient complains pain only about the knee. It can also present as low posterior buttock pain. Following details should be delineated when the patient complains of pain in and around hip region—location of the pain, duration, onset of the symptom, whether preceded by any trauma, progression of the pain, its severity, whether localized/diffuse/radiating, relation with exertion and rest, any aggravating/relieving factors, any diurnal variation including night pain, any remissions and exacerbations and early morning pains. If history of trauma is present, mechanism of injury and the treatments undergone should be inquired.

Limp

Limping is the next most common complaint. Inquire about the duration, progression, whether painful/painless, whether the patient feels that one of his lower limbs is short.

Limitation of Movements and Deformity

These are late symptoms. Enquire about their onset and progression.

Associated Symptoms

Whether there are any associated symptoms including fever, any discharging wounds, swelling, evening rise in temperature, constitutional/systemic symptoms, involvement of other joints including spine, early morning stiffness, sensory symptoms (numbness/paraesthesia), weakness should be asked.

Past History

Any hip problems during childhood, history suggestive of infection in the past, any injuries in and around hip in the past and their management, previous hip surgeries if any, history of tuberculosis, any systemic diseases, history of any prolonged drug intake and their details if known, should be enquired.

Personal History

Include occupation, recreational activities, smoking, and alcohol intake. Also enquire about the functional limitations because of the symptoms and use of any walking aids.

Family History

Any history of similar illness in the family members, history of tuberculosis and contact with them, any illness running in the family.

Summary of the History

By the end of the history, analysis all the information available. Hip joint pathologies fall into the following categories—Developmental, Sequelae of a paediatric hip disease, Traumatic, Infective, Inflammatory, Degenerative, Osteonecrosis, Neoplastic, Metabolic and soft tissue disorders about the hip.

Prerequisites for Physical Examination

The general prerequisites include—The examination bed is positioned away from the wall and should have a firm mattress. Patient should be undressed down to undergarments including removal of shoes. Patient should be accompanied by a family member or a health care professional of the same gender. Every procedure should be explained to the patient before performing.

Conventionally, physical examination is given in the order—inspection, palpation, movements, measurements and special tests. One thing to be kept in mind is that a sequence should be followed such that changing the patient's position is kept minimum and so the discomfort. All the examination done in standing position is completed before making the patient supine and so on.

Examination of Hip

- Walking—Gait
- Standing
- Squatting
- Sitting cross legged
- Sitting over the edge of the bed
- Lying on the examining bed
  - Supine position
  - Lateral position
  - Prone position

Gait

Common saying is ‘the physical examination begins when the patient walks into the exam room’. Careful observation of gait yields valuable information even before asking any questions to the patient. Observe the gait from the front, sides and behind. Also consider if the patient usually uses a walking aid. Common abnormal gait patterns seen in patients with hip pathology are as follows:

- Trendelenburg Gait: Patients are noted to move their trunk and head over the affected hip just prior to the stance phase of gait to prevent falling to the unaffected side. i.e. patient lurches on the affected side and the pelvis drops on the unaffected side. The Trendelenburg gait is seen in patients with abductor (gluteus medius) dysfunction, weakness, and denervation. It is also known as abductor limp or abductor lurch.
- Antalgic Gait: This gait is characterized by a shortened stance phase of the gait cycle. Any painful lower-extremity condition from hip to toes can cause it. In a patient with a painful hip condition, a lurch on affected side may also be present. This is because shifting the center of gravity of the upper body to a position closer to the femoral head reduces the counterbalancing force required in the abductor muscles, thus dramatically reducing the compressive force across the painful hip joint. But there is no pelvis droop or abductor dysfunction.
- Short Leg Gait: Seen in patients who have true shortening in a limb. The patient usually tries to compensate shortening by walking on their toes (equinus at the ankle) of the shorter limb. While standing, hip and knee of the longer limb are kept flexed. If the limb length inequality is such that it cannot be compensated, there will also be a pelvic drop on the shorter side. This in turn leads to dip of shoulder to the affected side. Scoliosis with convexity towards the shorter side can also be present.
- Stiff Leg Gait: Seen in patients with stiff hip or knee joint. In order to clear the ground during the swing through phase, the patient rotates the pelvis away from and then toward the body (circumduction).
- Steppage Gait: Seen in patients with foot drop or equinus deformity of the foot. In order to clear the toes off the ground, the knee flexion is exaggerated on the affected side (high step).

Patient Standing

From the Front

Look at the symmetry (length and girth) of both lower limbs noting the position of hip, knee and ankle. Also note the position of the shoulders and trunk. If limb length discrepancy is present, equinus of the ankle joint on the shorter side and flexion of

Fig. 1 Inspection from the front while patient in standing position

the knee on the longer side is evident. Rotational malalignment, if any will be evident. Any swelling in and around the hip including inguinal region, iliac fossa and around greater trochanter are noted. Gross muscle wasting of the quadriceps, if present is evident on comparing both sides. Visible bony landmarks are noted. Presence of pelvic tilt can be inferred by comparing the relationship between iliac crest on both sides. Causes for pelvic tilt include limb length discrepancy, scoliosis, and abduction/adduction deformity (Fig. 1).

Fig. 2 Inspection from the side while patient in standing position

From the Side

Lumbar region is inspected for increased lordosis which implies flexion deformity at the hip. Position of the knee can be better noted from the side (Fig. 2).

From the Back

Look at the symmetry of the shoulders. Asymmetry in the level of shoulders is suggestive of limb length discrepancy or spinal deformity. Look at the spinous processes of whole spine to assess the presence of scoliosis. If present, note the direction of the convexity of the curve. Also, note the position of PSIS on both sides to detect pelvic tilt. Look for the symmetry of the gluteal folds. Gluteal fold refers to the transverse crease between the buttock and the posterior thigh. Causes for asymmetry of gluteal folds include gluteal muscle wasting, dislocated hip, pelvic obliquity, and any collection (Fig. 3).

Fig. 3 Inspection from the back while patient in standing position. Note the gluteal muscle wasting on the left side

Skin all around is inspected for any scars, sinuses and ulcers. Scar, if present look at its location, whether surgical or traumatic, whether healed by primary or secondary intention.

Trendelenburg Test

Tendelenburg's test assess the efficiency of the hip abductor mechanism. Friedrich Trendelenburg described this test in 1897.

Method: The examiner stands or sits behind the patient. The patient is asked to stand on one leg while flexing the opposite hip to 30°. This position is maintained for 30 s. The same is repeated with the other leg (Figs. 4 and 5).

Interpretation: Normal response—The pelvis remains level or rises on the unsupported side because of the intact hip abductor function on the weight bearing side. Trendelenburg test positive (abnormal response)—The pelvis droops toward the unsupported side. The patient may try to compensate for this pelvic tilt by swinging his/her torso away from the unsupported side.

Fig. 4 Trendelenburg test—Negative (Normal Hip)

Causes: The abductor mechanism comprises of fulcrum (acetabulum & femoral head), lever arm (neck & trochanteric region) and power (gluteus medius). Insufficiency at any level produces a positive test. Examples include weakness of abductors, slackening of abductors due to upward displacement of the greater trochanter (congenital dislocation of the hip) and absence of a stable fulcrum (non-union neck of femur).

Fig. 5 Trendelenburg test—Positive

Squatting and Sitting Crosslegged

Patient is asked to perform squatting and sitting cross-legged which allows quick assessment of the hip functions preserved.

Patient Lying on the Bed: Supine Position

Inspection

With patient lying supine comfortably, look at the attitude of the limbs (Fig. 6).

Look for scars, sinuses, swelling and muscle wasting.

Visible bony landmarks (ASIS and Iliac crests) are inspected to detect pelvic obliquity.

By looking at the side, the gap between the lumbar region and the bed can be noted to detect any exaggerated lumbar lordosis (Fig. 7).

Standing at the foot end of the examination table, with the patient's lower limbs aligned in line with the body; compare the position of two malleoli. If any difference is present, limb length discrepancy exists. (This can be confirmed by measurement) (Fig. 8).

Palpation

Local Temperature is assessed with the dorsum of the hand (Fig. 9). Femoral artery can be palpated just below the midpoint of inguinal ligament (midway between ASIS and pubic tubercle). Volume of the arterial pulsation is compared on both sides. Absent or feeble pulsation on the affected side compared with the normal side constitutes a positive vascular sign of Narath. This implies the lack of bony support (femoral head)

Fig. 6 Inspection of the patient in supine position. Note the attitude of the left lower limb

Fig. 7 Inspection of the lying down patient from the side. Note the exaggerated lumbar lordosis

Fig. 8 Visual method to detect the limb length discrepancy

Fig. 9 Localizing the site for the palpation of femoral artery pulse

below against which the artery is readily palpable. Hence positive Narath sign is present in conditions causing destruction of femoral head and dislocated hip.

Tenderness: Hip joint: Anteriorly, the hip joint is located 2 cm lateral and 2 cm distal to the point at which the femoral pulse is palpable. Since hip joint is located deep, tenderness may or may not be elicited. In the presence of hip synovitis, firm pressure on greater trochanter and/or heel may elicit pain (Fig. 10).

Bony structures: Palpable bony landmarks including Greater trochanter, Iliac crest, Anterior and Posterior iliac spine, Pubic rami and Ischial tuberosity are examined for tenderness which may be suggestive of tendonitis or enthesopathy. Iliac crests and ASIS are palpated to confirm any tilt in the pelvis. Greater trochanter is palpated to detect any thickening/broadening/irregularity compared with the opposite side.

Fig. 10 Site for palpating the hip joint anteriorly—2 cm distal and lateral to the point where the femoral artery is palpable

Following landmarks which serve as a reference point while evaluating limb length and deformity are palpated and marked with a skin marker.

ASIS—The metal end of the tape is slide along the inguinal ligament from below for the first bony prominence.

Greater trochanter—Palpate the lateral surface of the upper thigh feeling the bony resistance from below upwards. The end of the bony resistance corresponds to the tip of greater trochanter.

Pubic tubercle—Bony prominence felt 2–2.5 cm lateral to the pubic symphysis.

Ischial tuberosity—Palpated in the inferior medial buttock with the hip flexed to 90°.

PSIS—corresponds to the dimple of venus.Medial joint line of the knee. Tip of the medial malleolus.

Range of Movement (ROM)

Hip joint mobility is described in three planes: flexion—extension, abduction—adduction, and internal rotation—external rotation. Normal ROM varies considerably but what is more important is to compare with the unaffected hip. ROM is recorded in degrees with the zero being the neutral or anatomical position of the joint.

Normal Range of Movement
Flexion—0–130°
Extension—0–15°
Abduction—0–40°
Adduction—0–30°
External Rotation in hip flexion—0–45°
Internal Rotation in hip flexion—0–45°
External Rotation in hip extension—0–45°
Internal Rotation in hip extension—0–35°.

Two things are to be remembered before going on to check for range of motion. First, it is important to distinguish the hip joint movements from the movements occurring in the adjacent joints (pelvis and lumbar spine). This should be done by stabilizing the pelvis and detecting the pelvic motion as soon as it occurs. Second, a patient with hip joint pathology usually develops deformity resulting from muscle contracture, muscle imbalance, joint destruction and/or joint instability. Once the deformity sets in, compensatory movements occur in the adjacent joints to maintain the equilibrium. These compensatory movements can completely mask the underlying deformity and result in a seemingly normal hip attaining neutral anatomical position. Therefore, deformity should be ruled out before examining for ROM. This is done by neutralizing the compensatory movements. This does not hold true for rotational deformities as they remain revealed most time.

Flexion Deformity

Flexion deformity of the hip prevents the patient's hip from being extended to the neutral (0°) position. This loss of movement is compensated by exaggerated lordosis at the lumbar spine to maintain the equilibrium. This compensatory hyperextension at lumbar spine can completely mask the deformity and the patient can lie flat on the examination table.

Thomas Test

Hugh Owen Thomas first described this test in the late 1870s to determine the flexion deformity of the hip.

Method

With the patient lying supine, both the hips are flexed. The hip being tested is then brought into extension, while maintaining the opposite hip in flexion. Flexion deformity is said to be present if the posterior part of the thigh cannot touch the bed (Fig. 11).

Fig. 11 Thomas test to reveal the flexion deformity. Remember—hand cannot be insinuated when the lumbar lordosis disappears

Alternative Method

With patient lying supine, the non-tested hip is gradually flexed until the lumbar lordosis is flattened (hand cannot be insinuated between the lumbar region and bed). The patient is asked to hold the limb in this flexed position with the hands placed around the knee. Care should be taken to detect any over rotation of the pelvis which would lead to false increase in the amount of flexion deformity. The hip to be tested is then allowed to hang into extension. The angle between the bed and the thigh of the limb being tested gives the amount of flexion deformity present. If the thigh of the tested limb can be brought completely down to the bed, no flexion deformity is present. Flexion deformity of knee, if present will prevent the thigh from touching the bed. In this case, the patient is brought down the bed so that knees are off the bed. Then the test is done in same way.

Coronal Plane Deformity

Abduction deformity prevents the patient's hip from being adducted to the neutral (0°) position. In order to bring the limb perpendicular to the floor, the pelvis drops on the affected side. (This results in functional lengthening on the affected side).

Conversely, Adduction deformity prevents the patient's hip from being abducted to at least a neutral position. As a compensatory measure, pelvis is lifted on the affected side. (This produces apparent/functional shortening on the affected side).

The degree of abduction/adduction deformity present can be determined by squaring the pelvis. When the line drawn connecting two ASIS is perpendicular to the midline of the body, pelvis is said to be squared. In the presence of Abduction deformity, ASIS on the affected side will be at a lower level compared with the normal side. The affected hip is moved in the direction of abduction to square the pelvis. Once the pelvis is squared up, the angle between the long axis of thigh and midline of the body is the degree of abduction deformity present.

Similarly, ASIS on the affected side will be at a higher level compared with the ASIS of the normal side, in the presence of Adduction deformity. Hence, the affected hip is moved in the direction of adduction till the pelvis is squared up. At this point, the angle between the long axis of thigh and midline of the body gives the degree of adduction deformity present.

Rotational Deformity

Rotational deformity cannot be concealed by the compensatory movements. The amount of deformity is determined by looking at the position of the patella.

Fig. 12 ROM. Checking for flexion

Fig. 13 ROM—abduction

Movements

Flexion

With patient lying supine, flexion deformity, if any should be unmasked and the hip is flexed further passively (knee kept in flexion) until a firm end is reached or pelvic movement starts. A hand is placed behind the upper pelvis to detect any pelvic movement. The angle between the long axis of thigh and the bed gives the maximum possible flexion attained. So if there is 20° flexion deformity and further flexion of up to 100° is possible, then the range of flexion is 20–100°. Also, observe the line of flexion. If the hip goes into external rotation with flexion, it is suggestive of a retroverted femoral neck as seen in slipped capital femoral epiphysis (SCFE) (Fig. 12).

Abduction

With the patient lying supine, first square the pelvis (to reveal any coronal plane deformity) and move the limb being examined laterally to note the range of

Fig. 14 ROM—adduction

abduction present. Pelvic tilt should be detected as soon as in occurs. There are two ways—first, with fingers grasp the opposite ASIS and anchor the same side ASIS with forearm. Second, flex the opposite leg over the edge of the bed and hold the same side ASIS with fingers. The angle between the axis of the thigh and the midline of the patient give the maximum possible abduction present (Fig. 13).

Abduction can also be tested with hip flexed. With hip flexed to 90°, move the knee towards the bed till pelvis starts lifting. The angle between the patient's thigh and an imaginary vertical plane drawn down the midline of the patient's body gives the amount of abduction present. Both the limbs can be examined simultaneously in this position. Normal hip abduction in flexion is about 60°.

Adduction

With patient lying supine and pelvis squared, the limb being examined is brought as far over toward the opposite side as possible before pelvis starts tilting. To make room for adduction, the opposite limb can be placed over the edge of the table or lifted by an assistant or the limb being examined is brought into slight flexion. The angle between the axis of the patient's thigh and the midline of the body gives the maximum possible adduction present. Adduction can also be tested with hip flexed. With hip flexed to 90° and pelvis stabilized, hold the knee and adduct the thigh across the midline. (Remember—If abduction deformity is present, adduction is not possible. Similarly if adduction deformity is present, abduction is not possible) (Fig. 14).

Rotation

External rotation and Internal rotation should be tested both in hip extension and hip flexion. Take care to detect any rotation taking place in the pelvis.

External Rotation and Internal Rotation in Hip Flexion

With patient lying supine, flex the patient's hip and knee to 90°. Stabilize the patient's knee with one hand and manipulate the foot with other hand to move the

Fig. 15 External rotation with hip in flexion

Fig. 16 Internal rotation with hip in flexion

hip externally and internally. It is important to remember that in this position, moving the leg towards the midline implies external rotation at hip and moving the leg away from the midline implies internal rotation at hip joint. The angle between the axis of the tibia and the imaginary midline bisecting the pelvis gives the amount of rotation possible (Figs. 15 and 16). Rotation in hip flexion can also be examined in seated position (patient sitting over the edge of the table with knee flexed). The maneuver is same as described above (Figs. 21 and 22).

External Rotation and Internal Rotation in Hip Extension

With hip and knee extended in supine position, roll the leg medially and laterally. By looking at the patella, the amount of rotation possible is determined (Figs. 17 and 18). This is a less accurate method. Rotation of hip in extension can be more accurately determined with patient prone. With patient lying prone, flex the patient' knee to 90° and rotate the leg internally and externally. Here also, remember that moving the leg towards the midline implies external rotation at hip and moving the leg away from the midline implies internal rotation at hip. The axis of the tibia is used as the indicator of the amount of rotation present (Figs. 19 and 20).

Fig. 17 Internal rotation with hip in extension (supine)

Fig. 18 External rotation with hip in extension (supine)

Fig. 19 Internal rotation with hip in extension (prone)

Fig. 20 External rotation with hip in extension (prone)

Fig. 21 External rotation with hip in flexion (sitting position)

Fig. 22 Internal rotation with hip in flexion (sitting position)

Sectoral Sign

If the internal rotation in hip flexion is restricted compared with the internal rotation in hip extension, it is suggestive of pathology in the anterosuperior part of the femoral head (Figs. 21 and 22).

Extension

(Remember—if flexion deformity is present, extension is not possible). With patient lying prone and pelvis stabilized with one hand, the hip is brought into extension till the pelvis begins to rotate. This gives the amount of extension present (Fig. 23). Hip extension can also be assessed in lateral position.

Fig. 23 Hip extension

Fig. 24 Telescopy test

Telescopic Test

It is done to assess the instability around the hip joint. With patient lying supine and hip flexed past 60° (approximately 90°) with slight adduction, grasp the lower end of femur firmly with one hand. Pelvis is fixed to the bed with the thumb of the other hand on the ASIS, while other fingers are kept embracing the greater trochanter. Gentle pull and push force away and towards the bed is given through the lower end of femur. If abnormal mobility is felt by the fingers around the GT, telescopic test is said to be positive. It indicates instability of the hip joint. Causes for telescopy include nonunion neck of femur with resorbed fracture ends, old unreduced posterior dislocation hip, DDH, pathological dislocation hip, girdlestone arthroplasty, septic sequelae of hip (Fig. 24).

Measurements

Leg Length Discrepancy (LLD)

Causes of LLD can be divided into two groups—that producing true leg length discrepancy and that producing functional or apparent leg length discrepancy. In true LLD, the actual lengths of the patient's two lower limbs are different. In functional LLD, patient's both lower limbs are same in length but one of the lower limb functions as if it is short or long compared with the other. This results from muscle or joint contractures. A discrepancy in limb length often causes pelvic obliquity.

Length Measurements

Apparent Length Measurement

With patient in supine position and limbs kept in line with the trunk, measure the distance from the patient's umbilicus or xiphisternum to the tip of each medial malleolus. Compare both. Causes for the difference in the apparent length measurements include pelvic obliquity, pelvic deformity, flexion deformity of hip or knee in one limb and a true leg length discrepancy (Fig. 25).

True Length Measurement

Squaring up the pelvis is a necessary prerequisite for true length measurement. The affected hip is manipulated such that both ASIS are in same level. The distance between the ASIS and the distal tip of medial malleolus is measured with the measuring tape on the affected side. The same is repeated on the opposite normal side keeping the limb in identical position as the affected limb. Both the

Fig. 25 Apparent length measurement

Fig. 26 True length measurement

distances are compared. This gives the amount of true shortening or lengthening (Fig. 26).

If true lengths on both sides are equal and apparent lengths are different, functional or apparent leg length discrepancy is present.

Segmental Measurements

If a true leg length discrepancy is detected, next step is to determine whether it is at femoral level or at tibial level or both. Measure the distance from the ASIS to the medial joint line of the knee and the distance from the medial joint line of the knee to the distal tip of medial malleolus. Compare on both sides.

Galeazzi Test

This test is useful to differentiate between the femoral and tibial length discrepancy by direct observation. With the patient lying supine, the knees are flexed to 90°. The heels placed together and are at same distance from the hips. Standing by the side of the table, look at the relative positions of the anterior aspect of the knees. Asymmetry denotes femoral length discrepancy. Standing at the foot end of the table, look at the relative positions of the superior aspect of the knees. Asymmetry denotes tibial length discrepancy (Fig. 27a, b).

The discrepancy in the femoral length can be either above or below the trochanter.

Supratrochanteric Measurement

Bryant's Triangle

With patient lying supine, draw an imaginary line from ASIS perpendicular to the bed. A second line drawn projected up from the tip of the greater trochanter to meet

Fig. 27 (**a**, **b**) Galeazzi test

Fig. 28 Bryant's triangle. Measuring the base of the triangle

the first line at right angle. This line forms the base of the triangle. A third line drawn from the tip of GT to the ASIS completes the triangle. Measure the distance between the tip of the GT and the imaginary line. The same is repeated on the opposite side and both the distance is compared. Any shortening denotes up riding of the trochanter. Causes include Coxa vara, destruction of femoral head, old dislocated hip, DDH, Nonunion neck of femur (Fig. 28).

Other tests used to determine the supratrochanteric shortening are qualitative.

Nelaton's Line

With the patient lying in the lateral decubitus position with the affected hip up, flex the knee and hip to 90°. Draw a line connecting the ASIS and the ischial tuberosity. Tip of the greater trochanter should lie at or below this line. If supratrochanteric shortening is present, GT tip will be palpated above this line (Fig. 29).

Fig. 29 Nelaton's line

Schoemaker's Line

With the patient lying supine, lines drawn connecting the GT and ASIS on both sides are projected up towards the abdomen. Normally both the lines meet above the umbilicus in the midline. Proximal migration of GT on one side causes the lines to meet on the opposite side. Proximal migration of GT on both sides causes the lines to meet below the umbilicus (Fig. 30).

Thigh Circumference Measurement

Thigh circumference should be measured equidistant from a fixed point (ASIS or knee joint line) on both sides. Differences in thigh circumference between two sides reflect chronic conditions leading to muscle wasting (Figs. 31 and 32).

Fig. 30 Schoemaker's line

Fig. 31 Thigh circumference measurement—determine a point from the knee joint line

Fig. 32 Measuring the Thigh circumference

Knee Examination

Vishal Kumar and Rajesh Kumar Rajnish

The clinical examination of a knee is to evaluate following aspects [1]:

1. Patello-femoral joint
2. Articular (meniscal and chondral) lesions and
3. Knee instability.

Often patient presents with chief complaints of:

1. Pain
2. Swelling
3. Mechanical symptoms like instability, giving way, locking.
4. Decreased range of motion
5. Deformity
6. Limp

The examination includes following steps:

1. Inspection
2. Palpation
3. Range of motion

Examination to be done in the following positions with both the lower limbs completely exposed:

1. Standing
2. Sitting

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3. Supine
4. Prone

Local examination:

1. Inspection while patient is standing and look for:

Alignment in terms of:

1. Genu Valgus (knock-knees)
2. Genu Varus (bow leg)
3. Genu recurvatum
4. Any swelling
5. Flexion deformity
6. Any Shortening
7. Gait of the patient

Inspection in Supine Position

Patient should lie down supine on examination table with both the lower limbs completely exposed and in identical position. Inspection is done from all around of the joint including the popliteal fossa and look

1. for the presence of any redness, scar, sinuses present on the skin over the knee.
2. Swelling: effusion in pre patellar, infra patellar or popliteal fossa.
3. Muscle wasting: Wasting (particular atrophy of the vastus medialis) of quadriceps occur in old, long term injury of the knee joint. However it may not occur in patient who is performing active muscle strengthening exercises following trauma.
4. Displacement of the patella

Palpation

Systematic palpation of all the bones around the knee joint is done. which include lower end of femur, patella, proximal end of tibia and fibula, tibial tubercle, patellar tendon and quadriceps tendon.

Temperature: local temperature to be compared with the opposite knee. Look for any rise in temperature. Increase in temperature signifies increased vascularity and is usually due to inflammation.

Tenderness: Joint line tenderness is done by flexing the knee joint and palpating the joint line with the help of thumb. Tenderness over tibial tubercle, patellar tendon, quadriceps tendon to be looked. Every attempt to elicit point tenderness is done.

Fluctuation test and patella tap are of particular importance in knee effusion. Look for the synovial thickening which is best appreciated in an extended knee, examiner grasps the edges of patella with thumb and middle finger and tries to lift the patella forwards. Normally, the bone can be grasped firmly but in cases with synovial thickening, fingers will slip off the edges of the patella.

Exact Point Tenderness

Injury to medial collateral ligament will produce characteristic tenderness at its femoral attachment. Tenderness over the ligament at joint level but not at bony attachment of the ligament is more suggestive of injury to the semilunar cartilage and less of the sprain to the deep fibers of the medial collateral ligament.

Tenderness at the joint level midway between the ligamentum patellae and the tibial collateral ligament is suggestive of tear of anterior horn of the medial semilunar cartilage.

Tests for Intra-Articular Fluid [2]

Cross Fluctuation

Cross fluctuation can be demonstrated only if large joint effusion is present. With one hand, the examiner compresses and empties the supra patellar pouch while with the other hand straddles the front of the joint below the patella, by squeezing with each hand alternately, a fluid impulse is transmitted across the joint.

The Patellar Tap

The supra patellar pouch is compressed with one hand to squeeze any fluid from the supra patellar pouch into the joint. With the other hand the patella is then tapped sharply backwards onto the femoral condyles. If the patella can be felt striking the femur and bouncing back again, test is considered to be positive.

The Bulge Test

This test is helpful in cases with very little fluid in the knee joint. After squeezing, any fluid out of the supra patellar pouch, the medial compartment of the joint is emptied by pressing on the inner aspect of the joint; that hand is then lifted away and the lateral side is sharply compressed to see a distinct ripple on the flattened medial surface as fluid is shunted across.

Assessment of Patello-Femoral Joint [2, 3]

For the assessment of patello–femoral joint, an accurate history, mechanism of injury, type and area of pain are the most important diagnostic points. The internal derangements of the knee joint mimic patellar problems. Patients with recurrent dislocation of knee frequently complaints of diffuse pain around the knee which gets aggravated by going up or down the stairs or hills. A feeling of insecurity in the knee may be present.

Q Angle

Clinically Q-angle is defined as the angle formed by the intersection between the lines drawn from the anterior superior iliac spine to the center of the patella and the line drawn from the center of the patella to the center of the tibial tuberosity. It is the line of pull of quadriceps mechanism and that of patellar tendon as they intersect at the center of patella. For accurate measurement of Q angle, it is recommended to take measurement in 30° flexion of knee. As in this position of the knee joint, patella is centered on the trochlear groove in more stable position.

Genu valgum, increased femoral anteversion, external tibial torsion, and a laterally positioned tibial tuberosity associated with increased Q angle. Increased Q angle may increase the lateral glide or tilt of patella; hence increased tendency of the patella to subluxate laterally.

Patellar Tilt and Glide

Patellar tilt indicates tightness of lateral restraints of the knee. This test is performed with the patient in supine position on the examination couch and the knee joint in 20° of flexion. The examiner places his fingers along the medial side of the patella with the thumb on the lateral aspect. If the lateral side of the patella can not be elevated above the horizontal plane or slightly past, the test is considered positive.

The glide test is performed with the knee in 0° and 30° of flexion. Patella is divided in to four quadrants visually and patella is moved passively medially and then laterally, measuring the excursion in the patellar quadrants. Normal patellar glide is one or two quadrants medially and laterally. If the patella glides laterally more than two quadrants, a medial restraints laxity is diagnosed; while when it glides less one quadrant, lateral restraints tightness may be a possibility.

The medial patellar femoral ligament (MPFL) is the main restraint to the lateral dislocation. The MPFL can be evaluated with the knee in full extension and the patella medially subluxated with the thumb as in the glide test.

Patella Tracking

Patellar tracking is assessment of decreased muscle power and ligamentous insufficiency. Rectus femoris and vastus intermedius muscles of quadriceps femoris apply an axial load while vastus lateralis and medialis components of quadriceps has oblique insertion and exerts pull to the patella in either direction. The medial and lateral retinaculum are the static constraints of the patellar tracking.

J Sign

It evaluates the dynamic patellar tracking. The patient is seated with examiner standing in front while the patient slowly extends the knee from flexion. A slight lateral subluxation of the patella as the knee approaches full extension indicates a positive J sign which is suggestive of patellar maltracking. Normally, patella move more superiorly than laterally.

Apprehension Test

The examiner manually subluxes the patella laterally by holding the relaxed knee in 20–30° of flexion. The patient suddenly complains of pain and resists any further lateral motion of the patella and this indicates a positive apprehension test.

Meniscal Lesion

Meniscal injury is often associated with nonspecific symptoms and with other ligamentous injury of the knee; hence it is difficult to diagnose. Clinician should have high index of suspicion if the patient have pain particularly, if it occurred after a weight-bearing sprain of the knee or after a prolonged squatting or following an episode of trauma.

Tests for meniscal lesions are a combination of knee flexion, tibial rotation and a stress on the joint line: this is the position where the posterior condyles roll back and the joint space becomes narrow, thus tightly engaging the menisci.

Tests for Meniscal Injury

McMurray Test

This is the most commonly done test for detection of meniscal injury. With patient is supine on examination couch, the examiner grasps the foot with one hand and palpates the postero-medial margin of the knee joint with the other hand. The knee is flexed completely and then slowly extended with simultaneous external rotation of the tibia on the femur while providing slight varus and valgus stress.

Occurance of a palpable click along the joint line or locking of the knee joint when the condlyes engage in the meniscal lesion; test is considered as positive for meniscal injury. Internal rotation of the leg tests the posterior horn of the lateral meniscus while external rotation tests the posterior horn of the medial meniscus. In acute injury the test result may be falsely negative, due to limited and painful range of motion.

Apley's (Grinding) Test

Apley's test is done with *the* patient in prone position on anexamination couch, the knee flexed to 90°. Then the leg is pulled upwards while holding the foot end to distract the joint and twisted along its axis to put rotational strain on the ligaments; this part of test will be painful if the ligaments are torn.

In the next part of the test patient in the same position, foot and leg is pushed downwards and twisted, when pain is felt while pushing a meniscal injury is diagnosed.

Thessaly Test

This test is based on dynamic reproduction of load transmission in the knee joint under normal or trauma condition. The test is done first on normal knee to teach the patient. The patient in standing position with the affected knee in 20° flexion with foot placed on flat surface, patient takes his whole body weight on that leg while examiner supports the patient by outstretched hand. Then patient rotates his knee and body to one side and then other side keeping the knee in 20° of flexion. Medial and lateral joint line pain during this manoeuvre indicates injury to the meniscus.

Knee Instability [2, 3]

Knee instability is usually defined as the direction to which the proximal tibia can abnormally reach, with respect to the distal femur (e.g. anterior, posterior, medial, lateral, rotatory). The direction of instability may be due to the affection of single or multiple structures. Knee instability occurs mainly due to injury to the anterior cruciate ligament, the posterior cruciate ligament, medial and lateral collateral ligament, postero-lateral and the postero-medial corner structures.

Stress Tests for Collateral Ligament

Abduction (Valgus) Stress Test

This test being perfomed with patient lying supine, and the limb in approximately 30° of abduction and 30° of flexion. Examiner's one hand is placed on the lateral aspect of the knee joint while the other hand supports the ankle. A gentle valgus or abduction stress is applied to the knee joint with slightly externally rotated leg. Stability of the knee joint flexed to 30° is observed and evaluated

Adduction (Varus) Stress Test

This test performed with adduction or varus stress to the knee joint with one hand placed on the medial side of the knee. The examination should be done with the knee both in full extension and in 30° of flexion.

Slide Tests

Examiner slides the tibia over femoral condyle, trying to subluxate it from the distal femur. Most commonly used tests for ACL and PCL injury evaluation are:

Anterior Drawer Test

This test is done to evaluate the ACL deficient knee joint. The test is performed with the patient in supine position, the hip flexed at 45°, and the knee flexed to 90°. The examiner stabilizes the patient's tibia by sitting on the patient's foot. Determine the amount of step-off between the femoral condyle and the tibial plateau by placing the thumbs over the joint line while exerting a smooth, gentle anterior pull on the tibia. The amount of forward displacement is compared with that on the normal side. Test is considered to be positive if there is greater anterior movement of the tibia as compared to the contralateral knee. This test is done in three different tibial rotational positions: at neutral and at 30° of internal and external rotation.

In PCL insufficiency, the tibia tends to slip back on the femur, with anterior movement as the slack in the PCL is taken up, may lead to false positive result. The correct starting point is determined by palpation. The tibial plateau and the medial condyle face each other in neutral position with a slight anterior step-off of the tibia (approximately 0.5–1 cm) and this is taken as the "zero point" for anterior and posterior drawer evaluation.

Knee effusion may prevent flexion to 90° and henceforth, insufficient force applied during test may lead to false negative Anterior drawer test.

The Lachman Test

This is highly sensitive test to detect anterior cruciate ligament deficient knee joint. This test can be done in acute traumatic, swollen knee for ACL injury, with the knee flexed 20–30° while the examiner uses one hand to grasp the thigh and stabilize it. The tibia is pulled anteriorly with the other hand and observed for tibial excursion. The end point of excursion is recorded as either a "firm" or a "soft" end point. A soft stop is highly predictive for ACL injury, while a hard stop can indicate an intact ACL, even in presence of good amount of tibial translation.

The end point is garded as:

Grade 1+: 0–5 mm more displacement than on the normal side

Grade 2+: 5–10 mm more displacement than on the normal side

Grade 3+: >10 mm more displacement than on the normal side.

A false-positive result can occur in a PCL efficient knee as the knee is pulled forward while false-negative results can be due to very strong hamstrings or in muscle spasm, meniscal tears, and third-degree MCL tears with postero-medial extension.

Pivot Shift Test

This test used to evaluate the rotatory instability of an ACL deficient knee. This test is painful. Hence, most of the times after the first attempt, the test is no more reproducible. The patient in supine position with fully extended knee, with tibia internally rotated while the examiner holding the foot with one hand and with other hand applying valgus stress at the knee joint. With flexion of the knee joint to about 20–30°, a jerk is suddenly felt by the examiner at the anterolateral corner of the proximal tibia. If the test is positive, tibia subluxates while extending the knee and relocates when it is flexed to 20–30° as the iliotibial band passes posterior to the center of rotation pushing backwards the tibial plateau inside the joint line.

Posterior Drawer Test

The posterior drawer test evaluates the PCL injury. This test is done similar to anterior drawer test with the patient's knee flexed to 90° and the foot stabilized by the examiner's thigh. A backward force is applied to the tibia. A posterior displacement of the tibia more than 5 mm, or a "soft" end point, indicates PCL insufficiency.

Posterior Sag Sign Test

The posterior sag sign is helpful in determining PCL injury. The test is done with patient lying supine on examination couch with knee in 45 or 90° of flexion to get maximum muscle relaxation. If the tibia sags backward, this is considered to be positive test and is suggestive of PCL insufficiency. Posterior sag can be shown by passive elevation of the leg in a fully extended position of knee, with the examiner applying the elevating force at the ankle. The test is interpreted as positive sag sign, if the tibia falls back on the femur in case of PCL insufficiency.

References

1. Rossi R, et al. Clinical examination of the knee: know your tools for diagnosis of knee injuries. Sports Med Arthrosc Rehabil Ther Technol. 2011;3:25.
2. Solomon L., Karachalios T. The knee. Apley's system of orthopaedics and fractures, chap. 20, 9th ed. London: Hodder Arnold; 2010. p. 547–85.
3. Miller III RH, Frederick MA, Canale ST, Beaty JH, editors. Knee injuries. Campbell's operative orthopaedics, 12th ed. Philadelphia: Mosby; 2013. p. 2052–211.

The Foot and Ankle

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The foot and ankle enables upright posture and locomotion in humans. The human foot has 28 bones and 57 articulations. Normal functioning of the foot and ankle, which is often taken for granted, depends on a complex interplay of bony architecture, ligamentous support, dynamic effects of the supporting muscles and overall control by the nervous system. Therefore, a problem in any of these can lead to potential problems, which can often be severly disabling for the patient.

Anatomy of Ankle (Talocrural) Joint

- The ankle joint is a uniaxial hinge joint and consists of articulations between the distal articular surface of tibia, medial malleolus, lateral malleolus and the talus.
- The *ankle mortise* is formed by the medial malleolus, the articular surface of distal tibia, the lateral malleolus and the inferior tibio-fibular ligaments.
- The body and dome of talus fit into the mortise. The superior surface of talus is broader anteriorly than posteriorly. To accommodate this broad anterior part in dorsiflexion, the fibula rotates laterally at the level of the inferior tibio-fibular syndesmosis.
- The capsule of the ankle joint is attached to the tibial and malleolar articular surfaces and to the trochlear surface of the talus. Anteriorly, it extends on to dorsal part of the talar neck.
- The *deltoid ligament*, the strongest ligament of the ankle is found on the medial side. It consists of superficial and deep parts. The *superficial fibres* of the deltoid ligament originate from the tip of the medial malleolus and fan out in three distinct bands. The anterior part (tibionavicular part) attaches to the navicular, the intermediate part (tibio-calcaneal part) attaches to the sustentaculum tali of calcaneus and the posterior part (posterior tibiotalar part) attaches to the talus.

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The *deep fibres* of the deltoid ligament (anterior tibiotalar part) originate from tip of medial malleolus and pass anteriorly to attach to the non-articular surface of medial part of talus.

- The lateral ligament complex of the ankle consists of three distinct bands. The *anterior talofibular ligament* originates from the tip of the lateral malleolus and attaches to the non-articular surface of the lateral talar neck. The *posterior talofibular ligament* passes from the tip of lateral malleolus to the lateral part of the posterior process of talus. The *calcaneofibular ligament* passes from the tip of lateral malleolus to the lateral surface of calcaneus.

Anatomy of Subtalar (Talocalcaneal) Joint

- The subtalar joint is a multiaxial hinge joint and consists of articulation between the talus and the calcaneus.
- The superior articular surface of calcaneus consists of three distinct facets; the posterior and the middle facets form the subtalar joint whereas the anterior facet is a part of the talocalcaneonavicular joint.
- The capsule of the subtalar joint is attached to the articular margins of the talus and calcaneus.
- The talus and calcaneus are bound by the lateral, medial and the interosseous *talocalcaneal ligaments*.
- The *cervical ligament* is lateral to the sinus tarsi; it passes from the superior surface of calcaneus and attaches to the extensor digitorum brevis and inferolateral tubercle on the talar neck.

Anatomy of Talocalcaneonavicular Joint

- The talocalcaneonavicular joint is a compound multiaxial joint.
- It consists of two parts; the *talocalcaneal part* is the articulation between the anterior articular facet of superior articular surface of calcaneus and talus and the *calcaneonavicular* part is the articulation between the anterior articular surface of calcaneus and the navicular.

Arches of Foot

The foot demonstrates two longitudinal and two transverse arches. The arches provide flexibility to the foot and also help in even dissipation of body weight.

Medial Longitudinal Arch

- Most important arch of foot, well formed on weight bearing (Fig. 1).
- Exaggeration of this arch is known as pes cavus and flattening is known as pes planus.

Fig. 1 Medial longitudinal arch

Fig. 2 Lateral longitudinal arch

- *Bones*: Formed by calcaneues, talus, navicular, cuneiforms and 1st–3rd metatarsals.
- *Supporting ligaments*: spring ligament, plantar fascia
- *Supporting muscles*: tibialis anterior, tibialis posterior, peroneus longus, flexor hallucis longus, abductor hallucis brevis and flexor digitorum brevis.

Lateral Longitudinal Arch

- Flattens out on weight bearing (Fig. 2).
- *Bones*: calcaneus, cuboid and 4th–5th metatarsals.
- *Supporting ligaments*: long and short plantar ligament and plantar fascia
- *Supporting muscles*: flexor digitorum brevis, flexor and abductor digiti minimi and peroneus longus, brevis and tertius.

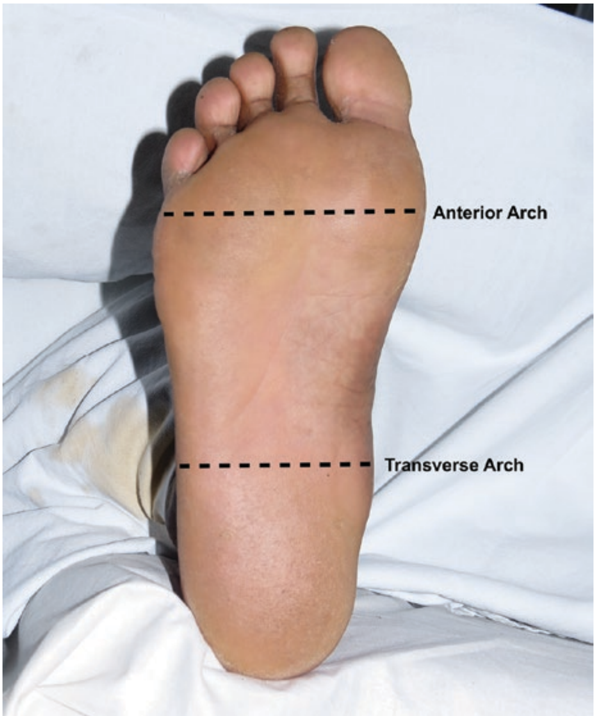

Fig. 3 Transverse and anterior arches

Transverse Arch (Fig. 3)

- Lies in coronal plane.
- One foot has one half of the transverse arch.
- *Bones*: all three cuneiforms and cuboid.

Anterior Arch (Fig. 3)

- Lies in coronal plane.
- *Bones*: heads of all metatarsals.
- *Ligaments*: intermetarsal ligaments and intrinsic foot muscles.

Inspection

Inspection of Shoe Wear

Always examine the shoe wear as it may give important information about foot problems:

- A patient with *foot drop* will have increased wear of the front (toebox) of the shoe; this happens because this part gets scraped along the ground in the swing phase.

- A patient with *intoeing gait* will have increased wear on the outer (lateral) part of the shoe.
- A patient with *valgus deformity* of the foot will have increased wear on the inner (medial) part of the shoe.

General Points in Inspection

- *Swelling*: this may be generalized, as in case of oedema or localized.
- *McKenzies sign*: egg shaped swelling over the lateral malleolus in case of lateral ligament complex injury (Fig. 4)
- Note whether there are any *scars*, and whether they are linear or geographic.
- Make a note of any *sinuses* around the foot and ankle. This is especially important in cases of tubercular and fungal infections.
- *Varicosites* may be present in the great saphenous vein or less commonly, the short saphenous vein. Also note whether there are any associated venous ulcers.

Attitude of the Limb

- Note whether the patient is able to stand unaided both feet and whether a walking aid is used. The foot is said to be *plantigrade* if on standing, both the heel and the metatarsals rest squarely on the ground.
- If the patient stands on his toes alone, it indicates an *equinus def*ormity. Similarily if the patient stands on his heel alone, it indicates a *calcaneus deformity*.

Fig. 4 McKenzie's sign

Fig. 5 Physiological heel valgus

- Make a note of any varus or valgus deformity of the heel. Generally, the center of the heel lies slightly lateral to the center of the calf, this is the *physiological heel valgus* (Fig. 5). Exaggeration of the normal lateral position of heel is termed as *'heel or hindfoot valgus'* and if the heel lies in a medial position, it is termed as '*heel or hindfoot varus'*. Note that whereas upto 5–10° of heel valgus is physiological, any amount of heel varus is pathological (Figs. 6 and 7).
- Make a note of *intoeing*, which is identified by the toes pointing inwards during standing and walking. Under normal circumstances, the toes point ouwards during standing and walking. Intoeing could be due to internal rotation at the level of femur, intorison of tibia or metatarsus adductus (Fig. 8). Many children with intoeing have spontaneous resolution by the age of 6 years. However, intoeing in adults is pathological.

Inspection from the Front

- Make a note of the relationship between the lateral and medial malleolus, the lateral malleolus lies approximately 1 cm below and behind the medial malleolus.
- Make a note of any adduction (inward deviation) or abduction deformity (outward deviation) at the level of the mid-foot.

Fig. 6 Pathological heel varus: note the severe heel varus (right side) in a 2 year old with neglected congenital talipesequinovarus. The opposite side shows physiological valgus

Fig. 7 Pathological heel valgus

- Inspect the metatarsals: Generally, the 1st ray is the longest followed succesively by the all the other rays, this is termed as the *Egyptian foot*. In some cases, the second ray is longest, followed by the first ray, this is termed as the *Greek foot*. Another variation is the *Rectangular foot*, in which the 1st–3rd rays are equal in length. Abnormal shortening of the metatarsal may be congenital (brachymetatarsia) or posttraumatic (Fig. 9).
- *Exostosis* around the foot may be found in several locations:

Fig. 8 Pathological intoeing: note right sided intoeing in a 2 year old with neglected congenital talipesequinovarus. This is attributable to adductus deformity at the forefoot and also due to tibial intorsion. The left side is normal

Fig. 9 Bilateral brachymetatarsia involving the fourth ray

- *Cuneiform exostosis*, involving the medial cuneiform, may be an asymptomatic finding in some patients.
- Fifth metatarsal base: an exostosis in this location can lead to problems with shoewear.
- Fifth metatarsal head: it is known as *tailor's bunion* or *bunionette* and is often assocaited with varus (medial deviation) of the fifth metatarsal, known as *quinti varus*.
- Calcaneus: prominence of the calcaneal tuberosity may cause problems with shoe wear, blisters and callosities. The term *Haglund's bump* is reserved for exostosis on the superolateral part of the calcaneal tuberosity.

• A *dorsal ganglion* may present as an asymptomatic swelling on the dorsum of the forefoot.

Fig. 10 Severe hallux valgus deformity

- Look for any obvious defomity of the toes:
  - *Hallux varus*: medial deviation of great toe
  - *Hallux valgus*: lateral deviation of great toe (Fig. 10)
  - *Mallet toe*: isolated flexion at the distal interphalangeal joints of toe.
  - *Claw toe*: flexion at the interphalangeal joint and hyperextension at metatarsophalangeal joints.
  - *Hammer toe*: flexion at proximal interphalangeal joint along with hyperextension at distal interphalangeal and metatarsophalangeal joints.
  - *Curly toe*: fixed flexion deformity of both interphalangeal and metatarsophalangeal joints, along with some degree of adduction of the toe. It is produced by interosseous muscle weakness.
  - *Syndactyly*: fusion of one or more digits.
  - *Polydactyly*: duplication of digits.
- Swelling and erythema of the first MP joint can happen in case of acute gouty arthritis. In severe cases, other MP joints may also be involved.
- Look for any abnormalities of the nails: ingrowing toe nail, acute or chronic nailfold infection (paronychia), fungal infections of the nail etc.
- Callosities may form on the dorsal apsect of toes due to persistent frcition from ill-fitting foot wear. These are termed as '*heloma durum*' or '*hard corns*'.

Inspection from the Medial Aspect

- The tendon of *tibialis posterior* lies immediately posterior to the medial malleolus.
- Inspect the *medial longitudinal arch* of foot in the standing as well as the lying down position. This arch is higher than the lateral longitudinal arch. Make a note of any exaggeration (cavus deformity) or flatenning (planus deformity) of the arch.
- A '*bunion*' refers to visible prominence on the medial aspect of the first metatarsophalangel joint and is associated with hallux valgus. It is formed, in due to bony overgrowth, soft tissue thickening and bursitis.

Inspection from the Lateral Apsect

- The tendons of *peroneus longus and brevis* lie just behind the lateral malleolus. Note if they are prominent.
- A '*bunionette*' is a visible prominence, similar to a bunion, seen on the lateral aspect of the foot, especially in tailors. It is thought to occur due to friction on the skin caused by sitting cross legged on the ground, or due to tight footwear.

Inspection from Posterior Aspect

- Check for heel varus or valgus, as described earlier.
- Note whether there is any broadening or irregularity of the heel.

Inspection of the Sole

- Check for any callosities. Soft callosities are known as '*heloma molle*' and hard callosities are known as '*heloma durum*'. Callosities occur in weight bearing areas of the foot.
- Check for any *verrucae* or *plantar warts*, which can be painful. Exquisite tenderness is elicited by side to side compression, as contrast to callosities, which are tender on direct pressure.
- *Trophic ulcers* may be seen in patients with neurological disorders.
- Fungal infection of the foot is especially common in atheles and is known as *athletes foot* or *tinea pedis*.

Palpation

Palpation should begin with assesment of local temperature first. All bony and soft tissue landmarks should be carefully palpated.

Bony Landmarks

- The *medial* and the *lateral malleolus* are subcutaneous and readily palpable.
- The *ankle joint line* can be palpated anteriorly. The examiner's finger can be traced along the anterior border of the medial malleolus to follow the anterior articular surface of the distal tibia. The joint line lies immediately distal to the articular surface.
- The *peroneal tubercle* of the calcaneus can be palpated just anterior to the lateral malleolus.
- The *sinus tarsi* is felt as a hollow anterior to the lateral malleolus.
- The *body of talus* can be palpated by plantarflexion of the foot and moving the thumb downwards from the distal tibia.
- The *navicular* can be identified by following the tendon of tibialis anterior onto it's insertion on the navicular. An *accessory navicular* bone, if present, is palpable immediately next to the navicular and may be tender at times.
- The *calcaneocuboid joint* can be palpated on the lateral aspect of foot.
- The *base of fifth metatarsal* is felt as a distinct prominence on the lateral aspect of foot.
- The *cuneiforms, shafts of metatarsals and phalanges* are subcutaneous and easily palpable.

Other Points in Palpation

- The tendon of *tibialis anterior* can be made prominent with resisted dorsiflexion of the foot. Similarily, the tendon of *extensor hallucis longus and extensor digitorum longus* can be made prominent by resisted dorsifelxion of the great toe and second to fifth toes, respectively.
- The tendons of *peroneus longus and brevis* become prominent with resisted eversion of the foot. Tenderness is indicative of trauma or tendinitis.
- The *Achilles tendon* can be easily palpated on the posterior aspect of the ankle; it becomes taut in dorsiflexion of the foot.
- Prominence of the calcaneal tuberosity, especially over its superolateral corner, is termed as *Haglund's bump*.
- The *retrocalcaneal bursa* lies in between the Achilles tendon and the calcaneal tuberosity. Its bursitis presents as a painful swelling on either side of the Achilles tendon.
- The *anterior tibial artery* can be palpated against the distal tibia, immediately lateral to the tendon of extensor hallucis longus.
- The *dorsalis pedis artery* can be palpated in the first web space.
- The *posterior tibial artery* can be behind the medial malleolus, immediately posterior to the tendon to flexor digitorum longus.
- The tendon of *tibilias posterior* can be made prominent by resisted or active plantarflexion of the foot. Tenderness along the tendon is indicative of tenditinitis and is the amongst the earliest findings in adult acquired flatfoot.

- The tendon of *flexor hallucis longus* can be made prominent by resisted or active plantarflexion of the great toe. Tendinitis of this tendon is often seen in ballet dancers as they have to dance on the tip of their toes. Snapping sounds may be noted in extreme cases as the inflammed and swollen tendon passes through it's fibro-osseus sheath. This phenomenon is known as *'hallux saltans'*.
- The *plantar aponeurosis* becomes prominent by dorsiflexing the first toe. Tenderness along the medial side of the anterior process of calcaneus (which is the calcaneal attachment of plantar aponeurosis) is typical of plantar fascitis.
- *Palpable nodules* (usually non tender) within the plantar fascia can occur in case of benign fibromatosis.
- Also note whether there are any palpable swellings around the foot and ankle.

Deformities

It should be borne in mind that the term '*deformity'* implies that the movement opposite to the deformity is not possible. Therefore true deformity must be differentiated from posturing, as may happen in case of small children or in patients with muscular imbalance. If a deformity is suspected, always try to correct the deformity by performing the movement opposite to the deformity. As an example, if you find a patient whose foot is in equinus, try to bring the foot into dorsiflexion. If you can dorsiflex the foot, it is not a true deformity.

Equinus and Calcaneus Deformities

- An equinus deformity is said to exist if the plantar-flexed foot cannot be brought to neutral position. The reverse of equinus is the calcaneus deformity.
- To determine the degree of equinus or calcaneus deformity, the examiner first tries to bring the foot into as much corrected position as possible (i.e. passive dorsiflexion for equinus deformity and vice versa). Next a line is drawn along the medial side of tibia and another vertical line is drawn along the medial border of foot. The angle between these two lines is measured by a goniometer. This measurement minus 90° represents the equinus or calcaneus deformity (Fig. 11).
- The *Silverskiold test* is used to differentiate between equinus due to contracture of the solues and the gastrocnemius muscles. The degree of equinus is assesed with the knee extended and flexed. If the contracture is within the gastrocnemius muscle the deformity decreases with knee flexion; this is because the gastrocnemius muscle crosses both the knee and the ankle joints. However, equinus deformity due to soleus contracture doesnot improve with knee flexion.

Varus and Valgus Deformities

- A valgus deformity refers to a than physiological lateral deviation of the heel, wherheas a varus deformity refers to medial deviation of the heel.
- Always measure the deformitites in standing as well as lying down positions.

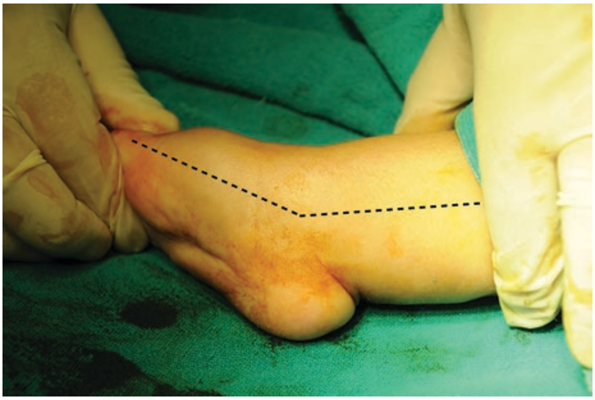

Fig. 11 Severe equinus deformity in an infant with congenital talipesequinovarus. To measure the equinus angle, a line is drawn along the medial side of tibia and another vertical line is drawn along the medial border of foot. This measurement minus 90° represents the equinus deformity

Fig. 12 Measurement of hindfoot valgus or varus alignment—A vertical line is drawn along the center of the calf (line A) and another vertical line drawn through the center of the heel (line B). The angle between these two lines denotes the varus or valgus angle of the heel

- In standing postion, examine the patient from the back. A vertical line drawn along the center of the calf and another vertical line drawn through the center of the heel define the valgus or varus angle (Fig. 12). This angle can be measured with a goniometer.
- For assessment in the lying positon, the patient is asked to lie prone with the knees flexed to 90°. The examiner grasps the heel between the thumb and index finger and tries to bring the heel into neutral positon. Varus or valgus defomity can be measured in the same way as in the standing positon.

Cavus and Planus Deformities

- Abnormal exaggeration of the the medial longitudinal arch is known as *cavus*. It is often associated with heel varus and termed as *'cavovarus'* (Fig. 13).
- Flatenning or absence of the medial longtitudinal arch is known as *planus*. It is often associated with heel valgus and termed as *'planovalgus'* (Fig. 14). Jack has proposed a classification of pes planus
  - Grade I: normal or slightly depressed arch on standing
  - Grade II: the medial arch completely flattens on standing
  - Grade III: the medial arch flattens and bulges towards the examiner in a convex fashion

Fig. 13 Equinocavovarus deformity after neglected sciatic nerve injury. Note also the trophic ulcer on the posterior aspect of heel

Fig. 14 Pes planus—note flattening of the medial longitudinal arch

Movements

Before assesing the range of movement, it is extremely important to ascertain the presence and degree of deformity at that joint. Only then can the examiner know about the true arc of motion of that joint. Both active and passive movements should be recorded and compared with the opposite side. Also note whether or not the movements are painless, painful throughtout the arc of motion (indicative of arthritis) or painful at the extremes (indicative of synovitis or extra-articular pathology).

Dorsiflexion and Plantarflexion (Figs. 15 and 16)

- Dorsiflexion and plantarflexion movements occur at the ankle joint. These can be tested with the patient sitting by the side of the bed or in the lying down position.
- To test active movements, the patient is asked to fully plantarflex and dorsiflex the foot from a neutral position.

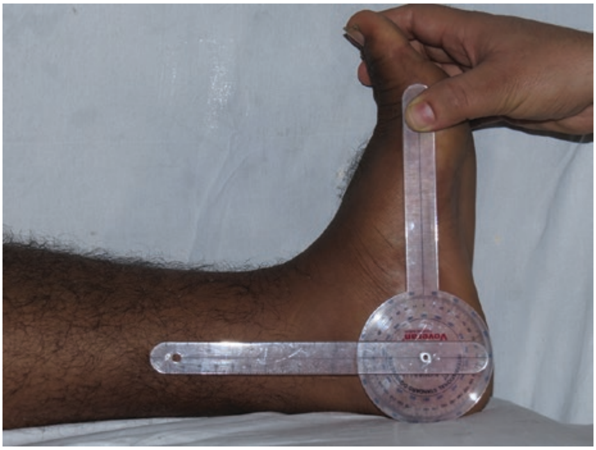

Fig. 15 Measurement of active ankle dorsiflexion

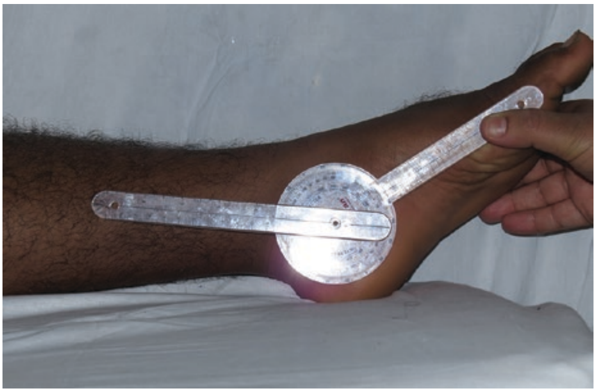

Fig. 16 Measurement of active ankle plantarflexion

- To test passive movements, the examiner grasps the patient's foot at the midfoot level with one hand and stabilizes the patient's leg by holding it with the other hand just above the malleoli. The foot is then brought into plantarflexion and dorsiflexion from a neutral position.
- Normal range in adults: dorsiflexion, 0–15°; plantarflexion, 0–55°.

Inversion and Eversion (Figs. 17 and 18)

- Inversion and eversion movements occur primarily at the subtalar joint.

Fig. 17 Active inversion

Fig. 18 Active eversion

- Assesment of passive range of movement is done with the patient prone and knees flexed to 90°. The examiner grasps the patient's heel with one hand and holds the patient's leg just above the ankle joint. The heel is moved by the examiner in eversion and inversion and the range of movement recorded.
- Normal range: inversion, 0–20°; eversion, 0–10°

Abduction and Adduction (Figs. 19 and 20)

- Adduction & abduction occur at the midfoot joints.
- The examiner grasps the patient foot at the level of the toes and the patient's heel with the other hand.
- The forefoot is then moved into adduction and abduction.

Fig. 19 Adduction

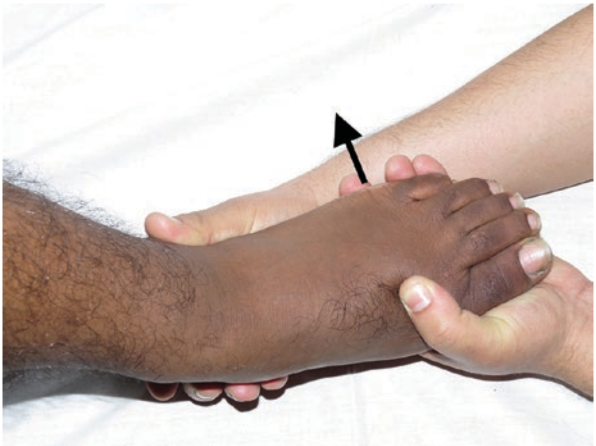

Fig. 20 Abduction

Pronation and Supination (Figs. 21 and 22)

- Supination: is a combination of plantarflexion, adduction and inversion. The patient sits on the side of the bed with the knees flexed to 90° and the examiner

Fig. 21 Supination

Fig. 22 Pronation

asks the patient to turn the sole inwards, so that it faces the other foot. Normal range: 0–35°
- Pronation: is a combination of dorsiflexion, abduction & eversion. The patient sits on the side of the bed with the knees flexed to 90° and the examiner asks the patient to turn the sole outwards, so that it faces away from the other foot. Normal range: 0–20°

Movements of Toes (Figs. 23 and 24)

- *Dorsiflexion and plantarflexion*: both active and passive range of movement is ascertained. Normal range at metatarsophalangeal joint: flexion 0–40°, extension 0–65°. Normal range at interphalangeal joint: flexion 0–60°, extension, 0°.
- *Abduction*: the examiner asks the patient to move the toes outwards. Both active and passive range of movement is ascertained.

Fig. 23 Toe dorsiflexion—dorsiflexion at metatarsophalangeal and interphalangeal joints should be noted separately

Fig. 24 Toe plantarflexion—plantarflexion at metatarsophalangeal and interphalangeal joints should be noted separately

Neurological Examination

A thourough neurological examination must be carried out in each case. The details of neurlogical examination can be found in the chapter of examination of the spine.

Motor Examination

The power of tibialis anterior (L4), extensor hallucis longus (L5), peroneal muscles (S1) and tibialis posterior (S1) should be ascertained and graded as per the MRC system.

Sensory Examination

Sensations should be checked according to the dermatomal supply of the lower limb. The area of anterior part of leg medial to the tibial crest and the medial border of foot is supplied by the *saphenous nerve* (L4). The skin in thefirst web space is supplied by the deep peroneal nerve (L5). The area of anterior part of leg lateral to the tibial crest and the whole of dorsum foot except the first web space is supplied by the *superficial peroneal nerve* (L5). The lateral border of foot and the sole of foot is supplied by the sural nerve (S1). The short saphenous nerve supplies the thin strip of skin on the posterior aspect of leg, in between the L4 and L5 dermatomes.

Special Tests

Tests for Stability of the Ankle Joint

- *Anterior Drawer Test* (Brostrom) (Fig. 25): this is done to check for the integrity of the anterior talo-fibular ligament (part of lateral ligament complex). The patient sits by the side of the bed with the legs hanging loose. The examiner

Fig. 25 Anterior drawer test

Fig. 26 Inversion stress test

holds the patient's leg just above the malleoli with one hand and the heel with the other hand. Next, the examiner tries to push the heel forward while pushing back at the leg. A positive test is indicated by abnormal anterior excursion of the talus (>3 mm), dimpling of the skin on the anterior aspect of ankle and pain. The displacement of talus increases with internal rotation of the foot.

- *Inversion Stress Test* (Fig. 26): this is done to check for the integrity of the calcaneofibular ligament. The patient sits in the same position as the anterior drawer test and the examiner holds the leg just above the malleoli. The patient is asked to fully dorsiflex the ankle and examiner's other hand grasps the patient's heel and tries to invert it. Abnormal opening on the lateral side and pain are indicative of torn ligament.
- *Lateral Stress Test* (Fig. 27): it is done to check for the integrity of the inferior tibiofibular ligament. The examiner holds the patient's leg just above the ankle and tries to push the heel laterally with the other hand. Abnormal lateral movement and pain are noted if the ligament is torn.

Test for Rupture of Tendo-Achilles

- In case of a complete rupture, a palpable gap is present at point approximately 2 cm above the insertion of the Achilles tendon. The examiner's fingers can be insinuated in this gap. This gap increases on dorsiflexion of the foot. Sometimes, a palpable gap may be absent if there is bridging fibrosis across the cut ends of tendon.
- Ask the patient to stand on the tips of toes. In case of partial rupture, the patient is not able to lift the heel off the ground as much as the normal side. This is known a as *'heel lag'*. This maneouvre is also accompanied by pain. In complete rupture, the patient is not able to lift the heel off the ground (Fig. 28).
- *Thompson's 'Squeeze' Test: The* patient lies prone with the feet projecting beyond the examining table. The examiner squeezes the patient's calf at a point just distal to its maximal girth and this leads to plantar flexion of the foot, if tendo-Achilles

Fig. 27 Lateral stress test

Fig. 28 Heel lag—this patient with right-sided tendo-achilles rupture was asked to stand on toes. Note that the patient is unable to do this due to weakness of plantarflexion on the affected side

Fig. 29 Thompson's 'squeeze' test

is intact. However, in complete rupture there is no plantarflexion of the foot. A *false-positive* result may be obtained in case of partial tear of the tendon or when there is bridging fibrosis across the ends of the tendon (Fig. 29).

- *O'Brien's Needle Test:* The patient lies prone. Under aseptic conditions a 25-gauge hypodermic needle is inserted into the calf at a point approximately 10 cm above the tuberosity calcaneus and just medial to the midline of the calf. The foot is then passively plantarflexed and dorsiflexed. With intact tendo-Achilles, the needle is seen to move in a direction *opposite* to the movement of the foot. Absence of this movement indicates complete rupture of the tendo-Achilles.

Test for Achilles Tendinitis and Bursitis

- In case of insertional Achilles tendinitis, pain is localized directly over the insertion Achilles tendon and resisted plantar-flexion at the ankle is painful.
- Also, walking on toes leads to pain.

Tests for Insufficiency of Tibialis Posterior Tendon

- *Tibialis posterior tenovaginitis:* The patient is asked to plantarflex and invert the foot while the examiner resists this movement. This maneouvre produces pain behind the medial malleolus (Fig. 30).
- *Double heel rise test:* The heel rise test demonstrates insufficiency of the tibialis posterior tendon. The examiner stands behind the patient and the patient is asked

Fig. 30 Testing for tibialis posterior tenovaginitis

Fig. 31 Double heel rise test

to stand up on the toes. As the heel is lifted off the ground, it tilts from valgus into varus position by action of the tibialis posterior. Absence of varus tilt on the affected side is indicative of tibialis posterior insufficiency (Fig. 31).

- *Single heel rise test:* This test is similar to the double heel rise, but the patient is asked to stand on toes of the affected limb, whereas the other limb is kept clear of the ground. Inability to perform this test indicates tibialis posterior insufficiecny (Fig. 32)
- *Too many toes sign:* The examiner stands behind the patient and examines the patient's foot. Seeing 'too many toes' on the lateral side is indicative of collapse of the medial longitudinal arch of foot. When positive unilaterally, this sign is indicative of tibialis posterior insufficiency.

Fig. 32 Single heel rise test

Test for Peroneal Spasm

Patient sits with legs hanging over the edge of the table. Forced inversion will lead to pain behind the lateral malleolus.

Tests for Peroneal Tendon Instability (Snapping Peroneal Tendons)

- Tears of the peroneal retinaculum can lead to abnormal excursion or even displacement of the peroneal tendons. Often, the displaced tendons reduce with an audible or palpable snap.
- Tenderness can be elicited behind the lateral malleolus.
- *Peroneal tendon instability test*: Starting from a position of dorsiflexion, the patient is asked to move the foot into maximal eversion, plantarflexion and finally inversion. After several cycles, this movement is reversed. The examiner's finger palpates for excursion of the tendons. Normally, there is an anterior glide of the

tendons but with a torn retinaculum, the tendons may sublux over the lateral malleolus or even dislocate.

Tests for Tasrsal Tunnel Syndrome

- Tarsal tunnel syndrome is caused by compression of the posterior tibial nerve in the tarsal tunnel.
- *Tinel's sign*: gentle percussion on the posterior tibial nerve behind the medial malleolus produces parasthesias in the distribution of the nerve (Fig. 33).
- *Dorsiflexion-eversion (Kinoshita) test*: the examiner brings the patient's foot and toes into maximal dorsiflexion and eversion. This produces paraesthesias in the distribution of the nerve and tenderness just behind the medial malleolus (Fig. 34).
- Torniquet test: the examiner applies a torniquet to the patient's calf and inflates it to just above the systolic pressure. Appearance of symptoms within 1–2 min confirms the diagnosis.

Fig. 33 Tinel's sign for tarsal tunnel syndrome

Fig. 34 Kinoshita test for tarsal tunnel syndrome

Examination of a Paediatric Patient

G. Nirmal Raj and Balaji Saibaba

Paediatric orthopaedic clinical evaluation by means history taking and examination are far different from that of an adult. The child's birth history, developmental history and family history have a significant bearing on the diagnosis of certain childhood orthopaedic problems. Most of the time, the history is elicited from the parents. Painless conditions like a deformity or a limp are brought to the clinician's attention only when the parents start noticing them. Hence, the exact time of onset of symptoms is often unknown.

History Taking

1. Patient demographics
   Knowledge about the child's age, sex, place of origin, socio-economic status and educational status of the parents should be recorded in all cases before eliciting the chief complaints. These basic details might not only help in arriving at a diagnosis, but also, in deciding the apt treatment plan for the child.
2. Chief complaints:
   The presenting complaint should answer the question: "What made the parents bring their child to the hospital?" The commonly recorded chief complaints include pain, deformities, limp, swelling, weakness and stiffness.
3. History of present illness:
   The treating orthopaedician should elicit and record a chronological clear history regarding each of the presenting complaints. This should include:
      Location
      Onset

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Duration/Frequency
Progression/Course
Quality/Severity
Aggravating/Relieving factors
Associated manifestations

The examiner should also determine the nature of response of each family member to the child's symptoms and the reasons for their concern. It is also essential to rule out the possibility of any secondary gains from the child's illness.

Note: Malingering and Battered baby syndrome should be ruled out.

4. Treatment history:
   Previous treatment history has a significant bearing in deciding the management plan for the child. A thorough treatment history staring from the onset of presenting illness is necessary in all cases. This should include details of all possible modes of prior intervention—medical, surgical, plaster, traction, massage, physiotherapy, "desi"/native treatment modalities, etc. The examiner should be able to determine if the prior treatment has altered the original course of the disease or not.
5. Family history:
   History of similar complaints among the siblings or the parents must be elicited. This might help to rule out certain genetic/familial syndromes, metabolic conditions, bleeding disorders and infectious ailments. *Note: The presence of skeletal dysplasias, scoliosis, clubfeet, developmental dysplasia of the hip [DDH], repeated fractures, rickets and neuromuscular disorders in family members should be specifically obtained. History of close contact with Tuberculosis [TB] patient is important in patients with suspected mycobacterial infection.*
6. Birth history:
   A thorough birth history including the prenatal, natal and neonatal periods is important in the evaluation of certain congenital, developmental and neurologic impairments. The following checklist should be kept in mind while eliciting a birth history.
   - Prenatal: Abortion, maternal infections [rubella, syphilis, herpes, etc.], diabetes mellitus, illicit drug use/alcohol abuse, etc.
   - Natal: length of pregnancy, duration and nature of labor/delivery, presentation at delivery [breech/vertex], oligo-/poly-hydramnios, singleton/twins/multiple, condition of the newborn at birth, birth weight and height, etc.
   - *Note: DDH and congenital muscular torticollis [CMT] are common with breech presentations.*
   - Neonatal: respiratory difficulties, convulsions, blood transfusions, asymmetry of face/limbs, muscle tone, deformities, birth trauma, etc.
7. Developmental history:
   The examiner should evaluate the child for delayed developmental milestones. The child's posture, functional development of the upper and lower limbs, activities of daily living, social development, speech and intellect should be assessed. The basic milestone history should include the following:

Head control, roll over, sit, crawl, pull up to a standing position, walk unsupported, run, climb stairs, hop on one foot
Hold/reach for/transfer objects, eat with a spoon, put on/off clothes
Social smile, wave "bye-bye", say "da-da" or "ma-ma", speak a few words/sentences
Sleeping patterns, Age of toilet training
Problems with behavior, relationship, scholastic performance

Orthopaedic Examination [1–5]

By and large, majority of the paediatric patients presenting with musculoskeletal ailments are unco-operative. Effective communicative skills and tender loving care towards the paediatric patient are the important pre-requisites for a successful clinical examination. The examiner has to be patient in establishing a strong rapport with the parents and the child. It is essential to comfort them and gain their confidence before proceeding with the examination. The practice of wearing a white coat can be avoided in a paediatric clinic to enhance the child's co-operation. The essential steps of examination should be adequately explained to the patient and the parents. The modesty of the paediatric and the adolescent patient must be maintained. Always examine the child in the presence of parents. Infants are better examined in the parent's lap. As a rule, the normal asymptomatic limb is examined before proceeding to the involved limb.

Orthopaedic clinical evaluation in a child can be broadly divided into two groups: screening examination and focused examination.

1. Screening examination:
   The aim of screening examinations is to identify the asymptomatic disorders that can cause significant morbidity if undiagnosed and untreated. The common disorders which are screened for are listed below:
   - Hip: DDH
   - Spine: Scoliosis, kyphosis, spinal dysraphisms, torticollis
   - Long bone: deformities, limb length discrepancies
   - Foot: clubfoot, calcaneovalgus foot, metatarsus adductus, intoeing
   - Digits: syn-/poly-dactyly, absence
     Note: DDH and scoliosis are the most commonly screened conditions.
     Screening for DDH:
     The two most commonly used tests for DDH screening include: Barlow sign and Ortolani sign.
     Barlow sign is done to identify whether the hip is dislocatable. The examiner attempts to subluxate or dislocate the femoral head from within the acetabulum by gently pushing the relaxed infant's hips laterally and posteriorly, with the leg in 90° of flexion and neutral abduction. If there is instability, the femoral head will dislocate from the acetabulum and then spontaneously reduce, with a distinct "clunk" when pressure on the leg is relaxed. This may be the only physical finding on examination.

Next, the examiner should determine whether the femoral head is dislocated out of the acetabulum by testing for the Ortolani sign. In neonates, it is usually possible to reduce the dislocated femoral head temporarily by gently abducting the hip and lifting the upper leg forward. A distinct clunk will be felt as the head is reduced. When pressure on the leg is released, the femoral head will dislocate again. If the hip is dislocated, physical findings may include limited abduction (normal abduction is approximately 90°), asymmetric thigh folds (excess on the affected side), and shortening of the leg compared with the opposite side.

One point to emphasize regarding these two maneuvers is that the examiner cannot elicit both the Barlow and Ortolani signs from the same hip. Either the femoral head is sitting in the acetabulum and can be temporarily dislocated on examination (Barlow sign), or the head is dislocated and can be temporarily reduced on examination (Ortolani sign).

Screening for Scoliosis:

The forward-bending test is a reliable means of screening for scoliosis. The examiner views the patient from the back during the test. The patient stands evenly on both legs, with the knees straight, and then bends forward at the waist, with the arms hanging free. The examiner evaluates the back for elevation of one hemithorax or flank relative to the other to determine the presence of a rotational deformity caused by scoliosis.

A quick screening for detecting other potential deformities or disorders can be done simply by observing the child during certain maneuvers. The child is asked to do the following:

- Hop off the examination table.
- Walk back and forth.
- Hop on one foot.
- Hop on the other foot.
- Heel-walk.
- Toe-walk.
- Walk on the lateral border of the feet.
- Squat down and stand up.

If the patient does all these without noticeable abnormality, the examiner can rule out muscular dystrophies, cerebral palsy, ataxias, Charcot-Marie-Tooth disease, septic arthritis in the lower extremity, tarsal coalition, patellar dislocation, and drop foot.

2. Focused examination:

Focused examination targets a particular joint or anatomical region based on the patient's chief complaints. The reader is advised to refer to relevant sections of this textbook for further details.

Certain ground rules of deformity assessment are outlined below. Whenever there is a deformity, the following things have to be evaluated:

- Location of the deformity: bone/joint/soft tissue
- Severity

- Status: Fixed/correctable
- Etiology
- Associated factors: muscle spasm, tenderness, pain with motion

Nomenclature: The terminology of an angular deformity ideally consists of two parts. The first part describes the site of the deformity. For example: cubitus [elbow], coxa [hip], genu [knee], and pes [foot]. The second part describes the direction of the deformity. For example: Valgus denotes an angulation away from the midline of the body distal to the anatomic part named (i.e., the distal segment is deviated away from the midline). In cubitus valgus, the forearm is directed away from the midline, distal to the elbow. On the contrary, Varus describes an angulation toward the midline of the body distal to the anatomic part named (i.e., the distal segment is deviated toward the midline). In coxa vara, the angle between the femoral neck and shaft is smaller than normal and the distal segment is angled toward the midline.

Measurement tool: Angular deformities are measured in degrees and are most accurately recorded using a hinged goniometer. However, when bony landmarks are not clear because of excess soft tissue coverage or other causes, the goniometer may give inaccurate results.

Methodology

1. The degree of cubitus valgus, or carrying angle, of the elbow is measured with the elbow at the zero starting position (i.e., with the elbow fully extended and at 0° of flexion). The goniometer is positioned on the volar surface of the arm and aligned with the midaxis of the humerus and the midaxis of the forearm.
2. Knee joint alignment is measured with the patient standing with the knee fully extended. The goniometer is aligned with the midaxis of the distal femur and proximal tibia.

Other Methods

1. The degree of *genu valgum* (knockknees) can be determined by measuring the distance between the medial malleoli when the knees are fully extended, the patellae are facing exactly forward, and the medial femoral condyles are brought together with moderately firm pressure to compress excessive subcutaneous fat.
2. The degree of genu valgum can also be determined by measuring the angle between the lateral surface of the thigh and leg. The clinical appearance of knock-knees is exaggerated when there is excessive subcutaneous fat on the thigh or atrophy of the calf (especially of the medial head of the gastrocnemius).
3. The degree of genu varum (bowlegs) can be similarly determined by bringing the medial malleoli together, firmly compressing them, and measuring the distance

between the medial femoral condyles. The patellae must be facing exactly forward because medial rotation of the lower extremities at the hips will result in the appearance of bowlegs.

The salient clinical features of some of the common paediatric conditions are discussed below.

Developmental Dysplasia of Hip

- History:
  1. First born
  2. Female > male
  3. Left hip > right hip
  4. Bilateral in 20%
  5. Breech delivery [frank breech with knee extended (20%) > single footling breech (2%) > double breech]
  6. Oligohydramnios
  7. Ligamentous laxity
  8. First term hyperthyroidism
  9. Postnatal positioning [hips swaddled in extension]
  10. Family history
  11. Associations: torticollis, metatarsus adductus
- Examination:

  Neonate:
  1. Barlow sign to identify dislocatable hips
  2. Ortolani sign to identify reducible hips
  3. Klisic's sign—line from GT to ASIS should continue medially and pass towards the umbilicus; in the dislocated hip, the GT is high and the line passes under the umbilicus
  4. Asymmetric groin creases, thigh folds, popliteal and gluteal creases

  Infant:
  1. Klisic's sign
  2. Decreased abduction: most reliable sign
  3. Galeazzi sign: Apparent limb length discrepancy due to a unilateral dislocated hip with hip and knee flexed at 90°; femur appears shortened on dislocated side

  Walking child:
  1. Klisic sign
  2. Decreased abduction
  3. Excessive internal and external rotation of the dislocated hips
  4. Pelvic obliquity
  5. Galeazzi sign
  6. Trendelenburg sign and gait
  7. Shortening : This is also evident by toe walking
  8. Increased lordosis (bilateral)

Perthes Disease

- History
  1. Age: 4–8 years [most common]
  2. Male > female
  3. Bilateral in 10–13%
  4. Family history
  5. Low birth weight
  6. Painless Limp : exacerbated by activity and relieved with rest
  7. Occasional Pain: Located in the groin, thigh, knee, greater trochanter; Aggravated by physical activity; Usually worse late in the day; Occasional night pain
  8. Associations: trauma, hereditary factors, coagulaopathy, type 2 collagenopathy, hyperactivity, passive smoking

  Note: The classic portrait of the child with LCPD—small, often thin, extremely active, constantly running and jumping, and limping after strenuous physical activities.
- Examination
  1. Abductor limp
  2. Decreased abduction and internal rotation
  3. Resistance to logroll
  4. When the hip is flexed, it may go into obligatory external rotation.

Slipped Capital Femoral Epiphysis

- History:
  1. Age: adolescence [12–15 years in boys and 11–13 years in girls]
  2. Male > female
  3. Left hip > right hip
  4. Bilateral in 20–40%
  5. Obesity
  6. Endocrinopathy :hypothyroidism [most common], hypogonadism, growth hormone deficiency, secondary hyperparathyroidism [in chronic renal failure], Primary hyperparathyroidism, panhypopituitarism [in intracranial tumors]
  7. Pain: Located in the groin, referred to anteromedial thigh and knee; Exaggerated with activity
  8. Unable to bear weight [in unstable SCFE]
  9. Prior pelvic radiation
  10. Syndromes: Klinefelter, Rubinstein-Taybi
  11. Associations: Blount disease, peroneal spastic flat foot, Perthes disease
- Examination:
  1. Antalgic limp
  2. External rotation attitude

3. Shortening
4. Thigh atrophy: But difficult to make out in obese children
5. Anterior hip joint tenderness
6. Restriction of FABIR [flexion, abduction and internal rotation]
7. Increased hip extension, adduction and external rotation
8. When the hip is flexed, it may go into obligatory external rotation
9. Hip flexion contracture and painful global restriction of movements is seen in Chondrolysis complicating SCFE.

Congenital Talipes Equinovarus

- History:
  1. Male > female
  2. Bilateral in 50%
  3. Associations: DDH
  4. Neuromumuscular diseases and syndromes [Arthrogryphosis, spina bifida, Down syndrome, Larsen syndrome, constriction band syndrome, etc.]
  5. Maternal smoking
  6. Treatment history
- Examination:
  1. small foot and calf
  2. shortened tibia
  3. medial and posterior foot skin creases
  4. hindfoot in equinus and varus : differentiated from more common positional foot deformities by rigid equinus and resistance to passive correction
     Note: postural clubfoot is fully (or nearly fully) correctable passively and does not exhibit atrophy or significant contractures and deep skin creases of a true clubfoot.
  5. midfoot in cavus
  6. forefoot in adduction and pronation

  Pirani score [modified]:

Findings	Score = 0	Score = 0.5	Score = 1
Curvature of lateral border of foot	Straight	Mild distal curve	Curve at calcaneocuboid joint
Severity of medial crease (foot held in maximal correction)	Multiple fine creases	One or two deep creases	Deep creases change contour of arch
Palpation of lateral part of head of talus (forefoot fully abducted)	Navicular completely “reduces”; lateral talar head cannot be felt	Navicular partially “reduces”; lateral head less palpable	Navicular does not “reduce”; lateral talar head easily felt

Severity of posterior crease (foot held in maximal correction)	Multiple fine creases	One or two deep creases	Deep creases change contour of arch
Emptiness of heel (foot and ankle in maximal correction)	Tuberosity of calcaneus easily palpable	Tuberosity of calcaneus more difficult to palpate	Tuberosity of calcaneus not palpable
Rigidity of equinus (knee extended, ankle maximally corrected)	Normal ankle dorsiflexion	Ankle dorsiflexes beyond neutral, but not fully	Cannot dorsiflex ankle to neutral

Congenital Vertical Talus

- History:
  1. Family history
  2. Associations: myelomeningocoele, arthrogryposis, spinal muscular atrophy, DDH, neurofibromatosis, trisomy 13–15 and 18
- Examination:
  1. Rigid rocker bottom deformity: The components include
     (a) fixed hindfoot equinovalgus
     (b) rigid midfoot dorsiflexion
     (c) forefoot abducted and dorsiflexed
  2. prominent talar head can be palpated in medial plantar arch; produces a convex plantar surface
  3. "peg-leg" or a calcaneal gait due to decreased push-off

Congenital Muscular Torticollis

- History:
  1. Breech delivery
  2. Associations: DDH, metatarsus adductus
- Examination:
  1. Cock robin appearance: Head tilt towards same side and chin rotated toward the contralateral shoulder
  2. Palpable mass or knot on the involved side in the body of the SCM muscle in the first three months of life
  3. Contracture of SCM
  4. Restriction of neck movements
  5. Ear anomalies: bat ear
  6. Flattening of occipital area
  7. Flattening of the ipsilateral face
  8. Plagiocephaly [in severe cases]
  9. Scoliosis

Sprengel Shoulder

- History:
  1. Bilateral in 10–30%
  2. Associations: rib cage and cervicothoracic chest wall asymmetry, Klippel-Feil syndrome, congenital scoliosis, torticollis, and pulmonary and renal disorders
- Examination:
  1. Absent or hypoplastic high riding medially rotated scapula
  2. Loss of long medial border of scapula
  3. Equilateral triangle like shape
  4. Asymmetric, painless, bony mass in the web of the neck
     Note: These patients have normal glenohumeral motion but severely restricted scapulothoracic motion
  5. Restricted abduction and flexion

References

1. Staheli L. Practice of paediatric orthopaedics. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2011.
2. Miller MD. Review of orthopaedics. 6th ed. Philadelphia: Saunders; 2012.
3. Herring JA. Tachdjian's pediatric orthopaedics, vol. 1. 4th ed. Philadelphia: Saunders Elsevier; 2008.
4. Weinstein SL, Flynn JM. Lovell and Winter's pediatric orthopaedics. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2013.
5. Canale ST, Beaty JH, Campbell WC. Campbell's operative orthopaedics, vol. 2. 12th ed. Philadelphia: Elsevier/Mosby; 2013.

Gait

Nirmal Raj Gopinathan and Prateek Behera

Gait can be defined as a cyclical pattern of musculoskeletal motion which carries the body forwards. Simplistically stating, gait can be considered as a pattern of locomotion. Normal gait is smooth, symmetrical and ergonomically economical, with each leg out of phase with the other [1, 2].

Gait is a reflection of functioning of neurological and musculoskeletal system of an individual. Abnormalities in integration and coordination at the level of the brain, spinal cord, peripheral nerves and the musculoskeletal system can lead to abnormal gait. Vision and the labyrinthine system aid the brain in coordinating the balance of the body. Abnormal gait patterns help in gaining some information about the source and supplements physical examination findings for reaching at a final diagnosis [1–3].

Examination of gait of a patient forms an essential part of orthopaedic physical examination. It can be examined in a clinic or in specialized gait laboratories [1, 4]. While it is often said that one can have some idea about gait abnormality by looking at the way a person is entering into the physician's chamber, the best to examine the gait of a patient is in a hallway with adequate space available for movements. Examination in a gait lab necessitates the availability of specialized equipments, motion sensors and adequate training of the examiner as the pre-requisites [1, 4].

The gait examination in a clinic or during exams should be done in the following way:

- Explain the patient that the examination involves him/her walking down the hallway in as much natural manner as possible and needs to be sufficiently exposed for a good examination.

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- The patient should be sufficiently undressed so that the lower back, iliac crests, gluteal folds and the rest of the lower limbs are visible.
- An assessment of lower extremity passive range of motion and muscle strength is beneficial before performing gait analysis.
- The patient should be asked to walk down the hallway and the examiner should evaluate and assess the trunk and each joint movement in all three planes (sagittal, coronal, and transverse) and observations should be made from side, front and back of the patient.
- The patient should walk barefoot and/or with the normal footwear that he/she uses. In case the patient is unable to walk without walking aids, the gait with use of walking aid should be examined.
- A straight white strip may be painted on the floor of the hallway and the patient asked to walk down the hallway along the strip; this helps in obtaining information about the foot progression angle and any imbalance of the patient.
- A note should be made of posture and symmetry before the patient starts walking.
- Position of the anterior superior iliac spine (ASIS), patella and the medial mallelous should be compared between the two lower limbs. Then the patient's gait is observed looking at the step length, stride length, step frequency, speed, and time spent in stance and swing phase, foot progression angle, the position of pelvis and the position of the shoulders. Any abnormality of the gait is noted.
- Analysis of the patient's gait requires that the examiner familiarizes him/her with the basics of gait as has been detailed below.

Phases of Gait Cycle

Each lower limbs alternates between two phases—stance and swing during the gait cycle. Gait cycle is the time interval between two consecutive initial contacts with the ground of the same foot. In stance phase, the limb is in contact with the ground while in swing phase there is no contact of foot with the ground. The limb in stance phase supports the weight of the whole limb while in swing phase it advances forward. Stance phase occupies 60% of the gait cycle and swing phase occupies 40% [1, 2, 4].

Stance Phase

Stance phase has constitutes the longer of the two phases of a gait cycle. It has been sub divided into five sub stages.

- *Initial contact (Heel strike)*—Stance phase starts when the heel of one of the feet strikes the ground
- *Load response (Foot flat)*—the foot gradually plantar flexes onto the ground and starts to bear weight

- *Mid stance (single leg stance)*—the foot becomes fully flat and bears weight of the whole body. Load response and mid stance constitute about 40% of the gait cycle.
- *Terminal stance* (*Heel off*)—the foot starts to come off the ground starting from the heel
- *Pre swing (Toe off)*—the stance phase ends when the whole toes of the foot come off the ground.

Swing Phase

Swing phase has been sub divided into three sub stages.

- *Initial swing (acceleration)*—it starts with toe off and continues as the foot is raised from the ground and the limb moves forward.
- *Mid swing*—it starts as the limb advances past the other limb which is in the stance phase; the knee extends, and the foot travels in a forward-swinging arc. This sub stage is important for forward propulsion.
- *Terminal swing (Deceleration)*—this occurs at the end of swing phase as the musculature of the forward-moving swing limb smoothly stops the limb and prepares it for initial contact with the ground to restart the gait cycle.

There are two periods of double leg support in each normal gait cycle. A double leg support occurs when one foot is in the heel strike state and the other in toe off state. The duration of double leg support varies with the speed of walking. When one walks with a slow speed, the duration of double leg stance increases. Double leg stance disappears and is replaced by double leg float (both the limbs are in air) during running.

Parameters of Gait

- *Base width (step width)*—Base width or step width is the distance between the two feet while walking. If the base is wider than normal, the examiner may suspect some pathology that may result in poor balance (cerebellar or labyrinthine), conditions indicating loss of sensation (diabetes or peripheral neuropathy) or musculoskeletal problem (like tight hip abductors).
- *Foot progression angle*—it is the angle that the foot makes with the path on which the subject is walking (often likened to footprints in the sand). The normal foot progression angle is approximately 10–15° externally.
- *Step length*—it is the distance between the two feet during double-limb support. It varies with age, sex, walking speed and disease state.
- *Stride length*—it is the distance one limb travels during stance and swing phases i.e. distance travelled from heel strike of a limb to the next heel strike of the same limb.

- *Cadence*—it is defined as the number of steps taken per minute.
- *Walking speed*—it is the distance travelled per minute usually mentioned as m/s.

Small children walk with greater cadence but smaller step and stride lengths, resulting in many quick, small steps [3–5]. As children grow, their step and stride lengths increase and cadence decreases. Step length increases linearly with increasing leg length.

Behaviour of Lower Limb Joints During Gait Cycle

- *Hip joint*—The hip joint function is to extend the limb from the flexed position during the stance phase and to flex the limb during swing phase. This necessitates proper and coordinated functioning of the hip extensors and flexors respectively. The hip abductors, femoral head and neck and the acetabulum play a central role in maintaining the stability of the pelvis during the single leg stance phase (mid stance phase). An abnormality in any one of the three components may lead to a Trendelenburg gait (described later).
- *Knee joint*—The knee joint goes from a state of flexion to that of extension during the gait cycle. The functions of the knee during gait are to bear weight, absorb shock, extend the stride length, and allow foot to move through its swing.
- *Ankle joint*—the ankle and foot act as a coordinated, interdependent unit during the gait cycle. At initial contact, when the heel normally strikes the ground the foot is in neutral position. The ankle then plantar-flexes 5–10° as the forefoot comes to rest on the ground. This initial plantar flexion is known as *first rocker*. The ankle dorsiflexes throughout mid-stance as the tibia moves forward over the plantigrade foot (*second rocker*). During *third rocker*, the ankle plantar-flexes and the heel rise to prepare for pushoff. Dorsiflexion of the ankle back to a neutral position is seen during swing phase to allow for clearing of the foot. In patients with peroneal nerve palsy and foot drop, dorsiflexion during swing phase is impaired.

Abnormal Gait Patterns

Deviations from a normal pattern of gait usually presents as a limp and lurch can occur for the below mentioned reasons:

- Secondary to pathology or injury affecting a specific joint and the surrounding musculature.
- As a compensatory mechanism for injury or pathology in some other joints on the same side.
- As a compensation to an injury or pathology affecting the opposite limb

While the above mentioned reasons are the commonly seen reasons in orthopaedic clinical practice for gait abnormalities, neurological conditions may also produce such abnormalities.

Cerebral palsy is a neurological condition with orthopaedic implications and it is known to produce gait changes [5]. Commonly seen abnormal gait conditions are listed below [1, 5]:

- *Antalgic (painful) gait*—Antalgic gait is a result of injury to the pelvis, hip, knee, ankle or foot. It is a protective gait and aims to prevent any further damage by removing weight from the affected leg as quickly as possible. This leads to a *short stance phase* on the affected limb and consequently a long stance phase on the contra lateral limb. The amount of time spent in each phase of gait cycle should be noted. In case the pathology is in the hip, the patient shifts the body weight over the painful hip so as to decrease the abductor pull and the effective joint reaction force on the effected hip. This leads to a sway towards the effected side. Thus a patient with painful hip has a sway to same side and a decreased stance phase of the affected limb. Causes of such a gait include osteoarthritis, infective arthritis, and fracture of femoral neck or head among others.
- *Trendelenburg's gait (abductor lurch)*—An abnormality in any one or more components of the abductor mechanism of the hip leads to a gait in which the patient lurches on the affected side and the pelvis drops on the opposite side. This abnormality may be in the hip joint per se or in the femoral neck or the abductor musculature. By leaning over towards the side of the weight bearing limb, the patient brings his or her center of gravity closer to the femoral head. This decreases the leverage of the patient's upper body weight and thus decreases the counterbalancing force that needs to be exerted by the abductor muscles. In case where there is an abnormality of abductor mechanism on both sides, the gait shows accentuated side to side movements resulting in a waddling gait. To qualify as trendelenburg's gait, the gait should be painfree. Causes of unilateral trendelenburg's gait include perthes disease, unilateral DDH, SCFE, non union of neck of femur fractures, mal-united neck or intertrocahnteric fractures, neglected long standing dislocation of hip, poliomyelitis, and paralysis of hip abductors. Waddling gait may be seen cases of bilateral DDH, pregnancy, myopathies affecting the abductor of hip.
- *Short limb gait*—A short limb gait is present when there is a true limb length discrepancy between the affected and the normal limb with the affected limb being shorter in length. There is seen a lateral shift on the affected side with the pelvis and the shoulder dropping down vertically on the affected side. The joints of the unaffected side may demonstrate exaggerated flexion or hip hiking may occur during the swing phase to allow the foot to clear the ground. The stance phase duration on both the sides is equal and is a differentiating point between antalgic and short limb gait. If the patient is asked to walk with a shoe raise equal to the amount of shortness of the limb then the pelvic drop and the shift to the opposite side gets reduced and this may be used for differentiating between a trendenlenburg's gait and short limb gait.

- *High steppage gait or foot drop gait or dragging gait*—Weakness or paralysis of the ankle dorsiflexors leads to foot drop. The patient is unable to dorsiflex the foot during the initial swing of the gait cycle and to avoid dragging the toes against the ground, the patient lifts the knee higher than usual. Also the initial heel strike phase is absent as the patient is unable to maintain the foot in neutral and thus the toes come in contact with the ground instead of the heel. Common causes include peroneal nerve palsy, sciatic nerve paralysis, cerebral palsy, myelodysplasia, CMT disease etc.
- *Gluteus maximus gait*—A gluteus maximus gait occurs in patients who have a weak gluteus maximus. The gluteus maximus normally locks the hip in extension as the contra-lateral limb is advanced for the next step. A patient with a weak gluteus maximus may thrust the pelvis forward and trunk backward, shifting the center of gravity posterior to the hip and thereby reducing the force that the gluteus maximus needs to generate to lock the hip in extension. This gait is seen in cases with polio affecting the gluteus maximus.
- *Equinus gait (toe walking)*—this is a form of childhood gait seen in patients with cerebral palsy, tight Achilles tendon, post burn contractures of the tendo Achilles and limb length discrepancy etc. It may be habitual in the very young and may be seen upto 3–4 years of age. Weight bearing is on the toes and also on some part of lateral border of the foot.
- *In toeing gait*—this type of gait may be seen during the developmental years of a child and tends to improve with age. It may be familial in many cases. It is seen in patients with metatarsus adductus, tibial bowing with tibial intorsion and in patients with persistently greater femoral anteversion.
- *Out–toeing gait*—normally the foot is external rotation during normal gait and the normal range of out toeing is between 0° and 30°. Greater degree of out toeing may be seen in toddlers and this tends to improve spontaneously. In case there is tibial extorsion, this will persist and may get worsened over time.
- *Arthrogenic (stiff hip or knee) gait*—Arthrogenic gait results from stiffness, laxity or deformity, and it may be painful or painless. In cases where the knee or the hip is fused or the knee has just been removed from a long leg or cylindrical cast, the pelvis needs to be elevated by exaggerated plantar flexion of opposite ankle and circumduction of the stiff leg to provide ground clearance. The entire leg is lifted higher than normal.
- *Psoatic gait*—this gait is seen in cases like Perthes' disease where the patient demonstrates a difficulty in swing through and may be accompanied by exaggerated pelvis and trunk movements. This may be caused by weakness or reflex inhibition of the psoas major. The classic manifestations are flexion, lateral rotation and adduction of the hip.
- *Quadriceps avoidance gait or hand to knee gait*—in a normal gait cycle, the knee is fully extended and locked in extension by the quadriceps during the mid stance. In cases where there is weakness of quadriceps like poliomyelitis, femoral nerve injuries and trauma the quadriceps fails to extend and lock the knee. Patient develops a compensatory mechanism in which the patient leans over the affected limb and uses his ipsilateral hand/fingers to produce extension of the knee. In case the patient is intelligent, he may use his hand through the pant pockets and thus avoid pressing the distal femur from outside.

- *Scissors gait*—this gait results from spastic paralysis of the hip adductor muscles as may be seen in patients of cerebral palsy. Here the knees are drawn together so that the legs can swing only with great effort. With each step one leg crosses directly over the other due to tight adductors of the hip. In cases where adductor contracture is associated with knee flexion, the patient appears to be crouching and the gait can then be called as crouch gait. This gait is also known as neurogenic or spastic gait.
- *Hemiplegic or circumduction gait*—a patient with hemiplegia or hemiparesis needs to lift the entire lower limb and swing it outward and ahead in a circle (circumduction at the hip). Additionally, the affected upper limb is carried across the trunk for maintaining balance. This type of gait thus involves classical movement of the affected upper and lower limbs both.
- *Ataxic gait*—ataxic gait is seen in patients with poor sensation or lack of muscle coordination. There is a tendency towards broad based gait to compensate for the poor balance. In patients with sensory ataxia as in tabes-dorsalis, syringomyelia, diabetes and leprosy, the patient has reduced sensations and the feet are often raised abnormally high by the patient and brought down with a slap. Such a gait is called as stamping gait. Patients with cerebellar ataxia walk with a lurch or stagger and all the movements are exaggerated.
- *Parkinsonian gait* (festinating gait)—this is classically seen in patients with Parkinson's disease. The patient has an attitude of flexion at the neck, trunk and knees i.e. there is a stooped appearance. The gait is characterized by rapid short steps (shuffling) with the upper limbs held stiffly. Upper limbs do not have their normal swing. The patient leans forward and can walk progressively faster as though unable to stop, this is known as festination and appears as if he is trying to catch his own centre of gravity. There is a lack of heel strike and toe off as well as of pelvic movements. Aetiologies include Parkinson's disease, Wilson's disease and cerebral atherosclerosis.

Crutch Walking

Crutch walking is more efficiently done with axillary crutches than any other type [6]. Four types of gait patterns have been described:

- Swinging crutch gait
- Four point crutch gait
- Two point crutch gait
- Three point crutch gait

Swinging Crutch Gaits

Two types of swinging crutch gaits have been described, the *swing-to* gait and the *swing through* crutch gait. These gaits are used when the patient is capable of bearing weight on the legs taken together but is unable to move the lower limbs individually. This usually happens in cases of paraplegia or paraparesis. Crutches are used to support weight of the body and the muscles of the trunk and pelvis are used to propel the body forward.

In the *swing-to crutch gait*, both the crutches are lifted and placed forwards a short distance. The weight of the whole body is taken on both the hands keeping the elbows straight and then the lower limbs are swung forwards so that the lower limbs are brought between the two crutches.

In the *swing-through crutch gait*, both the crutches are lifted and placed forwards a short distance. The weight of the whole body is taken on both the hands keeping the elbows straight and then the lower limbs are swung forwards so that the lower limbs are placed some distance forwards of the crutches. This gait pattern is quicker than swing-to gait but needs good balance of the legs to be successfully performed.

Four Point Crutch Gait

This type of gait is used when all or a part of the body weight can be borne on each foot but the patient has abnormality with balance and walks with a broad base. The sequence of movement is one crutch followed by contra-lateral lower limb e.g. right crutch; left leg; left crutch; right leg.

Two Point Crutch Gait

This type of crutch is useful when the patients both lower limb are affected (weak or painful) though they can take some amount of body weight. The pre requisite is good balance on part of the patient. The sequence is one foot and contra-lateral crutch moved forwards together and then alternating with other foot and its contra-lateral crutch.

Three Point Crutch Gait

This type of gait is used in cases where patients have one weak or painful leg which cannot take the patients weight while the other leg is fully sound and is able to take the patient's body weight on its own. The two crutches are meant to support the affected leg while the stronger leg takes the weight of the whole body without any support from the crutches.

The sequence is the affected leg and the two crutches are moved forwards together as a unit while the other stronger leg is moved independently.

References

1. Magee DJ. Assessment of gait. In: Orthopaedic physical assessment. 6th ed. St. Louis: Saunders; 2014. p. 981–1016.
2. Martell JM. Pelvis, hip and thigh. In: Reider B, editor. The orthopaedic physical examination. 2nd ed. Philadelphia: Saunders; 2005. p. 177–80.

3. Aronsson DD, Lisle JW. The pediatric orthopaedic examination. In: Weinstein SL, Flynn JM, editors. Lowell and Winter's pediatric orthopaedics. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2014. p. p87–128.
4. Karol LA. Gait analysis. In: Herring JA, editor. Tachdjian's pediatric orthopedics. 5th ed. Philadelphia: Saunders; 2014. p. 71–8.
5. Herring JA, Birch JG. The limping child. In: Herring JA, editor. Tachdjian's pediatric orthopedics. 5th ed. Philadelphia: Saunders; 2014. p. 79–89.
6. Stewart JDM, Hallet JP. Crutch walking. In: Traction and orthopaedic appliances. 1st ed. Edinburgh: Churchill Livingstone; 1975. p. 161–9.